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THE SOCIETY OF JESUS AND EARLY MODERN OPTICS

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For Becky

PREFACE

The seeds of this dissertation were sown while working as a graduate assistant in the History of Science Collections at the University of Oklahoma. During that time I helped organize education outreach, utilizing short activities to help the ideas and images within the rare books come to life. One particular activity I routinely did, involved giving individuals concave and convex lenses to play with, to learn how glass of different types was able to distort visual representation. The sense of wonder that ensued, from Kindergarteners to Tenured Professors, and the variety of questions I was asked, helped to awaken my own historical imagination and intrigue with the topic of early modern optics. While the project continued to take shape long after my time as a graduate assistant, the memories of playing with glass lenses helped motivate me at important junctures when the process of researching and writing seemed unending.

The actual project took root and grew from the enriching guidance of my dissertation committee: Rienk Vermij, Peter Barker, Kathleen Crowther, Steven Livesey, Kerry Magruder, and Jane Wickersham. Throughout the entire process Rienk Vermij demonstrated patience as I learned how to do research, but also gave his own expertise at important points that improved the project. His wise guidance is on every page of this dissertation and shapes (and will continue to shape) my own research intuitions. Kerry Magruder listened with enthusiasm during the entire process as I tried to formulate ideas, and even continued such efforts over Zoom calls when the task of finishing a dissertation was made all the more difficult by the Covid-19 Pandemic. Steven Livesey, Kathleen Crowther, and Peter Barker offered insightful comments and feedback on specific questions, and helped me avoid serious mistakes. Jane Wickersham graciously helped me jump between the world of the history of science to that of the history of religion, and in many respects make the project more interesting and of wider appeal. A special thanks to Peter Barker whose editorial help on the late stages of this project made the entire text more readable.

Many other individuals played an important role in helping this project come to fruition. The University of Oklahoma is a wonderful place to learn and research the history of science. The Department of the History of Science, Technology, and Medicine and the research support of the History of Science Collections in the University Libraries offers a top-notch situation for a graduate student to develop. I want to thank the librarians in the History of Science Collections, JoAnn Palmeri and Melissa Rickman, for their aid in research and for sharing in the joy of the research process. I was also fortunate to journey through graduate school with some incredible people. Nathan Kapoor, Anna Reser, James Burnes, Kraig Bartel, Margaret Gaida, Aja Tolman, and Younes Mahdavi all enriched my experience as a student. I spent 2017–208 as a member of a Dissertation Seminar at the Newberry Library in Chicago with graduate students from many disciplines. One hopeful outcome of that experience is that this dissertation is beneficial for more than historians of science. I also am thankful for short research trips to the special collections at the Newberry Library, Loyola University, the University of Chicago, St. Louis University, and the Linda Hall Library, each of which raised new questions and ideas. A Derdeyn-CMRS Scholarship from the University of Oklahoma Center for Medieval and Renaissance Studies provided me the opportunity to see rare books in select European libraries, as well as the cities and churches that were well-known to the historical figures in this study.

My family also supported and encouraged me throughout this process. The time to complete a dissertation is lengthy, and they gave me grace when the timeline kept expanding. My wife, Becky, especially deserves thanks. She kept nudging me along, and persevered herself throughout this project. It is to her this dissertation is dedicated.

ABSTRACT

This dissertation explores the investigation and explanation of optics among prominent members of the Society of Jesus during the early modern period. In doing so it aims to explain why it was that optics became one of the more important scientific subjects among the members of the Order. In addition to this it aims to explain how it was that their identity as members of the Order shaped their explanation of optics at a time when there was no agreed upon meaning of optics. As argued, this interaction between Jesuit identity and optical theory may best be understood as an act of confessionalization. The benefit of this categorization is that it allows for a complex analysis of optics among the Society of Jesus which avoids any essential identification of the relationship between science and religion. This dissertation, then, not only addresses why optics among the Jesuits should be understood as confessionalized, but also how the category of confessionalization may provide a path through the complex dynamics of early modern science and religion.

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INTRODUCTION

The history of the pre-suppression Jesuits (1540–1773) coexists alongside some of the most important changes in the history of optics. When Pope Paul III authorized the Society in 1540, optics used mathematics, physics, and human physiology to explain, among many other aspects, human cognition, God, the Eucharist, the preternatural, as well as how vision occurred and how art and architecture could be produced. By 1773, when Pope Clement XVII suppressed the Society, optics was mainly considered the study of light. In the period between the start of the Society and its suppression, optics became an area of investigation for which many members of the Jesuits were well known, and which the historiography has recognized as among their most focused efforts.[1]

Yet, to date, there has been no focused study to understand why optics took an important place in the intellectual pursuits of the Society. This dissertation fills such a gap in the historiography through a close analysis of the explanation and understanding of optics among prominent members of the Society of Jesus from its inception until the end of the seventeenth century.

The closest studies involving the Jesuits and optics have used the understanding of optics (or aspects of optics) as a lens for the formation of science in the early modern period.[2] Despite

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[1] William B. Ashworth, "Catholicism and Early Modern Science," in *God and Nature: Historical Essays on the Encounter between Christianity and Science*, ed. David C. Lindberg, and Ronald L. Numbers (Berkeley: University of California Press, 1986), 154–160; Agustín Udías, *Jesuit Contribution to Science: A History* (New York: New York, 2015), 47–50.

[2] Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995); Ofer Gal and Raz Chen-Morris. "Baroque Optics and the Disappearance of the Observer: From Kepler's Optics to Descartes' Doubt." *Journal of the History of Ideas* 71, no. 2 (2010): 191–217; Isabelle Pantin, "Simulachrum, Species, Forma,

the importance of such studies within their particular historiographical contexts, it is nevertheless noticeable that these investigations presume that science occurred in a nearly uniform way in the early modern period, according to the narrative of the "scientific revolution." The problem with framing the narratives in such a way is that the understanding of science among the Society of Jesus is made subsidiary to the broader scientific revolution narrative. As a consequence, the historiography of science among the Society is caught in a binary with the narrative of the scientific revolution: either science occurred among the Jesuits or it did not.

This dissertation takes a different approach by explaining the transformation and engagement of optics among the Jesuits according to their own terms. In addition to this it will also challenge certain tacit assumptions within the standard historiography of early modern optics. This will result in a clearer understanding as to how optics was understood and explained among members of the Society of Jesus, the influence of which undoubtedly shaped many intellectual and cultural aspects of early modern Europe through the instruction in their colleges and printing of their books. While the focus of the study is on early modern Europe, the attentive reader will notice at the edges of the argument and in the footnotes suggestions as to how the present analysis might be leveraged within the Jesuits' global context.

Before embarking on the study, it is important to clarify four prominent terms: optics; visual culture; Jesuit science; and confessionalized science.

Imago: What Was Transported by Light into the Camera Obscura?: Divergent Conceptions of Realism Revealed by Lexical Ambiguities at the Beginning of the Seventeenth Century." *Early Science and Medicine* 13, no. 3 (2008): 245–69; Sven Dupré, "The Return of the Species: Jesuit Responses to Kepler's New Theory of Images," in *Religion and the Senses in Early Modern Europe*, ed. Wietse de Boer and Christine Göttler (Leiden: Brill, 2013), 473–87.

Optics in Early Modern Europe

Between 1600 and 1700, the practice and understanding of optics changed. As the historian A. Mark Smith has cemented into the historiography, prior to 1600 the goal of optics was an explanation of "sight," whereas after 1600 it was mainly that of "light."[3] What he means by this is that prior to 1600, the assumed goal of optics was to explain the process of vision, and ultimately cognition itself. Thus, prior to 1600 optics explained how vision and cognition occurred, and so the mathematics, physics, and physiology involved, while drawn from discrete scientific disciplines, nevertheless coordinated together for the goal of understanding how vision occurred. Much of this changed in the seventeenth century as optics came to be understood as essentially a mathematical explanation of light, with the psychological and cognitive aspects removed.

The details of this transition and its implications are a matter of debate. Much depends on which optical aspect one centers on in the telling of the story. Among those with an interest in the intellectual history of optics, the centerpiece of the story is the work of Johannes Kepler, particularly his *Ad Vitellionem paralipomena* (1604) and *Dioptrice* (1611), which to many represent a sharp break from the medieval theory of optics known as "perspectivist" optics. While there is still some debate regarding whether Kepler intended to separate from the medieval past—as defended initially by Stephen Straker and now more recently A. Mark Smith—or whether Kepler was the last of the perspectivists—the opinion of David Lindberg—the majority agree that Kepler's optics was the watershed event in the formation of early modern optics.[4]

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[3] A. Mark Smith, "Getting the Big Picture in Perspectivist Optics." *Isis* 72, no. 264 (1981): 568–89; A. Mark Smith, *From Sight to Light: The Passage from Ancient to Modern Optics* (Chicago: University of Chicago Press, 2014).

[4] Stephen Straker, "Kepler, Tycho, and the 'Optical Part of Astronomy': The Genesis of Kepler's

Complementary to these studies on Kepler's relationship to the medieval past are those that consider the beginning of modern light theory, particularly Abdelhamid Sabra's *Theories of Light, from Descartes to Newton*, which focuses on the hallmark of modern optics, the theory of refraction.[5] While all these approaches and histories have important merit in uncovering the changes within the period, certain critiques to the intellectualist approach emerged from other historians interested in material culture, particularly those interested in the history of art and technology.

Among the earliest of these to argue against the over-intellectualization of the optical narrative were Samuel Edgerton and Martin Kemp, who demonstrated the role of linear perspective within early modern optics.[6] They showed that the boundaries between art and science, particularly with respect to optics, was much more fluid in the Renaissance and early modern periods, with many artists considering themselves engaged in the practice of optics. Occurring fairly contemporaneously, historians of technology and instruments, such as Rolf Willach and Vincent Illardi, traced the history of glass and lens making and their role on the

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Theory of Pinhole Images," *Archive for the History of Exact Sciences*, 24:4 (1981): 267–93; David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler* (Chicago: University of Chicago Press, 1976); Smith, *From Sight to Light*.

[5] Abdelhamid I. Sabra, *Theories of Light, From Descartes to Newton* (Cambridge: Cambridge University Press, 1981). A tempering of Sabra's account with a focus on Huygens, Fokko Dijksterhuis, *Lenses and Waves: Christiaan Huygens and the Mathematical Science of Optics in the Seventeenth Century* (New York: Springer, 2005).

[6] Samuel Y. Edgerton, *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution* (Ithaca: Cornell University Press, 1991); Samuel Y. Edgerton, *The Mirror, the Window, and the Telescope: How Renaissance Linear Perspective Changed Our Vision of the Universe* (Ithaca: Cornell University Press, 2009); Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven: Yale University Press, 1992).

formation of early modern optical devices.[7] The interests of the two traditions, that of art history and the history of technology, have even more recently come together in the work of Sven Dupré, who has shown the value of the artisan-practitioner's knowledge of the optical object and the social importance accorded the optical objects within a courtly context.[8] Thus, the material studies build upon the intellectual optical interpretation adding layers of nuance.

In addition to the materiality of the artistic and technological contexts, one might also add that of the anatomical and literary. As Tawrin Baker has recently shown, the functionality of the eye was a topic of far wider interest among physicians than historians had previously thought.[9] It is undoubtedly for this reason that the eye came to be a prominent topic within artwork and literature of the period, as changing optical theories permeated beyond the narrow confines of scientific discourse.[10] As a result, as many studies have demonstrated, the intellectual and

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[7] Rolf Willach, *The Long Route to the Invention of the Telescope* (Philadelphia: American Philosophical Society, 2008); Vincent Ilardi, *Renaissance Vision from Spectacles to Telescopes* (Philadelphia: American Philosophical Society, 2007). One might also consider the edited volume, Albert Van Helden, et al., eds. *The Origins of the Telescope* (Amsterdam: KNAW Press, 2010).

[8] For these themes see Sven Dupré, "Ausonio's Mirrors and Galileo's Lenses: The Telescope and Sixteenth-Century Practical Optical Knowledge." *Galilaeana* 2 (2005): 1000–1038; Sven Dupré, and Michael Korey. "Inside the Kunstkammer: The Circulation of Optical Knowledge and Instruments at the Dresden Court." *Studies in History and Philosophy of Science Part A* 40, no. 4 (2009): 405–20.

[9] Tawrin Baker, "Color, Cosmos, Oculus: Vision, Color, and the Eye in Jacopo Zabarella and Hieronymus Fabricius Ab Aquapendente," Ph.D. Dissertation, (Indiana University, 2014); also Tawrin Baker, "Kepler's Optics: Ocular Anatomy, the Visual Faculty, and the Continuity-Discontinuity Debate." *Studies in History and Philosophy of Science Part A* 59 (2016): 115–20.

[10] Eileen Reeves, *Galileo's Glassworks: The Telescope and the Mirror*. (Cambridge, MA: Harvard University Press, 2008) Eileen Reeves, *Evening News: Optics, Astronomy, and Journalism in Early Modern Europe* (Philadelphia: University of Pennsylvania Press, 2014); Sanam Nader-Esfahani, "Knowledge and Representation through Baroque Eyes: Literature and Optics in France and Italy Ca. 1600-1640.," Ph.D. Dissertation, Harvard University, 2016.

material cultures of early modern optics were not necessarily two distinct realms, but rather operated in a continuum.

The reader of this dissertation will become aware that analyzing the Jesuits and early modern optics problematizes many of these aspects. For instance, as pointed out in Chapter Three below, despite the importance of Kepler in the historiography of early modern optics, at the time, it was not clear to the Jesuits that he introduced such a radical break with the perspectivist past. Furthermore, as noted in both Chapter Three and Four, the distinction between the artistic and technological on the one hand, and the theoretical and mathematical on the other, was not a clear divide for them in the way one might infer based on the way the historiography prioritizes the mathematical and theoretical in the transition from sight to light.[11] As the examples of prominent Jesuits indicate, the artistic and technological both informed and were informed by the mathematical and theoretical. These aspects and many others will be noted throughout this dissertation with the goal of challenging many long-held assumptions about the progress of optics in the seventeenth century.

Visual Culture

In the last few decades "visual culture" has become a catchword in many different disciplines. Because of the overlap between optics and vision in the period before 1700, it is important for this study to understand how optical theory supported visual culture. To understand this, it is necessary to locate the term within its historiographic context and to differentiate what is meant in this dissertation from other uses of the term, many of which are associated with the

[11] For instance, A. Mark Smith emphasizes the role of the mathematical and theoretical in seventeenth-century optics. Smith, *From Sight to Light*, 373–416.

Jesuits.

As a term, “visual culture” has grown largely out of art history, as historians of art broadened the traditional boundary of art, which previously was relegated to painting, sculptures, and architecture.[12] Historians of science too have used visual culture as an analytical category, especially as a way to grasp the category of “the public.” For instance, as Iwan Morus shows in his study of the magic lantern, in the eighteenth century the act of attending an exhibition and experiencing the technology was a way in which “seeing” itself was enculturated and could establish a “public.”[13] Despite the importance of these investigations, it is noticeable that few have ventured into applying the notion of “visual culture” in the premodern period.[14]

It should be noted that within the history of early modern Jesuits, there exists a strong tradition of interpreting the development of the Jesuits through their artistic endeavors, the scope of which is now more commonly identified as “visual culture” rather than merely “art.”[15] Such studies have shown the way in which the Jesuit interest in visual productions — such as art, architecture, emblem books, and even shared assumptions about the nature and meaning of

[12] As Margarita Dikovitskaya also indicates, such a transformation also coincided with the overall cultural shift within history itself, Margarita Dikovitskaya, *Visual Culture: The Study of the Visual After the Cultural Turn* (Cambridge, MA: MIT, 2006), 5.

[13] Iwan Morus, “Seeing and Believing Science.” *ISIS* 97, no. 1 (2006): 109.

[14] A noticeable exception is Eileen Reeves in *Evening News*, 135–138.

[15] Evonne Levy, “Early Modern Jesuit Arts and Jesuit Visual Culture: A View from the Twenty-First Century.” *Journal of Jesuit Studies* 1 (2014): 66–87; Alison Fleming, “Jesuit Visual Culture: Communication, Globalization, and Relationships.” *Journal of Jesuit Studies* 6, no. 2 (2019): 187–95; and Mia M. Mochizuki, “Jesuit Visual Culture in a Machine Age,” in The Oxford Handbook of the Jesuits, ed. Ines G. Županov (Oxford: Oxford University Press, 2018), 1–35; Ralph Dekonick “The Society of Spectacle: The Jesuits and the Visual Arts in the Low Countries,” in *The Jesuits of the Low Countries : Identity and Impact (1540-1773): Proceedings of the International Congress at the Faculty of Theology and Religious Studies*, ed. Rob Faesen (Leuven: Peeters, 2012), 82.

images — demonstrate the rhetorical and cultural role of visual encounters in Jesuit cultural transformation.[16] They have also shown how the Jesuit interest in these mediums provided them with important strategies for spreading their Christian message, within Europe but also beyond Europe.[17] One historian, Evonne Levy, has gone so far as to suggest that the use of Jesuit images may effectively be considered early modern "propaganda," albeit not occurring in a standardized or essential fashion.[18]

This dissertation complements these previous analyses, which are overwhelmingly focused on the artistic aspects of Jesuit visual culture, to instead emphasize the philosophical and scientific visual culture that ran through many facets of the early modern Society of Jesus, an aspect of their visual culture which has received very minimal attention.[19] While the philosophical explanation of optics undoubtedly supported aspects of the art and architectural visual culture, those questions are for the most part not addressed in this dissertation. What is important is the way in which the theory of optics supported the experience of vision. Because the Society of Jesus formed at a point when optics had as its goal the explanation of sight, and

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[16] Ralph Dekoninck, *Ad Imaginem: Statuts, Fonctions et Usages de l'Image dans la Littérature Spirituelle Jésuite du XVIIe Siècle* (Genève: Droz), 2005. For a historical analysis of Dekoninck's work see Levy, "Early Modern Jesuit Arts and Jesuit Visual Culture," 75; For a background on the historiographical development of 'visual culture' more broadly, as well as its application to the early modern period, see Hal Foster, ed. *Vision and Visuality* (Seattle: Bay Press, 2009), particularly the essay by Martin Jay, "Scopic Regimes of Modernity," 3–28.

[17] John W. O'Malley and Gauvin Alexander Bailey, eds. *The Jesuits and the Arts: 1540-1773* (Philadelphia: Saint Joseph's University Press, 2006).

[18] Evonne Levy, *Propaganda and the Jesuit Baroque* (Berkeley: University of California Press, 2004). See also the edited volume, Elisabeth Oy-Marra and Volker R. Remmert, eds. *Le Monde Est une Peinture* (Berlin: Akademie Verlag, 2011).

[19] Volker R. Remmert, "Visuelle Strategien Zur Konturierung Eines Jesuitischen Wissensreiches," in *Le Monde Est une Peinture*, 85–108.

because in general the experience of sight was important in their religious and philosophical outlook, the way the theory of optics aligned with (or differed from) the broader culture of sight is an important consideration.

Although it is not my intention to identify an essential early modern visual culture, much less the establishment of a "hegemonic culture" in the early modern period or among the Jesuits, it is nevertheless important for this story to center the fact that optics provided a public, and often performative, function which could shape the public.[20] The important optical instruments of the period—telescope, microscope, even spectacles—all intended to function in the real world, not just theoretically. This was also the case for optical illusions, of which the Jesuits were among the chief creators. So, the fact that optics could produce effects is undoubtedly a reason many members of the Society of Jesus sought to understand and explain optics. What this study will aim to show is how optical theory supported aspects of their visual culture, and how visual culture shaped features of their optical theory.

So, as one reads this study, while the theories of optics are the focus, it is hoped that the reader will find ways to extrapolate the theory into the ordinary (and vice-a-versa) to demonstrate that optical theory and routine visual occurrences were closely related. In the process attention will be given toward understanding the degree to which the theories passively supported the aims of the broader visual culture and the degree to which optical theories were actively constructed to maintain important features of the visual culture.

At this point it is important to clarify what is meant regarding the cultural connection,

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[20] Martin Jay also questions any essentialist reading of early modern optics in "Scopic Regimes of Modernity," in *Vision and Visuality*, 3–28. For the role of visual hegemony see David Kleinberg-Levin, ed., *Modernity and the Hegemony of Vision* (Berkeley: University of California Press, 1993).

particularly because of the strong historiographical tradition of what is known as "Jesuit science."

Jesuit Science

In 1535 when Ignatius and the earliest "companions of Jesus" gathered together in Paris, it was not evident that they would come to define many aspects of early modern European Catholic culture. One of their greatest efforts was education. By Ignatius's death in 1556, the Jesuits had eighteen colleges; in 1580 the Jesuits had 144 schools, around 450 in 1630, and 850 by the middle of the eighteenth century.[21] In addition to this Jesuits served as confessors, created churches, traversed the globe, and preserved and transmitted significant amounts of information from antiquity and the medieval period.[22] Along the way the members of the Society aimed to propagate the Gospel and also establish and strengthen the position of the Roman Catholic Church within early modern Europe as well as their missional centers. Naturally, one of the tools that they used to aid in such cultural efforts was the explanation of science and mathematics, especially in the context of their schools and in the distribution of their printed books. A lot of attention has been given to the relationship between science and the Jesuits during the early modern period. Many of these studies have presented their investigations according to one of two different lines of interpretation

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[21] Mordechai Feingold, "Preface," in *Jesuit Science and the Republic of Letters*, ed. Mordechai Feingold (London: MIT Press, 2003), vii.

[22] A helpful starting place to understand the diverse cultural and intellectual contribution the Jesuits made are within the following volumes: John W. O'Malley, et al., eds. *The Jesuits: Cultures, Sciences, and the Arts, 1540–1773* (Toronto: University of Toronto Press, 1999); John W. O'Malley, et al., eds. *The Jesuits II: Cultures, Sciences, and the Arts, 1540–1773* (Toronto: University of Toronto Press, 2006); O'Malley and Bailey, eds. *The Jesuits and the Arts*.

Many studies have focused on identifying a particular "Jesuit" quality to their pattern of scientific investigation. This type of framing of the historical investigation shows significant influence from the "Merton thesis," and its belief that there are connections—whether economic or sociological—between scientific development and the social groups within which they occur. Because Robert Merton, who developed the thesis in a sequence of articles beginning in the 1930s, looked especially at the role of Puritanism on the formation of seventeenth-century English experimental science, this particular thesis (and its many adapted formulations) have significantly shaped analyses of science and religion in the decades following its inception.[23] Indeed, in a groundbreaking article on the Jesuits and science in 1989, the historian Steven Harris adapted the Merton thesis specifically to the Jesuits.[24] Similar historiographical interests are noticeable in the articles by William Ashworth, and more recently those of Mark Waddell or Sven Dupré.[25] The problem with these investigations, however, is that it assumes there was something identifiable as "Jesuit" which could be identified within the values and social structures of the Society of Jesus, and which could then be used to explain their particular form of science.[26]

A second prominent line of interpretation aims to identify positively that "real" science

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[23] Steven Shapin, "Understanding the Merton Thesis," *Isis* 79, no. 4 (1988): 594–605.

[24] Steven J. Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition." *Science in Context* 3, no. 01 (1989): 29–65.

[25] William B. Ashworth, "Light of Reason, Light of Nature. Catholic and Protestant Metaphors of Scientific Knowledge." *Science in Context* 3, no. 01 (1989): 89–107; Mark Waddell, *Jesuit Science and the End of Nature's Secrets* (Burlington, VT: Ashgate, 2015); Dupré, "The Return of the Species," in *Religion and the Senses*, ed. De Boer and Göttler, 473–87.

[26] Steven Harris explains the Merton thesis as "the elucidation of the scale of values uniting and motivating them (a group)"; Steven J. Harris, "Transposing the Merton Thesis," 30.

did indeed occur among the Jesuits. One of the chief instigators of this line of reasoning is the work of Mordechai Feingold.[27] The problem with these types of investigations, however, is that the framing of the question assumes the narrative of the scientific revolution, a historiographical framing which most historians no longer consider credible.[28] To assume that one needs to demonstrate positively the existence of science, is to assume that the narrative of the scientific revolution is the litmus test for the history of early modern science.[29] This particular framing of Jesuit science is the most prevalent, and is even noticeable in the recent book by Michael Gorman, *The Scientific Counter-Revolution*.[30] Despite the tremendous contribution that this work provides for the historiography of the Jesuits and science, the title itself betrays the framing of the Jesuits with respect to the scientific revolution.

This investigation borrows from each of these lines of research, and yet does so in a way that recognizes the historical circumstances within which the members of the Society of Jesus operated. So, rather than attempting to identify particular values of the Jesuits and then moving to explain their science from these, it instead locates the Jesuits within the broader historical

[27] Feingold, ed. *Jesuit Science and the Republic of Letters*; Mordechai Feingold, *The New Science and Jesuit Science: Seventeenth Century Perspectives* (Dordrecht: Kluwer Academic Publishers, 2003).

[28] For a helpful overview, see Kathleen Crowther, "The Scientific Revolution," in *The Oxford Handbook of Early Modern European History, 1350–1750*, ed. Hamish Scott (Oxford: Oxford University Press, 2015), 56–80.

[29] Other examples of analyzing the Jesuits with respect to the scientific revolution narrative, Michael Elazar, *Honorè Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks* (Dordrecht: Springer, 2011); Michael Elazar and Rivka Feldhay, "Jesuit Conceptions of Impetus after Galileo: Honoré Fabri, Paolo Casati, and Francesco Eschinardi," in *Emergence and Expansion of Preclassical Mechanics*, ed. Rivka Feldhay, et al. (Cham: Springer International Publishing, 2018), 285–323.

[30] Michael John Gorman, *The Scientific Counter-Revolution: The Jesuits and the Invention of Modern Science* (London: Bloomsbury, 2020).

context of the Reformation and Counter Reformation—or, as this dissertation contends, their "confessional" interests. Similarly, rather than using the narrative of the scientific revolution as the litmus test for science among the Society, the study first establishes the way many Jesuits valued vision and light and how they used optical instruments, and then it considers the degree to which these aspects cohere with the well-known narratives.

Such a framing also aids in the overall argument. As shown throughout, and argued in the conclusion, the Jesuits' relationship with early modern optics is best understood as "confessionalized science." To appreciate such a framework, it is necessary to consider this term.

Confessionalized Science

The framework employed in this dissertation is that of "confessionalized science." The term itself is inspired from the historiographic interest in "confessionalization" which first developed in the 1960s. This historiographical tradition used this term as a way to explain how the construction of confessions, and its attendant delimitation as to "who was in or out" shaped (and was shaped by) social, political, and intellectual interests and expressions. The term itself began as a way to explain Protestantism during the Reformation, especially within Germany. It also eventually came to explain not only Protestantism and its varieties, but also Catholicism. While it has been met with criticism, especially because it becomes difficult to determine when confessionalization ends and how confessional structures may explain the experiences of the non-elite, it is nevertheless a helpful analytic for this dissertation to identify how being Catholic shaped the explanation and significance of optics among prominent Jesuits.[31]

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[31] For a helpful overview of the development of the term and its associated problems, see Thomas A. Brady, "Confessionalization: The Career of a Concept," in *Confessionalization in Europe, 1555-1700: Essays in Honor and Memory of Bodo Nischan*, ed. John M. Headley, Hans

As the historian John O'Malley has helpfully indicated, the Jesuits in the sixteenth and seventeenth centuries, much less the Catholics, are not solely defined by their Counter-Reformation activities. There were many activities that the Jesuits participated in that were not directly related to the Counter Reformation or Reformation more broadly. For instance, the Jesuits engaged in certain well-known activities, such as the book trade and early modern education, which were not in themselves an activity explicitly intended as a counter to the Reformation. Many of these aspects may better be understood as activities of "early modern Catholicism," which is the term that O'Malley prefers.[32] Yet, O'Malley's critique aside, this dissertation will nevertheless show how the term "confessionalization" may be helpfully employed to identify key aspects of the interplay between science and religion among members of the Jesuit Order. Based on the analysis in the previous section, it is noticeable that the term is also helpful for framing the explanation of science among the Jesuits. By locating the expression of religion within a particular historical context and geography, confessionalization allows one to avoid some sort of essential relationship between "science" and "religion," while still paying close attention to the interaction between the two.[33]

In the context of the Society of Jesus and early modern optics, confessional interests notably shaped the Jesuits' path forward. This occurred in diverse ways, some quite subtle and others explicit. At the time when the Jesuits formed, the theory of optics underwent such drastic changes that the traditional presentations of sight and cognition were anything but stable. In this

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J. Hillerbrand, and Anthony J. Papalas (London: Routledge, 2017), 1–20.

[32] John W. O'Malley, "The Historiography of the Society of Jesus," in *The Jesuits*, 25.

[33] Rienk Vermij, *Thinking on Earthquakes in Early Modern Europe: Firm Beliefs on Shaky Ground* (Abingdon, UK: Routledge, 2021), 3–4.

context, confessional interests, in the form of the pedagogical curriculum as well as philosophical perspectives, shaped the path of the Jesuits throughout the optical chaos. These aspects, while influenced by pedagogical and institutional dynamics, had a mostly subtle influence on the transformation of optics. Other aspects, such as the identification of optical theories which had to be avoided, were much more explicit. Both subtle and explicit confessional efforts are present in this dissertation, and as a result the dissertation presents a complex story about the transformation of optics among the Jesuits during the early modern period.

One important outcome of this study is an explanation as to how the Jesuits transitioned their optical theory from “sight” to “light.” In the most ironic twist of all, it was the confessionalization of optics, which at one time enabled the Jesuits to maintain traditional patterns of optics, which enabled them to transition from “sight” to “light.” This surprising aspect, explained in Chapter Five, also indicates the flexibility that the term “confessionalization” brings with it, one which allows for the various contingencies inevitable in a historical analysis. Thus, as this dissertation demonstrates, confessionalization not only enabled many members in creating their theories of optics, oftentimes in support of traditional views, but in the second half of the seventeenth century it also enabled their ultimate transition away from the previous optical theories.

Argument Outline

In this dissertation I argue that the engagement of the Society of Jesus is best interpreted through their confessional interests. In an ironic twist, such interests both shaped their preservation of important aspects of perspectivist optics in the first half of the seventeenth century, while at the same time providing a path forward in the transformation of optics in the second half of the seventeenth century. The path from "sight" to "light" was that of confessionalization, but not in a linear path forward. Aside from reclaiming the dynamics of confessionalization in early modern optics (and science more broadly), it is hoped this dissertation will also problematize certain long-held assumptions regarding the transformation of early modern optics in the seventeenth century, since the path of the Jesuits within the development of optics departs from the standard narrative of the scientific revolution at important junctures.

This argument unfolds in five chapters. In Chapter One I explain the nature of optics during the period under consideration, 1540–1700. I lay out the nature of the perspectivist optical understanding and the important changes that occurred during the seventeenth century. Important in this chapter is the recognition that at the time the Society of Jesus formed, optics was undergoing a theoretical crisis. One of the important implications of this is that optics could be made to mean nearly anything.

In Chapter Two, I establish the way in which Jesuit optical interest developed as a path forward amidst changes in contemporary optical theory. The time at which this occurred was during the second generation of Jesuits, as they developed the pedagogical curriculum that would shape their efforts for years to come. What becomes apparent is that the development of Jesuit optical theory was intended to cohere with the broader visual and philosophical interests of the Jesuits. To establish this point, I consider the first two Jesuit works on optics, Juan Bautista Villalpando's *In Ezechielem explanationes* (1595–1604) and Franciscus Aguilonius's *Opticorum libri sex* (1613). Both texts demonstrate a strong overlap despite the fact that the authors neither studied together nor had a common geographical location.

It will also be clear, as Chapter Three addresses, why Johannes Kepler's *Ad Vitellionem* *paralipomena* was not problematic for the Jesuits to integrate. Relocating vision to the retina, as Kepler proposed, did not disrupt the Jesuit psychology of sight, even though it introduced important changes to the traditional understanding of how vision occurred. Instead, as the Jesuits consistently argued, both Kepler's theory and the more traditional view could be maintained at the same time. As this chapter will show, understanding how this occurs not only reveals important ways in which the Jesuits understood optics, but also demonstrates the dynamics of disciplinary relationships, such as how physics and mathematics relates, but also how optical theory supported the explanation of the Eucharist. Thus, the Jesuits' adoption of Kepler's optics is quite intelligible within their context and coheres with their wider confessional interests.

Chapter Four addresses the explanation of optics in the context of optical illusions. As will be shown, in some sense the members of the Society of Jesus who performed optical illusions, used them as a means toward defending traditional accounts of vision. Important in this explanation is the role of social intellectual jokes in the communication of seemingly contradictory ideas as well as the way such social jokes were communicated using important theological concepts. In the final chapter, Chapter Five, I demonstrate the unexpected twist that confessionalization itself supported the transition among the Jesuits from optics explaining "sight" to optics explaining "light." Thus, while many of the chapters have an emphasis on the role of confessionalization in the transformation of optics among the Jesuits, it will be Chapter Five where these issues become particularly evident.

In a study of this scope it is inevitable that certain materials will be left out, but what is presented proves persuasive enough not only to demonstrate the importance of confessionalization for giving shape to the science of the Society of Jesus, but also to aid future research on topics of similar scope.

CHAPTER ONE
EARLY MODERN OPTICAL KNOWLEDGE

Western optical theory prior to 1600 centered on the explanation of sight. This aspect, derived from the principles of the medieval optical tradition known as *perspectiva*, influenced many features of optics through the seventeenth century. Such explanations of sight would refer to, inter alia, mathematical principles, anatomical investigations of the eye, and study of reflection in mirrors or refraction in water. By the end of the 18th century however, due to in no small part to Newton and his influence, western optical theory converged into the understanding of light. This dramatic shift, from sight to light, occurred during the period from 1600 to 1700, as the understanding and explanation of optics transformed profoundly and cycled through many different iterations that helped to codify and explain both the preceding *perspectiva* tradition as well as modern western optical theory. This watershed century is the focus of this dissertation.

Optical knowledge provided immense utility in the early modern period as it could be used to construct new buildings, improve astronomical calculations, locate an approaching army or nautical features, inform the identity and composition of the human soul, or captivate the attention of the early modern public through the creation of anamorphic artwork.[34] Optical knowledge also provided the techniques and mechanics for early modern theatre, where one

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[34] Sven Dupré, "Images in the Air: Optical Games, Magic and Imagination," in *Spirits Unseen: The Representation of Subtle Bodies in Early Modern European Culture*, ed. Christine Göttler and Wolfgang Neuber (Leiden: Brill, 2008), 71–92; Richard Turck, "Optics and Sceptics: The Philosophical Foundations of Hobbes's Political Thought," in *Conscience and Casuistry in Early Modern Europe*, ed. Edmund Leites (Cambridge: Cambridge University Press, 1988), 235–63; Enrique García Santo-Tomás, "Fortunes of the Occhiali Politici in Early Modern Spain: Optics, Vision, Points of View." *PMLA* 124, no. 1 (2009): 59–75; Yvonne Petry, "Vision, Medicine, and Magic," in *Religion and the Senses in Early Modern Europe*, ed. Wietse de Boer and Christine Göttler (Leiden: Brill, 2013), 455–72.

could project all sorts of specters, ghosts, and images, and at the same time shaped more mundane aspects of daily life, such as the technology of eyeglasses for the improvement of ordinary, daily vision.[35] The knowledge of optics even proved to be a lucrative endeavor whereby the skills of the practical artisan came to be as important, if not even more important, than the natural philosopher.[36]

Optical knowledge also provided important philosophical explanations in the early modern period. Such an emphasis upon the philosophical explanatory power of optics did not originate in the period but developed out of the tacit expectations that had come to be attached to optics within previous periods, particularly within the perspectivist tradition. Not only did many individuals believe that optical theory should explain vision, light, artistic and architectural design, but that it also explained religious experience, demonic and preternatural activity, political authority, and justified the reliability and trustworthiness of the bodily senses and thus the foundations of philosophical knowledge itself. It is for this reason that optics, as the historian A. Mark Smith has argued, was ultimately about "sight" and not about "light," and served as a veritable "paradigm" for the knowledge of many different aspects.[37] It is because of the paradigmatic status of optics in the period before the early modern that optics and theology came to be closely intertwined, a relationship that was somewhat tacitly maintained because of the

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[35] Mary Thomas Crane, "Optics," In *Early Modern Theatricality*, ed. Henry S. Turner, (Oxford, UK: Oxford University Press, 2013), 250–269.

[36] For instance, Sven Dupré, "Ausonio's Mirrors and Galileo's Lenses: The Telescope and Sixteenth-Century Practical Optical Knowledge." *Galilaeana* 2 (2005): 1000–38; also Rienk Vermij, "Instruments and the Making of a Philosopher. Spinoza's Career in Optics." *Intellectual History Review* 23, no. 1 (2013): 65–81.

[37] A. Mark. Smith, "Saving the Appearances of the Appearances: The Foundations of Classical Geometrical Optics." *Archive for History of Exact Sciences* 24, no. 2 (1981): 73–99; Smith, *From Sight to Light*, 2.

instrumental role of optics in the explanation of sight and cognition.[38]

Yet, ironically enough, despite its paradigmatic importance, optical knowledge came to be increasingly uncertain in the early modern period. Optical technologies, such as the microscope and the telescope, and new social and cultural contexts introduced new questions beyond the scope of the inherited optical paradigms and their uniform explanatory power. While such uncertainties did not diminish the study of optics, but actually increased attention to its subject matter, they nevertheless call into question the status of optics as possessing a singular paradigmatic nature. As a result, to an extent, when one considers the big picture in early modern optics, without a clearly delineated paradigm, one could very well argue that there was no such thing as optics in the early modern period, despite the popularity of the field among early modern intellectuals. As this dissertation explores, this collapse of optical theory becomes even more interesting in the context of the religious changes of the Reformation and Counter Reformation in which one of the pressing issues was itself the explanation of sight and the way in which visual knowledge is construed.[39]

The commingling of these juxtaposed characteristics, both the popularity of optics as well as its theoretical uncertainty, has oftentimes escaped the historiography of optics within the period.[40] The actors of the period, as well as the historians who have written about them,

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[38] One of the more interesting accounts of this aspect is Dallas G. Denery, *Seeing and Being Seen in the Later Medieval World: Optics, Theology, and Religious Life* (Cambridge, UK: Cambridge University Press, 2005).

[39] One person who has also questioned such a connection is Matthew Milner, *The Senses and the English Reformation* (Burlington, VT: Ashgate, 2011), 25–28.

[40] Outliers to this trend are the following: Stuart Clark, *Vanities of the Eye: Vision in Early Modern European Culture* (Oxford: Oxford University Press, 2007), 6; Jurgis Baltrušaitis, *Anamorphic Art*, trans. W. J. Strachan (New York: Harry N. Abrams, Inc., 1977); Rosalie Colie, *Paradoxia Epidemica: The Renaissance Tradition of Paradox* (Princeton, New Jersey: Princeton

oftentimes refer to the mathematical precision of optics to aggrandize the clarity and confidence that optical knowledge could provide, whittling the concept into a manageable paradigm instead of wrestling with its broader context. Yet, oftentimes the most ardent defenders of optical clarity of the period argued for such conclusions alongside the illusory nature of optics.[41] Recognizing this symbiotic relationship between the clarity and illusory nature of optics in the early modern period is an important perspective not only for the modern historiography of optics, but also to make intelligible the various ways in which the members of the Society of Jesus engaged such a topic. As this chapter argues, the foundation of modern mathematical optics—to the extent that it did occur in the seventeenth century—occurred not as a natural conclusion or development from the past, but instead to create the new foundations of optical knowledge at a time when many early moderns lost their optical nerve.

Perspectivist Optics

The optical backbone of the early modern period was perspectivist optics. This learned tradition, which began in the 11th century with the Arabic intellectual, Ibn al-Haytham (965–1040), entailed a highly synthetic account of visual cognition from the Greek traditions of Aristotelian natural philosophy, Euclidian geometry, and Galenic physiology. Al-Haytham's synthesis later became known to the Latin West chiefly through the work of Robert Grosseteste (ca. 1168–1253), Albertus Magnus (ca. 1200–1280), Roger Bacon (ca. 1214–1292), John Pecham (d. 1292), and Erasmus Witelo (ca. 1230–1280). Understanding the basic elements of

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University Press, 1966); Lyle Massey, *Picturing Space, Displacing Bodies: Anamorphosis in Early Modern Theories of Perspective* (University Park, PA: Penn State Press, 2007).

[41] Lyle Massey argues this with respect to Descartes in Massey, *Picturing Space, Displacing Bodies*.

this optical tradition is integral to understanding the intellectual expectations given to optics in the early modern period, since early modern optics developed against the background of the perspectivist optical thought.

As the historian A. Mark Smith has cemented within the historiography, perspectivist optics is about "sight" and not about "light."[42] In other words, it provides a theoretical system explaining how vision mediates cognition between the mind and the external world. Perspectivist optical theory describes the visual world using three terms—lux, lumen, and color—two of which (lux and lumen) mean "light," albeit with two different meanings. Every self-luminous object radiated *lux* from an infinite number of locations in every direction. Such radiation occurs through the quality of *color*, which moves from the object to the eye in a straight path in the form of a *visual species* through a medium made transparent by the *lumen*, to the anterior surface of the eye. At this point visual sensation occurs as color, touching the surface of the eye like a seal touches wax, transmits the quality of color to the *visual humor* within the inner part of the eye itself.

An important aspect to note is that the *visual species* is an immaterial quality that lacks spatial extension. Yet, it operates and transmits to the eye according to mathematical properties and is based on the belief that every object emanates representations of itself in every direction. As it relates to vision, those that are the most perpendicular between the eye and the object are the strongest and so account for vision. Those that are oblique are refracted and are weaker. Perspectivist optical theory imagines what is known as a *visual pyramid*, between the anterior surface of the eye and the object seen, with the vertex located at the outer surface of the eye and

[42] A. Mark Smith, "Getting the Big Picture in Perspectivist Optics." *Isis* 72, no. 264 (1981): 568–89.

extending out to the object of sight. The species of the visualized object move between the object to the vertex according to the shape of the pyramid. So, while the species within the eye is not a mathematical object or anything that is corporeal, it takes on the form of the object it represents and its movement and efficacy is explained according to principles drawn from mathematics.[43]

The next stage in the visual process is the transformation of the visual species into an *intentional species*, and its subsequent transmission to the optic nerve at the back of the eye. The process of visual perception occurred through the analysis of the species in diverse areas of the brain. While Euclidean geometry explained the movement of the species between the eye and the object, it was generally recognized that after the species entered the eye, that it would move in non-rectilinear patterns, through the humors, the optic nerve, and into the proper location of the brain.[44] From all of this it should be clear that the reason such a process has been described as being about sight and not about light largely pertains to the aims of perspectivist optics, where sight itself is the end goal of the process, with the transformation of the species from a visual species to an intentional species and its subsequent reception in the various faculties of the mind.

It is valuable to note that while light-radiation was involved in the visual process, since it was both the property of an object which enabled color and the medium through which color was transported, it nevertheless was not a formal object of inquiry or explanation. It is for this reason that the optical tradition of burning mirrors, which explained how glass and other transparent materials could be used to focus light rays, circulated with minimal interest within the texts of

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[43] For an overview see Lindberg, *Theories of Vision*, 109–16.

[44] A. Mark Smith, *From Sight to Light*, 181–227; A. Mark Smith, "What is the History of Medieval Optics Really About?" *Proceedings of the American Philosophical Society* (2004): 180–94.

perspectivist optics.[45] The fire created by the burning mirrors was thought to be separate from the boundaries of perspectivist optics, although such a relationship would change in the sixteenth century in the context of improved glass as burning mirrors were thought not only to explain light but also became a topic related to the theory of image projection.

The thoroughgoing applicability of perspectivist optics to the late-medieval period spread beyond its constituent fields of geometry, natural philosophy, and human anatomy, to as diverse fields as philosophy, theology, art, architecture, and literature.[46] There is also some suggestion that during this time period, perspectivist optics, and its understanding that light transported color, came to be an important religious metaphor for understanding the experience of stained glass windows within late-medieval cathedrals, as the experience of the light through the color provided a tangible engagement with the image.[47] Indeed, throughout the medieval period the commingling of light and color, particularly within stained glass windows, came to be an important visual representation of the virgin birth, as the light itself came to be embodied within colored glass—the visual experience of which came to be associated with Mariology.[48]

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[45] Gérard Simon, "Behind the Mirror," *Graduate Faculty Philosophy Journal* 12 (1987), 311–50.

[46] Katherine H. Tachau, *Vision and Certitude in the Age of Ockham: Optics, Epistemology, and the Foundations of Semantics, 1250–1345* (Leiden: Brill, 1988); Robert Pasnau, *Theories of Cognition in the Later Middle Ages* (Cambridge: Cambridge University Press, 1997); Suzanne Conklin Akbari, *Seeing Through the Veil: Optical Theory and Medieval Allegory* (Toronto: University of Toronto Press, 2004); Dallas G. Denery, *Seeing and Being Seen in the Later Medieval World: Optics, Theology, and Religious Life* (Cambridge, UK: Cambridge University Press, 2005); Peter Brown, *Chaucer and the Making of Optical Space* (Oxford: Peter Lang, 2007).

[47] Rayna Kalas, *Frame, Glass, Verse: The Technology of Poetic Invention in the English Renaissance* (Ithaca: Cornell University Press, 2007), 41.

[48] Cynthia Hahn, "Visio Dei: Changes in Medieval Visuality," in *Visuality Before and Beyond the Renaissance: Seeing as Others Saw*, ed. Robert S. Nelson (Cambridge, UK: Cambridge University Press, 2000), 181.

From all of this, it should not be a surprise, then, to learn that from 1300–1600 there was significant manuscript attestation of perspectivists' works, and from 1450–1700 there were numerous printed editions of the works. For instance, A. Mark Smith notes over 210 manuscripts within the perspectivist tradition in this period. The *Perspectiva* of John Pecham (d. 1292) was published first in 1483 and was reprinted nine times throughout the sixteenth century, including an Italian translation.[49] The most significant publications of perspectivist optics came in two editions of Witelo's *Perspectiva*, the 1535 edition edited by Georg Tannstetter and Petrus Apianus, and the 1572 edition, published alongside Ibn al-Haytham's optics in Latin translation, produced by Frederic Risner.[50]

That the perspectivist system was still expected to explain sight may be noticed in the opening page of Risner's 1572 edition. There it states: "There are three types of vision: Optics, Catoptrics, and Dioptrics."[51] Throughout the seventeenth century it was common for the standard categories of optics—optics, catoptrics, and dioptrics—to be referenced as the three types of vision. While the use of mirrors in optics (catoptrics) and the use of lenses (dioptrics) were often designated as their own category with their own terms, conceptually these three should be understood as all part of the much broader category of optics, an organization that stretches from the ancient period up into the early modern period. Optics as a category could show up in a wide

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[49] Smith, *From Sight to Light*, 278; David Lindberg, "Introduction," in *John Pecham and the Science of Optics: Perspectiva Communis*, ed. David C. Lindberg (Madison, University of Wisconsin Press, 1970), 29–30.

[50] Witelo, *Vitellonis Mathematici doctissimi peri optikes*, ed. Georg Tannstetter and Petrus Apianus (Nuremberg: Joann Petreius, 1535); Alhacen, *Opticae Thesaurus Alhazeni Arabis libri September, nunc primum editi*, ed. Federico Risnero (Basil: Episcopios, 1572).

[51] Alhacen, *Opticae Thesaurus Alhazeni Arabis*, verso of title page: Triplicis visus, directi, reflexi & refracti, de quo optica disputat, argumenta.

variety of literature, such as theological works, scientific works, as well as poetry, to name a few.[52] One of the biggest intellectual questions regarding optics within the period was the degree to which these three optical categories related to the practice of vision. Investigating this question significantly shaped the Jesuits' approach to optics.

Certain important changes occurred during the sixteenth and early seventeenth centuries which introduced new questions about the legitimacy of perspectivist optics and the degree to which optics explained sight.

Sixteenth-Century Developments

Perspectivist optics went through a transformation due to novel cultural and scientific developments in the sixteenth century, which eventually laid the groundwork to some of the major changes seen in the early modern optical tradition. This transformation was largely on account of the improved techniques in making glass and mirrors by Venetians, which were then widely traded abroad.[53] The new glass-making techniques contributed to a cultural interest in mirrors and a discussion on the boundaries between what was seen and what was unseen, as well as a general increased use of instruments that made use of glass and reflective substances.[54] A considerable amount of the interest in mirrors and reflection pertained to the metaphorical and

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[52] For a recent example on the relationship between optics and poetry see Jane Partner, *Poetry and Vision in Early Modern England* (Cham, Switzerland: Palgrave Macmillan, 2018).

[53] Sven Dupré, "Trading Luxury Glass, Picturing Collections and Consuming Objects of Knowledge in Early Seventeenth-Century Antwerp." *Intellectual history review* 20, no. 1 (2010): 53–78.

[54] Yvonne Yiu, "The Mirror and Painting in Early Renaissance Texts." *Early Science and Medicine* 10, no. 2 (2005): 187–210; Nancy Frelick, ed. *The Mirror in Medieval and Early Modern Cultures: Specular Reflections* (Turnhout, Belgium: Brepols, 2016); Nancy Frelick, "Introduction," in *The Mirror in Medieval and Early Modern*, 1–29.

abstract, but the prevalence and improvement of the actual device definitely contributed to interest in the mechanics and mathematics of vision.[55]

Thus, alongside the ongoing tradition of perspectivist optics in the sixteenth century, there developed a tradition of practical mathematics, on mirrors and lenses, which continued into the seventeenth century. The knowledge of practical optics, such as what could be performed by optical instruments and materials such as glass and mirrors, made significant transformations to optics in the sixteenth century. It is important to note that such efforts coincided with the rise of the mathematician within European intellectual contexts such that the knowledge of mathematics provided an important avenue through which one could address the loftier goals of natural philosophy.[56] As a result mathematical knowledge could be leveraged as a source of philosophical knowledge.

The relationship between practical mathematics and optics also extended into the realm of human anatomy. An example of this was an increased understanding of the human anatomy, and with it, a greater understanding as to how the eye functioned. For instance, Andreas Vesalius (1514–1564), Realdo Colombo (ca. 1515–1559), Felix Platter (1536–1614), Jacques Guillemeau (1550–1612), André de Laurens (1558–1609) and Helkiah Crooke (1576–1635), all interpreted the functionality of the eye as like an "internal eyeglass" which could magnify "anything written or imprinted." Colombo himself assumed that the invention of the eyeglass followed from the

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[55] A helpful overview that makes this point, although in a broader context is Mark Pendergrast, *Mirror Mirror: A History of the Human Love Affair with Reflection* (New York: Basic Books, 2004).

[56] As an example, Sven Dupré, "Ausonio's Mirrors and Galileo's Lenses: The Telescope and Sixteenth-Century Practical Optical Knowledge." *Galilaeana* 2 (2005): 1000–1038.

recognition of the eye's analogy to a crystalline lens.[57]

The context of the anatomical investigations also proved important for the philosophical understanding as to how the mechanism of vision worked, particularly the debate over *intromission* and *extramission*. The argument centered upon whether vision occurred by visual rays proceeding from the eye to the object (extramission), or whether they proceeded from the object to the eye (intromission). While the difference of understanding involved the disciplinary division between mathematics and physics, it had a tangible component in the practical application of the theory: physicians of the sixteen and seventeenth centuries determined the functionality of the eye as an analogy of glass lenses. What this meant is that when they worked to correct sight with eyeglasses, they typically operated off assumptions drawn both from intromission and extramission models of vision to correct the visual process. So, for instance, while physicians might subscribe to the passive philosophy of intromission, wherein images enter the eye, the active model of extramission provided a powerful explanatory principle for understanding how eyeglasses might aid in the correction of vision.[58] What this means is that the technology of optics, particularly eyeglasses, albeit seemingly mundane, could provide a site of active philosophical debate about fundamental questions of vision, epistemology, and cognition.

These technological developments also created questions that bordered on the fanciful and the preternatural. One example of this is natural magic. Natural magic was a scientific tradition that flourished in the Renaissance and early modern period, which claimed to be able to work wonders because of its knowledge of the hidden (though natural) properties of things.

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[57] Quoted in Reeves, *Evening News*, 139–140.

[58] Katrien Vanagt, "Suspicious Spectacles. Medical Perspectives on Eyeglasses, the Case of Hieronymus Mercurialis," in *The Origins of the Telescope*, 118–120.

These were often referred to as “secrets of nature.”[59]

The rise of natural magic, as will be discussed in detail later, is important to dwell on as it will unite the aims of Johannes Kepler (1571–1630) and the Society of Jesus. Both not only sought to develop improved representations of the underlying mathematics involved in optics, but also sought to diminish the popular appeal of the natural magicians. At the moment, however, the point to note is that the sixteenth century produced more optical instruments, texts, and questions, some of which introduced questions foreign to the perspectivist tradition, but which were nevertheless important pressing optical questions at the time. Johannes Kepler's critique of the perspectivist tradition was not entirely mounted against the tradition itself, but against natural magic traditions of the time. Thus, it is important to delve into a brief exposition on natural magic to understand how Kepler and eventually the Society of Jesus responded to this movement.

Of the natural magic works in the sixteenth century, Giambattista della Porta's (1535–1615) *Magia naturalis*, first published in 1558 in four books, and then in 1589 in an expanded twenty books, was likely the most popular. Within these editions, it is noticeable that Della Porta took a particular interest in optics, as it not only was included in the shorter first edition, but in the second edition was also expanded considerably. Della Porta also composed a second book, explicitly on refraction, *De refractione* (1593), and as a result recognized himself as being the first to discover the telescope.[60]

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[59] William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton: Princeton University Press, 1994).

[60] Arianna Borrelli, “Thinking with Optical Objects: Glass Spheres, Lenses and Refraction in Giovan Battista Della Portas Optical Writings.” *Journal of Early Modern Studies* 3, no. 1 (2014): 39–61; Paolo Galluzzi, “The Secret of the Eyeglass,” in *The Lynx and the Telescope* (Leiden: Brill, 2017), 1–24.

For those interested in optics the seventeenth century, however, Della Porta's Book 17 in the second edition of the *Magia naturalis* was his most widely noted contribution. In this book Della Porta explains several optical devices, such as burning mirrors, various image reflections and mirrors, as well as various ways to cast an "image into the air," a trick that captured the imagination of many in the early modern period and which will be given more analysis later. Della Porta also included an extensive analysis of the topic of burning mirrors, a topic which (as noted above) was not officially within the perspectivist tradition but which came to be significant in the standard optical tradition of the seventeenth century. Della Porta's inclusion of burning mirrors especially demonstrates the way in which the natural magic tradition proved to be an important genre for the transmission and interest in important areas of early modern optics.

Among the tricks which captivated the imagination of those in early modern Europe, however, pertained to one technique whereby one might project an "image into the air." Della Porta writes,

> That by night an Image may seem to hang in the Chamber: In a tempestuous night the Image of any thing may be represented hanging in the middle of the Chamber, that will terrifie the beholders. Fit the Image before the hole, that you desire to make to seem hanging in the Air in another Chamber that is dark; let there be many Torches lighted round about. In the middle of the dark Chamber, place a white sheet, or some solid thing, that may receive the Image sent in: for the spectators that see not the sheet, will see the Image hanging in the middle of the Air, very clear, not without fear and terror, especially if the Artificer be ingenous.[61]

The published record of early modern optics demonstrates how many individuals sought to recreate this trick and utilize it to interpret important aspects of optics, vision, and religion. The trick relies upon the viewer not noticing the sheet hanging in the air, and so its power is in the trick. But the conceptual framework for it raised many important questions about the nature

[61] Giambattista Della Porta, *Natural Magick* (London: Printed for John Wright, 1669), 365.

of light and images, and it is for this reason that it will be given more attention in Chapter Four below.

Alongside Della Porta, one could also place John Dee's (1527–1608) edition of Euclid, the activity of Oronce Fine (1494–1555) in Paris, and many others who show interest in optical natural magic in the context of the sixteenth century. It is undoubtedly for this reason that the earliest editions of Witelo as well as the popular edition of Euclid's *Optica et catoptrica* (1557) by Jean Pena (1528–1558), all underlined the importance of learning optics so that one was not tricked by the optical illusions often utilized by charlatans. As Jean Pena says in his Preface titled, "De usu Optices," one important implication of improved optical instruments, is the way in which one may be deceived in their vision. Of those who deceive, he notes how "cunning women" "fool the eyes of men" with their mirrors into believing that they see images which do not actually exist.[62] It is likely because of such a context that the editor of Witelo's text, Frederich Risner, explained in the preface of his 1606 work on optics, *Opticae libri quatuor ex voto Petri Rami* that the purpose of learning optics is "to judge the truth and falsehood of the visible things accurately and carefully."[63] The fact that both Pena and Risner mention numerous optical illusions that could be produced using optical tools, such as ghosts, images in the air, and demons, demonstrate how the techniques of optical illusions, largely set aside in the perspectivist tradition, became a way to show the appeal of obtaining optical knowledge.

The sixteenth-century developments in themselves did not bring an end to perspectivist

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[62] Jean Pena, "De usu optices," in *Euclidis Optica et catoptrica*, ed. Jean Pena (Paris: Andreas Wechulus, 1557), bbivr: Quid ergo prohibet mulieres versutas hoc speculo, hominum oculos ludificare, ut evocatos manes mortuorum se videre existiment, cùm tamen aut pueri aut statuae alicuius delitescentis simulacrum in aëre extra speculum videant?

[63] Quoted in Sven Dupré, "Images in the Air," in *Spirits Unseen*, 73.

optics. What they did do, however, is to garner a significant interest in optical theory among the public, particularly on account of the popular tricks that could be performed through improved glass and mirrors. The role of natural magic in shaping the expectations of sixteenth-century optics is difficult to overstate and is quite apparent as one turns toward the more well-known optical developments of the seventeenth century.

The Keplerian Turn

In 1604 Johannes Kepler produced a sharp critique of the perspectivist system in his *Ad Vitellionem paralipomena*. In this work he effectively separated the task of the individual working on mathematical optics from the natural philosopher, establishing a tradition within optics that contributed to the undermining of the perspectivist system in the seventeenth century. In understanding Kepler, however, it is necessary to note that his critique of optics arose out of a culture of visual tricks and illusions, and not one that was incipient to the later mechanical philosophy or merely theoretical traditions.[64]

Kepler never intended to undermine the perspectivist tradition. In 1602, two years before the *Ad Vitellionem* was published, Kepler mentioned in a letter to his patron Herwart von Hohenburg that he intended the book as a prelude to his new astronomy, providing him with the principles of a "Universal Astronomy."[65] Thus, as he states in the "Preface" to the *Ad Vitellionem*

[64] This is in contrast to the following: Straker, "Kepler, Tycho, and the 'Optical Part of Astronomy'," 267–93; Lindberg, *Theories of Vision*; Smith, *From Sight to Light*; Gal and Chen-Morris, "Baroque Optics and the Disappearance of the Observer," 191–217.

[65] Kepler mentions this in a book to Herwart von Hohenburg in 1602, two years before the publication of his *Ad Vitellionem*. See Raz Chen-Morris, *Measuring Shadows: Kepler's Optics of Invisibility* (University Park, PA: Penn State Press, 2016), 3.

> Because all celestial observation takes place through the mediation of light or shadow, and because the media between the stars and the eye have a variety of modifications, and because those things that we observe in the heavens are either motions…or arcs…or luminous bodies…hence arises the third, *optical*, part of astronomy.[66]

Nevertheless, woven throughout his reframing of Witelo's optics were the following four methodological contributions to visual optics, which had a noticeable impact on the following century: redefining the ontology of light; explaining the camera obscura; redefining the physiology of the eye; and, perhaps most importantly, introducing the distinction between two types of visual representations, "pictures" and "images," the former being the object seen and the latter being the object imagined.

The first of these methodological contributions, redefining the ontology of light, came in the opening section of the work. As previously mentioned, while perspectivist optics used light as an instrument to explain the process of vision, it in itself was not physical. For Kepler, however, light itself was the offshoot of sphericity, with both light and sphericity images of the Divine Trinity. In such an explanation God was at the center of the sphere, the circumference was Jesus Christ, and the space between the Holy Spirit. The uniqueness of his explanation, which has strong resonances with a Neoplatonism, mixed with his own particular Lutheran interests, provided Kepler with a metaphysical understanding of light that enabled him to understand the visual process as, in its essence, mathematical.[67] In the process he eliminated the need for visual qualities or visual species and in its place explained that light was in itself a physical-mathematical entity, a point of subtle distinction but nevertheless important for grasping

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[66] Johannes Kepler, *Optics: Paralipomena to Witelo & Optical Part of Astronomy*, trans. William H. Donahue (Santa Fe: Green Lion Press, 2000), 3.

[67] David Lindberg, "The Genesis of Kepler's Theory of Light: Light Metaphysics from Plotinus to Kepler," *Osiris* 2 (1986): 4–42; Owen Gingerich, "Kepler's Trinitarian Cosmology," *Theology and Science* 9, no. 1 (2011): 45–51.

the vision that Kepler had for his optics.[68]

The impact of his analogy becomes apparent when considering his explanation of the camera obscura and its analogy to the eye. Although the camera obscura was known among the perspectivists as a way to record an eclipse, it had become in the sixteenth century one of the most entertaining and imaginative optical feats within early modern Europe, largely through the publications of Giambattista Della Porta. In fact, when Kepler explains the understanding of the camera obscura, in Chapter Two of his *Ad Vitellionem*, he does so by directly addressing Della Porta's optical trick utilizing the camera obscura. The aspect which Kepler criticized Della Porta for was the failure on Della Porta's part to explain the theoretical foundations of the camera obscura; Della Porta only wished to explain an application of it. In particular, the point that Kepler wished to make about the camera obscura was a clarification as to why the image projected through the aperture was a luminous object, and not the shape of the aperture. His explanation is based upon his understanding of light as essentially geometrical. As a result, the projected image contains numerous overlapping luminous points, rather than an image of the actual luminous body as would be the view of the perspectivists.[69]

Kepler's most profound explanation of the camera obscura came when he compared its functionality to that of eye. Such an explanation, as Kepler notes, is rooted in the work of a late-sixteenth century anatomist. The anatomist whom Kepler borrows the analysis from is Felix Platter, whose optical and anatomical understanding, while possessing its own ingenuity, nevertheless was more derivative from his contemporaries than most of the historiographical on

[68] Kepler, *Optics*, trans. Donahue, 19.

[69] Kepler, *Optics*, trans. Donahue, 68–71.

Platter has recognized.[70] For Kepler, however, the significant aspect within Platter was the analogy Platter drew between the eye and the camera obscura. Such a comparison provided an important angle to critique certain errors within the perspectivist understanding of vision. As Kepler notes

> Optical writers say it is an image (*imaginem*), when the object itself is indeed perceived along with its colors and the parts of its figure, but in a position not its own ...An image (*imago*) is the vision of some object conjoined with an error of the faculties contributing to the sense of vision. Thus, the image is practically nothing in itself, and should rather be called imagination.[71]

Through this explanation, Kepler, and particularly his reception, contributed to the demise of the perspectivist optical system. Nevertheless, the camera obscura and human cognition itself still necessitates an explanation as to what occurs in the visual process. As a result, Kepler states the following later in Chapter Five: "Since hitherto an Image has been a Being of the reason, now let the figures of objects that really exist on paper or upon another surface be called pictures."[72]

When considering Kepler's optics it is worthwhile to reemphasize a point that is often quickly passed over within Kepler's *Ad Vitellionem*, namely the way in which Kepler's optics came about within a context of what might be called *visual jokes*, a term which historians have adopted to address the various tricks of vision within the early modern period.[73] It is for this reason that Kepler engaged Della Porta's explanation of the camera obscura. The broader

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[70] On this point, see Baker, "Color, Cosmos, Oculus," 154.

[71] Kepler, *Optics*, trans. Donahue, 77.

[72] Kepler, *Optics*, trans. Donahue, 210.

[73] Paula Findlen, "Jokes of Nature and Jokes of Knowledge: The Playfulness of Scientific Discourse in Early Modern Europe.," *Renaissance Quarterly* 43, no. 2 (1990): 292–331.

intrigue of visual and optical jokes will be given more attention later in this chapter, but on account of its under explored importance in Kepler's optics, a few comments are important to make here.

Although Kepler does not belabor the point, he too was deeply impressed by his own experience of a camera obscura at the Dresden Kunstkammer, a court museum of sorts, in which many intellectual and social jokes were topics of frequent interest.[74] Reflecting on this experience Kepler states

> I saw at Dresden in the elector's theater of artifices ... A disk thicker in the middle, or a crystalline lens, a foot in diameter, was standing at the entrance of a closed chamber against a little window, which was the only thing that was open, slanted a little to the right. Thus when the eyesight travelled through the dark emptiness, it also, fortuitously, hit upon the place of the image, nearer, in fact, than the lens. And so since the lens was weakly illuminated, it did not particularly attract the eyes. But the walls were also not particularly conspicuous through the lens, because they were in deep darkness.[75]

Yet, the importance of visual jokes is nearly entirely missed within the historiography of Kepler, likely because it does not address the continuity debate about Kepler's optics, namely whether Kepler's optics marks a separation from the perspectivists or whether it derives from the perspectivists. Nevertheless, it is quite apparent that Kepler himself experienced a camera obscura, which significantly altered his understanding of an optical experiment. That this activity was important for Kepler's understanding of optics may be noticed in his fictional work, the *Somnium*, which explains how he would frequently perform the camera obscura trick in front of

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[74] As the catalogue of Sven Dupré and Michael Korey indicate, the fact that optics was among the most important topics within the Dresden Kunstkammer may be noticed by the way in which the optical objects on display were updated in the early to mid-seventeenth century as new optical instruments developed; Sven Dupré and Michael Korey. "Inside the Kunstkammer: The Circulation of Optical Knowledge and Instruments at the Dresden Court." *Studies in History and Philosophy of Science Part A* 40, no. 4 (2009): 405–20.

[75] Kepler, *Optics*, trans. Donahue, 194.

large groups. In it he explains

> During those years in Prague I often carried out a special procedure in connection with a certain observation. Whenever men or women came together to watch me, first, while they were engaged in conversation, I used to hide myself from them in a nearby corner of the house, which had been chosen for this demonstration. I cut out the daylight, constructed a tiny window out of a very small opening, and hung a white sheet on the wall. Having furnished these preparations, I called in the spectators. These were my ceremonies, these were my rites.[76]

So, Kepler's own optics and later interests indicates the role that visual jokes played within the formation of his optics. The fact that the context of optical illusions proved important for Kepler, a person who significantly shaped the theoretical foundations of early modern optics, is an important point to notice. Despite the attention that the historiography gives to the strict mathematical and theoretical aspects of early modern optics, a large amount of interest—if not the majority—was shaped by the ability to delude the eye.

The Rise of Mechanical Views

The development of optics after Kepler experienced many changes. The combination of lenses contributed to the creation of the telescope and microscope, both of which raised new questions about the process of vision as well as the nature of light. For Kepler, such technological developments further reinforced his optical ideas that he explained in his *Dioptrice* (1611), an important work on the telescope. In particular, in the *Ad Vitellionem* Kepler had expressed that visual rays would converge together after traversing a convex lens. In the *Dioptrice* Kepler built upon this and established the way in which the convergence of these rays is at a distance proportional to the convexity of the lens through which they pass. Such a

[76] Johannes Kepler, *Kepler's Somnium: The Dream, or Posthumous Work on Lunar Astronomy*, trans. Edward Rosen (Madison: University of Wisconsin Press, 1967), 57–58.

principle enabled Kepler to explain the process of magnification and its relationship to lenses. It is on account of such explanatory value that Kepler's *Dioptrice* became the leading theoretical work on the telescope as well as refraction until the 1660s at which time mathematicians in France, England, and Holland, particularly James Gregory (1638–1675), Isaac Barrow (1630–1680), Isaac Newton (1642–1727), and Christian Huygens (1629–1695) built upon and surpassed Kepler's work.[77]

As the historian Olivier Darrigol notes, however, while many writers adopted Kepler's geometrical understanding of light, most of them never adopted his idea that it was archetypical of the Trinity, because of the decline in Neo-Platonism and the way in which the mechanical philosophy sought to replace scholastic Aristotelianism. Without such a metaphysical orientation within the explanation of optics after Kepler one of two types of explanations developed, both of which used a metaphor. The first metaphor was that of fluid, the second projectile motion. A brief account of each of these will be in order because they were metaphors of wide utilization at the time when prominent individuals within the Jesuit Order developed their own optical explanation.[78] They are also important because of the way they provided a way to explain optics by mechanical philosophers without resorting to the type of metaphysics that Kepler did.

The mechanical philosophy began in the seventeenth century as a critique of Aristotelian natural philosophy maintaining that intrinsic natures of objects no longer served as a useful explanation for the way in which the world operated. It also rejected substantial forms, non-mathematical qualities, and the importance of occult properties, such as sympathies and

[77] Antoni Malet, "Kepler's legacy: telescopes and geometrical optics, 1611–1669," in *The Origins of the Telescope*, 281–300.

[78] Olivier Darrigol, *A History of Optics from Greek Antiquity to the Nineteenth Century* (Oxford: Oxford University Press, 2012), 37.

antipathies. The explanations that it developed understood the world as operating with its constituent parts as if by a clock.[79] One of the most impassioned defenders of the mechanical philosophy was René Descartes (1596–1650), who used optics as a way to articulate and communicate the new mechanical philosophy. The value that optics had within the formation of Descartes's mechanical philosophy may be noticed by the way in which his study of optics permeated his scientific development throughout his entire life. For instance, within his earliest notebooks, completed 1619–1621, there are early analyses about the techniques of refraction. The most important contributions he made to optics were within *The World, or Treatise on Light* (1633 but published posthumously) and the *Dioptrics* (1637), although it is noticeable that his ideas of corpuscular light that he made within these two works continued throughout his lifetime, such as in the three essays *Geometry*, *Meteorology*, and *Dioptrics*, which were attached to his *Discourse on Method*, as well as one of the last books he published, the *Principles of Philosophy* (1644).[80]

Descartes stands as the first person who realized the interpretive significance of Kepler's optics, especially the role that Kepler assigned to light. Collectively in his *The World* and *Dioptrics* Descartes developed a theory of light which was based on its instantaneous propagation.[81] Deviating from the perspectivist understanding of light (lumen) as the incorporeal influence that renders a medium transparent, Descartes put forward the idea that light was a

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79 Peter Dear, "The Mechanical Universe from Galileo to Newton," in *The Intelligibility of Nature: How Science Makes Sense of the World*, (Chicago: The University of Chicago Press, 2008), 15–38.

80 Jeffrey K. McDonough, "Descartes' Optics," in *The Cambridge Descartes Lexicon*, ed. Larry Nolan (Cambridge: Cambridge University Press, 2010), 550–59.

81 Darrigol, *A History of Optics*, 41.

movement or action that is transmitted to the eye. To substantiate such an interpretation, he explained that vision occurs analogously to a blind man using a cane to encounter the world, through pressure. As he explains, like a blind man experiencing the world through the reverberations of the cane, so also does light transverse to an individual's eye through the reverberations of the air around. In a different analogy, as Descartes explained in *The World*, light operated as instantaneous propagation, as if a contiguous chains of balls.[82] One of the implications of this line of interpretation is that, with regard to vision, as Descartes would come to explain, vision itself only records sense impressions and not knowledge of the actual object itself.[83]

Naturally, Descartes's exploration of optics in *The World* was followed by his investigation of *Dioptrics*. It is within the *Dioptrics* that Descartes's interpretation of Kepler's retinal image occurs. Whereas Kepler had not exploited the explanation with a clear diagram in his *Ad Vitellionem*, in Descartes *Dioptrics* he includes a detailed illustration that demonstrates how the image refracts through the crystalline lens and projects upon the retina. Yet, as Descartes explains in the *Dioptrics*, the visual process occurs not through the reception of the visual species, but rather through the reception of the visual color, which he takes to be a physical property and not a visual quality, as the perspectivists had considered previously.[84] Among Descartes's other ideas is the notion of a virtual image which converged on the retina. As he explains

> We must be aware of assuming that in order to sense, the mind needs to perceive certain images transmitted by the objects to the brain, as our philosophers commonly suppose;

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[82] Darrigol, *A History of Optics*, 39.

[83] Dear, "Mechanism: Descartes Builds a Universe," in *Revolutionizing the Sciences*, 85.

[84] Darrigol, *A History of Optics,* 47.

> or, at least, the nature of these images must be conceived quite otherwise than as they do… They have had no other reason for positing these images except that, observing that a picture can easily stimulate our minds to conceive the object painted there, it seems to them that in the same way, the mind should be stimulated by little pictures which form in our head to conceive of those objects that touch our senses.[85]

It is important, however, to recognize that whereas Kepler sought to account for the mathematics of optics and within that the role of diffraction through the crystalline lens, Descartes has as his interest a theory of knowledge itself. Such a distinction helps to explain why Descartes's optical account was much more influential than Kepler, shaping both the development of seventeenth-century optics as well as leaving a legacy within the historiography of early modern optics and visual theory.[86]

While Kepler created the theory of optics, it was Descartes who popularized it through his writings and theories of knowledge. It should be noted, however, that Descartes was by no means the only interpreter of Kepler. As Katrien Vanagt has demonstrated, among physicians such as V.F. Plempius, Descartes's conclusions were easily sidestepped because Kepler considers his results in the context of a disembodied eye. What this means is that its functionality should not be merely limited to a fully automatic process since human bodies are more complex than being automatic machines.[87] Yet for all its ingenuity, Plempius's divergent account of Kepler's optics did not seem to possess as widespread appeal as Descartes's own optics.

As will be noted in later chapters, the members of the Jesuits departed from the

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[85] René Descartes, "Discourse on Method," in *Discourse on Method, Optics, Geometry, and Meteorology*, trans. Paul J. Olscamp (Indianpolis: Hackett Publishing, 2001), 89.

[86] Darrigol, *A History of Optics,* 37.

[87] Katrien Vanagt, "Early Modern Medical Thinking on Vision and the Camera Obscura. V.F. Plempius' Ophthalmographia," in *Blood, Sweat, and Tears: The Changing Concepts of Physiology from Antiquity into Early Modern Europe*, ed. H. F. J. Horstmanshoff, Helen King, and Claus Zittel (Leiden: Brill, 2012), 569–93.

conclusions of Descartes's optics, even though they show a considerable interest in it.[88] Many members of the Jesuit Order never considered Kepler's optics to be an epistemological threat—indeed, for them Kepler provided a clearer explanation for image projection and visual focus, both important elements. It is also worth noting that Descartes's optics was listed as among the useful explanations of vision within Jesuit writings prior to 1650. It was only in the second half of the seventeenth century that his works came to be recognized as suspect. Yet, even as certain Jesuits took issue with his scientific works, his optical texts were still cited and integrated into their own optical works, albeit with the problematic passages excised.[89]

Descartes was not the only mechanical philosopher which made significant use of seventeenth-century optics. Thomas Hobbes (1588–1679) demonstrated the widespread importance of optics, as a tool useful not only for geometry, but also for social commentary. In his *A Minute or First Draught of the Optiques*, he claims

> I shall deserve the Reputation of having been the first to lay the ground of two Sciences, this of Optiques, the most curious, and that other of natural Justice, which I have done in my book de Cive, the most profitable of all other.[90]

Yet, in contrast to Descartes, for whom the psychology of sight ultimately had a material causation, Hobbes maintained important psychological elements, which were connected to a physiological component. For instance, for Hobbes clear vision was connected to psychological

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[88] For instance, as noted in Chapter Three below, Kircher's diagram of the eye is the same as what was in Descartes's works even though Kircher himself does not attribute it as such.

[89] A similar point made by Roger Ariew, "Descartes and the Jesuits: Doubt, Novelty, and the Eucharist," in *Jesuit Science and the Republic of Letters*, ed. Mordechai Feingold (Cambridge, MA: MIT Press, 2003), 157–94.

[90] Quoted in Franco Giudice, "The Most Curious of Sciences: Hobbes's Optics," in *The Oxford Handbook of Hobbes*, ed. Al P. Martinich and Kinch Hoekstra (Oxford: Oxford University Press, 2016), 162.

interests, which are dependent upon the motions around the heart.[91] Images themselves are connected to emotions, to pain and to pleasure. Hobbes rejected Kepler's notion of the retinal image, which he called "figured light." Instead he stated that the image is understood in the brain through what he called "phancie."[92] Of particular importance in Hobbes's optical thought is the way in which optics, and particularly optical illusions, provided a pattern that was emblematic of political and social activity.[93] Such a leap between the social, mathematical, and optical, is a good reminder that optical knowledge was not clearly an end in itself, but could prove beneficial for social and political goals. Obtaining optical skill not only gave one philosophical prowess but also political prestige.

Two other seventeenth-century opticians are important to mention, Christiaan Huygens (1629–1695) and Isaac Newton (1642–1726). As Fokko Dijksterhuis notes, Huygens was the first person to fully mathematize the nature of light. In so doing he combined a more mathematical understanding of optics, primarily described in his *Dioptrics*, and combined that with a physical understanding of optics, as indicated in his *Treatise on Light* (1690). In contrast to Kepler, who had addressed similar mathematical and physical questions pertaining to the telescope, Huygens was able to make use of a general theory of refraction, which had been developed by Willebrord Snel (1580–1626) in 1621, but published by Descartes in 1637, who

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[91] Giudice, "The Most Curious of Sciences: Hobbes's Optics," in *The Oxford Handbook of Hobbes*, 165.

[92] Giudice, "The Most Curious of Sciences: Hobbes's Optics," in *The Oxford Handbook of Hobbes*, 166.

[93] Richard Turck, "Optics and Sceptics: The Philosophical Foundations of Hobbes's Political Thought," in *Conscience and Casuistry in Early Modern Europe*, ed. Edmund Leites (Cambridge: Cambridge University Press, 1988), 235–63.

had found it independently.[94] Among the significances of Huygens's theory of refraction is the way in which it did not use a mechanical explanation for the way in which light behaved, but rather one that was only mathematical. Such a development stands out in contrast to many other opticians in the seventeenth-century, as Alan Shapiro notes, on account of the way in which Huygens was able to make the leap from optical understanding based upon physical principles, such as in Kepler, Descartes, Hobbes, and others, to one that was based only upon mathematics.[95]

While the full analysis is beyond the scope of this study, it is nevertheless important to note the impact of Newton at the end of the seventeenth century. In 1664, Newton wrote "On Colours" in his philosophical notes, an important passage in which it becomes evident that Newton discarded Descartes's optical principles in favor of a view that was atomistic in nature, and that its movement was wavelike. One of his most enduring contributions was his experiment where he identified the way in which light was composed of colors.[96] Due to the radical nature of his optics, its earliest reception received a considerable amount of scrutiny, some of which involved members of the Society of Jesus, most notably in his exchange with Ignace Pardies in the *Philosophical Transactions* in 1672. While initially Pardies questioned the meaning of Newton's optical experimentation, Newton eventually clarified the experimentation and Pardies was satisfied. Not every Jesuit was as easily convinced as Pardies. For instance, the Jesuit Francis Line (1595–1675) as well as Bertrand Castel (1688–1757) were never fully convinced of

[94] Dijksterhuis, *Lenses and Waves*, 1–4.

[95] Alan E. Shapiro, "Images: Real and Virtual, Projected and Perceived, From Kepler to Dechales." *Early Science and Medicine* 13, no. 3 (2008): 270–312.

[96] Darrigol, *A History of Optics*, 83–85.

the validity of Newton's optical experiments and their scientific and philosophical meaning.[97] Newton's optical experiments came to fruition in his 1704 *Opticks*, which brought together his optical thought from the past thirty years. The impact of Newton's *Opticks* was most significant in the eighteenth century, both because of the importance of optics within his natural philosophy but also because of the influence of his optics on eighteenth-century British society.[98]

From this overview of the *Keplerian turn* and its subsequent mechanization, it is evident that an important cause for the deviation of early modern optics from perspectivist optics was the role of instruments.[99] The improved optical tools created the context for the refinement of optical knowledge. Yet, what is also apparent is that the existence of competing optical explanations, at least until Newton, indicate the way in which there were disparate optical traditions coexisting at the same time. This observation reinforces the important point of this chapter, that there was no singular "optics" in the early modern period. Such a point will help elucidate why the members of the Society of Jesus were not in conflict with other early modern optical understandings, but were establishing their own optical path alongside the plurality of views.

Before concluding the overview of optical knowledge in the early modern period it is also worthwhile to address more fully a topic that has shaped this overview and which has been of recent interest in the historiography of early modern optics—optical illusions.

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[97] Though a few other Jesuits were not satisfied with Newton's interpretation. Agustín Udías, *Jesuit Contribution to Science: A History* (New York: New York, 2015), 48.

[98] G. N. Cantor, *Optics After Newton: Theories of Light in Britain and Ireland, 1704-1840*. (Manchester, UK: Manchester University Press, 1983).

[99] On the role of instruments in the transformation of optics, see Ilardi, *Renaissance Vision from Spectacles to Telescopes*.

Vanities of the Eye

One of the curiosities of early modern optical knowledge is that at the same time many individuals in early modern Europe developed greater clarity and mathematical models for the explanation of optics, many others decried the tremendous amount of optical uncertainty. So, for instance, while Kepler and Descartes might have provided a clearer explanation of the role of mathematics in the explanation of sight—a development which was woven into the early histories of the scientific revolution and optics—it is noticeable that their contemporaries decried the resulting instability of vision. Methodologically (and figuratively) they had lost their optical nerve.

This historiographical aspect has received a significant amount of attention because of the recent work of the historian Stuart Clark. In 2007 he published *Vanities of the Eye*, which argued that between 1450 and 1650, individuals in early modern Europe did not experience an increased rationalization of sight by way of greater understanding of perspective art and the anatomy of the eye.[100] Rather, they experienced a significant unsettling as to how vision occurred.[101] The reader of Clark's book will instantly realize that the foundation of his visual instability developed from his work on demonology, as the preternatural possesses an important role in *Vanities of the Eye*.[102] This aspect is important because among the points that Clark wishes to raise is the role of

[100] For the interpretation that the history of vision is that of the ever-increased rationalization of sight, see William Ivins and Martin Kemp: William Ivins Jr. *On the Rationalization of Sight: With an Examination of Three Renaissance Texts on Perspective* (New York: The Metropolitan Museum of Art, 1938); Kemp, "Linear Perspective from Dürer to Galileo," in *The Science of Art*, 53–98.

[101] Clark, *Vanities of the Eye*.

[102] Stuart Clark, *Thinking with Demons: The Idea of Witchcraft in Early Modern Europe* (Oxford: Oxford University Press, 1999).

the preternatural in the unseating of vision's reliability.

Clark's account is important because it provides a robust context within which to situate the histories of science and optics, a point that Clark is aware of but is beyond the scope of his book. So, while Clark mentions aspects of early modern optics, such as Kepler's optical theory, and even concludes with Descartes's theory of cognition, he nevertheless sidesteps any in-depth analysis of the history of science to draw attention to the widespread visual uncertainties at the time and the way in which they were popular topics of conversation within early modern culture more broadly.

Yet, if one looks back at Clark's sources, one may see that the interrelationship between the visual and the optical within those sources. For instance, if one looks at George Hakewill's (1578–1649) *Vanities of the Eye* (1615) which was the inspiration of Clark's book, one not only notices Hakewill's mention of Witelo's optical book, but even more interestingly, it is cited alongside Aristotle's *De Sensu* in a context which explains the importance of optical theory, the species, and visual sensibility.[103] So, located within the spark of Clark's idea are the very relationships that motivate important aspects of this dissertation: the exploration of the relationship between vision and optical theory among the members of the Jesuit Order.

Admittedly, prior to Hakewill, Kepler, and other early moderns, questions surfaced as to the reliability of the sense of sight and the role of optical theory within it. At the same time, that the perspectivist optical theory was integrated into the Latin West from Ibn al-Haytham, theories of the imagination, the visual species, and demonology developed. The Arabic philosopher Ibn Sina (d. 1037) possessed ideas on the power of psychological influence and the way in which

[103] George Hakewill, *Vanities of the Eye* (Oxford: Joseph Barnes, 1615), 51 in a chapter titled "Of the false report, which the eie makes to the inner faculties, in the apprehensiō of natural things"

vision might actually influence a person, which were widely circulated during the thirteenth and fourteenth centuries. One adaptation of this, the disease of lovesickness—a form of enchanted love which could influence the actions, emotions, and psychological faculties, and which inspired popular theatre, poetry, and theological reflection—became a necessary question for optical writers to address. So, for instance, the prominent perspectivist Witelo, who Johannes Kepler directed his optical criticisms toward, wrote a thirteenth-century treatise on love sickness and the way in which optical theory might be utilized to disprove such popular opinion.[104]

Various optical tricks also circulated within the tradition of natural magic. For instance, in the medieval text, the *Secretum Philosophorum*, there are numerous examples of optical tricks which are adapted from perspectivist optics. It explains how to use mirrors to distort images from different angles, and how to use multiple mirrors positioned in such a way as to project multiple images of the same object. For the purposes of casting images into the air the following description is important:

> You can also make a mirror out of a convex mirror in which an image will appear outside, and this is how it is done. Take an ordinary (that is, a convex one) and scrape off the lead and put it in a box which is not too deep, so that the convexity is towards the bottom of the box, and the concavity is outwards. Then put something dark between the bottom of the box and the mirror, such as a black cloth or some such thing, and do this so that the visual ray is better reflected. Then if you attentively gaze in the mirror, you will see your image outside the box, in the air between you and the mirror. An image also appears outside in columnar and pyramidal mirrors, as is taught in perspective.[105]

As Robert Goulding notes, the mirror in question is likely one mentioned in a brief

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[104] Mary Frances Wack, "From Mental Faculties to Magical Philters: The Entry of Magic Into Academic Medical Writings on Lovesickness, 13th-17th Centuries," *Eros and Anteros* (1992): 9–31.

[105] Translated by Robert Goulding in Robert Goulding, "Deceiving the Senses in the Thirteenth Century: Trickery and Illusion in the Secretum Philosophorum," in *Magic and the Classical Tradition*, ed. Charles Burnett, and William Francis Ryan (London: Warburg Institute, 2006), 156.

passage in John Pecham's *Perspectiva*. In Part II, Pecham compares iron or steel mirrors with "common glass mirrors coated with lead."[106] During the medieval period mirrors were not uniform in construction, as this text implies, and so depending on the type of mirror involved, one could create a different optical effect.[107] It is likely this subtlety in the type of mirror used that the *Secretum* intended to address. By placing dark cloth behind the newly scraped glass mirror, one could create an optical effect where the location of the image appeared not actually within the mirror but somewhere in front of it. While the technical specifics are not clear from the text, the imaginative effect draws the reader into pursuing the particularities to obtain such an outcome.

From both examples what is important to note is that the scientific explanation of optics and theories of visual instability began circulating together long before the early modern period, an aspect that would be entirely missed by modern historians if one limited their investigation to the well-known optical works within the perspectivist canon. Yet, as those in the sixteenth century knew, optical tricks were of widespread appeal and provided an important avenue through which the mathematician could demonstrate the importance of their skill and the way in which they could influence optical knowledge.

For instance, in his "Mathematical Preface" to the first English edition of Euclid, John Dee includes such a description

> Yea, so much, to scare, that, if you, being (alone) nere a certaine glasse, and proffer, with dagger or sword, to foyne at the glasse, you shall suddenly be moved to give backe (in maner) by reason of an Image, appearing in the ayre, betwene you & the glasse, with like hand, sword or dagger, & with like quicknes, foyning at your very eye, likewise as you do at the Glasse. Straunge, this is, to heare of: but more mervailous to behold, than these my wordes can signifie. And neverthelesse by demonstration Opticall, the order and

[106] Pecham, *John Pecham and the Science of Optics*, 163.

[107] On the development of mirrors, see Ilardi, *Renaissance Vision from Spectacles to Telescopes*.

cause thereof, is certified: even so, as the effect is consequent.[108]

This optical trick, which was the occasion for Johannes Kepler's ire at Giambattista Della Porta mentioned above, was one of a wide collection of optical tricks within the early modern period that could involve the camera obscura, magic lanterns, or various meteorological phenomenon such as miraculous images in the sky. It was an important trick not only for the outcomes which it could accomplish, but also because of the way the knowledge of the trick—particularly the mathematical knowledge—became a way of delineating insiders and outsiders to the particularities of the trick. It is also a great example of an optical joke, which was itself an important intellectual genre within early modern optics because it enabled one to address contradictions without necessarily addressing the philosophical implications of the contradictions.

Optical Jokes

As explained in this chapter visual knowledge was widely considered uncertain in the early modern period, a thesis which has become more popular as of late. As a result, more recent histories have developed, largely social in nature, challenging the thesis of the slow rationalization of sight and have shown that vision was anything but certain in the early modern period.[109]

One specific area of optics that made extensive use of the social and cultural interest in

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[108] John Dee, "Preface," in Euclid, *Elements of Geometrie of Euclid of Megara*, ed. John Dee (London: John Daye, 1570), b.jv.

[109] The social meaning of vision is explored from many different angles in Robert Nelson, ed. *Visuality Before and Beyond the Renaissance: Seeing as Others Saw* (Cambridge, UK: Cambridge University Press, 2000).

visual uncertainties was that of the broader interest in *scientific jokes*. As noted above, this is the context within which Della Porta operated, and which Kepler gave attention to in his *Ad Vitellionem* as well as in his own optical interests. As Paula Findlen has shown, these scientific jokes were *serious jokes* intended to reveal otherwise hidden properties. Such jokes also had an important social element to them. For those who understood the jokes, those who could interpret the hidden properties, were among the learned. Those who could not, were ignorant. In this way, the act of a scientific joke was in itself an act to demonstrate one's virtuosity, but it also became an important act of inclusion and exclusion.[110] If one were *in* on the joke, then one was among those included. If not, one was ignorant. A well-known type of optical joke in the period was casting images into the air, which has been referenced in previous sections, and which clearly demonstrates the way in which a serious joke could engage religious and philosophical beliefs, while at the same time addressing fundamental principles of optical theory.

The popular interest within early modern Europe for casting images into the air oftentimes involved questions surrounding the preternatural and religious miracles. As a result, the genre within which the techniques for casting images into the air circulated was natural magic—an amalgamation of practical scientific feats which did not fit within traditional Aristotelian natural philosophy and yet were not considered to be forbidden magic.[111] Likely owing to its widespread interest among the literate public, natural magic, including the tricks for casting images into the air, came to be a matter of concern among most of those who studied optics and visual knowledge within early modern Europe. As previously addressed, it was the

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[110] Paula Findlen, "Jokes of Nature and Jokes of Knowledge: The Playfulness of Scientific Discourse in Early Modern Europe." *Renaissance Quarterly* 43, no. 2 (1990): 292–331.

[111] Eamon, *Science and the Secrets of Nature*.

misunderstanding of the optics of casting images in the air that motivated Johannes Kepler to explain how the camera obscura worked and its relationship to the eye.

One of the earliest depictions of an image cast into the air occurs within a manuscript on the instruction of war, from the middle of the fifteenth century. The image depicts a magic lantern, a device with a candle in the center and mirrors around half of it, which enabled one to reflect an image from the mirror toward another location. In this manuscript, it was taught that one could project the image into the air, and that the image would hang within the air without needing a surface upon which to be projected. The image in question was that of a monster, and it was thought that such a projection would be able to scare away the opposing army.[112]

The tradition of casting images into the air for the sake of military prowess did not cease in the fifteenth century. For instance, in his *Three Books of Occult Philosophy* in 1531, Cornelius Agrippa (1486–1535) explained how one could project images on the moon's surface, which was thought to be able to then reflect such images in turn. As he explained, beyond establishing bewilderment among the populace, the device itself would also prove "very profitable for Towns and Cities that are besieged" because it would allow them to send messages. Of particular interest, and representative of the general magical aspect of optics, Agrippa states that such a device was known to Pythagoras as well as "some in these days." He then he identifies himself as part of the select few.[113]

While modern optical sensibilities might wonder about the viability of such techniques

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[112] Sven Dupré, "Images in the Air: Optical Games, Magic and Imagination," *Early Science and Medicine* 13 (2008): 225–27.

[113] For part of the background see, Wolfgang Lefèvre, ed. *Inside the Camera Obscura–Optics and Art Under the Spell of the Projected Image* Berlin, (Germany: Max Planck Institute for the History of Science, 2007), 43.

and the viability that an image might be actually visible within the air, for those in the fifteenth and sixteenth century these optical techniques garnered widespread interest and came to be adopted to many different contexts. It was widely believed that the Devil and witches were able to procure visual tricks, such as casting images into the air, and as a result the mysterious techniques came to be of wide interest.[114] As but one example Gottfried Smoll's *Manuale rerum admirabilium* (1610) explains how one is able to cast the form of a "demon" or "shadowy animal," into the air.[115] Because of this many natural magicians seized the opportunity to demonstrate not only their mathematical prowess, but equally so their philosophical importance. It is undoubtedly because of the cultural and philosophical appeal of optics that Della Porta adopted it as one of his most interested topics. And it is on account of the cultural intrigue of images in the air that he addresses the technique involved in both the first and second edition of the *Magia naturalis*.

The specific book in Della Porta's *Magia naturalis* that discusses casting images into the air is Book Four in the 1558 edition, and Book 17 in the 1589, both of which include the casting of images into the air. The 1558 edition includes a single technique for casting images into the air, using a cylindrical mirror in a darkened room to project a ghastly figure. This optical technique used the ability of a cylindrical mirror to distort and amaze, but also drew upon a more theoretical mathematical problem, known as Ibn al-Haytham's problem—named because it was a problem introduced by the medieval Arabic optician—involved in how to locate the point of reflection upon a spherical convex mirror. Once one became quite skillful at this then one could

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[114] This is the point made by Reginald Scot in *The Discoverie of Witchcraft*, ed. Brinsley Nicholson (London: Longmans, 1886), 257–58.

[115] Gottfried Smoll, *Manuale rerum admirabilium* (Hamburg: Frobenius, 1610), 80–82.

project an image onto the spherical mirror whose original location was not visible to the audience. Hence, the projected image would be considered in the air because its existence was not readily present. Due to the importance of this optical feat within the tradition of images in the air, and particularly among the Jesuits, it will be addressed in Chapter Four below.

An example of this type of anamorphosis is figured in image 1.1, taken from Jean François Niceron's *La perspective curieuse* (1663). This image shows the normal image on a grid in the center of the page. The normal image is deformed into the curved image, just beyond the image in the center. To see the original image reformed, one would place a cylindrical mirror at the center of the deformed image, where the semicircle is visible. To recreate the experiment as Della Porta imagined, one would place the deformed image (or something like it) a considerable distance from the cylindrical mirror such that nobody in the room would know where the reflected image on the mirror originated. Yet, because it was so difficult to coordinate the location of the deformed image with the cylindrical mirror, the mathematics of this technique became a topic of widespread interest, both among natural magicians as well as mathematicians.

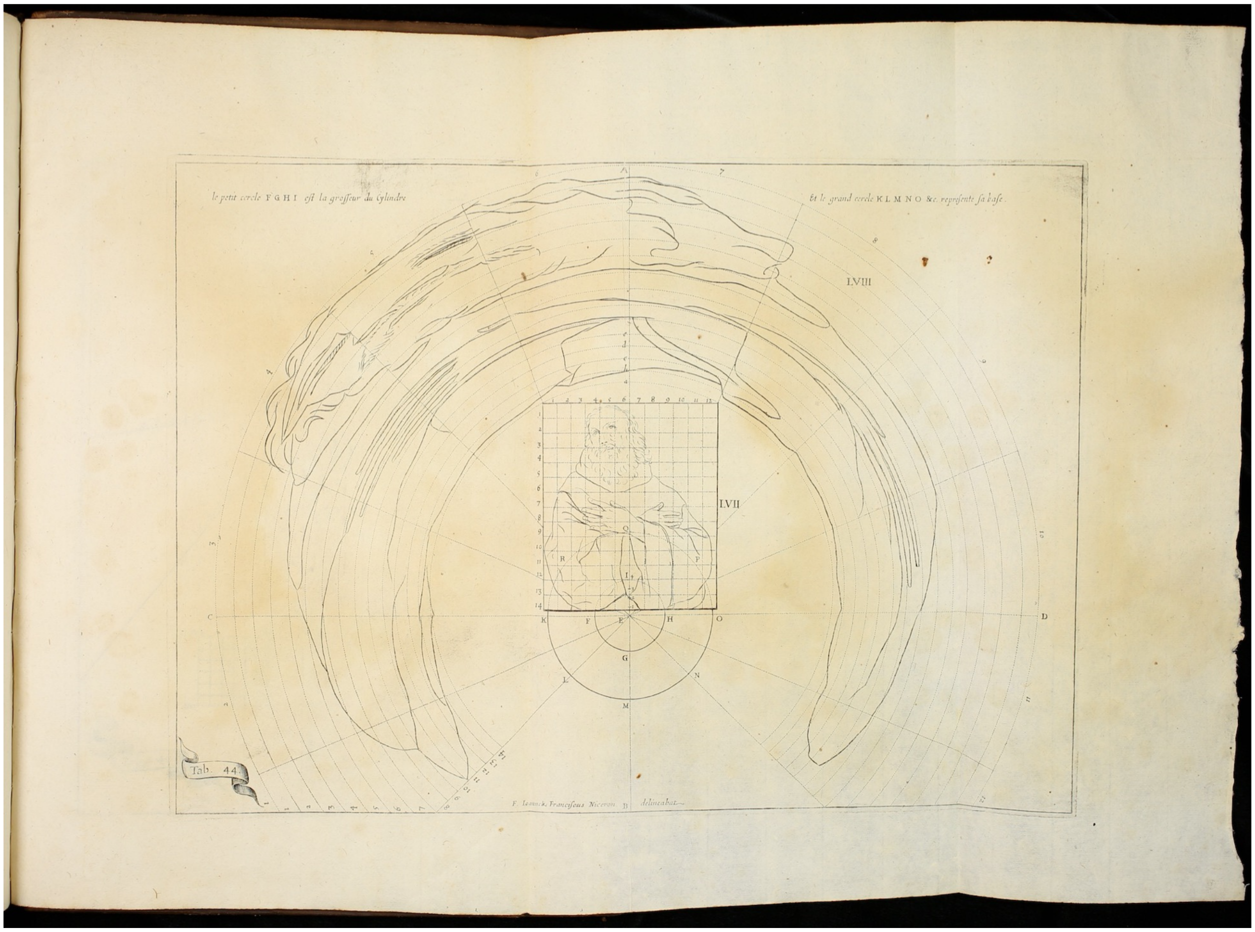

Image 1.1 — "Image in the air" with cylindrical mirror
Jean François Niceron, *La perspective curieuse* (Paris: Jean du Puis, 1663), table 44.
Image courtesy of the History of Science Collections, University of Oklahoma Libraries

The most well-known section of Della Porta's optics is in the 1589 edition, quoted in the section above on sixteenth-century developments in optics. This description for casting images into the air, which is a more traditional camera obscura and so different from Ibn al-Haytham's problem, encompasses the way the natural magicians used the imaginary interests of the early modern public to capture intrigue. The performative aspect of this, that one could terrify the onlookers with the knowledge of such a trick, reflects the widespread appeal of optical natural magic and reminds of the value of knowing the secrets of such a trick. So, what is important to note is that Della Porta's casting of the image in the air with the camera obscura, which is the trick that Kepler criticized, is only one such popular technique for casting images into the air within early modern Europe.

Images in the air were not the only optical joke at the time. One further optical trick, which blended together both art and science, was anamorphic illustrations. Such drawings, which appear distorted when standing from a particular angle, could be utilized in a variety of situations, most notably in political or religious contexts. For instance, in a particularly notable anamorphosis from 1535, the portraits of Charles V, Ferdinand I, Pope Paul III, and Francis I could be identified when viewed from either the left side or the right side. However, when viewed straight ahead, all one is able to see are villages, trees, and individuals on horses.[116] Similarly, anamorphic representations of Charles I were distributed throughout England by the Royalists in the period after the King's execution in 1649.[117] While anamorphoses developed out of the context of perspective art, they nevertheless reinforce the fact that optics and art were still nearly inseparable during the sixteenth century and much of the seventeenth century.[118] Image 1.2 shows a standard anamorphosis from the period. In order to see the reformed images, one would place a mirror between points RP on the top image, or on YX on the bottom image and look at them from the vantage point of the left-hand side of the image. Doing so would project images like the two in the center of the page.

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116 Baltrušaitis, *Anamorphic Art*, 13.

117 Baltrušaitis, *Anamorphic Art*, 28.

118 For a similar point, albeit not about Niceron, see Sven Dupré, "The Historiography of Perspective and Reflexy-Const in Netherlandish Art," in *Netherlands Yearbook for History of Art/Nederlands Kunsthistorisch Jaarboek* (Leiden: Brill, 2011), 34–61.

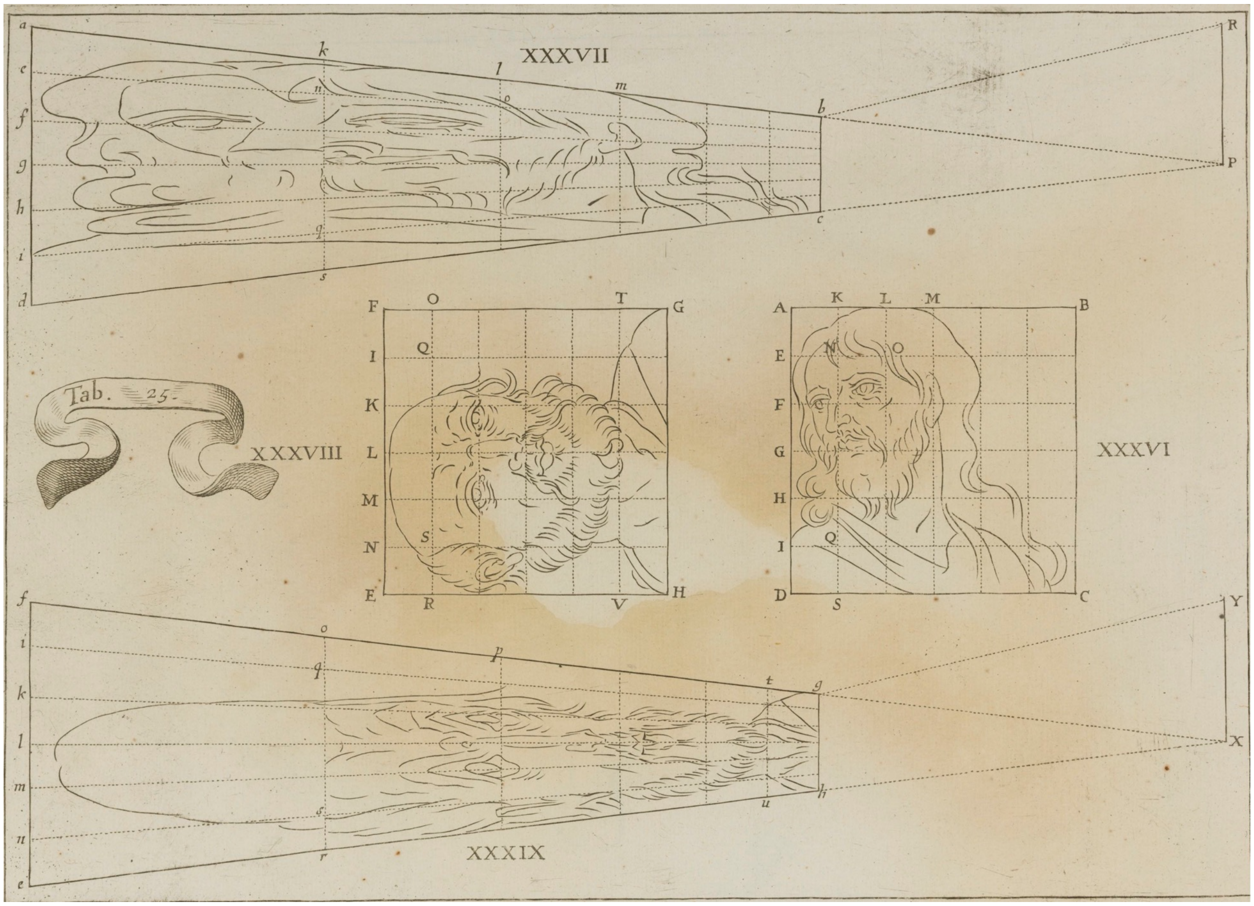

Image 1.2 — Example of anamorphosis
Jean François Niceron, *La perspective curieuse* (Paris: Jean du Puis, 1663), table 25.
Image courtesy of the History of Science Collections, University of Oklahoma Libraries

Anamorphic images also eventually came to be a tool of philosophical and scientific discourse. This thesis has been put forward more compellingly by Lyle Massey, who argued recently that the foundation of Descartes's epistemic doubt and his critique of optical theory derived as much from his experience and attempts to understand anamorphosis as it did with anything merely abstract or philosophical.[119] The present point is not to defend or to criticize Massey's thesis, although aspects of it will be addressed below. Rather, it is important to

119 Massey, *Picturing Space, Displacing Bodies*.

demonstrate that the subtleties of artistic and optical jokes introduced serious philosophical and scientific reflection on the meaning of vision, optics, and cognition itself. So, for instance, while Kepler's optics relied upon mathematical explanations, particularly its adoption of the camera obscura as an analogy with the eye, its rhetorical appeal is more intelligible within the context of optical jokes and their relationship to optical illusions.[120]

In the case of optical illusions, optical jokes were of wide social and political interest, not to mention their theoretical and scientific importance. As a result they were an important avenue through which early moderns, and particularly the members of the Society of Jesus, addressed certain visual uncertainties. Paired with the genre of natural magic, it provided an avenue through which many Jesuits both maintained their fidelity to perspectivist optics and Aristotelian natural philosophy, while at the same time addressing the questions of visual instability that were so widely popular at the time.

Conclusion

The transformation of optics in the seventeenth century did not necessarily imply the complete eradication of perspectivist optics and its tacit utilization for philosophical knowledge. Optics still sought to explain vision, and as such, ultimately cognition. Thus, while the historiography often emphasizes the way optics was necessarily transformed through Kepler and Descartes into a more mathematical subject matter, removed from its philosophical underpinnings, this storyline fails to appreciate the complexity of the period and the way in which the widespread questions of visual instability were woven into the transformation of

[120] For a similar point, see Sven Dupré, "Inside the Camera Obscura: Kepler's Experiment and Theory of Optical Imagery," *Early science and medicine* 13, no. 3 (2008): 219–244.

optics.[121] The clarity of mathematics provided a path forward within the wider context of the optical instability of the period.

It is within such a context of visual and optical manipulation that the Society of Jesus established themselves. Due to the intellectual and social significance of optics within early modern Europe, many members of the Society of Jesus came to be actively involved in optical discussions. They offer the historian a lens by which to understand the optics of the period in greater detail. Not only is one able to gain a valuable perspective on the process of optical change, subtly problematizing tacitly held historiographical assumptions about optics in the seventeenth century, but glimpses into the broader cultural and religious appeal of optical change are also available. The members of the Society of Jesus did not become adept in optics for the sake of their Counter-Reformational efforts. Yet, as the following chapters relate, their approach and style of optics bears the marks of their Counter-Reformation confession. At times it occurs as a passive background feature, such as in the use of religious images in optical experiments, and at other times as a more active feature, generating direct optical explanations to accord with confessional beliefs, such as with the Eucharist. Both aspects are important to notice not only for understanding the thinking of the Jesuits, but also to better appreciate the complexity of science in the age of confessional thought.

In the following chapters, I show how optics was embedded not merely within Jesuit scientific and mathematical culture, but more broadly within their religious and cultural transformation. Along the way the Jesuits used the optical instabilities to their advantage, rather than as a limitation, to articulate an understanding of optics which would not only be appealing

[121] A recent example which misses entirely the visual instability of the period is Ofer Gal and Raz Chen-Morris, *Baroque Science* (Chicago: University of Chicago Press, 2013).

to the youth of early modern Europe, but would also reflect important features of their religious confession.

CHAPTER TWO
OPTICS WITHIN THE SOCIETY OF JESUS

"[Optics]…useful for both Mathematicians and Philosophers"
—Franciscus de Aguilonius, 1613.[122]

For the members of the Society of Jesus, optics was philosophically important. In the context of the previous chapter, this should not be entirely surprising—optics supplied the explanation of cognition and was integrated into philosophical theory. Jesuit mathematicians used optics as an opportunity to articulate the philosophical importance of mathematics. Since the sixteenth century many mathematicians among the Society of Jesus had worked to demonstrate the importance of their mathematical work. Due to the widespread reach of optics at the time, encompassing the understanding of light, vision, and images, optics provided an apt arena within which to argue for the philosophical importance of mathematics. Thus, optics came to be an important topic for Jesuit mathematicians in part because it demonstrated the importance of mathematics itself.

This chapter explains how certain influential Jesuit mathematicians used optics to advocate for the philosophical importance of mathematics. I will show that Jesuit mathematicians consistently referred to the concept of visual species to demonstrate the philosophical importance of mathematics. Such a rhetorical appeal came out of the attention that the members of the Jesuit order gave to Aristotle's *De Anima*, a text which outlined the relationship between the senses and knowledge itself and which received focused interest in the sixteenth century amidst philosophical concerns about the nature of the human body and

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[122] Franciscus de Aguilonius, *Opticorum libri sex* (Antwerp: Plantin, 1613), frontispiece: Philosophis iuxtà ac Mathematicis utiles.

cognition, within which vision was given special attention.

I will then show the way in which such philosophical interest merged with mathematical optics at the beginning of the seventeenth century. I will pay special attention to the earliest treatment of optics by two Jesuits, Juan Bautista Villalpando's *In Ezechielem explanationes* (1595–1604) and Franciscus de Aguilonius's *Opticorum libri sex* (1613). Both Villalpando and Aguilonius discussed optics within the framework of Aristotle's *De Anima*. The similarity of their approach is even more remarkable because they never had a common place of education or study. Next, I will show that the interplay between mathematics, the *De Anima* tradition, and the visual species was a consistent theme among Jesuit scholars throughout the seventeenth century. Mathematics was consistently used to maintain the relevance of the visual species.

The application of mathematical to the visual species will also be an important theme in Chapter Three and Four below. There I will show that seventeenth-century optics reinforced for the Jesuits the idea of visual species, rather than eliminated it. This qualifies the received narrative on the history of early modern optics, as most narratives of optics in the seventeenth century assume that the visual species came to be easily eliminated.[123] Yet, for members of the Society of Jesus, the visual species did not easily disappear from the theory of optics, even as the content of optics gradually changed in the seventeenth century.

Before addressing the philosophical importance of optics, it is necessary to locate the subject matter within one of the Jesuits' greatest cultural creations, mathematics.

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[123] For the standard narrative, see Gal and Chen-Morris, "Baroque Optics and the Disappearance of the Observer," 191–217; Smith, *Sight to Light*, 373–416; Lindberg, *Theories of Vision*, 188–208.

Jesuit Mathematics

The members of the Jesuit Order were never destined to become skilled in optics, or even to engage in intellectual culture. In 1535 when the first seven "companions of Jesus" came together, it was anything but clear that their movement of spiritual renewal would significantly shape early modern intellectual culture. The lifestyle that they originally cast for themselves was that of itinerant ministers, taking along with them only the material belongings which they were able to carry. Within three decades, however, by the 1550s and 1560s, they had grown to number several thousand, and had established permanent residences throughout Europe, South America, India, and China.[124] In the process, from their official establishment in 1540 until their suppression in 1773, the Society of Jesus came to be a significant cultural and intellectual force both in Europe and around the world.[125] It is within this broader intellectual narrative that the engagement of members of the Jesuit Order with the science of optics finds its place.

Historians have for some time focused on the role that Jesuit mathematicians played in the transformation of intellectual culture from 1540–1773. The adoption of mathematics as a strategic effort by certain Jesuits mirrored the broader European culture, as the fifteenth through the eighteenth centuries experienced a rise of the "mathematicus."[126] While the Jesuits did not necessarily produce the most innovative mathematical works at the time, their early adoption of printing their mathematical works paired alongside their vast networks created an influence both

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124 John W. O'Malley, *The First Jesuits* (Cambridge, MA: Harvard University Press, 1993), 51–90.

125 Dale Van Kley has recently put forward this thesis in his book Dale K. Van Kley, *Reform Catholicism and the International Suppression of the Jesuits in Enlightenment Europe* (New Haven: Yale University Press, 2018).

126 Mario Biagioli, "The Social Status of Italian Mathematicians, 1450-1600," *History of Science* 27 (1989): 41–95.

within and beyond the Jesuit Order.[127] The less clear aspect of this is how exactly mathematics came to be an important cultural and intellectual production of the Jesuits.

A tradition in the historiography of Jesuit mathematics emphasizes the struggle of the Jesuit mathematicians in establishing the legitimacy of their work. This narrative highlights the debate over the ontology of mathematics and the struggle various mathematicians had in articulating the ontological status of mathematics, particularly against the background of Aristotelian natural philosophy.[128] Yet, while some leading Jesuit natural philosophers sought to prevent mathematics from being recognized as a true science, Christoph Clavius (1538–1612), and those whom he taught, sought to invest mathematics with the same status as philosophy. So, when Clavius's mathematical works were brought together and published in the *Opera mathematica*, the book was intended to emulate in size and ornateness the famous *Disputationes metaphysicae* by Clavius's confrere Francisco Suarez (1548–1617).[129]

The historian James Lattis has argued that it was actually the practical utility of mathematics, particularly in the calendrical reform of 1581, which allowed Clavius to increase the importance of mathematics among the Jesuits.[130] More recently, the historian Michael

[127] Gorman, *The Scientific Counter-Revolution*. Romano Gatto, "Jesuit Mathematics," in *The Oxford Handbook of the Jesuits*, ed. Ines G. Županov Oxford University Press, 2018), 637–69. Others have very subtly recognized the Jesuits's influence. For instance, Matthew Jones has an entire chapter titled "Geometry as Spiritual Exercise," which assumes the influence of the Jesuits without arguing for the point as such, Matthew L Jones, *The Good Life in the Scientific Revolution: Descartes, Pascal, Leibniz, and the Cultivation of Virtue* (University of Chicago Press, 2008), 15–54.

[128] Hellyer, *Catholic Physics*, 119–22.

[129] Gorman, *The Scientific Counter-Revolution*, 30. On the influence and importance of Suarez, see Robert Maryks and Juan Antonio Senent de Frutos, eds. *Francisco Suárez (1548-1617) Jesuits and the Complexities of Modernity* (Leiden: Brill, 2019).

[130] James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of*

Gorman has built upon Lattis's suggestion of the importance of the calendrical reform by showing that within publications of Jesuit educational theorists as well as within Clavius's personal letters there was the recognition that it was important to learn mathematics as a Counter-Reformation activity. Gorman notes Clavius's concern that the Protestants were outperforming the Catholics in mathematical instruction which would enable them to gain more influence in their particular social locations. So, what Clavius envisioned was the creation of a network of trained mathematicians which could increase the visibility of the Jesuits at the courts of Catholic princes as well as bolster the influence and prestige of the Jesuit colleges throughout early modern Europe.[131] Thus the act of establishing mathematical instruction, as conceived by Clavius, was itself an act of confessionalization since it would both bolster the Catholic Church against the Protestants and also demonstrate the ingenuity of the Jesuit Order.

Jesuit mathematicians increasingly sought to establish the importance of mathematics. Within this program, the adoption of optics by certain members of the Jesuit Order becomes significant. When considering how optics came to be a topic of interest, what becomes quite evident is that any identification of optics as a designated science was not of first importance among the Jesuit Order in the sixteenth century. This aspect becomes apparent when considering the construction of the mathematics curriculum by Christoph Clavius, who beginning in the 1560s actively worked to institute the teaching of mathematics among the Jesuit pedagogical curriculum.[132] The finalized Jesuit pedagogical curriculum, known as the *Ratio Studiorum* (1599)

Ptolemaic Cosmology (Chicago: University of Chicago Press, 1994).

[131] Gorman, *The Scientific Counter-Revolution*, 18–22.

[132] On the role of Clavius in instituting Jesuit mathematics, see Romano Gatto, "Christoph Clavius' "Ordo Servandus in Addiscendis Disciplinis Mathematicis" and the Teaching of Mathematics in Jesuit Colleges at the Beginning of the Modern Era." *Science & Education* 15

bears the marks of Clavius's influence and shaped teaching at many Jesuit colleges throughout Europe.[133] A short analysis of Clavius's pedagogical suggestions gives some indication as to how optics fits within the overall mathematical understanding of mathematics.

When looking at Clavius's proposed mathematics curriculum, which he developed and presented to various Jesuit officials at the Roman College in the 1580s and 1590s, what becomes apparent is that he never specifically mentions "optics." Instead, he makes frequent mention of *perspectiva*, as well as topics oftentimes considered to be optical. Two in particular demonstrate that the more philosophical side of optics in the perspectivist tradition circulated alongside the more practical side. These are sundials and what were known as burning mirrors. Although mirrors were used most often, lenses were also used increasingly to project light and cause an object to catch fire.

For instance, in the sequence in which mathematics was to be finished in two years, during the first year, one should study "perspective" (*perspectiva*) as well as "a brief treatment of sundials."[134] Clavius also states that those who were not interested in mathematics should study "Perspective (*perspectiva*) together with *The Burning Glass*. I (Clavius) will write this up. Oronce Finé has published *The Burning Glass."*[135] For those wishing a longer course of

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(2006): 235–58.

[133] It is even quite likely that Villalpando's commentary on Ezekiel evidences Clavius's optical influence. On the influence of Clavius, see Jesús Paradinas Fuentes, "Las Matemáticas En La "ratio Studiorum" De Los Jesuitas," *Llul* 35 (2012): 129–162.

[134] Christoph Clavius, "Teaching Mathematics in Jesuit Colleges (c. 1581 and 1594)," in *Jesuit Pedagogy, 1540-1616: A Reader*, ed. Cristiano Casalini, and Claude Nicholas Pavur (Boston: Institute of Jesuit Sources, 2016), 290. See also *Monumenta paedagogica Societatis Iesu*, ed. Ladislaus Lukács (Rome: Institutum Historicum Societatis Iesu, 1965–1992), 7:114.

[135] Clavius, "Teaching Mathematics in Jesuit Colleges (c. 1581 and 1594)," in *Jesuit Pedagogy, 1540-1616: A Reader*, 287. See *Monumenta paedagogica Societatis Iesu*, ed. Lukács: 7:112.

mathematical study, *perspectiva* was studied in its relationship to particular disciplines, such as astronomy, geography, or music. Clavius states

> On account of the mathematical music theory, I would choose out of all of these, Giordano's *Arithmetic*. Still, if time is too short, all this can be left out or put off to the very end, together with algebra; especially if we should want only those things that bear on astronomy and geography and are reduced to them, like the description of clocks, perspective (*perspectiva*), and so forth.[136]

It becomes clear that Clavius conceptualizes optics within the perspectivist tradition. By this it is quite likely that he intends something similar to John Pecham's *Perspectiva communis*, as on one occasion he mentions that the teaching of perspective could make use of Clavius's own text, or "the common one," an epithet often used for Pecham's optical work.[137]

It is worth noting that Clavius also incorporates texts on burning mirrors into the mathematical curriculum, particularly an early sixteenth-century text, Oronce Finé's *Burning Glass* (1551). Finé (1494–1555), who was the first to teach mathematics as royal lecturer in the college established by Francis I of France, popularized many aspects of mathematics in the sixteenth century through his numerous mathematical works.[138] His work on burning mirrors

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[136] Clavius, "Teaching Mathematics in Jesuit Colleges (c. 1581 and 1594)," in *Jesuit Pedagogy, 1540-1616: A Reader*, ed. Cristiano Casalini, and Claude Nicholas Pavur (Boston: Institute of Jesuit Sources, 2016), 284. See also *Monumenta paedagogica Societatis Iesu*, ed. Ladislaus Lukács, 7:110.

[137] The *Perspectiva communis* exists widespread in both manuscript and printed formats. According to David Lindberg's assessment it exists in sixty-two manuscript copies in the thirteenth century, twenty-nine from the fourteenth century, twenty-six from the fifteenth century, two from the sixteenth century, one from the seventeenth. It was first printed in 1482 or 1483, being reprinted nine times throughout the sixteenth century, including an Italian translation. By 1627 the eleventh Latin edition of the work had been produced in Europe. David Lindberg, "Introduction," in *John Pecham and the Science of Optics*, 29.

[138] Angela Axworthy, "Oronce Fine and Sacrobosco: From the Edition of the *Tractatus de sphaera* (1516) to the *Cosmographia* (1532)" in Matteo Valleriani, ed. *De Sphaera of Johannes De Sacrobosco in the Early Modern Period: The Authors of the Commentaries* (Cham: Springer, 2020), 186–187.

explained how to reflect light rays using a parabolic mirror to ignite a fire wherever the light rays were focused. Finé's text was quite popular in the sixteenth century as Clavius's inclusion of it in his curriculum confirms.[139]

Finé's text is also worth noting because it demonstrates both the popularity of burning mirrors in the period as well as the way this knowledge circulated separately from the perspectivist optical tradition. In the previous chapter I noted that analyses of burning mirrors were not included in the canon of perspectivist optics. Yet, since antiquity, interest in burning mirrors circulated in many texts for a variety of reasons. For instance, it was widely believed that in antiquity Archimedes used burning mirrors to defend the city of Syracuse from the invading Roman ships.[140] In the thirteenth century, Roger Bacon defended the existence of the visual species and explained the metaphysical importance of light in his book on burning mirrors, written near the same time that he produced his *Perspectiva*.[141]

In the sixteenth and seventeenth centuries the explanation of burning mirrors had both a mathematical and symbolic meaning, in parallel with the interest of Archimedes and Roger Bacon. For instance, it allowed one to demonstrate one's mathematical prowess through actually creating the intended fire, while it also proved an important symbol of spiritual or theological knowledge. The Jesuits follow a similar pattern. In perhaps the earliest Jesuit publication on burning mirrors, *Speculum ustorium* (1613), half the text is a historical explanation of burning

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[139] See "Teaching Mathematics in Jesuit Colleges (c. 1581 and 1594)," in *Jesuit Pedagogy, 1540-1616: A Reader*, 289.

[140] Pendergrast, *Mirror Mirror*, 60–62.

[141] Pendergrast, *Mirror Mirror*, 72. For a broader cultural history of burning mirrors, see Gregory Lynall, "'Bundling Up the Sun-Beams': Burning Mirrors in Eighteenth-Century Knowledge and Culture," *Journal for Eighteenth-Century Studies* 36, no. 4 (2013): 477–490.

mirrors and their cultural lore, and the other half is a fairly basic mathematical explanation.[142] Alongside the mathematical aspects of burning mirrors in Jesuit texts, it is noticeable that burning mirrors came also to be a symbol for love, as well as the Eucharist itself. For instance, the Jesuit theologian Heinrich Engelgrave used the burning mirror as an analogy for the Eucharist, both in the text as well as in the imagery.[143]

Clavius's incorporation of burning mirrors in the Jesuit mathematical curriculum demonstrates how his conception of optics is broader than the perspectivist tradition. It is for this reason, too, that sundials were considered optics in his mathematical program. But the inclusion of burning mirrors also likely indicates the way in which his mathematical curriculum intended to address topics of common interest in the sixteenth century.

Based upon the curriculum within Clavius's own works, the interpretation and study of optics served the broader goals of mathematics itself, particularly geometry, rather than the specific goals of optics. Clavius seemed to favor his own textbooks for such instruction. His inclusion of optics nevertheless bears particular consideration for understanding the timing of the publication of Maurolyco's optical work, an issue which will be considered later in this chapter.

In addition to Clavius's mathematical curriculum, a further Jesuit document that significantly shaped Jesuit education and practice is worth mentioning—Antonio Possevino's *Bibliotheca selecta* (1593). Possevino (1533–1611) was himself an educational theorist whose

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[142] Francisco Ghevara, *Speculum ustorium verae ac primigeniae suae formae restitutum* (Rome: Bartholomaeus Zannetti, 1613). The text clearly interprets mathematics as stemming from Clavius and burning mirrors as part of optics.

[143] Heinrich Engelgrave, *Lux Evangelica, Pars I* (Antwerp: Widow and Heirs of Joannes Gnobbarus, 1654), 433.

Bibliotheca oftentimes circulated as a companion to the more well-known *Ratio studiorum*.[144] In the *Bibliotheca* Possevino states that individuals should learn optics to depict objects correctly, particularly for artistic and architectural purposes. As he explains it is optics that explains how a picture is created for the eye to see it with correct proportion and according to the principles of depth and distance. As he states, "with painting, optical reasoning is used."[145]

Possevino's statement here draws attention to another important aspect of optics among the Jesuits, namely the role of perspectival art and its relationship to mathematical optics. At the time the Jesuits developed their interest in optics, the more philosophical side of perspectivist optics was not altogether distinct from the artistic side of perspectival art. The two existed on a continuum, with common interests in mathematical representation, and were not as clearly delineated as the modern historiography often suggests.[146]

So, while Clavius's mathematical curriculum did not have a strong emphasis on mathematics for the sake of artistic construction, Possevino's inclusion of artistic elements of optics in such an important Jesuit book on pedagogy and cultural transformation demonstrates how optics among the Jesuits was pursued in more than a strict mathematical context. Later chapters will continue to attest to this aspect, particularly in the way in which Jesuits responded to significant changes in optical theory, such as the optics of Kepler.

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[144] John Donnelly, "Antonio Possevino, S.J. as a Counter-Reformation Critic of the Arts.," *Journal of the Rocky Mountain Medieval and Renaissance Association* 3 (1982): 153–64.

[145] Antonio Possevino, *Bibliotheca selecta*, *Vol 2* (Rome: Typographia Apostolica Vaticana, 1593), 2:313: Sané verò cum Pictura utatur optica ratiocinatione. For background on Possevino, see *Jesuit and Arts* 1540-1773, 127; Koen Vermeir,"Historicizing Culture: A Revaluation of Early Modern Science and Culture," in *Cultures Without Culturalism: The Making of Scientific Knowledge*, ed. Karine Chemla and Fox Keller, (Durham: Duke University Press, 2017), 232.

[146] This point is recently made in Sven Dupré, ed. *Perspective as Practice: Renaissance Cultures of Optics* (Turnhout: Brepols, 2019).

From this overview one may begin to recognize that in the sixteenth century, as one might expect, the Jesuits adopted perspectivist optics as important aspect in their mathematical instruction. Yet, fitting with the broader transformations of the sixteenth century, they also adopted aspects important to their own identity and confessional practices, such as the theory of sundials, as well as those of general interest, such as burning mirrors. This version of optics is generally maintained throughout the seventeenth century. So, for instance, in the history of optics included at the beginning of Claude Dechales's (1621–1678) *Cursus mathematicus* (1690), he includes artistic manuals, sundial treatises, and works on burning mirrors, as well as the more traditional works on optics.[147]

Optics was of interest to mathematicians, but also philosophers. At the same time that the new mathematical curriculum was pursued by the Jesuit mathematicians, certain other optical questions emerged, much more philosophical in nature, which created a context for mathematicians to demonstrate the philosophical importance of mathematics.

The Eye in the Jesuit *De Anima* Tradition

The 1586 version of the Jesuit educational system, the *Ratio studiorum*, states the following: "In the second book of the *De Anima*, on the exposition of the senses, philosophy should not digress in Anatomy, and similarly, of the things which are medicine."[148] In the version of 1591 and the finalized form of 1599, the *Ratio studiorum* states similarly, following

[147] Claude Dechales, *Cursus seu mundus mathematicus, 3 volumes* (Lyon: Anissonius, Joan Posuel, and Claude Rigaud, 1690), 64–74.

[148] *Monumenta paedagogica Societatis Iesu,* ed. Lukács, 5:106: In secondo vero libro de Anima, expositis sensoriis, non digrediantur philosophi in Anatomiam, et caetera, quae, medicorum sunt.

the principle established in 1586.[149] As Ignatius put forth among the first generation of Jesuits, and as later Jesuit affirmed, medical topics, similar to legal topics, were of lesser value than theology and philosophy, and so were routinely removed from the educational curriculum, particularly in the sixteenth century.[150] Nevertheless, despite the *Ratio studiorum*'s statement, beginning in the second half of the sixteenth century, many Jesuit authors actively engaged contemporary texts regarding human anatomy, particularly the anatomy of the eye, in their *De Anima* commentaries. This indicates the philosophical importance that the earliest Jesuit authors gave to the sense of sight, an aspect which continued throughout their philosophical writings, particularly in the first half of the seventeenth century.

The discussions on the human body were especially important in the commentaries on Aristotle's *De Anima* Book II. It is here that Aristotle delineates the relationship between sensation and knowledge by stating that "The ground of this difference is that what actual sensation apprehends is individuals, while what knowledge apprehends is universals, and these are in a sense within the soul itself."[151] The history of this particular passage is extensive since it explains the way in which knowledge is created. The sixteenth century evidenced a wide array of theories as to how intellectual knowledge occurred and its particular relationship to an individual's soul.[152]

While the complexities of the topics addressed in sixteenth-century *De Anima*

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[149] *Monumenta paedagogica Societatis Iesu*, ed. Lukács, 5:398.

[150] Jos V. M Welie, "Ignatius of Loyola on Medical Education: Or, Should Today's Jesuits Continue to Run Health Sciences Schools?", *Early Science and Medicine* 8 (2003), 26–43.

[151] Aristotle, *De Anima* II, 417b 21–23.

[152] Katharine Park, "The Organic Soul.," in *Cambridge History of Renaissance Philosophy* (Cambridge, UK: Cambridge University Press, 1988), 464–84.

commentaries goes beyond the purview of this study, it is nevertheless important to note that the Jesuits were active participants within such discussions. For instance, in Francisco Toledo's commentary on the *De Anima*, published in 1575, there is an extensive treatment of the eye's anatomy in the *quaestio*, "whether the eye makes vision from the senses."[153] Among the aspects analyzed, Toledus not only covers the usual philosophical components involved in the study of vision, such as lumen and color, which Aristotle had addressed in Book II, Chapter 8 of the *De Anima*, but also the anatomy of the eye with extensive analysis of both Galen and Vesalius, an aspect not included in Aristotle's *De Anima*.[154] There is similar interest within the Coimbra commentary on *De Anima* published in 1598. Similar to Toledus, this commentary discusses the importance of the description of the eye by Galen (129–216) and Vesalius (1514–1564). The commentary, however, goes beyond Toledus in adding to this anatomical understanding a question as to whether the visual process occurs in the retina or in the crystalline humor. In this commentary in particular, the authors not only discuss the anatomy of the eye, but also whether the process of vision occurred in the crystalline humor or in the optic nerve, and the relationship between the eye and the discipline of *perspectiva*.[155]

Naturally, then, the topic of the visual species — its nature, relationship to *perspectiva*, and its role in the eye's anatomy — proved to be an important topic within these Jesuit commentaries. Daniel Heider notes that there was not one uniform understanding of Aristotle or of "species" within the commentaries of the Jesuits in this period. Rather, as he contends, there

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[153] Francisco de Toledus, *Commentaria, una cum quaestionibus, in tres libros Aristotelis de anima* (Venice: Giunti, 1585), 85v: *Quaestio XVI. An oculus fit sensorium visus*.

[154] Toledus, *Commentaria*, 85v–86v.

[155] *Commentarii Collegii Conimbricensis S. J. In tres libros de Anima Aristotelis Stagiritae* (Coimbra: Antonius a Mariz, 1598), 188.

was a variety of interpretations and understandings, indicative of the way in which the Jesuit authors were expanding the bounds of traditional Aristotelian understandings of cognition.[156]

In her study of the Jesuit *De Anima* commentaries, Alison Simmons found that the Jesuits drew important distinctions between the ontological and material nature of the species and its role in the visible process. As she notes, the authors go to great lengths to substantiate the significance of the "species," and the way in which it illuminates the intellect. As Simmons indicates, all of these authors are quite fascinated by the way in which something physical can influence the immateriality of the soul. As a consequence the senses are in some way an active faculty: they elicit (elicere), produce (edere, proferre), effect (efficere) or serve as the active cause of (causa activa) sensation.[157] Using analogies pulled from visual theory and the science of vision, such as light illuminating objects hidden inside a colored vase, the process of cognition occurs as the intellect is illuminated by the physical forms of the species.[158] Based on Simmons's observations, the most significant aspect is her observation that the Jesuits' detailed focus on the *De Anima* commentaries framed their theological ideas about the soul, the senses, and intellectual cognition, and that these ideas were not abstract concepts but they were connected to the physical natures of the senses.

Jesuit commentators on Aristotle's *De Anima* did not merely reproduce arguments and understandings of the medieval past. Commenting on this aspect, the Jesuit Francisco Suarez

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[156] Daniel Heider, "Introduction," in Daniel Heider, ed. *Cognitive Psychology in Early Jesuit Scholasticism* (Neunkirchen-Seelscheid, Germany: Editiones Scholasticae, 2016), 1–11.

[157] Alison Simmons, "Jesuit Aristotelian Education: *De Anima* Commentaries," in O'Malley, et al., eds. *The Jesuits*, 530.

[158] Simmons, "Jesuit Aristotelian Education: *De Anima* Commentaries," in O'Malley, et al., eds. *The Jesuits*, 531–533.

says this about Aristotle's understanding of the eye after pointing out some of Aristotle's deficiencies: "many things about the fabric and dissection of the parts of the human body" were unknown at this time; however, "this was the fault of that age, not of the man"[159] Thus the adoption of human anatomy as a topic of interest within the *De Anima* commentaries represent the intention to do more than merely perpetuate antiquarian thought, but to frame the understanding of the eye within contemporary discourse.

In the Jesuits' explanations of the *De Anima* certain emphases emerge with respect to the sense of sight. One is the way in which the sense of sight was regarded as philosophically more important than the other four senses. Sight stood as the only sense the experience which was not understood as being a comparative quality—a sense of greater or lesser extent.[160] Such an observation reinforces a particular Jesuit debate at the time about the relationship between the sense of sight and the post-mortem life. The question at issue was whether the sense of sight prior to death functioned similarly to the sense of sight after the body was resurrected from the dead. Most Jesuits assumed this to be the case, which implied the ability for one to attain spiritual insight in the present, even prior to death.[161] This particular spiritual knowledge,

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[159] Quoted in Michael Edwards, "Body, Soul and Anatomy in Late Aristotelian Psychology," in *Matter and Form in Early Modern Science and Philosophy*, ed. Gideon Manning (Leiden: Brill, 2012), 43.

[160] Coimbra, *De Anima*, 272.d.e It should be noted that not all agreed in the supremacy of the visual experience. At the beginning of the sixteenth century, Charles de Bovelles composed his Liber de sensibus (1509) in which he argued that hearing was superior to sight. Within the development of Christian theology such an indication was likely connected to Romans 10:17, faith came from hearing: fides ex auditu. Hilmar Pabe, "Interior Sight in Peter Canisius' Meditations on Advent," in Wietse De Boer, Karl Enenkel and Walter Melion, eds., J*esuit Image Theory*, (Leiden: Brill, 2016), 266.

[161] Bernd Roling, "Light from Within - the Debate on the Glorified Body in Jesuit Theology: Francesco Suárez, Adam Tanner and Rodrigo Arriaga," in Danijela Kambaskovic, and Charlest T. Wolfe, eds., *Cognitive Psychology in Early Jesuit Scholasticism*, 123–159; "The Senses in

oftentimes referred to as the "beatific vision," shows up not only in philosophical works, emblem books, and biblical commentaries, but also books on optics. Examples like this reinforce the way in which optics functioned among the Jesuits as a cultural field, cutting across many diverse subject areas.[162]

The widespread Jesuit network of colleges, and the many textbooks they wrote, put them in a position where they were among the chief popularizers of the eye's anatomy. Such information was even included in vernacular texts of wide distribution. This popularization was important for the Jesuits, I argue in this chapter, not merely for the sake of information, but because the eye's anatomy was intricately linked to the question of visual certitude. This in its turn relied upon the axiomatic role of the visual species in the attainment of true knowledge.

The Visual Species

Before specifically addressing important aspects of optics among the members of the Jesuit Order, attention should be given to their development of the "visual species." In the first chapter it was explained that the visual species was the mechanism whereby visual intelligibility could occur. Visual species were representations of visual objects which enabled the mind to see the actual object they represented. According to Aristotle, it was not possible to think apart from

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Philosophy and Science," in Herman Roodenburg, ed. *A Cultural History of the Senses in the Renaissance* (London: Bloombury, 2014), 110.

[162] The Jesuit authors were not without precedent in affirming the significance of the visual sense. Plato referred to "the eye of the soul" intending to convey the ethical significance of the eye, Plato, Republic VII, 527d. In his Metaphysics, Aristotle wrote, "we prefer sight, generally speaking, to all other senses… [O]f all the sense, sight best helps us to know things, and reveals many distinctions." Aristotle, Metaphysics, 980a25. In his *Summa Theologica*, the medieval theologian and philosopher Thomas Aquinas listed sight and hearing as "most concerned with beauty…which ministers to reason." Thomas Aquinas, Summa Theologica, II.1 xxvii.

the representation of pictures within the eye, and so from within his thought the "sensible species" was established as an explanation for both vision and cognition.[163] The adoption of such a theory of sensation and cognition expanded significantly within the work of Galen, as the physical brain and its various chambers were connected to various qualities of the species, whether visual or sensible. Both for Aristotle as well as for Galen, the object of sight was color, and its mode of transportation was the intervening medium made transparent by the lumen.[164] How precisely this worked, such as the relationship between the species and the actual object and the materiality of the species, were thorny questions of immense debate, particularly in the late-medieval period.[165] For the purposes of this dissertation the only important point, and the one maintained consistently by all of the Jesuit mathematicians, is that the species did in fact represent the visualized object, an essential aspect for the explanation of cognition undergirding optical theory.

This connection between the process of vision and cognition would have important consequences in the Christian period, as the visual species came to be associated with theological understanding. For instance, St. Augustine (354–430), used the theory of the visual species to explain the way in which vision occurred, interweaving together the identity of various visual species, and the way in which such species were able to reveal different theological truths.[166]

The visual species was maintained and extensively reinforced in the formation of the perspectivist optical tradition, in the work of Ibn al-Haytham, Witelo, and Roger Bacon, the

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[163] Smith, *From Sight to Light*, 32.

[164] Smith, *From Sight to Light*, 32, 43–46.

[165] Smith, *Sight to Light*, 246–250.

[166] Smith, *From Sight to Light,* 152–153.

medieval intellectuals who organized the perspectivist optical theory into a unified system. Al-Haytham developed an explanation of the visual process which involved punctiform analysis of light and color between the object seen and the eye itself, such that an object and its representation within the visual species occurred such that every point on the body had a corresponding point on the visual species. What this entailed was an understanding in which singular visual rays corresponded to locations on the visual species, such that the entirety of the object was represented in the species, and thus the object was fully represented within the eye—and ultimately within cognition itself.

Al-Haytham's development of the visual species was transmitted in the Latin West within the optical works of Roger Bacon, particularly his "multiplication of the species."[167] This theory explained the way in which an object emits species at all angles, which accounted for how the same object could be seen from multiple different angles and positions. More will be said about this in Chapter Three, where I will explain why many Jesuits did not find it problematic to adopt Kepler's optics within their overall understanding of vision. After William of Ockham (1295-1347) challenged the validity and reality of the visual species in the fourteenth century, as the historian Katherine Tachau has demonstrated, their vigorous return in the wake of his criticisms reinforces the widespread importance that the visual species had within so many facets of late-medieval intellectual thought.[168] For the most part, until the Jesuits formed in the sixteenth century, the visual species remained an important aspect of visual and philosophical explanations. And as is evident from within the formation of Jesuit philosophical development,

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[167] Smith, *From Sight to Light*, 266–270.

[168] Katherine H Tachau, *Vision and Certitude in the Age of Ockham: Optics, Epistemology, and the Foundations of Semantics, 1250-1345* (Leiden: Brill, 1988).

species in general, and visual species in particular, gained particular importance.

One example may serve to illustrate the importance of the visual process in the attainment of knowledge among the members of the Order. In one of the best known theological treatises on the natural world at the beginning of the seventeenth-century, *The Ascent of the Mind to God* (1615), the Jesuit Cardinal, Robert Bellarmine (1542–1621), includes an extensive appeal to the role of vision in the process of attaining knowledge. Bellarmine intended the treatise to be interpreted as following in the spiritual tradition of Bonaventure's *Itinerarium* (mid-thirteenth century). Consequently Bellarmine presented his work, like Bonaventure, as a pilgrimage. The goal of the text is to lead the individual through correspondences, such as between the natural world and man's human condition, and then present their significances in the context of divine theology.[169] And so, as Bellarmine states, one ought to "lift up the eye of the mind to God, and consider how great virtue, power, and efficacy reside in the Lord your God."[170]

That Bellarmine intends to evoke more than mere metaphor, and that the visual and the cognitive were interrelated may be noticed in an extended passage within which the occasion of spiritual knowledge is vividly explained using the physiology of vision.

> In order to exercise this sense, a man must have a visive faculty distinct from the Soul, which properly lives; there must be an Object, I.e. A colour'd Body, plac'd without himself; there must likewise be the Light of the Sun, or some luminous Body; there must be a medium, i.e. a transparent Body; there must be a sensible species, which must reach from the Object to the Eye; there must be a Bodily Organ, I.e. An eye furnished with various humors, and fleshy tunicles; there must be sensitive Spirits, and Optick Nerves, by which the Spirits may have Passage; there must be a proportionate distance, and the Application of the Faculty. Behold what assistances Men, and other Creatures, need to

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[169] Paul G. Kuntz, "The Hierarchical Vision of St. Robert Bellarmino," in *Acta Conventus Neo-Latini Turonensis*, ed. Jean-Claude Margolin (Paris: J. Vrin, 1980), 959–977.

[170] Bellarmine, *De ascensione mentis in Deum* (Rome: Jacobus Mascardus, 1615), 44: Attolle nunc, anima, oculos mentis ad Deum, & cogita quanta virtus, quanta efficacitas, quanta potentia in Domino Deo tuo fit.

perform one vital Action![171]

What is important to note within this passage is the clear detail that Bellarmine provides in his explanation as to how the visual process occurs. It is quite evident that Bellarmine did not intend to explain the visual process. The work is a theological reflection on the process of attaining wisdom and this particular passage serves to explain the intricacies involved in acquiring wisdom. Nevertheless, it is important to notice that the eye's anatomy, and the existence of the object within the eye receive such detailed attention. This exquisite detail, in a context that does not require it, underscores the way in which the processes involved in vision served as an analogy to the way in which knowledge acquisition occurs. Bellarmine did not intend to provide a clear articulation of the optics of vision; but his ready access to the theory of vision demonstrates how the physiology and optics of the eye proved important for the Jesuits for more than mere mathematical problems.

Within such a context Jesuit authors used a consistent analogy, in which the ontology of the visible species was explained in terms of statues of Caesar, saying that a species is an "image" or "statue" of Caesar. Such an identification is verbatim in all the Jesuit authors up until the latter part of the seventeenth century.[172] The analogy states that a visible species represents

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[171] English from Robert Bellarmine, *The soul's ascension to God*, trans. H. Hall (London: Robert Gibson, 1703), 68; Original Latin text in Bellarmine, *De ascensione mentis*, 97: Ac ut in actione videndi ponamus exemplum. Homo ut vident, eget potentia visiva quae distincta est ab anima, quae propriè vivit; eget obiecto, idest, corpore colorato extra se posito, eget lumine Solis, aut alicuius abterius corporis luminosi; eget medio, idest, corpore perspicuo; eget specie sensibili, quae ab obietto ad oculos deferatur; eget organo corporali, idest, oculo variis humoribus, & tunicis carneis instructo; eget spiritibus sensitivis, & nervis opticis, per quos spiritus illi transeant; eget distantia proportionata; eget applicatione potentiae. Ecce quantis adminiculis indigent homines, & animantia caetera.

[172] Villalpando, *In Ezechielem, Vol 2*, 56; Aguilonius, *Opticorum*, 48; Zacharia Traber, *Nervus opticus sive tractatus theoricus* (Vienna: J. C. Cosmerovius, 1675), 43; Kircher, *Ars magna*, 160–161; Gaspar Schott, *Magia universalis naturae et artis* (Würzburg: Henricus Pigrin, 1657),

an object, similar to how a statue of Caesar represents Caesar.[173] What such an explanation intends to convey is the way in which a singular species may meaningfully communicate about a common object, without necessitating a clear ontological identification. Thus, similar to how various statues of Caesar evokes the knowledge and identity of a singular Caesar, so also does a singular species provide meaningful knowledge about a universal object.[174]

Mathematics was more than a tool of optics, but was embedded in the underlying philosophical explanation for how one obtains knowledge from an object—aspects which will become clearer by considering the earliest Jesuit works on mathematical optics which set a precedent for many decades following.

Jesuit Mathematical Optics

The visual species was a major justification for the philosophical importance of optics. This follows naturally from the perspectivist optical tradition. Recall that the visual species provided the mechanism for obtaining knowledge of the natural world and that it operated according to mathematical, anatomical, and physical principles. It was for this reason, as shown in the preceding two sections, that the philosophers developed an interest in the anatomy and physiology of the eye. As the following sections will show, the earliest Jesuit mathematicians explained the relationships between the mathematics of optics and its relationship to vision and

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1:77; Grimaldi, *De lumine*, 284.

[173] For example, Aguilonius, *Opticorum*, 48: quo pacto Caesaris imago, etsi ab ipso toto genere diffideat, eum tamen expressa similitudine repraesentat.

[174] The precise origin of the statue metaphor is difficult to clearly identify, but likely goes back to Roger Bacon and Bonaventura. Thomas Maloney, "Roger Bacon on the *Significatum* of Words," in Lucie Brind'Amour and Eugen Vance, eds., *Archéologie du signs* (Toronto: Pontifical Institute of Mediaeval Studies, 1983), 187–211.

cognition for similar reasons.

The following sections provide an analysis of the earliest mathematical optical treatises by the Jesuits, looking in particular at Maurolyco's *Photismi de lumine et umbra* (1611), Villalpando's *In Ezechielem explanationes* (1595–1604), and Aguilonius's *Opticorum libri sex* (1613). These texts formed the basic framework for Jesuit mathematical optics until the middle of the seventeenth century, and so they deserve special attention.

Through an analysis of these texts, I will show that the Jesuits adopted perspectivist optics as their theoretical framework for explaining mathematical optics. I will show that these authors aligned their mathematical theories with the analyses of the Jesuit philosophers. I will also show that this continued throughout the seventeenth century in later Jesuit mathematical works and philosophical works, reinforcing the way in which optics was an important confessional tool for the activity of early modern Jesuits.

Francesco Maurolyco, *Photismi de lumine et umbra*

Among the earliest books on optics used by the Jesuits was that of Francesco Maurolyco (1494–1575). The book exists in two editions, the *Photismi de lumine* (1611) and the *Theoremata de lumine et umbra* (1613).[175] The book itself represents a fairly concise summary of basic perspectivism in the sixteenth century. Its importance within the history of optics pertains to the way it explains how concave lenses aid to correct myopia (nearsightedness), the first explanation in the history of optics.[176] What is often forgotten in the usual history of optics,

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[175] Francesco Maurolyco, *Photismi de lumine* (Naples: Tarquinius Longi, 1611); Francesco Maurolyco, *Theoremata de lumine et umbra* (Lyon: Barthélemy Vincent, 1613).

[176] Smith, *Sight to Light*, 338.

however, is that his works exist in print form on account of the Jesuits. Maurolyco died in 1575 without having published any of his optical works, and it was the Jesuits who preserved the manuscripts and supported their printing, at least in the 1611 edition. Such an active role on the part of the Jesuits in the formal printing of his optical works would have a lasting impact on their own intellectual trajectory, as his works were cited regularly in the first half of the seventeenth century. While not formally a Jesuit, Maurolyco's edited works nevertheless formed an important piece of the Jesuit optical tradition.

Francesco Maurolyco was a Benedictine abbot. He became, however, influential in helping the early Jesuit Order organize their mathematics curriculum during his time as a Professor of Mathematics at the University of Messina, in 1569.[177] As previously noticed, among Clavius's important sources when establishing the mathematical curriculum were the scientific works of Maurolyco. It should not be a surprise, then, that Clavius helped publish the preserved manuscripts of Maurolyco's optical developments from the sixteenth century. In addition to aiding in the work's publication, Clavius added editorial insertions throughout both the *Photismi de lumine* as well as the *Theoremata*.[178] The notes to the reader state, "Moreover, through the judgement and notes of Father Clavius, which we insert among the demonstrations of the author, but in a different type, we aim at greater clearness and at your convenience."[179] For the history of Jesuit optics, these insertions are quite significant, as they are the only printed text by Clavius

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[177] Latis, *Between Copernicus and Galileo*, 19.

[178] Letters between Clavius and the wealthy nobleman, Giovanni Giacomo Staserio, indicate the way in which Staserio was the patron of the publication of the 1611 edition. Riccardo Bellè, "Il Corpus Ottico Mauroliciano: Origini E Sviluppo." *Nuncius Istituto e Museo di Storia della Scienza Firenze*. (2006): 13.

[179] Maurolico, Francesco. *The Photismi De Lumine of Maurolycus: A Chapter in Late Medieval Optics*, trans. Henry Crew (New York: The Macmillan company, 1940), 4.

explicitly on the topic of optics.[180]

Maurolyco self-identifies his work as standing within the tradition of the perspectivists, identifying both Roger Bacon and John Pecham by name among the authors that he follows.[181] For instance, it is noticeable that he maintains the distinction between "lux" and "lumen" and uses the visual pyramid and visual species to explain the process of sight.[182] Yet, he parts ways with Pecham, Bacon, and other perspectivists. Largely drawing upon the most recent anatomical investigations, such as Vesalius, he reassesses the problem of myopia (nearsightedness) and explains that it is caused by the curvature of the face of the eye's outer lens. As he explains, curved glass is able to affect the visual rays in such a way that they will meet appropriately at the back of the eye, the novel aspect of Maurolyco's optics.[183] What is quite interesting in this regard is that Maurolyco's optical explanation departs from the idea that the lens is a sensitive substance. According to the dominant view, the visual process occurred less with respect to the outer lens, and more with the angle in which the visual rays project the species within the center of the eye. By attributing the location of the species's projection within the eye to the curvature of the anterior surface of the eyeball, Maurolyco contends that the structure of the eye's surface affects the project of the species within the eye. And, it also implies that there is not fixed location for the center of vision, but that it is a contingent aspect based upon where the object is,

[180] Ugo Baldini suggests that these notes might provide an early clue as to optical instruction at the Collegio Romano, in "The Academy of Mathematics," in *Jesuit Science and the Republic of Letters*, 74–75, n. 14.

[181] For instance, Francesco Maurolico, *The Photismi De Lumine of Maurolycus: A Chapter in Late Medieval Optics*, trans. Henry Crew (New York: The Macmillan company, 1940), 110.

[182] Maurolyco, *Photisimi*, 69–75.

[183] Maurolyco, *Photisimi*, 69–80.

the structure of the eye, and any spectacles an individual might be using. While Maurolyco's contention is noticeable in previous optical writers, as Mark Smith points out with regard to Ibn al-Haytham's *Perspectiva*, it was nevertheless a fairly unrecognized point in the sixteenth century.[184]

Maurolyco, however, did not dismiss the *perspectiva* tradition in its entirety. On occasion he explicitly cites both Roger Bacon and John Pecham and their respective optical works. In one location he also mentions that the visual process includes the transmission of the "species of visible objects" (*visibilium species*) to the back of the eye.[185] He also explained vision using the visual pyramid and the principle of intromission. In his chapter on shadow and reflection he writes,

> A source of light therefore radiating through any aperture, produces an infinity of pyramids which, because they do not increase in the same proportion as the intervals between the surfaces gradually unite into one; and finally all become a single pyramid, joined together by the space between the surfaces, the form of the pyramid varying slightly in accordance with the foregoing corollaries.[186]

This quote addresses the camera obscura and the way an image forms through an aperture as a composite from the overlapping visual pyramids from the projected object. It came to be a prominent citation among Jesuit authors because the camera obscura provided a way to hypothesize not only about how vision occurred, as addressed in the first chapter of this dissertation, but also about the legitimacy of the visual species.

The broader context of this passage in Maurolyco's work also explains how eyeglasses work effectively, and as such provides added significance to the inclusion of the camera obscura

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[184] Smith, *From Sight to Light*, 288, 340.

[185] Maurolyco, *Photismi de lumine* (1611), 69.

[186] Maurolyco, *The Photismi De Lumine of Maurolycus*, trans. Henry Crew, 30.

within it. As noted in the first chapter, historians have regarded the analogy between the camera obscura and the eye as a significant development within the history of optics because this comparison effectively transforms the eye and the visual process into a mechanical process, thereby dismantling the perspectivist optical theory. Maurolyco's explanation here, which easily adapts to the camera obscura, shows how such a narrative was not clearly apparent to the historical actors themselves. More attention will be given to similar lines of reasoning among members of the Jesuit Order in Chapter Three of this dissertation.

From all of this, it is apparent that Maurolyco's text in many respects stands as a transitional bridge between the medieval and the early modern understanding of optics, integrating newer understandings, particularly of the science of refraction as in the case of eyeglasses, within the more traditional perspectivist models of optics. What this means is that near the beginning of the process of Jesuit mathematicians organizing the mathematical curriculum, one of the earliest sources of knowledge was fortuitously one of the most informed mathematical and optical texts of the period. The Jesuits were updating the traditional view of optical knowledge in light of recent technological developments.

While Clavius worked to publish Maurolyco's works, two other Jesuits, Juan Bautista Villalpando (1552–1608) and Franciscus Aguilonius (1567–1617), worked to publish their own mathematical explanations of optics.

Juan Bautista Villalpando, *In Ezechielem explanationes*

The work of Juan Bautista Villalpando and Franciscus Aguilonius reinforces an important connection; their mathematical optics serves not merely to explain the mathematics of light, the sundial, or architecture, but it also pays important attention to the philosophical concerns of sight, such as those raised by the *De Anima* commentaries explained earlier in this chapter. The importance of this component, as will be shown, may be instantly noticed by the way in which each author actively incorporated the “species” in their explanation of vision, an aspect of optics that was noticeably absent in the Latin edition of Ibn al-Haytham produced in the sixteenth century.[187]

The first focused explanation of optics specifically by a Jesuit shows up in the biblical commentary, the *In Ezechielem explanationes* (1596–1604). The three-volume *In Ezechielem explanationes* represents a collaborative project between two Spanish Jesuits, Jerónimo del Prado, a theologian, and Juan Bautista Villalpando, a mathematician and architect. The work covers both the exegesis of the book of Ezekiel as well as the mathematics of the Jerusalem Temple. An understanding of optics within this commentary reinforces the previous point connecting optics and the *De Anima* tradition, and shows the way in which optical explanations were woven into the explanation of art and architecture.

Del Prado was born in the Spanish southern province of Jaén in 1547 and entered the Society of Jesus in 1572. In 1580 he became the teacher of Sacred Scripture at the small Jesuit College in Baeza. It is quite probable that it was in Baeza, perhaps around 1583, that he developed the acquaintance with the mathematician and architect Juan Bautista Villalpando.[188] Villalpando was born in Córdoba in 1552, and, as he explains in the dedication to Volume One, he owed a lot of his education to King Philip II, and he had studied mathematics with the chief

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[187] Thomas Frangenberg, “Perspectivist Aristotelianism: Three Case-Studies of Cinquecento Visual Theory,” *Journal of the Warburg and Courtauld Institutes* 54 (1991), 142.

[188] René Taylor, “Hermetism and Mystical Architecture in the Society of Jesus,” in Rudolf Wittkower, and Irma B. Jaffe, eds., *Baroque Art: The Jesuit Contribution* (New York: Fordham University Press, 1972), 67.

architect of Philip II, Juan de Herrera.[189] However, the untimely death of Del Prado in 1595, one year before the publication of volume one, meant that Villalpando was responsible for the entirety of Volume Two and Three. This development explains why the second and third volumes, both published in 1604, contain comparatively more mathematical and scientific ideas, and Volume One is largely devoted to exegetical analysis.

The stated purpose of the commentary series, as identified in the first volume, was to reconcile the biblical accounts of Solomon's Temple as described in 1 Kings and 2 Paralipomena (known as Chronicles in the Protestant tradition) and the Temple of Jerusalem as described in Ezekiel. Notably, such an explanation involved both exegetical and scientific analysis. What this suggests is that in the scope of their analysis the different biblical texts had to be shown to agree not only in their theological sense, but also in the scientific dimensions described.[190] Villalpando's intellectual concerns should be understood as located within a topic of much wider interest in the seventeenth century. In addition to his book, it is known that other commentaries on Ezekiel generally indicated an interest in the way in which Ezekiel could be used to determine the nature of geometry more broadly.[191] As the historian Teresa Morrison points out, interest in the Temple, and perhaps Ezekiel more broadly, continued throughout the seventeenth century, most notably in the Walton's *Polyglot* and Isaac Newton.[192] Such widespread interest reinforces

[189] Juan Bautista Villalpando, *In Ezechielem explanationes, Tome I* (Rome: Aloysius Zannetti, 1596–1604), 1:V.

[190] Villalpando, *In Ezechielem explanationes,* 1:IX–XIII.

[191] One example is Matthias Hafenreffer's *Templum Ezechielis* (Tübingen: Johannes Bernerus, 1613), which contains an appendix explaining the nature of Geometry. Of note is the fact that Hafenreffer indicates that Michael Maestlin and Johannes Kepler each helped Hafenreffer explain what he meant by geometrical proportion.

[192] Tessa Morrison, "Introduction," in *Juan Bautista Villalpando's Ezechielem Explanationes: A*

not only the importance of this book, but also the explanation of optics within it.

Among the theological justifications for such extensive mathematical renderings was the belief that Ezekiel was an expert geometrician and as such would have embedded expert mathematics in his explanations.[193] The final form of the biblical book of Ezekiel describes both a judgment on the nation of Israel as well as the future establishment of the renewed Kingdom, with particular attention given to the new Temple and its various furnishings. The explanations of the proportions of the Temple, the nature of sound within it, and the optical foundations (as will be shown), imply a scientific wisdom, which Villalpando worked to reveal. Interest in these proportions was likely influenced by Juan de Herrera, the chief architect of Philip II who notably produced the Escorial palace-monastery.[194] Herrera had previously composed the book *Sobre la figura cúbica* that explained the way in which harmony and proportion reveal divine inspiration similarly to Villalpando's later sections on sound and geometric harmonies within the Jerusalem temple.[195] Such an interest in proportions in mathematics, as Villalpando explains, even enables one to explain the proportion of the Temple with Jesus's body.[196] Architecture theory was made intelligible through divine harmonies, within which optics was included as background to the architecture of the Temple.

In the opening of Volume Two Villalpando connects optical theory and divine order

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Sixteenth-Century Architectural Text, trans. Tessa Morrison (Lewiston, NY: Edwin Mellen Press, 2009), 83.

[193] Juan Bautista Villalpando, *In Ezechielem explanationes,* 2:19.

[194] Morrison, "Introduction," in *Juan Bautista Villalpando's Ezechielem Explanationes*, 50.

[195] Morrison, "Introduction," in *Juan Bautista Villalpando's Ezechielem Explanationes*, 6.

[196] Juan Bautista Villalpando, *In Ezechielem explanations*, 2:140.

together by showing how they are related through the topic of architecture. Villalpando explains that the five classical architecture orders, Doric, Ionic, Corinthian, Tuscan, and Composite, as well as the later Vitruvian, were all revealed by God to King Solomon in the tenth century BCE. Vitruvianism plays a particularly important role, as an intermediary between the time of Solomon and the early modern period, and thus the study of Vitruvius (c. 80 BCE–15 BCE) provides an avenue through which one might understand the wisdom of Solomon—and ultimately the divine architectural plan of the Temple itself.[197]

The purpose of reclaiming such knowledge was for more than mere antiquarian interest. As Villalpando explains, his architectural design is not merely for the artisan or the architect, but also for the theologian, "so that it might be conducive to the Theologians so that they might form a mental idea or image of the Temple in the mind."[198] There is a close conceptual relationship between the scientific and mathematical merits of the work and its perceived theological significance. It is also on account of the mental formation of the Temple that the topic of optics receives particular attention.

In Villalpando's assessment, optics involved the assessment of light and vision, all perspectivist topics. Throughout this section Villalpando cites theorems from John Pecham's *Perspectiva communis*, although he does not identify the author.[199] He also describes the way light moves rectilinearly and how eclipses help one to prove this point. These explanations are thin and give the impression that they were included due to the nature of scholastic reasoning in

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[197] Juan Bautista Villalpando, *In Ezechielem explanationes,* 2:62.

[198] Villalpando, *In Ezechielem* explanations, 2:Lectori: disputatis ijs, quae essent necessaria, & quae potissimum Theologis conducerent ad imaginem Templi cogitatione informandam.

[199] This is suggestive of the way in which Pecham's *Perspectiva communis* was a well-known work in the sixteenth century

which one gradually moves through a particular topic. It becomes clear that Villalpando is most interested in optics because it provides an explanation of how cognition itself occurs.

When explaining the nature of the mental image Villalpando goes to great length to analyze the "fascination" of the eyes, which is the idea that one was able to affect change on another person through the emission of visual rays away from one's eyes. In the period the "fascination" of the eye was a general term that could be used to explain many different effects caused by one's visual powers. Villalpando includes two such examples. First, he explains the existence of the eye's fascination by following a passage from Pliny's *Natural History*, Book VII, which refers to individuals within the Triballi and Illyrii in Africa who are able to kill people through the power of the visual rays proceeding from their eyes. He also explains the fascination of the eyes with the classic example of the menstruating woman and the bloody mirror, which had existed since antiquity, and which explained how a menstruating woman looking into a mirror would cause a vapor to appear, thereby demonstrating how visual rays proceed from the eye. Both examples operated on an extramissionist model of vision and show the way in which these optical topics, while pertaining to the theories of magic at the time, nevertheless also actively borrowed from discussions within standard optical theory—in this case the debates between extramissionism and intromissionism.[200]

When the fascination of eyes does occur, a point which Villalpando does not categorically deny despite his defense of the intromissionist theory of vision, it occurs through the effect of the Devil upon one's mental faculties. He substantiates this point through quoting a

[200] Villalpando, *In Ezechielem explanations*, 2:52. Berthold Hub, "Aristotle's 'Bloody Mirror' and Natural Science in Medieval and Early Modern Europe," in Nancy Frelick, ed., *The Mirror in Medieval and Early Modern Cultures Specular Reflections* (Turnhout, Belgium: Brepols, 2016), 32–71.

portion of a sermon by John Chrysostom (347–407). The occasion of Chrysostom's sermon is the biblical text of Galatians 3:1 "O foolish Galatians! Who has bewitched (lat. *fascinauit*) you, to not obey the truth?" Due to the way the Latin text of Galatians 3:1 includes the word from which "fascination" is derived, this sermon frequently circulated with theories of fascination. For Villalpando it allowed him to maintain the fascination of the eyes (which was widely discussed in the period) while at the same time denying the extramissionist model of vision. Thus, as he states "it (the fascination of the eyes) becomes an attack by demons," and hence is not something induced by one's own activity of eyesight.[201] What is important to note is the way that Villalpando borrows from optical theory in order to substantiate a philosophical perspective on these two topics of widespread interest.

The next important topic Villalpando addresses is the relationship between the visual species and the objects of sight. That the visual species was an important topic in Villalpando's explanation may be noticed in his inclusion of two small engravings to explain the process. It occurs in a section where Villalpando explains how it is light (lux) which enables the transmission and reception of all forms.[202] Villalpando also explains the rectilinear propagation of light, using as an example the experience of an eclipse to demonstrate such an effect. Villalpando's explanation incorporates a diagram of the eye with the visual species noticeably included within the eye itself. Not only does this underscore Villalpando's understanding of the mental visualization, but it also reaffirms the interconnectivity between vision, the visual species, and the mathematical material world.

[201] Villalpando, *In Ezechielem, Tome II,* 53: daemonis insultu factum fit.

[202] Villalpando, *In Ezechielem, Tome II*, 48. Among the sources listed: Plato, Seneca, Chalcidius, Lactantius, Galenus, Hippocrates, Aristotle, Euclid, Ptolemy, Alchindi, Vitello.

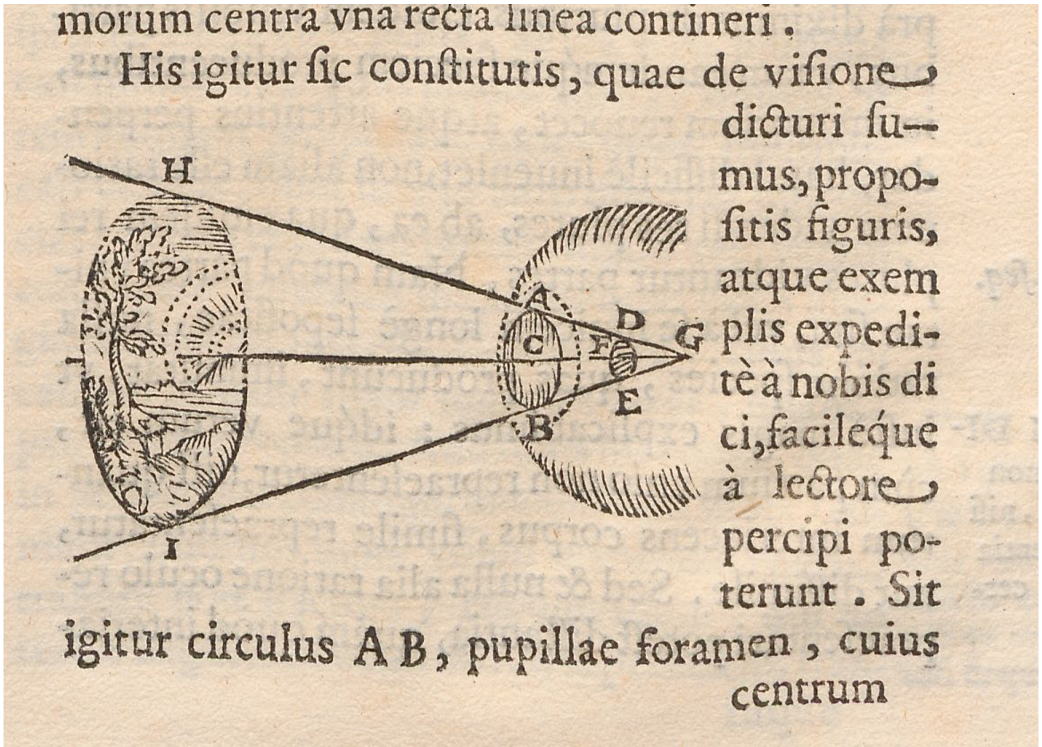
morum centra vna recta linea contineri .
His igitur ſic conſtitutis, quae de viſione dicturi ſumus, propoſitis figuris, atque exemplis expeditè à nobis dici, facileque à lectore percipi poterunt . Sit igitur circulus A B, pupillae foramen, cuius centrum

Image 2.1 — A depiction of the visual species entering the eye
Juan Baptista Villalpando, *In Ezechielem explanationes* (1596-1604), Tome II, 57
Image courtesy ETH-Bibliothek Zürich, Rar 861 fol.

It's clear that Villalpando wants to maintain the importance of the visual species, but that he does not want to limit the final result of cognition to the visual species alone, but to the response of the soul to the species. To explain this point, Villalpando refers to both Aristotle's *De Anima* as well as Augustine's *Ad Genesim* chapter twelve, situating his analysis of optics squarely within the intellectualized form of vision as advocated by Augustine.[203] Thus in Villalpando's theory of optics, the *De Anima* tradition merges with the theology of Augustine, creating the context for more than the explanation of vision, but also for the relationship between the soul and cognition itself.

Villalpando emphasizes the way that Aristotle's explanation of vision, with the received

[203] Villalpando, *In Ezechielem, Tome II,* 55-57.

visual species, may be understood as being in accord with St. Augustine's explanation of "spiritual" vision in his *Ad Genesim.*[204] This same explanation will be used in later Jesuits, most notably in Aguilonius, described in the following section. The visual species was important, but true cognition occurred on account of more than the species itself.

Villalpando's explanation of the spiritualized vision or the fascination of the eyes does not deviate from perspectivist optics or Aristotelian theories of cognition. Rather, the point is that in Villalpando mathematical optics could be utilized for theological or philosophical explanations. Such concerns in themselves created a culture of vision around mathematical optics which had wider influence than merely Villalpando's book. It is within these philosophical and theological adaptations of mathematical optics that one can see the influence of confessionalization on the construction of optics among the members of the Society of Jesus.

Upon the publication of the book Pope Sixtus V was quite displeased. As a result, he established an Inquisition, headed by Cardinal Toledo, to look into Villalpando's ideas. Additionally General Father Aquaviva appointed a Jesuit committee to consider the degree to which Villalpando's ideas were considered orthodox, particularly regarding whether the exegesis of Ezekiel's future Temple of Jerusalem was in fact the same as Solomon's Temple. In the end Villalpando was cleared of heresy, and the proceedings did not stop him from continuing to equate the accounts of 1 Kings and 2 Paralipomenon with Ezekiel.[205]

Overall Villalpando's text is quite important for understanding the axiomatic role of optics within Jesuit intellectual thought. This point is underscored by the inclusion of optics in a book that is concerned with architecture. Villalpando's book is also of importance because the

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204 Villalpando, *In Ezechielem, Tome II,* 54.

205 Morrison, "Introduction," in *Juan Bautista Villalpando's Ezechielem Explanationes*, 80.

explanations accorded to optics are indicative of a broader appeal to optics among Jesuit authors, especially due to the author's close association with the famed Collegio Romano. Villalpando resided in Rome from 1591 or 1592 until 1606, correlating to the entire process of the publication of the volumes. It is probable that he would have worked with Clavius, who was there at the same time.[206]

The following section will show that many of Villalpando's optical themes recur in a contemporary of his, Franciscus Aguilonius. Noting such similarities is important because as far as the historical record attests, the two never met. The fact that there is a similarity confirms that optical theory developed among Jesuit mathematicians according to a shared intellectual outlook.

Franciscus de Aguilonius, *Opticorum libri sex*

The first known published book by a Jesuit devoted solely to the topic of optics, published in Antwerp in 1613 by the Moretus Press, was Franciscus de Aguilonius's (1567–1617) *Opticorum libri sex*.[207] As Aguilonius explains in the Preface, he wrote the *Opticorum* as an introduction to optics, with plans for two later treatises, one on catoptrics and a second on dioptrics.[208] Such a tripartite organization fit a fairly familiar pattern for studying optics, following in the tradition of Euclid, Ibn al-Haytham, Witelo, and Pecham.[209] Among historians

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[206] Ugo Baldini, "The Academy of Mathematics," in *Jesuit Science and the Republic of Letters* (Cambridge, MA: MIT Press, 2003), 62.

[207] Franciscus de Aguilonius, *Opticorum libri sex* (Antwerp: Viduam et Filios Io. Moreti, 1613).

[208] Aguilonius, *Opticorum libri sex*, p. **4v.

[209] One may notice this tripartite division on the engraving frontispiece of Frederich Risner's edition of Witello: "Triplicis visus, directi, reflexi, & refracti, de quo optica disputat, argumenta", Witello, *Opticae Thesaurus*.

of optometry, sections in Book II represent an important development in the understanding of binocular vision.[210] Certain other historians have been quite interested in Book I, where Aguilonius proposes a color theory in which it was possible to mix colors and produce new ones. In addition to introducing a novelty that stood in contrast to standard color theory, it indicates that Aguilonius envisioned artists as readers of his book.[211] The most consistent interest in the book by historians has been on account of the frontispiece and six engravings, all of which were produced by the Flemish artist, Peter Paul Rubens.[212]

What has not received adequate recognition is the way that Aguilonius's book fits within the development both of the Jesuit Order as well as sixteenth and seventeenth-century optics more broadly. The content of the book is itself not remarkable. It borrowed from many of the well-known optical works at the time. But the philosophical and moral framing of the content is what is noteworthy, all aspects that specifically integrated within Jesuit philosophy and which demonstrate the role of optics in the confessionalization of Jesuit intellectual culture in the early seventeenth century. Although there is no known correspondence between Aguilonius and Christoph Clavius, it is noticeable that Aguilonius's *Opticorum*, and the projected successive books, would have filled the need for a work on perspectivist optics, as noted above in Clavius's

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210 Nicholas J. Wade, *A Natural History of Vision* (Cambridge, MA: MIT Press, 1998).

211 Charles Parkhurst, "Aguilonius' Optics and Rubens' Color," *Nederlands kunsthistorisch jaarboek* 12 (1961): 25–49.

212 Historians of science, and their editors and publishers more specifically, have utilized many of these engravings on published books to represent various aspects of early modern science, allowing them to achieve a seeming canonicity for representing essential aspects of early modern science. See Peter Dear, *Discipline & Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995). It is also quite common on book covers, such as William Shea, *Science and the Visual Image in the Enlightenment* (Canton, MA: Science History Publications, 2000).

explanation. And its subsequent reception among the Jesuits demonstrates the way the *Opticorum* was the definitive starting point for optical theory among subsequent Jesuit mathematicians and theologians. Because of all this, it is important to reconstruct its intellectual framework and heritage.

Franciscus de Aguilonius was born in Brussels in January 1567, to a family of notable repute within Spain. Aguilonius's father, Pedro de Aguilonius, was from the region of Aragón, Spain, and had worked as secretary to King Philip II of Spain during an embassy to France.[213] Franciscus studied at the College of Clermont from 1580-1583, but likely did not study mathematics until his time at Douai, while becoming a Jesuit.[214] In 1589 Aguilonius began teaching Latin grammar at Douai, receiving his Master degree in 1591 and received his tonsure in 1596.[215] In 1598 Aguilonius was moved to Antwerp to become the Confessor.[216] He became

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[213] August Ziggelaar, François de Augilónius, S.J. (1567–1617), scientist and architect (Rome: Institutum Historicum S.I., 1983), 29–30. Demonstrating his allegiance to Spain and to the Holy Roman Emperor, during this time Pedro wrote a short pamphlet about Duke Charles of Burgundy, great-grandfather of Emperor Charles V, dedicating it to Philip II. The title of the book was *Historia del Duque Carlos de Borgoña, bisagüelo del Emperor Carlos Quinto*.

[214] August Ziggelaar, François de Augilónius, S.J. (1567-1617), scientist and architect (Rome: Institutum Historicum S.I., 1983), 34. This point is based upon the fact that in 1588 the Jesuits had added a mathematics course as part of the philosophy curriculum.

[215] According to Van Helmont, Aguilonius experimented in chrysopoea in the late 1590s, although failed. However, he does point out that Aguilonius chemically changed several gems, and that the Jesuits were selling them to churches throughout Italy for decoration. Martha Baldwin, "Alchemy and the Society of Jesus in the Seventeenth Century: Strange Bedfellows." *Ambix* 40 (1993): 45.

[216] August Ziggelaar, François de Augilónius, S.J. (1567-1617), scientist and architect (Rome: Institutum Historicum S.I., 1983), 38–40. During his time at Antwerp, Aguilonius also worked as the "Procurator," the "Admonitor," as well as the "Prefect of Health." The experience as Confessor even shaped his reflection on the science of vision, as he uses the example of hearing unusual confessions of Princes to normalize dreams that might otherwise seem bizarre. If it was normal for a Prince to have a strange Confession, so also is it normal to have a bizarre dream. Aguilonius, *Opticorum libri sex*, 234.

the Vice-Rector in 1611, and then the Rector in 1614.[217] The timing of the production of the book, in 1613, came at a pivotal time not only in Aguilonius's own career, but as we will see, in the establishment of the Jesuit Order in the city of Antwerp.[218]

In 1598 the Jesuit college in Antwerp, now in operation for thirteen years after its reopening in 1585, received a new rector, Carolus Scribani (1561–1629), who worked to increase the prominence of the Jesuits at Antwerp and the significance of the college for the town.[219] When he arrived at the college the most pressing issue for Scribani to address was the replacement of the school building. To do this Scribani needed the approval of the city officials. In a letter written in 1606, Scribani appealed to the city officials for a new building, and in the process suggested that a mathematics school would improve the city of Antwerp. The Antwerp City Archive contains two copies of this request, one in Dutch and one in French. It reads

The above-mentioned fathers are prepared to arrange eventually to teach mathematics,

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[217] August Ziggelaar, *François de Augilónius, S.J.,* 40–41.

[218] Aguilonius, though, would not live to complete his efforts, as he died in 1617, at the age of fifty-one years, before completing the catoptrics or dioptrics. The manuscripts containing part of each of "catoptrics" and "dioptrics" exists at the archive in Bibliothèque royale de Belgique, MS 5780 f. 215-315. Some historians recognize them as part of the lecture notes of Aguilonius's student, Gregory de Saint-Vincent. For this, see Ad Meskens, "Jesuits, Mechanics and the Squaring of the Circle," in I*nnovation and Experience in the Early Baroque in the Southern Netherlands: The Case of the Jesuit Church in Antwerp*, ed. Piet Lombaerde (Turnhout, Belgium: Brepols, 2008), 68.

[219] Ad Meskens, "The jesuit Mathematics School in Antwerp in the Early Seventeenth Century," *The Seventeenth Century* 12, no. 1 (1997): 12. Scribani himself was a Jesuit theologian, born in Italy and trained at Cologne. Two treatises he was well known for was a popular adaptation of the Spiritual Exercises for ordinary people, as well as his V*eridicus Belgicus*, which used St. Bonaventure and Pelagius to explain the differences between orthodox and heretical theology. This latter text went through Dutch, Latin, and German translations. Louis Châtellier, *The Europe of the Devout: The Catholic Reformation and the Formation of a New Society* (Cambridge: Cambridge University Press, 1989), 82.; H. Höpfl, "The Political thought of the Jesuits in the Low Countries," in Rob Faesen, and Leo Kenis, eds. *The Jesuits of the Low Countries: Identity and Impact (1540-1773): Proceedings of the International Congress at the Faculty of Theology and Religious Studies* (Leuven: Peeters, 2012), 62.

> which is not taught at any university, not at Louvain nor anywhere else, yet is the basis for many of the arts which will prove useful to a commercial metropolis such as this [Antwerp]. Not merely to the adornment and honour of the city, but also to benefit those who would deal in commerce in all Flanders.[220]

It is quite significant that the letter explicitly mentions the University of Louvain. In contrast to many other regions of Europe, Louvain was one particular University where the Jesuits were not allowed to teach philosophy. What this implies, as Vanpaemel points out, is that the instruction of mathematics, a subject considered inferior to philosophy, would not have been considered a threat by those in Louvain.[221] For our purposes, what is significant about this is that it helps to indicate how the establishment of a mathematics school at Antwerp—which was itself modeled on Clavius's own interest in creating mathematics schools in prominent locations in Europe—was a strategic development so that the Jesuits could better establish themselves in the city.[222] As a result, the production of Aguilonius's book was not only important for mathematical instruction, but equally for rhetorically constructing the identity of the Jesuits in early seventeenth-century Antwerp. Aguilonius's book not only included the instruction of mathematics, as noted here, but also the plan for the production of the Jesuit Church in Antwerp, of which Aguilonius served as chief architect, and which was intended to serve as a model

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[220] Quoted in de Angelo de Bruycker, "To the Adornment and Honour of the City: The Mathematics Course of the Flemish Jesuits in the Seventeenth Century." *BSHM Bulletin* 24, no. 3 (2009): 138.

[221] G. H. W. Vanpaemel, "Jesuit Science in the Spanish Netherlands," in *Jesuit Science and the Republic of Letters*, ed. Feingold, 394. Vanpaemel even surmises that this explains why the Jesuits in the Flandro-Belgian province declined later in the seventeenth century. Angelo de Bruycker, "To the Adornment and Honour of the City: The Mathematics Course of the Flemish Jesuits in the Seventeenth Century." *BSHM Bulletin* 24, no. 3 (2009): 139.

[222] Judith Pollmann, *Catholic Identity and the Revolt in the Netherlands, 1520-1635* (Oxford: Oxford University Press, 2010), 143–146; On the role of mathematics schools by Clavius and its relationship to the mathematics school in Antwerp, see Vanpaemel, "Jesuit Science in the Spanish Netherlands," in *Jesuit Science and the Republic of Letters*, ed. Feingold, 136–37.

church for the Jesuits as they established their identity throughout the world, both in Europe and beyond.[223]

Following the pattern of many other Jesuit books during the late sixteenth and first half of the seventeenth centuries, the *Opticorum* was published at the Plantin-Moretus Press.[224] It received a sizable, though not unusual, print run of 1100 copies, comparable with 1263 copies of Rubens's engravings.[225] It was dedicated to Inigo Borja, one of the most respected governors ruling for Spain in the southern Netherlands during the period in which the *Opticorum* was produced and published, whose grandfather had been third Superior General of the Jesuit Order.[226] As the frontispiece indicates, the subject of the book, optics, was "useful for both philosophers and mathematicians."[227] Such a phrase not only fit the hybrid nature of optics in the

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[223] Jeffrey Muller, "The Jesuit Strategy of Accommodation," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 485–89.

[224] The exact role of the Jesuits in the Antwerp book trade is a story still waiting to be fully told. It is interesting to note that before the suppression of the Jesuits in 1773, the Jesuits never had their own printing press. However, many printers in Antwerp at the time, identified the location of their printing house near a Jesuit location, Paul Begheyn, "Jesuits in the Low Countries and their Publications," in Begheyn, Paul, Bernard Deprez, and Rob Faesen, eds. *Jesuit Books in the Low Countries 1540-1773: A Selection From the Maurits Sabbe Library* (Peeters: Leuven, 2009), xxiii. The significance of the Plantin Press among the Jesuits might be recognized by the fact that it published the first bibliography of Jesuit publication in 1608, the *Illustrium scriptorum religionis Societatis Iesu catalogus*, which was organized by the Spaniard Pedro de Ribadeneira. P. Begheyn, "The Jesuits in the Low Countries: Apostles of the Printing Press," in Faesen, Rob, and Leo Kenis, eds. *The Jesuits of the Low Countries : Identity and Impact (1540-1773): Proceedings of the International Congress At the Faculty of Theology and Religious Studies* (Leuven: Peeters, 2012), 132–33.

[225] Ad Meskens, "The Jesuit Mathematics School in Antwerp in the Early Seventeenth Century," *The Seventeenth Century* 12, no. 1 (1997): 14.

[226] Fernando González de León, *The Road to Rocroi: Class, Culture, and Command in the Spanish Army of Flanders, 1567-1659* (Leiden: Brill, 2009), 105–06.

[227] Aguilonius, *Opticorum*, frontispiece: *Philosophis iuxtà ac Mathematicis utiles*.

period, but also aligned with the philosophical and pedagogical interests of Jesuit mathematicians in the late-sixteenth and early-seventeenth centuries as they sought to establish mathematics as a significant part of the philosophical curriculum.

There are many aspects in Aguilonius's presentation of optics that demonstrate an overlap with Maurolyco's and Villalpando's works. The clearest is the way Aguilonius locates the significance of optics within the philosophical framework of Aristotle's *De Anima*, particularly Book II, Chapter 7.[228] Similar to Villalpando, Aguilonius utilizes Aristotle's text as a framework for understanding the various parts of the visual process, such as "lux," "lumen," and "color." Also similar to Villalpando, Aguilonius is concerned with the intromission and extramission distinction. As noted above, standard perspectivist optical theory adopts the intromissionist framework, which became particularly important among the members of the Society of Jesus because of the necessity of the maintaining the trustworthiness of the visualized image.[229] Where he departs from Villalpando is in the way he complicates the intromissionist and extramissionist divide by suggesting that the eye itself projects light. This is most evident in the iris of the eye as well as in various other situations, such as in the glowing eyes of a cat, as well as the head of a fish.[230]

As Aguilonius notes, such an identification is not his own observation, but derives from the Coimbran commentary on Aristotle's *De Anima*.[231] In the Coimbran commentary it is

[228] See Aguilonius, *Opticorum*, 17, 36.

[229] See the contributions in Daniel Heider, ed. *Cognitive Psychology in Early Jesuit Scholasticism* (Neunkirchen-Seelscheid, Germany: Editiones Scholasticae, 2016).

[230] Aguilonius, *Opticorum*, 17.

[231] Specifically Book II, Chapter 7, Question 5, Article 3; Aguilonius, *Opticorum*, 17.

explained that it is plausible that pupils are "inborn of light," since it would be insufficient to merely say that the pupils receive light without acknowledging the light of the pupils themselves.[232] The commentary notes the necessity of the "spirit" judging the object of the eye, noting that it is because of this aspect that one is able to explain how remote objects are not intelligible by the eye itself since the eye could not judge them. Nevertheless, it is the pupil which receives the species and the crystalline humor which judges, all activities which occur internal to the eye itself.[233] For his part Aguilonius locates the Coimbran analysis within the development of his own anatomical understanding of the eye, which he outlines in Book I. He explains the parts of the eye and notes that the pupil and crystalline humor are diaphanous, thereby not emitting light itself.[234] Similarly, as he notes, it is the cat's iris which is colorful, not the pupil.[235] Such additions should be recognized as expanding upon the Coimbran commentaries, rather than departing from them. They also clearly demonstrate the way that Aguilonius locates his explanation of the eye and its anatomy as a development of the Jesuits' philosophical curriculum.

Similar to Villalpando, Aguilonius also explains the visual species not merely with respect to Aristotle, but also by incorporating St. Augustine's (354–430) *Genesim ad litteram*, Book 12, chapter 16.[236] The particular context in Aguilonius is the one noted in the section

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[232] Coimbra, *De Anima*, 164: Non est tamen inficiandum pupillae non nihil esse innatum lucis, ut quasi tessera hospitem, & affinem suum, hoc est, lucem, qua species uehitur, se se extrinsecus insinuantem recipiat, eique ut minister familiaris praesto adsit.

[233] Coimbra, *De Anima*, 164.

[234] Aguilonius, *Opticorum*, 17.

[235] Aguilonius, *Opticorum*, 18.

[236] Aguilonius, *Opticorum*, 48.

above, where he explains how the species is similar to the image of Caesar. Among the points that he wishes to clarify is the way the species represents a universal form even while it might differ in certain respects. So, "the image of Caesar, although it disagrees with the whole group, it however exhibits an express similitude."[237] He further explains that the species is a virtual quality and not a formal quality, the reason given being that it is the crystalline humor that receives the species.[238] Presumably, if it were formal, and hence based upon matter itself, then the humor could not receive the species. To further substantiate this point, he notes that St. Augustine explains that the "species" was a "spiritual" component and "is called form without matter."[239]

So, similar to Villalpando, Aguilonius locates the species within the philosophy of Aristotle, and yet appeals to the spiritualized explanation of Augustine when specifying the relationship between the object, the species, and cognition. More attention will be given to this aspect in later sections, especially when noticing that certain later Jesuit mathematicians writing about optics identified the species as being the formal cause, in contrast to Aguilonius—a development which occurred in response to changing explanations of the eye's anatomy.

While Aguilonius is committed to Aristotelian cognition influenced by Augustine, as just explained, his book also shows an interest in integrating this framework across multiple competing philosophical systems. For instance, at one point Aguilonius states, "Light takes nothing else with it than the image of things, which you can call forma, or simulacrum, or

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[237] Aguilonius, *Opticorum*, 48: quo pacto Caesaris imago, este ab ipso toto genere dissideat, hum tamen expressa similitudine repraesentat.

[238] Aguilonius, *Opticorum*, 48–51.

[239] Aguilonius, *Opticorum*, 49: vocantur formae sine materia.

idolum, or species, or spectrum: that does not matter, provided that you only mean what represents the thing."[240] As Isabelle Pantin points out, this statement was borrowed verbatim from a contemporary medical writer, Hieronymus Fabricius ab Aquapendente (1537–1619).[241] Notice that each of these synonymous terms has an origin in a philosophical system competing with the Aristotelianism that Aguilonius champions. So for instance, "simulacrum" was the term used in Lucretius's (99 BCE–55 BCE) *De rerum natura*, a philosophical work from antiquity which Aguilonius cites throughout the entire *Opticorum*, and which develops a theory of optics based on atomism.[242] Yet, while its clear that his philosophical framework champions the species of Aristotelianism, he nevertheless states that one may adopt the mathematics of a competing theory and then translate it into the Aristotelian visual species. In many ways, then, what Aguilonius's book does is provide a point for translating competing optical opinions into versions of Aristotelian cognition. This was an important pedagogical move for Aguilonius (and the Jesuits more broadly) since the Jesuits sought to restore early modern Europe to Catholic culture, within which Aristotelianism supplied the philosophical framework for key aspects of Catholic theology, such as the Eucharist.[243]

Similarly to Villalpando, Aguilonius integrates architecture and optics. As he claims in

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[240] Aguilonius, *Opticorum*, 75: Non aliud quam rerum imaginem (lux) assumit, quam sive formam, sive simulachrum, sive idolum, sive species aut spectrum apelles, nihil interest, si modo id solum, quod rem repraesentat, intelligas. It is interesting to note that in Aguilon's Index, "Species, Imago, Forma, Simulachrum" are all listed as synonymous with the others the others. For each, the index instructs the reader to "vide" the others. For instance, "Species. Vide Forma, Imago, Simulachrum."

[241] Pantin, "Simulachrum, Species, Forma, Imago," 259, n. 45.

[242] Pantin, "Simulachrum, Species, Forma, Imago," 262.

[243] This will be an important topic in Chapter Three and Five below.

the introduction to Book VI, which deals with a wide range of architectural constructions, the integration of the two subjects is based upon Vitruvius's own claim in the first book of his architectural work that "The architect should not be ignorant of optics."[244] The clearest indication of Aguilonius's interest in Vitruvianism is in Books III and IV, where he treats the standard list of fallacies from the perspectivist optical system. Yet, rather than treat the visual fallacies in the abstract, as is often the case among the perspectivists such as Ibn al-Haytham or Witelo, Aguilonius uses many practical examples often drawn from architecture to demonstrate the visual fallacy.[245] For example in Proposition 40 and 41 he explains how intervals on an object seem smaller the farther they are from the eye. This may impact how one views a column looking downward (Proposition 40) or looking upward (Proposition 41).[246] Following these there are several "consequences" to be drawn, such as the way taller buildings or columns appear to recline when viewed from the base. It was based upon this principle that the Greek classical artist and architect Phidias created a statue which had segments that were farther apart at the top, but which did not appear as such at the bottom, as Aguilonius notes in a full-page epigram inserted in the middle of the book.[247]

As one considers the role of practical optics in Aguilonius's book, in architecture as well as scenography and painting, it is clear that avoiding visual deception is a real concern for

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[244] Aguilonius, *Opticorum*, 456: Optices non ignarum vult esse Architectuur.

[245] Sven Dupré makes a similar point, Sven Dupré, "Aguilón, Vitruvianism and His *Opticorum Libri Sex*," in *Innovation and Experience in the Early Baroque in the Southern Netherlands: The Case of the Jesuit Church in Antwerp*, ed. Piet Lombaerde (Turnhout, Belgium: Brepols, 2008), 65.

[246] Aguilonius, *Opticorum*, 258–260.

[247] Aguilonius, *Opticorum*, 263.

Aguilonius. For instance, throughout the work Aguilonius uses the occasion of teaching optics to address visual jokes. One such instance, which Rubens included on one of the vignettes, is the way in which the distance and location of an object changes based upon whether or not one eye is open or two eyes are open. A common optical joke that could demonstrate this was reaching out to touch a stick, and then closing one eye. It would appear to the person reaching their hand out that the stick had shifted, as illustrated in Image 2.2.[248]

Image 2.2 — Depiction of optical trick with Putti holding stick
Franciscus Aguilonius, *Opticorum libri sex* (1613), 151
Courtesy of The Linda Hall Library of Science, Engineering & Technology

But Aguilonius's interest in visual deception involved more than mere tricks; it also had

[248] Aguilonius, *Opticorum*, 154.

theological applications. This is most apparent when looking in the *Opticorum* at the beginning of the Propositions in Book III, which deals with visual fallacies. The first proposition generalizes about the importance of vision and the way it is developed from sensation itself. Immediately after this proposition Aguilonius cites a section from a commentary on *De Anima* by the 3rd century theologian, Tertullian (155–220).

> It is not permitted for us to call into doubt the senses, lest we should even in Christ Himself, bring doubt upon the truth of their sensation; lest perchance it should be said that He did not really 'behold Satan as lightning fall from heaven;' that He did not really hear the Father's voice testifying of Himself; or that He was deceived in touching Peter's wife's mother; or that the fragrance of the ointment which He afterwards smelled was different from that which He accepted for His burial; and that the taste of the wine was different from that which He consecrated in memory of His blood. On this false principle it was that Marcion actually chose to believe that He was a phantom, denying to Him the reality of a perfect body.[249]

Tertullian was an important theologian from the 2nd and 3rd centuries, who was instrumental in shaping the doctrine of the Trinity.[250] In his *De Anima* commentary Tertullian is claiming that it was disbelief in Jesus's bodily sensations that contributed to heretical explanations of the Trinity in which Jesus was not considered to be both fully human and fully divine. The importance of this for Aguilonius, then, is to contend that maintaining the reliability of any human sensation is important because it supports the humanity of Jesus as being both human and divine. In a subtle indication of its theological importance, Aguilonius provides the study of optics with an important theological justification—the deity of Jesus. This move also

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249 Aguilonius, *Opticorum libri sex*, 214: Non licet nobis in dubium sensus istos revocare, ne & in Christo de fide eorum deliberetur; ne fortè dictatur, quòd falsò satanam prospectarit de caelo praecipitatum: aut falsò vocem Patris audierit de ipso testificatam: aut deceptus sit cùm Petri socrum tetigit: aut album posteà unguenti senserit spiritum, quod in sepulturam suam acceptavit: alium posteà vini sapore, quod in sanguinis sui memoriam consecravit. Sic enim & Marcion phantasma eum maluit credere, totius corporis in illo dedignatus veritatem.

250 Justo González, *The Early Church to the Dawn of the Reformation*, vol. 1 (San Francisco: HarperSanFrancisco, 1984), 73–77.

locates Aguilonius firmly within the Counter-Reformation efforts of the Catholic Church in which it was a common tactic by Catholic intellectuals to demonstrate the continuity of their beliefs with the early Christian Patristics, such as Tertullian. The aim of such rhetoric was to reinforce the claim that Catholics were on the side of orthodox theology, in contrast to the Protestants.[251] So, while it is not at all clear that Aguilonius is casting the Protestants in the vein of Marcion's thought, his interest in Tertullian was likely a strategic move, and is an indication of the way optics served the confessional interests of the Society of Jesus.

To be clear, Aguilonius's text involves more than interest in the way vision occurs. For instance, he addresses the use of a sundial, the projection of shadows on the moon, as well as whether the sun has sunspots. Yet Aguilonius's book should be understood as emphasizing the importance of vision within the perspectivist optical tradition. And his integration of practical optics, following Vitruvius, not only shows a similarity with Villalpando, but also fits the reception and interest of his book among other Jesuits. Alongside books like Villalpando's and Aguilonius's, there were many other Jesuit works on practical optics which would cite them as reference points to understand philosophical issues. One in particular, Jean DeBruevil's (1602–1670) *La perspective practique* (1642) explains how to create various architectural constructions and light projections intended for use in Jesuit buildings. In the Preface DeBruevil recognizes that alongside his practical optics there were more philosophical questions, which one would be able to answer in other works, such as Aguilonius's.[252]

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251 On the doctrinal debates at Trent and its enduring influence in Catholic thinking, see John W O'Malley, *Trent: What Happened at the Council* (Cambridge, MA: Belknap Press of Harvard University Press, 2013).

252 Jean DeBruevil, *La perspective practique* (Paris: Melchior Tavernier and François L'Anglois, 1642).

In the context of the Counter Reformation, many members of the Jesuits constructed church buildings and schools, as well as religious images and statues. the interest in such constructions extended beyond representing them in proper proportion based upon mathematical optics, but also to consider how constructed images related to the philosophy of sight. This connection will be given more attention in the final section of this chapter, especially since it has received attention as of late.[253] At the moment, though, what is worth noting is that the subtle interweaving of the practical and philosophical side of optics represents an important element of confessionalized optics among the Jesuits, as the instruction in creating art and architecture would often circulate alongside texts that provided the more philosophical explanations. This circulation continued into the eighteenth century, reusing Jesuit texts which were originally produced in the early seventeenth century.[254]

As already mentioned, Aguilonius died prior to completing all his optical works. What remains, however, are manuscripts relating to his dioptrics and catoptrics in the form of lecture notes by Gregory de Saint-Vincent. Consisting of 100 folios, the manuscripts are basic optical problems in catoptrics and dioptrics, fitting the standard problems. For instance, there is a treatment of "Alhazen's problem," as well as many different geometrical problems relating to Apollonius's *Conics*. It is also evident that Aguilonius had intended the dioptrics and catoptrics to be interrelated with the *Opticorum*, as there are references to the published *Opticorum*.[255]

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[253] Dupré, "The Return of the Species," in *Religion and the Senses*, ed. De Boer and Göttler, 473–487.

[254] João Cabeleira Marques Coelho, "Inãcio Vieira: Optics and Perspective as Instruments Towards a Sensitive Space," *Nexus Network Journal* 13, no. 2 (2011): 315–335.

[255] Van Looy, Herman. "A Chronology and Historical Analysis of the Mathematical Manuscripts of Gregorius a Sancto Vincentio (1584–1667)." *Historia Mathematica* 11, no. 1 (1984): 57–75; Ad Meskens, "The Jesuit Mathematics School in Antwerp in the Early Seventeenth Century,"

However, the text is quite fragmentary, with many deletions and blank folios, and does not include the rhetorical, religious, or philosophical asides that are included in the *Opticorum*. Because of this, I suggest that the manuscripts are more representative of Gregory de Saint-Vincent's notes and likely not Aguilonius's personal text.

Jesuit authors clearly read and used Aguilonius's book after it was published. This is noticeable not only among their scientific works, such as Christoph Scheiner's *Oculus* (1619) and Mario Bettini's *Apiaria* (1642), but also among non-scientific works. For instance, the Jesuit theologian Cornelius Lapide cites Aguilonius's Book I on the nature of an image and how the eye perceives an image in a few different locations. Not only does this reinforce the way optics provided a cultural field for the Jesuits, but it also underlines the importance of images among the Jesuits. Alongside his citations from Aguilonius, Lapide also summarizes the opening section of Jan David's emblem book *Duodecim speculum* (1610) where David explains that like a rainbow reflecting the sun, so also images are reflections of the thing they are intended to point toward.[256]

It is also clear that non-Jesuits read Aguilonius's book. Hugo Sempilius (1596–1654), in his *De Mathematicis Disciplinis*, briefly mentions Aguilonius for properly accounting for the anatomy of the eye. Yet, not all were as enthusiastic about Aguilonius's religious interpretations. Aguilonius's emphasis on the moral and theological aspects of sight, aspects reflective of his confessional interests, were quite apparent to his contemporary readers. The physician, Vopiscus Fortunatus Plempius (1601–1671) criticizes Aguilonius for being "theological" and "moral" in

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The Seventeenth Century 12, no. 1 (1997): 16.

[256] Cornelius a Lapide*, Commentarius in epistolas canonicas* (Venice: Hieronymus Albritius, 1717), 71.

his reasoning with respect to light.[257] Such a criticism is very interesting because Plempius sought to maintain the basic Aristotelian theory of cognition, similar to what Aguilonius ultimately maintained.[258]

Aguilonius helped to substantiate a mathematical, philosophical, and religious Jesuit visual culture in seventeenth-century Antwerp. This is seen not only in the significance of his book, but also by noticing its role within the construction of the Jesuit Church in Antwerp. As mentioned, the specific situation of Aguilonius's optical treatise fit the focus on architecture that the Order had at the time, and in the context of Antwerp was used rhetorically to fit with the construction of the church, which occurred at the same time of the book's printing.[259] It is quite likely that Aguilonius's intention behind the book was more than the procurement of a mathematics school in Antwerp. It was also intended to support the construction of the Jesuit Church of Saint Ignatius, now referred to as the Church of Carolus Borromeus.[260] In fact, the influence of the church came to be so great that it became a model for other Jesuit churches, even

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[257] Vopiscus Fortunatus Plempius, *Ophthalmographia, sive tractatio de oculi fabrici* (Amsterdam: Hendrick Laurensz, 1632), 64; Hugo Sempilius, *De mathematicis disciplinis* (Antwerp: Plantin, 1635) 63–64.

[258] Vanagt, "Early Modern Medical Thinking on Vision and the Camera Obscura," in *Blood, Sweat, and Tears*, 569–93.

[259] Piet Lombaerde, "The Façade and the Towers of the Jesuit Church in the Urban Landscape of Antwerp during the Seventeenth Century," in *Innovation and Experience in the Early Baroque in the Southern Netherlands: The Case of the Jesuit Church in Antwerp* (Turnhout, Belgium: Brepols, 2008), 67–76.

[260] Ad Meskens, "The Jesuit Mathematics School in Antwerp in the Early Seventeenth Century," *The Seventeenth Century* 12, no. 1 (1997): 14. The Dutch Jesuit writer Maximilian van der Sandt, oftentimes known as Sandaeus, wrote the emblem book *Maria Gemma Mystica* in 1631, in which he compared the qualities of the Virgin to the properties of precious stones and their utilization in construction. Knaap, "Marvels and Marbles in the Antwerp Jesuit Church," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 385–386.

influencing those in Rome.[261]

Later Jesuit Optical Writings

Many later Jesuit authors echo similar optical ideas as those of Villalpando and Aguilonius, firmly located within the theory of perspectivist optics and its strong overtones of Aristotelian theories of cognition. For instance, Nicholas Zucchi (1586–1670), Gaspar Schott (1608–1666), Honoré Fabri (1608–1688), Andreas Tacquet (1612–1660), Ignace Pardies (1636–1673), and Pierre Ango (1640–1694) all composed important optical books and in them supported the identification of the species as involved in explaining the process of sight.[262] The importance of the visual species even persisted in the context of the most well-known transformation of optics, the adoption of the retinal image by Johannes Kepler and subsequent non-Jesuit mathematicians. This will be addressed more in Chapter Three.

Nevertheless, beginning in the 1660s, certain Jesuit authors (though not exclusively Jesuit authors) began to introduce important terminological distinctions to differentiate between the visual image and the image as it is located within geometrical space. This differentiation was an important part of the transformation of many of the underlying principles of perspectivist optics. It also reveals a point of difference between the way that Aguilonius conceptualized optical

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[261] Orazio Grassi, building a church in Rome, was going to follow the lead of the Flemish Jesuits, and thus counteracts the prevailing narrative that influence flowed from Rome out. In this case Belgium influenced Rome. Evonne Levy, "Early Modern Jesuit Arts and Jesuit Visual Culture: A View From the Twenty-First Century." *Journal of Jesuit Studies* 1 (2014): 70.

[262] Niccolò Zucchi, *Optica philosophiae, experimentis et ratione, pars prima* (Leiden: Guilleimum Barbier, 1652), 1:113, 170; Gaspar Schott, *Magia universalis*, 88; Honoré Fabri, *Physica, id est, scientia rerum corporearum* (Lyon: Laurentius Anisson, 1670), 80; Andreas Tacquet, *Opera mathematica* (Antwerp: Jacob Meursius, 1669), 209; Ignace Pardies, *Theses mathematicae de optica* (Paris: Alexandre Milon, 1671), 4; Pierre Ango, *L'Optique* (Paris: Estienne Michellet, 1682), 187.

knowledge and the nature of the visual species with those Jesuits that came after him, who adopted many of the tenets of early-seventeenth-century optics.

At the same time these authors explored the meaning of vision and the object of sight, others performed experiments into the nature of light. Among the biggest interests by these authors was the degree to which light should be considered a substance, a question which not only influenced the adoption of perspectivist optics by the Jesuits, but also certain theological formulations, such as the physics of the Eucharist. In prevailing histories of optics the mechanical philosophy and the subsequent mathematization of nature created the context for the inevitable transformation of light. But among the Jesuits it was the rise of experimentation with two instruments, the barometer and the air pump, which created the necessary occasion for articulating new theories of light.[263] The transformation of light among the Jesuits will be given more attention in Chapter Five as well.

What is of interest, however, is that among the Jesuit mathematicians the transformation of sight and that of light were not connected. In other words, certain Jesuits introduced terminological distinctions to explain the objects of sight—thereby modifying the foundation of perspectivist optics and the role of the species within it—and yet these aspects had nothing to do with the changing theories of light. This stands in stark contrast to the prevailing narratives of the history of optics in the seventeenth century, which consistently explains the change from the "sight" optics of the perspectivists to the optics of "light" as one growing out of the other. The fact that the Jesuits do not fit this standard narrative is an important aspect which will be given more attention throughout this dissertation. The broad narratives which periodize the history of optics into the history of sight and the history of light do not pay adequate attention to the

[263] For the standard view, see A. Mark Smith, *From Sight to Light*, 373–416.

complexities of the period.

Before concluding this introductory analysis of the Jesuits and optics, more attention should be given to one particularly important topic, the relationship between optics and images among the Jesuits.

Optics and Images among the Society of Jesus

Religious images provided an important means used to propagate the faith and to further the goals of the Catholic Church in the Counter Reformation.[264] While the utility of images in religious practice was not anything new, their contentiousness in the Reformation contributed to their reaffirmation during the Council of Trent, in 1563 during the twenty-fifth session.[265] And, as noted by many Jesuit historians, images, and the expansive theory surrounding them, proved one of the more consistent topics of interest among early modern Jesuits.[266] In addition to single images many members also popularized emblem books—collections of images which oftentimes paired together a poem or short moral exhortation to establish the rhetorical and religious meaning of the image.[267] According to estimates, their efforts to produce these books contributed

[264] Jeffrey Smith, *Sensuous Worship: Jesuits and the Art of the Early Catholic Reformation in Germany* (Princeton: Princeton University Press, 2002); Dekoninck, *Ad Imaginem*; De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*.

[265] John O'Malley, "Trent, Sacred Images, and Catholics' Senses of the Sensuous," in Marcia B. Hall, and Tracy E. Cooper, eds. *The Sensuous in the Counter-Reformation Church* (2013: Cambridge Unviersity Press, 2013), 28–48.

[266] Walter Melion, "Introduction," in Wietse De Boer, Karl A. E. Enenkel, and Walter Melion, eds. *Jesuit Image Theory* (Leiden: Brill, 2016), 1–54.

[267] For a background see "Introduction," in Peter M. Daly and Richard G Dimler, *The Jesuit Emblem in the European Context* (Philadelphia: Saint Joseph's University Press, 2016), 1–21.

to nearly twenty-five percent of all emblem books within early modern Europe.[268] Emblem books in particular came to be important tools of confessionalization since the same image could be reprinted and distributed in multiple locations with languages appropriate to the context used in the inscription.

One of the leading Jesuits of the second generation, Jerome Nadal (1507–1580), demonstrates this aspect.[269] During the 1570s and 1580s, Nadal traveled throughout Europe to homogenize the message of the Jesuits and to provide social, political, and religious stability in the generation just after the death of Ignatius.[270] He distributed sacred images sent to him by the second General of the Order, Francis Borja, to be used for religious reflection but also as a focal point for homogenizing the Christian teachings of the Jesuit Order.[271] After his trip these images, along with others, were published and distributed in a three-volume emblem book, *Adnotationes et meditationes in Evangelia.* First published in 1595, the elaborate book was intended for Jesuit seminarians, guiding them through a process of meditation by incorporating visual and textual descriptions of the many important events contained in the Gospels by following the liturgical calendar.[272] Thus, at the time Villalpando and Aguilonius were producing the first Jesuit books

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[268] Daly and Dimler, *The Jesuit Emblem in the European Context*, 34.

[269] G. Richard Dimler, "Current Jesuit Emblem Studies: An Overview," In *Emblem Studies in Honour of Peter M. Daly*, ed. Michael Bath, Pedro F. Campa, and Daniel S. Russell (Baden, Germany: Verlag Valentin Koerner, 2002), 72.

[270] Jonathan Wright, *God's Soldiers: Adventure, Politics, Intrigue, and Power: A History of the Jesuits* (New York: Doubleday, 2004), 47.

[271] Dimler, "Current Jesuit Emblem Studies: An Overview," 71. Forty-eight of Nadal's illustrations were mentioned in the correspondence between Borja and Nadal. Borja sent pictures to Nadal in 1561.

[272] Joseph P. Lea, ed. *Annotations and Meditations on the Gospels*, 4 Vols. (Philadelphia: Saint Joseph's University Press, 2014).

on optical theory, Jesuit image theorists were developing a culture and theory of images, within which sight was equally important.

Naturally, then, some historians have suggested that among the important elements driving the Jesuits' adoption of mathematical optics was the way it supported the theory of images.[273] In particular, as Sven Dupré contends, certain Jesuits avoided developments in optical theory because they contradicted the visual species while "species, and the Aristotelian psychology of the soul in which they were embedded were crucial elements in the Jesuit theory of spiritual exercises."[274]

Dupré's argument builds upon the suggestions of the historian of Jesuit art, Walter Melion, who points out that within late-sixteenth-century Jesuit theory, images could be understood as "species, simulacrum, figure, speculum, exemplum, and imago."[275] The parallelism of terms here within Melion's explanation should not matter since, as noted above, Aguilonius's *Opticorum* similarly equivocated the various words used to describe the object of vision, such as species, simulacrum, and forma. Yet, as noted there, despite Aguilonius's seeming equivocation, he nevertheless intended to frame optics in terms of Aristotelian cognition and the more common "species." As Melion and Dupré's indicate, late-sixteenth century Jesuit image theory functioned similarly. Thus, the adoption of multiple terms is not intended to

[273] Gitta Bertram, "Elevating Optics: The Title Page by Peter Paul Rubens of Franciscus Aguilonius's Opticorum Libri Sex (1613) in its Historical Context," *Explorations in Renaissance culture* (2016): 221–23.

[274] Sven Dupré, "The Return of the Species: Jesuit Responses to Kepler's New Theory of Images," in *Religion and the Senses in Early Modern Europe*, ed. Wietse de Boer, and Christine Göttler (Leiden: Brill, 2013), 475.

[275] Walter Melion, "'*Quae lecta Canisius offert et Spectata Diu*': The pictorial images in Petrus Canisius's *De Maria Virgine* of 1577/1583," in Walter S. Melion, and Lee Palmer Wandel, eds. *Early Modern Eyes* (Leiden: Brill, 2010): 237.

disavow the philosophical importance of Aristotelian cognition, but is a means toward explaining diverse visual traditions in terms of Aristotelianism.

It is important to consider the legitimacy of arguments such as Dupré's and the degree to which one may connect the theory of optics with the theory of images among the Jesuit Order, on account of Aguilonius's attention to architecture identified in the section above. In addition, two Jesuit image theorists, Jan David (1545–1613) and Louis Richeome (1544–1625), who were contemporaries of Aguilonius and exerted tremendous influence on Jesuit image theory throughout the seventeenth century, indicate to the role of optical theory in image theory.[276] But before addressing the image theorists, more must be said about Aguilonius's explanation of the visual species and its bearing upon the relationship between artistic images and optical theory.

It was noted above that Aguilonius explained the way in which the visual species was similar to a statue of Caesar. In the process he states the following: "What is the effigy of Caesar, whether painted, or engraved, or embossed, or flat, or like an amulet or statue, fabricated in such a manner?…the visual species is not demonstrated in this manner."[277] As noted, the point that Aguilonius makes is that the eye cannot receive a formal species because it necessarily will change upon entering the eye. It is notable, then, that in Aguilonius's explanation he borrows from artistic and architectural designs to differentiate the species (at least philosophically) from the object in question. This does not mean that art does not convey truth—at one point he says that art "imitates" nature—but that within his theory of optics images themselves were not

[276] The best book on Jesuit image theory is in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*.

[277] Aguilonius, *Opticorum*, 51: Qualis est Caesaris effigies, sive picta, sive sculpta, sive caelata, sive plana, sive bullae aut statuae in modum conficta…Huius generis non esse visibiles species demonstrator.

conveyors of the visual species.[278]

Aguilonius identified a relationship between the visual species and art; so also did contemporary emblematic authors. Jan David was an image theorist and emblem book writer who is often cited alongside Nadal as being one of the leading emblem theorists shaping the Jesuit emblem tradition.[279] In one of his earliest books, *Veridicus Christianus* (1601), David identifies many moral characteristics about a true Christian. In one image in particular David explains the moral importance provided within the act of seeing. As the caption reads, "He who does not guard what he looks at, allows death to enter through the windows." In this context what is meant by "window" is the eye itself.

[278] Aguilonius, *Opticorum*, 43: ars nature aemula.

[279] Melion, "Introduction," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 9.

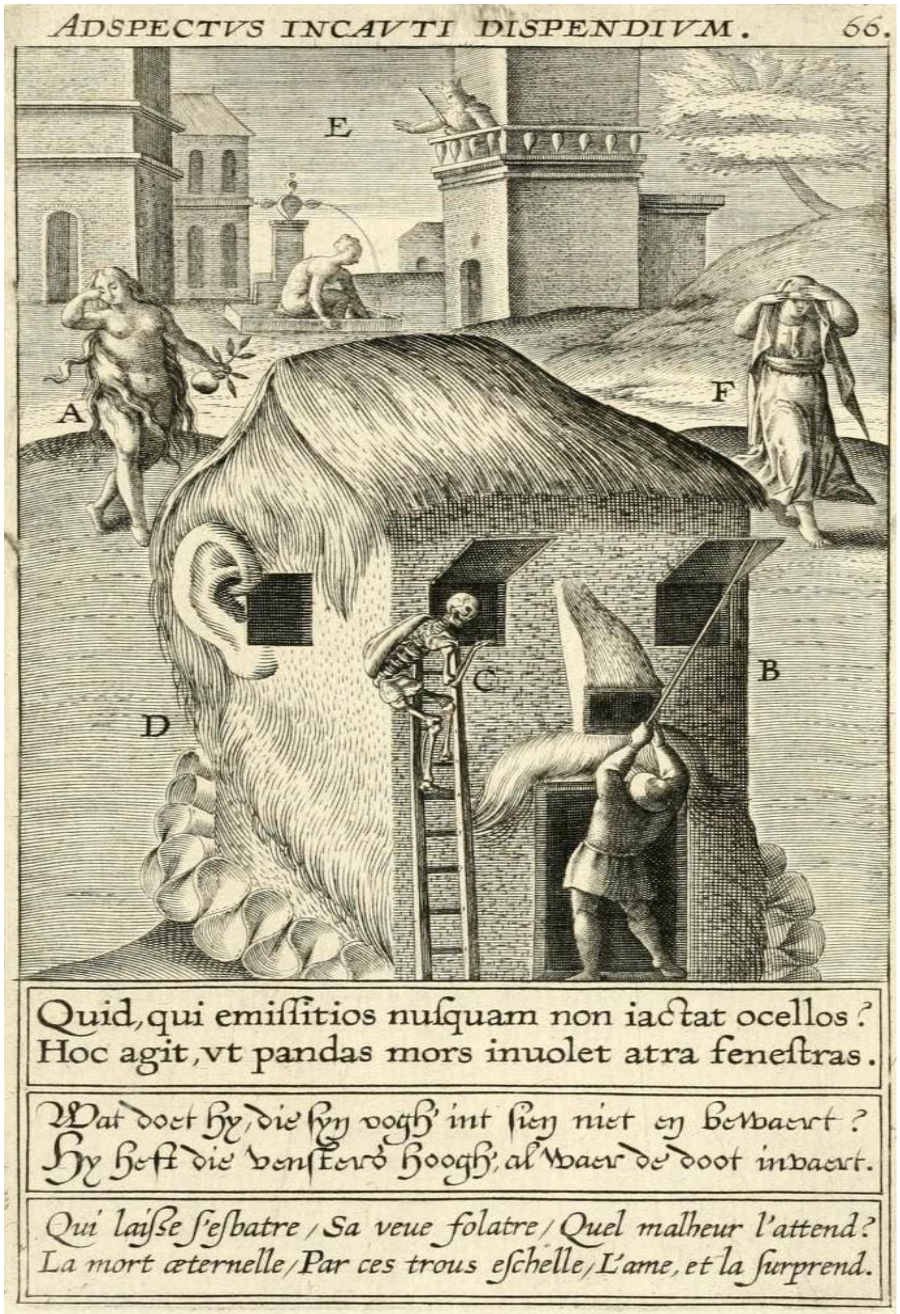

Image 2.3 — The dangers of vision
Jan David, *Veridicus christianus* (1601), 218.
Digital image courtesy of the Getty's Open Content Program

It is likely that this particular image was not only intended to uphold the importance of sight, but equally to engage in polemically against the iconoclasts and to justify the utility of religious images in churches and other devotional contexts.[280] David locates this emblematic image and its meditation on the nature of the eye and sight with respect to the debate between intromissionism and extramissionism: "Up to this hour the most intelligent philosophers dispute the way in which vision takes place: whether the ejaculation of rays from the eye to the object, or the admission of the species of the thing seen into the eye."[281] Yet, at the same time, he states that the nature of the eye, and hence vision itself, is of such a complex nature that it is beyond comprehension. "The eye is such an excellent and rare structure, that its ingenuity escapes a just comprehension."[282] David's statement here is important because, while he recognizes the appeal of the broader philosophical and mathematical analysis with respect to optics and the way vision occurs, the actual reality of vision is beyond such intellectual analyses. So, while he recognizes the interdependence of optical theory upon image theory, he nevertheless does not draw a clear line of influence.

One of the clearest examples of the way in which optics was a visual cultural field may be noticed in one of the leading Jesuit emblematic writers and theorists on vision in the first half of the seventeenth century, Louis Richeome (1544–1625) and his *La peinture spiritual* (1611). As Ralph Dekoninck explains, Richeome's activity occurred at a time when the Jesuits in France were establishing their authority and influence, particularly with regard to sacred images.[283]

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[280] On the apologetic nature of Jan David, see Melion, "Introduction," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 9.

[281] Jan David, *Veridicus christianus* (Antwerp: Plantin, 1601), 218: In hanc usque horam disputant acutissimi Philosophi qua ratione fiat visio: an radiorum ex oculis in obiectum ejaculatione, an vero specierum rei visae in oculos admissione.

[282] David, *Veridicus Christianus*, 281: oculos tantae esse excellentiae tamque rarae structurae, ut subtilissima fugiat ingenia iusta ipsorum comprehensio.

[283] Ralph Dekoninck, "The Jesuit *Ars* and *Scientia Symbolica*: From Richeome and Sandaeus to

During this time period he wrote *La peinture spirituelle* (1611), a book on the role of the emblematist, images, and the sense of sight, the influence of which extended beyond his particular region of France.

Much of the text of *La spiritual peinture* pertains to the classification of images into various types, such as whether they are in accordance with nature or are metaphorical. This interest on the part of Richeome, which relates to his earlier lesser-known book *Tableaux sacrez* (1601), represents a much wider interest on the part of the Jesuits to locate sacred images upon a firm theoretical and theological foundation.[284] Richeome's interest in the "Marvels of Sight and of the Painting" and its three sections provide an important resource for understanding the role of images among members of the Jesuit Order.[285] Following a chapter that explains the marvels of sound and its relationship to vision, the section on marvels of sight is important because it indicates many contemporary philosophical and scientific questions with regard to images, vision, and their explanation.

In the first chapter, while explaining the basics of vision he states that what he is referring to is "the image of the image, or as the philosophers say, the species and semblance of the image, which flies through the air, and enters into the eye."[286] The issue that Richeome aims to explain is how vision occurs, particularly with respect to the eye and the object seen. Yet, in the context of the book, Richeome does not comment abstractly on the nature of the visual process, but

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Masen and Ménestrier," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 74.

[284] For the background to this see Wietse de Boer, "The Early Jesuits and the Catholic Debate about Scared Images," in De Boer, Enenkel, Melion, eds. *Jesuit Image Theory*, 53–73.

[285] Louis Richeome, *La spiritual peinture* (Lyon: P. Rigaud, 1611), 138-150.

[286] Richeome, *La spiritual peinture*, 138. "On dict, que c'est l'image de l'image, ou comme parlent les Filosofes, l'espece &semblāce de l'image, qui vole par l'air, & paruient à l'oeil.

specifically about viewing religious imagery. His comment about the visual species demonstrates the way in which these emblem writers shared a broader visual culture with the Jesuit mathematicians, such as Villalpando and Aguilonius.

It is not surprising, then, that Richeome also shows an interest in reinforcing the philosophical tenet that vision was a passive activity, and not an action produced by the eye itself. Richeome states that vision occurs like other senses, through the reception of the impression. "Vision happens similar to the other senses by the reception of the thing that is represented, and not by the diffusion of vision."[287] Thus, like the Jesuit mathematicians and like David, Richeome was an intromissionist. The important point to notice here is that Richeome borrows the visual species from the philosophy of sight to explain how vision occurs, with the ultimate goal being establishing the trustworthiness of the cognitive process and the reliability of images within the visual process. Thus, Jesuit mathematicians were adapting the visual species in optics, at the time as one of the most well-known Jesuit emblem writers.

David and Richeome, two theologians and emblematists, confirm that the optical theory expounded by Villalpando and Aguilonius was part of a shared visual culture that permeated many other aspects of the Jesuits' confessional efforts. The question of the visual species and the reliability of the sense of sight necessarily was a concern among both Jesuit mathematicians and theologians. Yet, it is going too far to claim that there was a consistent and codified theory of sight that everyone used, at least among the earliest Jesuit texts on optics. As will be shown in later chapters, the fact that there was no consistent overlap between the theory of images and optics does not mean that optics could not be employed as a strategy of explanation among

[287] Richeome, *La spiritual peinture*, 141: la veüe se faict comme les autres sentimens par la reception de la chose representée, & non par la diffusion de la veüe.

certain Jesuits. As noted in later chapters, as Jesuits changed their understanding of the eye's anatomy, so the theory of the visual species also changed, and hence the relationship between optical theory and image theory changed as well.

Conclusion

As shown in the preceding chapter the earliest Jesuit optical writers, particularly Villalpando and Aguilonius, developed their optics with a strong relationship to the *De Anima* commentary tradition. For them it was important not only to explain the mathematics of sight, but more importantly, the way in which it contributed to cognition. For both authors, sight was itself a spiritual process, like Augustine's explanation of sight, within which the physical act of seeing was itself a means toward seeing. Their goal was to maintain the existence of the visual species—but the ultimate explanation of sight and cognition itself were left as being some sort of spiritual activity. Despite such a spiritualized understanding of the process of vision, it was nevertheless important for both authors to explain the nature of vision, emphasizing the way in which mathematics could be used to explain the process of vision. Many of these features continued throughout the seventeenth century in the explanation and articulation of optics by members of the Society of Jesus.

This chapter also drew attention to the way in which the discourse on optics overlapped with the work of the theologians and emblematists. While it was noted that both groups of individuals recognized an overlap in their conceptualizations, especially about the visual species in the act of visual cognition, they nevertheless did not demonstrate any clear lines of influence or any centralized Jesuit understanding of optics. Yet, the fact that there was an overlap among some of the ways that vision was conceptualized reminds one that Jesuit mathematicians would have understood their own optical work alongside other lines of confessionalized optics. While the overlap between mathematicians, theologians and emblematists is probably on account of their location in history, and the way in which the perspectivist account of optics proved the most useful and widespread at the time, it is nevertheless an important point to maintain and one which is often obscured when the history of seventeenth-century optics is treated as a jump from the medieval past to the optics of the great individuals who departed from the past. The history of optics in the seventeenth century was far more complex and the major achievements of the well-known seventeenth-century opticians were not as widespread or well-known as the story often demonstrates, a point which will now be further reinforced in the following chapter as the reception of Kepler's optics among the Jesuits is given more attention.

CHAPTER THREE
THE POINT OF THE VISUAL SPECIES: THE CAMERA OBSCURA, KEPLER, AND THE JESUITS

"Moreover, they [the species] are formal, not just virtual, images of objects."
—Christoph Scheiner, 1619.[288]

The camera obscura, and optical instruments more broadly, proved the existence of the visual species. At least this became the uniform opinion of the members of the Society of Jesus during the seventeenth century. This was a shocking development, especially since, as noted in the previous chapter, the visual species had been considered virtual, and hence not the form of the object. Yet, the implication of the camera obscura, as Christoph Scheiner and other Jesuits noted, was that the species was formal, meaning it was an actual Aristotelian form. For Jesuit mathematicians the camera obscura also gave an important justification for the significance of the mathematician—their skills could represent the visual species, and thus provided a gateway for cognition itself.

This interpretation—that the camera obscura did not prove problematic but was helpful for the understanding of vision among the Jesuits—runs contrary to much of the historiography. Within the history of Jesuit optics, the early modern Jesuit Christoph Scheiner is well-known for providing the Jesuits with a firm understanding as to the nature of the visual process, particularly regarding the camera obscura. Yet, recently his explanation has been treated as if it were an avoidance of the most recent optical developments—particularly Kepler's optics.[289] Such a line

[288] Christoph Scheiner, *Oculus: Fundamentum opticum* (Innsbruck: Danielem Agricolam, 1619), 137: Easdem insuper formales non virtuales tantum esse obiectorum imagines.

[289] Pantin, "Simulachrum, Species, Forma, Imago," 245–269; Dupré, "The Return of the Species," in *Religion and the Senses*, 473–487.

of interpretation reinforces the traditional narrative of the Scientific Revolution and privileges the successes of Kepler and others as the turning point in the history of early modern European optics. The Jesuits, who do not follow such a trajectory, become cast as intellectual holdouts to the new optics since their optical path forward deviates from the common narrative.

A careful consideration of Scheiner's reception of Kepler's optics, and its subsequent influence, will demonstrate that his activity should not be seen as a compromise, but as a synthesis. For Scheiner, as well as later Jesuit authors who read and interpreted Scheiner's work, Kepler's optics did not introduce an end to the perspectivist optical theory. The "lux" "lumen" and "visual species" could still be maintained, albeit with certain modifications. As this chapter argues, Kepler's optics was not incommensurate with perspectivist optics and Aristotelian philosophy, at least as explained and understood by Jesuit mathematicians in the first-part of the seventeenth century. Indeed, as the chapter will explain, the responses of the Jesuits to Kepler's optics and optical instruments more broadly, reveals arguments that are very similar to those found within the medieval perspectivist tradition.

The chapter begins by locating the mathematical, philosophical, and rhetorical importance of the camera obscura within early Modern Europe. It then analyzes in more detail the role of Johannes Kepler within the reception of the camera obscura and the overall history of optics and vision. Having established such a background, the main section of the chapter then reconstructs Christoph Scheiner's optical theory, its reception among the Jesuits, and then its importance within the history of optics in the middle of the seventeenth century. I will show that Scheiner easily interpreted Kepler's optics within the perspectivist tradition, which was then subsequently accepted by most Jesuit authors as being correct. In the process attention will be given to the way Scheiner adopted instruments as effective tools for reinforcing fundamental aspects of perspectivist optical theory—particularly the visual species. One of the outcomes of this is the close connection between mathematical instruments and cognition among the Jesuits in the first half of the seventeenth-century, an adoption which showed how mathematical methods overcame doubts as to the reliability of the sense of sight.

The Camera Obscura

A camera obscura, a "dark room" or space wherein images are projected, was a theatrical and practical device that captured the imagination of many from 1600–1800.[290] During this time the camera obscura came to be utilized in a wide array of contexts—as an aid for artists or surveyors, as a tool for mathematicians and philosophers, as well as a theatrical feat widely theorized among natural magicians. It also became the most important development in optics and the explanation of vision. The new interest in the camera obscura is intriguing, however, since it was an adaptation of optical projection techniques which had been known within the perspectivist optical tradition for centuries.

Prior to the seventeenth-century camera obscura, it was known since at least the optical texts of Ibn al-Haytham that one could project light and color through a hole in a door or in a piece of paper.[291] The former was something analogous to the cameras obscurae of the early modern period and the latter a type of projection known as a "pinhole camera," where one could project an image through a small hole in a piece of paper. In one experiment Ibn al-Haytham

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[290] Wolfgang Lefèvre, "The Optical Camera Obscura I: A Short Exposition," in Wolfgang Lefèvre, ed. *Inside the Camera Obscura–Optics and Art Under the Spell of the Projected Image* (Berlin: Max Planck Institute for the History of Science, 2007), 9.

[291] Abdelhamid Sabra, "Alhazen's Optics in Europe: Some Notes on What It Said and What It Did Not Say," in *Inside the Camera Obscura*, ed. Wolfgang, 53–57.

states:

> When several candles are at various distinct locations in the same area, and when they all face a window that opens into a dark recess, and when there is a white wall or [other white] opaque body in the dark recess facing that window, the [individual] lights of those candles appear individually upon that body or wall according to the number of those candles; and each of those [spots of light[appears directly opposite one [particular] candle along a straight line passing through the window. Moreover, if one candle is shielded, only the light opposite that candle will be extinguished, but if the shielding body is lifted, the light will return.[292]

This received important extension in the work of the thirteenth-century Arabic optician Kamal al-Din al-Farisi who adopted al-Haytham's theory to explain that one could actually see a projected picture, such as passing clouds or flying birds, moving in reverse direction within the darkened room or upon the pinhole camera.[293] This observation provided the context for the use of projection techniques to aid in the observation of astronomical events, such as eclipses, in medieval astronomy. Yet, conspicuously, it never came to be applied to the projection of a picture within the eye, even though Ibn al-Haytham's theory of vision explained the eye's reception of the visual forms analogously with light and color projection through a window or aperture.[294]

The explosion of interest in the way the camera obscura could explain vision did not occur until the sixteenth century, and even then the topics were not always discussed together. As noted in the first chapter, it was during this time that the physician Felix Platter introduced in a passing statement that the eye operated similar to a camera obscura, an insight which had a

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[292] Alhacen, *Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen's De Aspectibus, the Medieval Latin Version of Ibn Al-Haytham's Kitab Al-Manazir*, trans. A. Mark Smith (Philadelphia: American Philosophical Society, 2001), 2:379.

[293] Sabra, "Alhazen's Optics in Europe," 54.

[294] Sabra, "Alhazen's Optics in Europe," 54, n. 34.

profound impact upon Johannes Kepler's optics.[295] In fact, as Katrien Vanagt suggests, since physicians were reticent to adopt the analogy between the camera obscura and the eye, only significantly doing so in the middle decades of the seventeenth century, Kepler's ready adoption stands as an important development within the theories of early modern vision.[296] Kepler's uniqueness is further revealed when considering the optical book of Maurolyco, discussed in the previous chapter, which was originally produced in the sixteenth century but not published until after Kepler's works. While Maurolyco treats the camera obscura towards the beginning when discussing light, there is no explicit suggestion in the section on the eye that the camera obscura is related to the way the eye operates.[297]

The reticence of early modern physicians to adopt the analogy between the camera obscura and the eye had to do with the importance of the visual humors in the perspectivist optical theory and the way in which the new analogy introduced various unexplainable aspects, not the least of which was how vision (and hence cognition) could be understood. It was this very point that the French intellectual René Descartes perceived within Kepler's optics, which encouraged him to jettison the visual species and to adopt mechanical and mathematical models for vision, thus altering the foundation of cognition itself.[298]

Yet, the reticence of the physicians and the cognitive skepticism which the camera

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[295] Vanagt, "Early Modern Medical Thinking on Vision and the Camera Obscura," in *Blood, Sweat, and Tears*, 571.

[296] Vanagt, "Early Modern Medical Thinking on Vision and the Camera Obscura," in *Blood, Sweat, and Tears*, 571–72.

[297] See Francesco Maurolico, *The Photismi De Lumine of Maurolycus: A Chapter in Late Medieval Optics,* trans. Henry Crew (New York: The Macmillan company, 1940), 24–30; 150–121.

[298] Darrigol, *A History of Optics*, 39–49.

obscura provided Descartes were issues well-known within the medieval period. For instance, when discussing the projection of the visual species (which he calls "form") within the eye Ibn al-Haytham states

> But the form cannot extend from the surface of the *glacialis* [edge of the center of the eye] to the hollow of the nerve along straight lines and still preserve the proper arrangement of its parts, for all of those lines meet at the center of the eye. In that case, when they are extended along straight lines past that counterpoint their relative positions will be reversed, so the rightward [radial lines] will fall to the left, and vice versa, and the higher ones [will be] lower and the lower ones higher. Therefore, if the form extends along straight radial lines, it will contract at the center of the eye to form a virtual point; and since the center of the eye [in terms of its visual components] lies at the center of the entire ocular globe and in front of where the hollow of the nerve flexes, if the form is extended from the center as a single point along a single line, it will arrive at the place where the hollow of the nerve flexes as a single point.[299]

To avoid this issue, Ibn al-Haytham assumes that the visual rays within the eye are not able to extend beyond their point of convergence in the center of the eye. So, as the projected species from the object enter the eye, they refract to such an extent that they are focused on a point at the center of the eye. As he notes "if the form was extended on straight radial lines it would be congregated at the centre of the eye and become as it were a single point."[300] Yet, the rays do not extend physically beyond that point at the center of the eye because that would introduce a distorted image on account of the rays reversing after their point of convergence. So, while Ibn al-Haytham knew of the potential issue of a flipped image within the eye, the justification that this was not the case depended on the belief that it would be illogical for this to be true, since common experience demonstrates that one sees the world right-side-up, not reversed.

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[299] Alhacen, *Theory of Visual Perception*, trans. Smith, 2:419.

[300] Quoted in Alistair Cameron Crombie, "Expectation, Modelling and Assent in the History of Optics: Part I, Alhazen and the Medieval Tradition; Part II, Kepler and Descartes," in *Science, Art and Nature in Medieval and Modern Thought* (London: The Hambledon Press, 1996), 313.

As others have noted, there are many important points within Ibn al-Haytham's explanation.[301] Despite his recognition of the importance of experimentation, particularly with the projection of light (noted above) his explanations involved logical deductions without clear anatomical insight. The knowledge of the eye's anatomy provided Kepler with a significant impetus to introduce important criticisms to the perspectivist model. Yet, by a similar token, it was the knowledge of the eye's anatomy which motivated the Jesuit Christoph Scheiner to refashion arguments from the perspectivists considering the new anatomical knowledge, indicating that Kepler's critique did not logically bring about the end of perspectivist optics.

Before explaining this, however, more attention needs to be given to Kepler's explanation of vision, particularly his explanation of the "Aristotelian problem," and its utility in explaining the way in which vision occurs.

Johannes Kepler's Challenge

Within perspectivist optics, vision occurred through the reception of an object's color—the visual species—transported through the medium made translucent by the lumen. Thus, the species themselves were comprised of the qualities of the object's color. An important part of this understanding is that the visual species itself was not technically a spatial body. It was a quality. While it did scale proportionally between an eye and the object according to the visual rays of a pyramid, and this was useful for explaining depth perception, it nevertheless was not in itself mathematical.

In his *Ad Vitellionem paralipomena* (1604) Johannes Kepler challenged this doctrine.

[301] Alistair Cameron Crombie, "Expectation, Modelling and Assent in the History of Optics," 310–320.

Eliminating the visual species from the explanation of vision, Kepler contended that the image on the retina was itself composed of mathematical lines of light. As explained in Chapter One, one of the goals that Kepler had for such a methodological move was to establish optics on firm mathematical ground without philosophical assumptions, particularly those associated with perspectivist optics. He wrote

> How this image or picture is joined together with the visual spirits that reside in the retina and in the nerve, and whether it is arraigned within by the spirits into the caverns of the cerebrum to the tribunal of the soul or of the visual faculty; whether the visual faculty, like a magistrate given by the soul, descending from the headquarters of the cerebrum outside to the visual nerve itself and the retina, as to the lower courts, might go forth to meet this image—this, I say, I leave to the natural philosophers to argue about.[302]

Whether or not he succeeded in that—especially since he invoked the nature of God to provide an ontology for mathematics—is beyond this dissertation and this chapter. What is important, however, is the way he utilized the camera obscura to justify the view that visual species do not exist and that images are formed on the retina from mathematical rays. Such a point is based upon his understanding and solution of an ancient mathematical and optical problem, known as "Aristotle's problem," introduced by the camera obscura.

The standard explanation since antiquity for how light behaves when passing through an aperture involved the explanation that the image formed was the composite representation of the visual pyramids, the spherical shape of which is provided by the aperture through which it passes. So, for instance, the projected image of a circular astronomical feature, such as a full moon, through a pinhole camera would produce a circular image projected through the hole. A more difficult situation to explain, known since at least Aristotle, was why a round image results when light falls through a square aperture. This problem ran contrary to expectation, since one

[302] Kepler, *Optics*, trans. Donahue, 180.

would expect a square image projected through a square aperture. The explanation that Aristotle gave to this problem was that the overlapping cones produce the brightest circle in the middle, and hence a spherical image, and that the light that would have been projected in the corners of the square aperture was too weak for the eye to see.[303] As Kepler said later, it is this problem alone that left Aristotle's account of vision defective.[304] A pictorial representation of the Aristotelian problem may be noticed on the frontispiece below of a Jesuit book devoted to the mathematical problem of the quadrature of the circle, where the sunlight projected through a square aperture produces a circular projection on the ground below.

303 Aristotle, *Problems* XV 6, 911b 3-25.

304 Pantin, "Simulachrum, Species, Forma, Imago," 251.

Image 3.1 — A depiction of the Aristotelian problem
Gregory St. Vincent, *Opus Geometricum quadraturae* (1647), frontispiece
Image courtesy of The Linda Hall Library of Science, Engineering & Technology

Within the perspectivist optical tradition there were varying explanations passed down for the resolution of this problem. One of the more recent and prominent in the sixteenth and seventeenth centuries, put forward by Francesco Maurolyco, involved the understanding of the camera obscura wherein the image was flipped. Maurolyco envisions a series of Pyramids with a singular base on the luminous body and an apex just before the aperture. Such pyramids would be inverted, projecting an infinity of images of the luminous body on the other side of the square aperture.[305]

Kepler, however, differed in his explanation. In Chapter Two of his *Ad Vitellionem*, Kepler explains how he understands the projection of a circular object through a square aperture. His explanation developed not based upon a light source and an aperture, but instead using a book (symbolic of the light source), string (symbolic of the light rays), and polygon aperture. What he did was connect the string from the book through each of the corners of the polygon to the ground, simulating the light rays projected from the light source through the aperture. Kepler discovered that "the round shape is not that of the visual ray but of the sun itself, not because this is the most perfect shape, but because this is generally the shape of a luminous body."[306]

From this Kepler developed the theory that an infinity of lines could connect from the luminous source to the ground and that this would project an image of the light source and not that of the aperture. Thus, whereas Maurolyco assumed an infinity of pyramids projecting from the same light base, Kepler assumes an infinity of pyramids projected from an infinity of points on the light source. So, while Maurolyco uses the pyramid to explain the projection of the image, Kepler explains the whole process, even the creation of the pyramids, based upon the projection of light itself. In the end both arguments arrive at strikingly similar conclusions—it is an infinity of rays from the luminous source that produce the image of similar sphericity—yet, Maurolyco

[305] Maurolico, *Photismi de lumine et umbra*, Theorema XXII, 16–19.

[306] Kepler, *Optics*, trans. Donahue, 56.

assumes the existence of the pyramid and for Kepler it is a mere byproduct of the light rays themselves. While a subtle difference, its philosophical implications were substantial.

Kepler realized that there were philosophical implications, and states many of these in an Appendix at the end of Book One, Chapter One, where he explains how his theory of vision explicitly counters Aristotle. Rather than stating that color enabled vision, as Aristotle and the Jesuits had affirmed, Kepler states that it was light itself that enabled vision, not color.

> For the reason why color has the power of moving the instrument of vision, is because it is of the nature of light. And so it is a primary and inherent property of light to alter the walls (and therefore the eyes).[307]

The importance of this statement pertains to the way in which Kepler has reversed the relationship between color and light within perspectivist optics. Whereas the perspectivist theory explained that color was primary and light secondary. Here, Kepler is stating that light is primary and color is secondary.

Kepler seems not to have fully understood—or at least been unwilling to clarify—the full philosophical implications of his observations. Thus when one considers Kepler's broader optical works, it is apparent that Kepler himself might not have been fully aware of the impact of his conceptual ideas. This may be noticed from his *Dioptrice*, in Proposition 61 where he refers to the species as the object "received by the retina [that] passes through the continuity of the spirits to the brain [where it] is…delivered to the threshold of the faculty of the soul"[308] Thus, despite his insistence in 1604 that he desired to completely obviate the visual species, he nevertheless borrows the language to explain what was transported through the telescope.

The particularities of the Jesuit reception of Kepler have received recent attention by

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[307] Kepler, *Optics*, trans. Donahue, 45.

[308] Smith, *Sight to Light*, 370, n. 79.

historians, particularly Isabelle Pantin. As she contends, not only did Scheiner know about Kepler's optics, which Scheiner himself does not hide and which historians have known for some time, but so also did Aguilonius. She makes her claim based on the way in which Aguilonius's explanation of Aristotle's problem closely follows Kepler. Aguilonius cites the camera obscura in two locations: Book I, in the context of explaining color, and Book V, in the context of astronomy and the pinhole cameras. A brief consideration of these instances is important because of the way it explains the role of the camera obscura within Aguilonius's thought regarding the camera obscura, color, and the visual process.

In Book I, Proposition 42, Aguilonius explains the relationship between light and color. He states: "Light raises false colors and, as a proper hypostasis, carries them (false colors) cut off away from objects."[309] In this context, he introduces the camera obscura as an example to explain this aspect. It is notable that this proposition occurs immediately before Proposition 43, in which Aguilonius identifies the nature of the visual species, indicating the particular importance of the camera obscura for clarifying the visual species itself. The experiment that he describes is a theatrical scene where it is possible to project inverted images within a darkened room. It is evident that Aguilonius intends not only to use this experiment to explain the way light and color work, but also to counter popular charlatans and necromancers who similarly make use of this trick to demonstrate demonic activity. Although Aguilonius himself does not identify Della Porta as the necromancer, many later Jesuits interpret this passage directly with respect to Della Porta.[310]

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[309] Aguilonius, *Opticorum libri sex*, 46: Lumen colores otiosos suscitat, & ceu propria hypostasis decisos ab obiectis vehit.

[310] As one example, Mario Bettini, "Apiarium VI," in *Apiaria universae philosophiae mathematicae* (Bologna: Johannes Baptistae Ferronius, 1642), 1:36.

For Aguilonius, however, it is the nature of light and color which demonstrates that the techniques of those like Della Porta do not project various illicit aspects. As he notes, "The colors that appear here, have no other origin than those which we said above to be cut off from the real things, and carried with the light through the transparent medium."[311] Since Aguilonius is following standard perspectivist optical theory, the explanation of the camera obscura follows naturally from the principles of light and color, which Aguilonius himself notes at the beginning of this Proposition by referring to previous Propositions about the qualities of color and light.[312]

The second explanation of the camera obscura occurs at the end of Book V, when discussing astronomy and pinhole cameras. The explanation of the camera obscura is particularly significant in this section because it occurs in a section where Aguilonius explains the trajectory of light, which not only includes an explanation of pinhole cameras but also the projection of light through square apertures, the "Aristotelian problem." Before explicitly addressing the Aristotelian problem, Aguilonius identifies the role of the "trajectory of light," which is the title of the section.[313] Among his interests is the explanation as to how light projects through apertures, both circular apertures as well as triangular and square apertures. It is notable that Aguilonius does not follow Maurolyco's explanation of the overlapping pyramids to explain how the image forms on the other side of the aperture, especially since Aguilonius has noted Maurolyco at other points of his work.[314] Rather, following his presentation that what is

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[311] Aguilonius, *Opticorum libri sex*, 47: Porro colores, qui hic apparent, non alij profecto sunt, quam illi ipsi quos supra a veris resecari, atque una cum lumine per medium diaphanum deferri diximus.

[312] Aguilonius, *Opticorum libri sex*, 46.

[313] Aguilonius, *Opticorum libri sex*, 443: De luminis traiectu.

[314] For instance, Aguilonius, *Opticorum libri sex*, 405.

projected through the aperture are light rays that form a pyramid from a point, Aguilonius explains that the Aristotelian problem may be resolved in similar fashion:

> The cause of this thing is, therefore, that which we said a little before, namely, that the pyramids of illumination, which proceed from the individual points of the body of the sun through the square openings in the screens are arranged in a circle.[315]

It is here that Aguilonius's explanation resembles Kepler's quite closely, as he explains that the problem may best be resolved by understanding the image to be the product of an infinity of light rays. It very well may be the case that Pantin is correct and that Aguilonius knew about Kepler's optics. This suggestion is especially probable since immediately after the explanation of the Aristotelian problem, he relates it back to the camera obscura of Book I which explained the theatrical tricks of this optical phenomenon.[316] This was the same connection which Kepler made between the pinhole camera and the optical trickery of Della Porta. Yet, rather than follow Kepler's own philosophical assumptions that the image was composed of light rays, Aguilonius explains that it was a "form" (forma) projected through the aperture—language which Pantin explains indicates Aguilonius's reticence to adopt Kepler's optics wholesale.[317]

The more pressing point, however, is whether it was problematic and a cognitive problem, for Aguilonius to simultaneously make use of light projection while at the same time retaining visual forms, and hence the "visual species." To help clarify this point, it is necessary to turn toward the Jesuit Christoph Scheiner who, more so than Aguilonius, recognized the

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[315] Aguilonius, *Opticorum libri sex*, 450: Est igitur huius rei ea causa, quam paulo ante diximus, nempe quod illuminationum pyramides, quae a singulis punctis solaris corporsi per quadrilatera cratium foramina procidunt, in orben disponantur.

[316] Aguilonius, *Opticorum libri sex*, 451.

[317] Pantin, "Simulachrum, Species, Forma, Imago," 245–69; Sven Dupré ultimately follows Pantin in his own chapter, Dupré, "The Return of the Species," 473–87.

necessity for clearly explaining not only the mathematics of what was involved, but equally so the physics of it. Having clarified Scheiner's position, it will then be possible to return to Aguilonius and other Jesuits to clarify the issue regarding the Aristotelian problem and how their particular response reflects a position that is faithful both to Kepler and perspectivist optics.

Christoph Scheiner's Optical Synthesis

Christoph Scheiner provided Jesuit mathematicians with an explanation as to how optics and vision related. Christoph Scheiner integrated aspects of the new optics into the perspectivist optical theory. Such a development occurred within the context of various optical investigations, such as investigations of sunspots, defenses of Copernicanism, as well as anatomical investigations of the eye. To understand Scheiner's optical thought and its later influence among the Jesuits, it is necessary to construct important features of his optics within its particular historical contexts. As a result it will become apparent that Scheiner perceived no incompatible relationship between the new optics and perspectivist optics.

Christoph Scheiner was born in 1573 in Swabia. As a student he attended the Jesuit grammar school in Augsburg from 1591-1595. He entered the Society of Jesus in 1595 and took his vows in 1598, after which he worked as a Latin teacher in the Jesuit grammar school of Dillingen until 1601. He then transferred to Ingolstadt where he studied philosophy and theology and obtained a celebrity status through the invention of his artistic drawing device, the pantograph. He was promoted to doctor 1609, after which he taught mathematics and Hebrew at the University of Ingolstadt. It was during this time that Scheiner observed sunspots and thus began the debate with Galileo Galilei over whether the sunspots were on the face of the sun or whether they were satellites orbiting around the sun.[318] Scheiner's optical investigations contributed to the production of an interpretive consensus on the nature of light and vision among the members of the Jesuit Order for much of the seventeenth century.

Sunspots and Disquisitiones

Scheiner's assimilation of the new Keplerian optics into his own theory of optics occurred during the second decade of the seventeenth century, particularly from 1611–1614 during the Sunspot Controversy. It was during this time that Scheiner came to use the Keplerian theory of image formation to justify and explain how the image of sunspots formed on the canvas of his instrument. At the same time Scheiner oversaw the production of a disputation by one of his students on mathematics, a section of which reveals Scheiner's earliest response to the optics introduced by Kepler. An analysis of both will provide important context for understanding Scheiner's more substantive contributions to the theory of optics and vision in his *Oculus* (1619) and *Rosa Ursina* (1632).

The oldest surviving record of telescopic observations of sunspots by someone from the west is from 1610 by Thomas Harriot (1560–1621). Near the same time the East-Frisian Lutheran pastor David Fabricius (1564–1617) and his son Johannes (1587–1616) were similarly involved in the investigation of sunspots. During Spring 1611 the two used a telescope repeatedly to observe sunspots, and, by the end of Spring 1611 published their observation and argumentation that the spots were indeed upon the sun and not passing clouds. Their work was largely ignored. Due to the philosophical difficulties of introducing an imperfect sun, Scheiner

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[318] Franz Daxecker, *The Physicist and Astronomer Christopher Scheiner: Biography, Letters, Works* (Innsbruck: Leopold-Franzens-University of Innsbruck, 2004), 9–10.

began studying sunspots in 1611 to determine their legitimacy. Such investigations led to a series of letters between him and Galileo between 1611 and 1613. Ultimately Scheiner decided that the spots were not actually upon the sun, but instead were satellites that wandered around the sun. As he explains in his first letter, however, such a conclusion was based less on the necessity of maintaining a perfect sun as it was on his confusion that the sunspot images did not return to the same location in a consistent manner.[319]

For the purposes of this chapter, it is Scheiner's letter, the *Accuratior Disquisitio* that is most pertinent for understanding Scheiner's theory of light and vision. The letter itself responds to many of the criticisms Galileo had introduced about Scheiner's understanding of the sunspots. More so than the previous letters, this one deals with the issue of visual certitude and actively engages many important features of the Aristotelian understanding of vision.

Scheiner introduced some of his own critiques of the Aristotelian theory of vision. Near the beginning of the letter Scheiner recognizes the importance of the Aristotelian *De Anima* tradition for theorizing about vision and image representation. Scheiner writes

> I applied the telescope to my eye in the usual way and kept an eye open (which can be done) while inserting a smooth reed, and I drew it gently back and forth across the corneal membrane, and I saw it most consistently. Due to this most certain experience, the repeated assertion of Aristotle, that a sensible thing placed over the sense does not produce a sensation, must be explained in the case of the eye if it were wholly covered, for in this instance the eye excludes all light necessary for seeing, as is evident in the case of the eyelids.[320]

It is evident that Scheiner's criticism of Aristotle, which undoubtedly he intends to be humorous, equally serves as a way to maintain the trustworthiness of light in the visual process.

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[319] Eileen Reeves and Albert Van Helden, "Introduction," in Eileen Reeves and Albert Van Helden eds. *On Sunspots* (Chicago: University of Chicago Press, 2010), 62.

[320] Christoph Scheiner, *Accuratior Disquisitio*, trans. Eileen Reeves and Albert Van Helden, in *On Sunspots*, 215.

For, parallel to the reed across the eye would be the satellite moving in front of the sun. Yet, despite his belittlement of Aristotle's *De Anima*, Scheiner maintains important features of the perspectivist optical theory, particularly the visual species.

Immediately following this explanation Scheiner then addresses certain criticisms of his sunspot projections, particularly the role of impurities within the glass lenses on his helioscopes, the instruments which he used to project the images of the sun. Within his explanation three important aspects are noteworthy. First, Scheiner uses a theory of camera obscura projection similar to Maurolyco, where a visual pyramid projects toward the aperture and then is inverted and flipped afterward. Second, Scheiner does not explain that the image is projected upon the retina at the back of the eye, as Kepler had done, but upon the crystalline humor, like Maurolyco's explanation. Third, in explaining the projected image within the crystalline humor, Scheiner explains that it receives from the light ray the "species."[321] Based upon these few examples it is evident that at the time in which Scheiner composed his sunspot letters that his explanation of optics was fully within the domain of perspectivist optics. His would shift soon after.

Most historians consider Scheiner's earliest engagement with Kepler's optics to be in his *Oculus* of 1619. However, in 1614 Scheiner presided over a disputation for one of his students, Johan Locher, which includes a discussion of the camera obscura that appears to be informed by Kepler's optics. It is horrendously difficult to identify authorship of disputations, since sometimes it is the student who defends it while at other times the presiding professor. One anecdotal piece of evidence by a contemporary indicates that at least the authorship of this

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[321] Noted in the text, Christoph Scheiner, *Accuratior Disquisitio*, trans. Eileen Reeves and Albert Van Helden, in *On Sunspots*, 215.

disputation was considered to be Scheiner. In an Appendix at the end of his short biography of Galileo published in 1633, Leo Allatius includes a list of Christoph Scheiner's publications, one of which is the 1614 disputation.[322] Whether or not Scheiner composed the work is not necessary to determine now; instead, the point is that Scheiner at least consented to the ideas put forward in this book, such as the adaptation of Kepler's optics.

The disputation itself covers a wide array of topics, most of which are related to Scheiner's wider scientific investigations, such as sunspots, celestial motion, tides, and gravity. For the purposes of optics it is Disquisition 36 that is the most interesting. The Disquisition itself pertains to pinhole cameras and the trajectory of light in the camera, a topic which would have been of concern for Scheiner because of his efforts in the Sunspot Controversy with Galileo.

The beginning of the explanation is very similar to Kepler, especially Kepler's theory of projected light rays. After explaining the experiment of the pinhole camera, the disputation states, "rays of both bright light and color are woven together following straight lines."[323] The rays converge toward the apertures and then diverge in "radiant cones" after passing through the aperture. It is apparent that the text aims to translate the perspectivist optical understanding, noted in Maurolyco, where pyramids project from the light source, to an explanation in a similar fashion as Kepler. The disputation states, "As the object (the sun) is divisible, so are the radiant cones divisible." Thus, the visual pyramid was itself composed of light rays, explaining the

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[322] Leo Allatius, "Galilaeus Galilaeus," in Stefano Gattei, ed. *On the Life of Galileo: Viviani's "historical Account" & Other Early Biographies* (Princeton: Princeton University Press, 2019), 107.

[323] Georgius Locher, *Disquisitiones mathematicae, de controversiis et novitatibus astronomicis. auas Praesidio Christopher Scheiner in Alma Ingolstadiensi Universitate, propugnavit Joannes Georgius Locher, Mense Septembri* (Ingolstadt: Elisabeth Angermariam, 1614), 73: Radij tam lucidorum quam coloratorum secundum rectas seruntur lineas.

visual pyramid by way of Kepler's light rays.

The natural implication of this explanation is that the projected images through the aperture are comprised of individual light rays, an optical phenomenon that would potentially raise issues for the more traditional view of the visual species, especially since it was this observation which Kepler considered to be among the reasons to jettison the species in the explanation of optics. Likely aware of this, the disputation states the following:

> It may also be put, although I do not concede this, a point may be seen or that sight happens from a point. First it might be said, such a point relates to the rays scattered from it and collected within it as the center of a circle to its semidiameters of the circle. And when it pours out all those rays, it will not actually be divisible, but will be virtually divisible. Or we might say that the point in itself is not divisible but that it is divisible in its rays, and this suffices. Or, finally, we might say it is just divisible by degree but not by quantity. I add also to this that the hemisphere of rays from one point, they do not all fall within the eye. Rather, a few within the rays do, according to the capacity of the pupil. Of these, however, only the one which is least oblique to the eye will be sensed, while the others are obfuscated. And so, from one point comes one sensible ray, which is the image of the indivisible point.[324]

It is evident from the explanation here that Locher, and conceivably Scheiner as well, realized the implications of understanding projections through the camera obscura as being light rays—it eliminated the visible species and the reality of the object seen. The explanation provided, namely that a light ray possesses a point that is sensible provides an important rebuttal

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[324] Georgius Locher, *Disquisitiones Mathematicae, de Controversiis et Novitatibus Astronomicis. Quas sub Praesidio Christopher Scheiner* (Ingolstadt: Elisabeth Angermariam, 1614), 73–74: Posito etiam, sed non concesso, punctum videri, aut sub puncto visionem fieri; dicitur primo, tale punctum se habere ad radios sparsos & ad se collectos, ut se habet centrum in circulo ad semidiametros; cumque; omnes istos radios fundet, erit non actu, sed virtute tantum divisibile: vel dicemus, illud in se non esse divisibile, sed in radiis suis, & hoc sufficere: aut tandem dicemus, ipsum gradu dividi, non quantitate. Adiungo etiam hoc, hemisphaerium radiosum unius puncto, in oculus non cadere nisi sub radiis paucis secundum capacitatem pupillae, quorum tamen unus tantum qui minimè ad oculum obliquus est, sit sensibilis, reliquis obfuscatis. & sic ab uno puncto unus venit radius sensibilis, qui instar puncti est impartibilis, etc.
Cf. Johann Georg Locher, *Mathematical Disquisitions: The Booklet of Theses Immortalized By Galileo,* trans. Christopher Graney (Notre Dame Indiana: University of Notre Dame Press, 2017), 86. Graney's translation is a helpful reference point, but this translation is my own.

of Kepler's optics. Essentially a thought experiment, the issue raised demonstrates that Kepler's theory of light projection (assuming Locher and Scheiner engaged it here) did not necessarily imply the destruction of the visual species. The image below demonstrates what the disputation sought to explain.

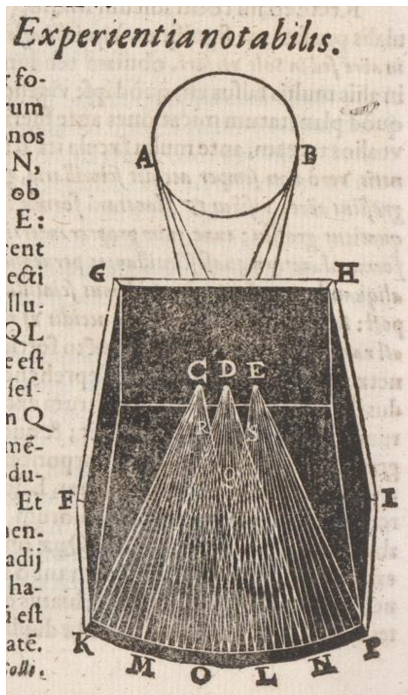

Image 3.2 — Example of projected light rays through an aperture
Georgius Locher, *Disquisitiones mathematicae* (1614), 72.
Image courtesy of The Linda Hall Library of Science, Engineering & Technology

> The disputation continues
>
> From this it is evident that any one point sends out a visible ray to the hemisphere, and the same point is seen in one after another, this place or that place, within this ray or that one. Moreover, the visible species is not only in the nature of the things seen, but in such a case probability what is seen has been communicated by light and color, it being that which was observed motionless in that place, as if seeing the object itself, not as direct, reflected, or refracted, all of which daily experience testifies. And according to this it is also clear, the visual species of things are true formal images of the visualized things.[325]

[325] Locher, *Disquisitiones Mathematicae*, 74: unde evident est, punctum quoduis mittere radios

The final sentence of the text deserves further elaboration. Recall, from Aguilonius's earlier explanation of the visual species that the species was virtual and not formal. What Aguilonius meant by this is that the species within the eye did not maintain its quantitative or geometrical figure within the eye—hence it became virtual within the eye. The reason Aguilonius posited this, and one which many medieval perspectivists echoed, was that the crystalline humor could not accept a physical species. Surprisingly, the final statement of Scheiner's text reverses such a point, indicating that the visual species itself was not merely virtual, but was formally real. This point, which recognizes that the image on the retina bears not merely a qualitative relationship to the visualized object but equally so a structural and mathematical relationship, will be given more consideration by Scheiner (and other Jesuits) as this relationship is not just a quantitative, mathematical relationship, but carries a quality, essence, or philosophical nature. An implication of this is that mathematical instruments and artistic construction are not merely tools of representation, but could be leveraged to create real representations of reality—otherwise known as visual species.

By comparing the *Disquisitiones* with the *Accuratior Disquisitio* it is evident that the projection of images through a camera obscura introduced an important shift in the way in which Scheiner understood and could explain not only optics and light projection, but more importantly, vision itself. The *Disquisitiones*'s explanation that image projection occurs with an infinite number of light rays from the light source shows the same line of thought as Kepler (if

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visibiles ad hemisphaerium, & in alio alioque loco atque; situ illud idem punctum conspici sub aliis aliisque; radiis. Item species visibiles non tantum in rerum natura esse, sed in tali casu probabiliter videri, eo quod ibi spectentur immotae tanquam *obiectum Quod*, & ut alij vocant, tanquam lux & color communicatus, non tanquam directus, reflexus, aut refractus, testante quotidiana experientia. E quo etiam patet ulterius, species rerum visibiles esse veras formales rerum visarum imagines.

not drawn explicitly from Kepler) by indicating that images are formed from light rays themselves. Yet, although the *Disquisitiones* demonstrates a certain reticence as to the precise philosophical implications of the new optics, it nevertheless does not recognize any contradiction in what is identified. In fact, as will be shown in Scheiner's later works, the *Oculus* (1619) and the *Rosa Ursina* (1630), Scheiner's hidden intellectual legacy is that of Roger Bacon's multiplication of the species, which simultaneously maintained the projection of light and the visual species at the same time.

The *Oculus* and the *Rosa Ursina*

The intellectual background of the *Disquisitiones* provides an important context for understanding Scheiner's more well-known optical treatises, the *Oculus: Fundamentum opticum* (1619) and the *Rosa Ursina* (1632). The first of these is devoted to understanding the anatomical and philosophical significance of vision; the second to sunspots and astronomy. Yet, due to the way his astronomical investigations shaped his theory of vision, the *Rosa Ursina* also contains a considerable amount of information on the theory of optics and vision. In large part the optical arguments put forward in the *Rosa Ursina* are very similar to those in the *Oculus*, the main differences being the images included in the *Rosa Ursina* more clearly articulate some fundamental points, noted below. The significance of Scheiner's two optical works among the Jesuits is difficult to overstate. They were highly quoted and recognized for their philosophical importance. As the Jesuit Blancanus (1566–1624) commented in his *Sphaera Mundi* (1620), in the *Oculus* in particular, Scheiner explained the basis of cognition itself.[326]

[326] Giovanni Biancanni, *Sphaera Mundi* (Bologna: Sebastiani Bonomij, 1620), 445: P. Christophori Scheiner Societatis nostrae, opus recens editum, verùm abstrusis experimentis, ac nova necessariaque rerum cognitione refertum.

As indicated already, recent interpretations have argued that Scheiner implements a compromise between traditional perspectivist optics and Aristotelian natural philosophy.[327] Whereas Kepler argued that the projection on the retina was "picture," Scheiner clearly states that it was a "species," clearly noticed in the first part of Book 3, "On the visible species."[328] While Isabelle Pantin's assessment of Scheiner's reading of Kepler's optics is well-articulated, what it lacks is a thick description as to how Scheiner's interpretation of Kepler emerged and its relationship to the tradition of perspectivist optics, particularly Ibn al-Haytham and Roger Bacon. As indicated, in the medieval period these authors developed sophisticated explanations as to how vision occurs which maintained the importance of the visual species. Scheiner borrows from their works in key places in his *Oculus* to demonstrate the resonance between Kepler's optics and the more standard views of perspectivist optics. While he does deviate from their tradition in one respect, namely that the species was formal and not virtual, he nevertheless interprets Kepler as an extension of this well-defined optical tradition. Though Scheiner does not clearly specify his motivations for deviating from Kepler's optics, there are suggestions that he was motivated by the illogicality of it as well as the resonance of perspectivist optics with the Counter-Reformation theology, particularly the Eucharist. More will be made of this last aspect in the final section of this chapter.

The frontispiece of the *Oculus* is unavoidably confessional, clearly indicated by the triumphal image of the Hapsburg eagle at the center of the image, holding two scepters just above a sword. On either side of the frontispiece are images which, as Eileen Reeves has demonstrated, strategically use the phenomenon of projected images as a rhetorical tool to

[327] Pantin, "Simulachrum, Species, Forma, Imago," 245–269.

[328] Scheiner, *Oculus*, 125: De speciebus visibilibus.

aggrandize the power and prestige of Emperor Ferdinand II in the war against the Protestants (the Thirty Years War, that had just started).[329] For instance, as Reeves contends, the two cameras obscurae beneath the mountain on the left side of the frontispiece each enter complexly into the particular situation of Ferdinand in 1619. As she notes, these cameras obscurae comment on the "expansion" (bottom) as well as "illumination" that occurs after the diminution of the image. Such a change in identity, from being made small and insignificant to being larger and more prominent, serve as a prophetic pronouncement to the situation of Ferdinand in 1619 since it was during this time that the regions of Moravia, Silesia, Upper and Lower Lusatia, Upper Austria, and Bohemia had joined rebel forces against the Counter Reformation. Yet, by 1621, Ferdinand II would be restored to fame and prominence.[330]

Such a similar connection, between optical knowledge and technique and political authority, may be noticed on other Jesuit optical works produced during the Thirty Years War.[331] Yet, to be clear, the frontispiece was likely completed after the text itself, near 1617 as the approbations indicate. Rather, the point then is not that Scheiner composed the *Oculus* directly for the sake of its religious implications, but that its reception and the content of optics at the time could easily be projected as being rhetorically, if not philosophically, important for the cause of the Catholic Counter Reformation. This aspect, while not directly determining the

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[329] Reeves, *Evening News*, 167-72. Reeves's hypothesis is further reinforced by the fact that the two printings of the Oculus during the Thirty Years War, one in 1619 and a second in 1621, both contain the frontispiece, whereas the frontispiece of the 1651 printing does not contain the frontispiece, although it still contains the same dedicatory letter. This is confirmed at LHL, OU, and Newberry.

[330] Reeves, *Evening News*, 170.

[331] For instance, Johann Caspar Helbling, *Tubus optico-geometricus novus disputatus* (Freiburg: T. Meyer, 1632)

content of the optical works, nevertheless serve to remind about the rhetorical and political importance that optical knowledge itself could provide.

Image 3.3—Various cameras obscurae
Christoph Scheiner, *Oculus: Fundamentum opticum* (1619), frontispiece
Courtesy of The Linda Hall Library of Science, Engineering & Technology

The frontispiece simultaneously constructs its meaning within the context of Scheiner's most recent sunspot investigations, with hints of the Confessional importance as well. The close connection between instruments, confessionalization, and optics pervades not only this frontispiece but also the text and explanation of optics itself. On the right side of the image there are two cameras obscurae that indicate the way the frontispiece intended to enter into discourse with respect to the sunspot controversy. The first, in the lower-right corner is a projection with a Dutch telescope, the same type that Galileo had used in recording sunspots. The inscription beside this projected image states "it does not enter unchanged," suggesting the inferiority of Galileo's astronomical observation and its inverted image of sunspots when projected, such as Galileo did when observing sunspots.[332] Just above it, there is a camera obscura with two convex lenses, with a man looking into the first one, which is the same type of telescope that Kepler had introduced into his *Dioptrice* (1611). It is this type of projection that Scheiner came to adopt in 1617 since it provided a projection which avoided the flipped image.[333] It is important to note that the Galilean telescope only inverts the image when projected, not with direct observation. Conversely, the Keplerian telescope inverts the image with direct observation, but does not do so with projection. The contrast between the two images, the one in the lower right projecting the failed Galilean image and the one above that of Scheiner's image, uses the context of the all-important sunspot controversy to prompt the attentive reader as to the importance of Kepler's optics for the broader debate that Scheiner was in with Galileo. So before ever encountering the content of Kepler's work, the informed reader of this image would know that Kepler was not an

[332] Scheiner, *Oculus*, frontispiece: non integer intrat.

[333] Reeves, *Evening News*, 170.

intellectual to be wary of, but was one influential in the sunspot debate.

Despite the religious and political trajectory that the frontispiece projected back onto the text of Scheiner's optics, the text itself provides very little specific connections to political or religious contexts. Instead it details Scheiner's anatomical investigations of a bull's eye and his explanation of the philosophical importance of this in the context of the perspectivist and Aristotelian tradition. As the approbation of the text states, the work deals with "Optical Fundamentals, on the Eye and on the inspection of visible species, both upside down and erect."[334] Through a detailed anatomical investigation of the eye—which other Jesuits indicate Scheiner did on several occasions at the Collegio Romano—the projection of the image at the back of the eye was determined, and as Scheiner states, it revealed the "species."[335]

The very beginning of the *Oculus* recounts the history of mathematics and optics among Jesuit authors, noting Aguilonius, Villalpando, and Blancanus, all Jesuits who had addressed optics in the two decades before the *Oculus* was published. Similar to the previous Jesuits, particularly Aguilonius, Scheiner identifies the way in which optics is useful both to Natural Philosophy (or Physics) and Mathematics.

> Both Physics and optics each are occupied with visible things and the organ of vision; although in a different mode. For geometry, as the Philosopher attests in Book II of Physics, Chapter 20, considers lines, but not to such an extent as they are physical: Perspective, however, considers mathematical lines, but not to such an extent as they are mathematical. Therefore, truly, both investigate the same thing, but by different ways.[336]

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[334] Scheiner, *Oculus*: Fundamentum opticum de Oculo & specierum visibilium inspectione tam eversa quam erecta.

[335] Cf. Scheiner, *Oculus*, 37.

[336] Note that it is a textual error. The actual citation comes from Book II, Chapter 2. Scheiner, *Oculus*, A: Utrique enim tam Physici quam Optici circa visibilia, & organum visus versantur; modo tamē diverso. Geometria enim, teste Philosopho, l. 2. Phys. t. 20. de Physica linea considerat, sed not quatenus est Physici: Perspectiva autem mathematicam quidem lineam, sed non quatenus Physica est.

The borrowing of this text at the beginning of his work reinforces an important point that Scheiner wishes to make in the *Oculus*, namely, the way the subject matter of optics straddled the subject matter of both mathematics and physics. It also serves as a reminder that the mathematician nevertheless addresses topics which are oftentimes otherwise reserved for philosophers. Additionally it reminds the reader why it is that a mathematician is not only integrating anatomy into his mathematical explanation (which is the main subject matter of the book), but equally so the philosophical topic of the species.

The content of Book I and II of Scheiner's *Oculus* pertain to the anatomy of the eye and the way in which refraction occurs within the eye. It is here that Scheiner explains that the lens of the eye refracts the light rays, and that the rays cross paths at the anterior of the crystalline humor, and ultimately project upon the retina. It is within this section that one sees the way in which the *Oculus* extended the explanation of optics from the *Disquisitiones*, most clearly seen in the similarity between the image here of the eye and that of the *Disquisitiones* shown above in Image 3.2.

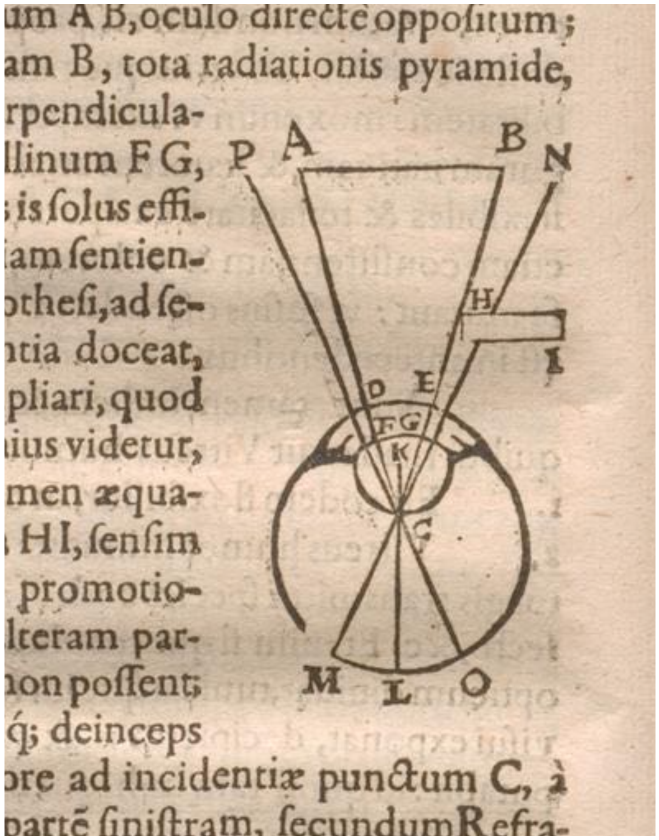

Image 3.4 — Projected species into the eye
Christoph Scheiner, *Oculus: Fundamentum opticum* (1619), 98
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Much of this section recounts his anatomical experience as well as explanations as to why the crystalline humor could not be the formal instrument of vision and that it was instead the retina. It is here also that Scheiner reveals his belief, like in the *Disquisitiones*, that it was through a single point that visual knowledge was created.

> All rays through which some visible point is brought to the organ of sight, are and are called visual rays. But some of them are not the principle or secondary, they are as if mediated and different. The principle, primary and immediate or formal one, is that one that enters and so to speak is sensed by the organ of sight itself, which senses the form of color.[337]

[337] Scheiner, *Oculus*, 73–74: Omnes radii per quos punctum aliquod visibile in organum visus derivatur, sunt et dicuntur radii visorii, sed aliqui minus principales & secundarii sive mediati & deferentes; unus autem principalis, primarius et immediatus seu formalis est is, qui ipsum id

Collectively these first two books provide background for the more important topic of the *Oculus*, book three, in which he explains why the picture on the retina should indeed be understood as the species. It is here that he tries to make the case that such an understanding stands in close connection to the understanding of optics within the perspectivist tradition.

Within Book III Scheiner also argues that his explanation of the visual species, which is borrowed from Kepler, represents the same aspect as found in Ibn al-Haytham as well as Roger Bacon. It was noted in Chapter One that Roger Bacon developed an expanded form of Ibn al-Haytham's projection of the species, wherein the qualities of an object are radiated to another object by way of light. So, for instance, fire radiates heat, which in turn may multiply within water so that the water obtains the quality of heat.[338] At key moments in his *Oculus*, Scheiner reminds the reader of the theory of the multiplication of species and how it may absorb the new theory of optics. Scheiner notes that within Bacon's theory of optics, the species would continue in the eye "to the optic nerve."[339] Thus, the point that Scheiner wishes to make is that the projection of the species on the retina, which implied a movement of the species beyond the crystalline humor, finds a similar explanation within the perspectivist optical theory itself. In the clearest interpretation of Kepler through the lens of Roger Bacon, Scheiner cites a section from Book 3 of the *Perspectivae* where Roger Bacon states, "Vision is greatly improved and completed by such an infinity of refracted rays, by means of which every visible object is seen,

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organum visus, quod formam coloris sensit, ingreditur, et ut ita dicam sentitur.

338 Smith, *Sight to Light*, 262–266.

339 Scheiner, *Oculus*, 119–120.

besides being seen by means of the rectilinear, perpendicular way."[340]

The quotation proves to be a shrewd move on the part of Scheiner, and introduces an aspect which Kepler had not fully accounted for, namely the multiplication of species. The similarity between the infinity of "refracted rays" introduced by Roger Bacon and Kepler is the reason that Scheiner introduced it at this point. What Scheiner's theory addressed was the way in which vision could occur through the adoption of individual visual rays. Fundamentally this is the way that Scheiner adopts the pencil rays of Kepler's optics—through the lens of Roger Bacon's multiplication of species. Such a response also demonstrates why Kepler's optics actually did not necessarily prove that light was itself a mathematical body, since, as Scheiner contends, one could still assume that a ray of light possessed a point which could no longer be divided, an idea that has as its background similar ones put forward by Ibn al-Haytham and Roger Bacon as noted in the section on the camera obscura.

Involved in Scheiner's explanation of optics and his defense of the visual species were various instrumental and performative activities. The most noticeable was the way he used a spherical chamber at the court of Maximillian to demonstrate the projection of the species within the eye. He notes this in the *Rosa Ursina, "*In his palace at Innsbruck, he built a great globe, with a radius of many feet. When entered, we admitted the species of external things through a convex lens onto the concave wall."[341]

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[340] Roger Bacon, *Roger Bacon and the Origins of Perspectiva in the Middle Ages: A Critical Edition and English Translation of Bacon's Perspectiva, with Introduction and Notes*, trans. David Lindberg (Oxford: Clarendon Press, 1996), 293; Scheiner, *Oculus*, 202.

[341] Christoph Scheiner, *Rosa Ursina, sive sol* (Bracciano: Andreas Phaeus, 1630), 110: qui in palate suo Oenipontano, maximum globum, ad semidiametrum multorum pedum extruxit, in quem introgressi, admittebamus rerum externarum per lentem convexam in parietem concavum species. Cf. Scheiner, *Oculus*, 191.

It is important to note that these experiments were not conducted in isolation, but instead were publicly performed at the court of Maximillian, Archduke of Austria. The importance of the public activity demonstrates that the influence of Scheiner's optics extended beyond mere academic books, but were popularly and playfully well known. The importance of these events was noticed by later Jesuits, such as Kircher, as not only important evidence for the way vision works and the species projects, but conceivably also as a way to remind and reinforce the confessional maintenance of the visualized species.[342]

Part of the larger argument of Scheiner's theory of optics, present in both the *Oculus* and the *Rosa Ursina*, involved the interrelationship between instruments and vision, particularly the relationship between the eye and the telescope and the eye and the water globe. That Scheiner intended to interrelate the telescope and the eye may be noticed by the numerous distinctions he makes between the way in which in a lens over a window, which he deems *Ars*, is related to an image projected without any technological aid, a *Pictura*. Such an interrelationship is much more artfully projected in Scheiner's 1632 book, the *Rosa Ursina*.

[342] On the importance of the performative aspect of optics in the early modern period, see Sven Dupré, "Inside the Camera Obscura: Kepler's Experiment and Theory of Optical Imagery," *Early Science and Medicine* 13, no. 3 (2008): 219–244.

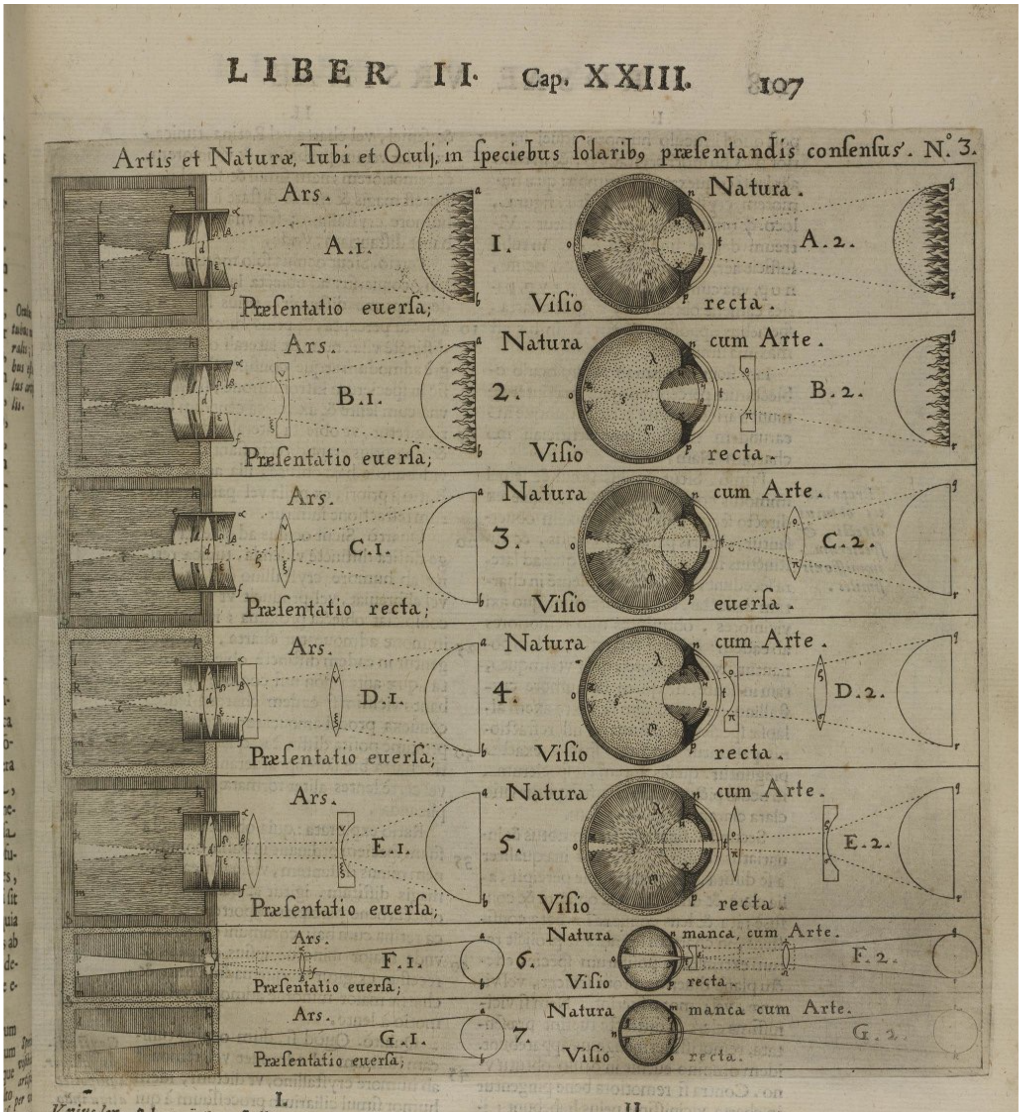

Image 3.5 — Comparison of the telescope (left) with the eye (right)
Christoph Scheiner, *Rosa Ursina* (1630), 107
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Among the points that Scheiner wishes to demonstrate is to show how the reversal of the image through a camera obscura may easily be corrected with lenses, a point similarly raised on the frontispiece of the *Oculus*. At the same time, the large rhetorical point is to demonstrate that the utilization of lenses to project images is of a similar nature as the way the eye itself is able to project images. Thus, just as the telescope preserves the image, albeit with a change in size in orientation, so also do the images within the eye. The fact that the comparison between the telescope and the eye plays such a large part within the *Rosa Ursina*, with five full-page engravings such as the one above, also demonstrates the way in which it was not only Kepler's *Ad Vitellionem* which had an influence on Scheiner's optical thought, but equally so Kepler's work on the telescope, the *Dioptrice* (1611).

In the end, Scheiner's greatest contribution to optics among the Jesuits had to do with his optical synthesis, cutting across the camera obscura, telescope, and human eye. The novelty (and surprise) was that the species was not virtual, but formal. And, the tradition of perspectivist optics could be used to demonstrate such a point. More than the eye itself, however, this novel insight suggested that mathematics and optical instruments themselves gave knowledge of the actual object itself—through the visual species. This is the point that Scheiner implies in a less known work on the optical instrument of the pantograph, which was published in the year after the *Rosa Ursina*.

The Pantograph

From the preceding explanation, it is apparent that Christoph Scheiner did not recognize a conflict between Kepler's optics and Aristotelian natural philosophy and perspectivist optics, but rather assimilated them. Much of his explanation relied upon the idea of the multiplication of the species as put forward by medieval opticians, particularly Ibn al-Haytham and Roger Bacon, an explanation that was as much theoretical as it was tangible. One further aspect reinforces this point, Scheiner's work with the optical instrument, the pantograph. With this instrument Scheiner shows the way in which the justification of the visual species relied not merely upon theoretical propositions, but could be woven into practical optical contexts. This point also reinforces a secondary thesis of this chapter, that Jesuit mathematicians conceptualized instruments as providing important philosophical explanations.

As noted previously, the pantograph provided Scheiner with widespread notoriety during the first decade of the seventeenth century. This device enables one to create drawings with similar proportions. Scheiner developed the instrument while an instructor of mathematics and Hebrew at Ingolstadt from 1610-1616. At one point Duke Wilhelm V of Bavaria invited him to Munich to demonstrate the instrument.[343] While Scheiner did not invent the instrument himself, as it was very similar to a device created by the famed Renaissance artist Cigoli, he made it popular among the Jesuits, and used it as a device to express some of the practical aspects of optics.

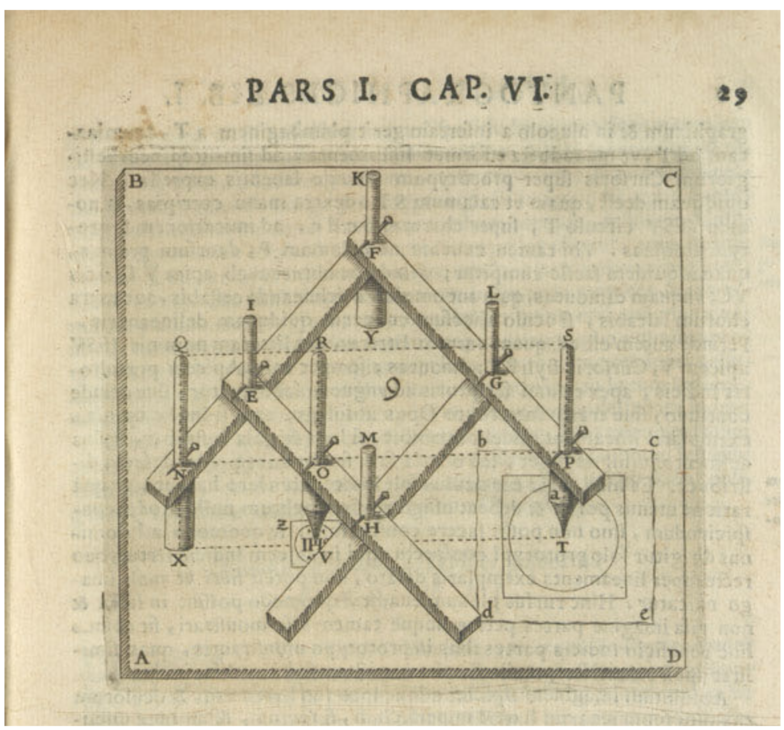

Image 3.6 — Picture of the pantograph
Christoph Scheiner, *Pantographice* (1631), 29.
Courtesy Biblioteca Nazionale Centrale di Firenze

[343] Franz Daxecker, *The Physicist and Astronomer Christopher Scheiner: Biography, Letters, Works* (Innsbruck: Leopold-Franzens-University of Innsbruck, 2004), 5–10. His publication on the treatise, dedicated to Paolo Savelli, however, did not occur until 1631.

The book locates the importance of the topic within the broader interest among the Jesuits in the rhetorical and emblematic use of images, as discussed in Chapter One. Yet, in contrast to the point made there—that the earliest Jesuits differentiated optical theory from image use—Scheiner's optical theory, and especially his explanation of whether optical theory and image theory were as separate as Aguilonius considered them. For instance, in the Preface to the *Pantographice* Scheiner states, "A small picture teaches what many writings do not teach."[344] Such a statement, as Volker Remmert indicates, represents not merely the idiosyncrasies of Christoph Scheiner, but may be taken as more representative of the broader approach toward visual images on the part of the Jesuits in the first part of the seventeenth century.[345]

Throughout the book Scheiner explains how the Pantograph enables one to transfer the species from one picture to another. While he does not include the theoretical discussion of light cast within the camera obscura, as discussed in the *Disquisitiones*, *Oculus*, and *Rosa Ursina*, it is noticeable that the use of a single line to construct a proportional reproduction in the *Pantographice* borrows from the same conceptual and theoretical understanding of the visual species. Recall that the theoretical basis of the visual species was that there was a singular point which could not be divided any further and which was projected in a line from the visualized object. In interpreting the Pantograph, which created a one-to-one correspondence between points on a particular image and those on a reproduced and proportional image, Scheiner indicates that the Pantograph charts such lines and points. For instance when explaining the potential of the device, he describes it as being able to recreate "as true images or optical species

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[344] Christoph Scheiner, *Pantographice, seu ars delineandi* (Rome: L. Grignani, 1631), Dedication: *Docet parva pictura, quod multi Scripture non dicunt.*

[345] Volker R. Remmert, "Visuelle Strategien Zur Konturierung Eines Jesuitischen Wissensreiches," 85–108.

from visual objects."[346] Mathematical lines are more than theoretical, such as suggested in Kepler's optics, but they are practical and tangible—aspects fully experienced with the Pantograph.

Yet, despite the importance of the species, Scheiner nevertheless maintains that the materiality of the Pantograph does not illustrate the physicality of the optical process. This observation comes from a section toward the end of the book, where Scheiner explains how "objects at a distance" act upon an individual. As he explains, similar to the sunlight moving across the horizon, so objects, and in the context of the work presumably pictures, act upon an individual, "the contact is not physical, but optical."[347] Such a statement further demonstrates the way Scheiner conceptualized the pantograph as a device to project the visual species, not as physical entities (which of course the species were not) but as optical ones.

The connection that Scheiner makes between the pantograph and the visual species is quite remarkable. What he does is to reinforce the importance of the camera obscura with its one-to-one point correspondence to reinforce the philosophical nature of mathematical knowledge. So, while the inverted image in the eye was a shocking development for many early moderns, for Scheiner at least, it proved important in justifying mathematical knowledge and the role of instruments in obtaining such knowledge.

Later Influence of Scheiner

It is apparent when considering the members of the Jesuit Order who addressed questions

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[346] Scheiner, *Pantographice*, 31: verum etiam imagines seu species optics ab obiectis visibilibus.

[347] Scheiner, *Pantographice*, 92: sic Sol oriens vel occidens horizontem, montes, sylvas: qui contactus non physici sed sunt optici"

of optics, the visual species, or the anatomy and physiology of the eye, that Christoph Scheiner was the main authority for adopting important features of the new optics within traditional Aristotelian natural philosophy and perspectivist optics. Scheiner's collective optical works provided an important authority for the understanding of optics among the Jesuit colleges in the seventeenth century.

One interesting example serves to illustrate the importance of Scheiner's optics in the following decades. In a public disputation from 1633 at the Lithuanian College in Vilnius there is an extensive analysis of Scheiner's account of the eye in which the focus was on the ways in which Scheiner's understanding differed from the Jesuit Aguilonius as well as the medieval perspectivist Witelo. The text itself illustrates the way that Scheiner's text provided an important translation of the eye's anatomy from the perspectivist tradition to the theory of seventeenth-century optics. The authors of the text illustrate the way that it was not within the crystalline humor that the "species" was received, a word intentionally chosen throughout the text, but it was upon the retina.[348]

The authors of the disputation also draw attention to Scheiner's point that the reliability of vision depends on the multiplication of the species and that a single point projected within the eye was enough to maintain vision's trustworthiness. So, while multiple species would project within the eye, it was only one point that was sensible from the projected object—the one that formed a perpendicular between the eye and the object.[349] Immediately following this section the authors then address the standard scholastic distinction between the "lux" and "lumen" and

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[348] Jan Rudomina, *Illustriora theoremata et problemata mathematica* (Vilnius: Typis Academicus, 1633), Cv.

[349] Rudomina, *Illustriora theoremata et problemata mathematica*, C2r.

introduce the topic of "primary" and "secondary" color—the latter being the accident of an object and the former being the substance. This explanation, which occurs in Thomas Aquinas (1225–1274), was a common conceptualization of transubstantiation within medieval and early modern Catholic theology.[350] Such a point, which Scheiner's optics can preserve, is important because the way in which "color" is projected as the "intentional species." The points they wish to make is that Scheiner's optics, with its refocused species on the retina, nevertheless maintains this important aspect. And as a reminder of the confessional importance of optics the authors note that the explanation of Scheiner provides an explanation of the Eucharist, lest "in the venerable sacrament an unbeliever is deceived in the deed, not believing beneath the species of the bread and the wine was the true body of Christ."[351]

Although the disputation does not identify these heretics, it is probable that the intended referents were Protestants, who would have denied the traditional Aristotelian distinction between accident and substance, and hence the transubstantiated Eucharist itself. That Scheiner's *Oculus* engaged more directly with Reformation disputes may be reinforced by the recent work by the historian Eileen Reeves. In her *Evening News*, Reeves produces a close analysis of Scheiner's frontispiece and his station on the *Oculus*, aspects of which were addressed above. In addition to this Reeves analyzes the anatomists that Scheiner mentions and notices that he fails to mention one in particular—the Hungarian nobleman and Protestant Johannes von Jessen. During the years surrounding the publication of the *Oculus* Jessen had worked to establish anti-Habsburg, and thus anti-Catholic, support, while at the same time disseminating anti-Jesuit

[350] Hellyer, *Catholic Physics*, 90–102.

[351] Rudomina, *Illustriora Theoremata et Problemata Mathematica* (1633), C3V: De facto decipitur in venerabili sacramento infidelis, non credens sub speciebus panis & vini verum corpus & sanguinem Christi.

pamphlets. His anatomical understanding also differed from Scheiner's, especially because Scheiner defended the retinal reception of the visual species, whereas Jessen had located the focus of sight in the center of the eye, in the crystalline humor. As Reeves muses, Scheiner's lack of attention to Jessenius—whom Kepler found quite useful—creates the impression of a literary, and likely anatomical, denigration of visual knowledge.[352] Thus, the pairing of anatomical knowledge and theological fervor, as found in the disputation from Vilnius, increases the importance of Scheiner's text not only as assimilating the new optics, but also as an important vehicle for maintaining Catholic orthodoxy at such a crucial moment, during the Thirty Years War.

Yet, despite the importance of Scheiner's work for maintaining Catholic Orthodoxy, there are signs that certain members of the Jesuit Order nevertheless found one aspect particularly troubling: the inverted retinal image.

One example occurs in a disputation from 1630. Although the disputation does not directly address the reception of the new optics or mention Kepler, it is quite clear in the attached engraving that it evidences such knowledge. For instance, when looking at the illustration below it is clear that the focal point of the optical image is located upon the retina. An indication that Scheiner's optics was not altogether certain is the fact that this disputation includes a refracted image not only at the anterior to the eye, at the pupil, but also in the center of the eye, in the crystalline humor. This preserves the proper orientation of the image in the eye, and avoids "visual confusion" as several later Jesuits came to refer to the inverted image. Like Kunitsch's disputation, the Jesuit Mario Bettini includes a double-refraction within the crystalline humor. As Bettini notes, "The experimentation by our Scheiner especially provoked controversy, not only in

[352] Reeves, *Evening News*, 172–175.

the small book on the eye, but also in the large tome on the sunspots."[353]

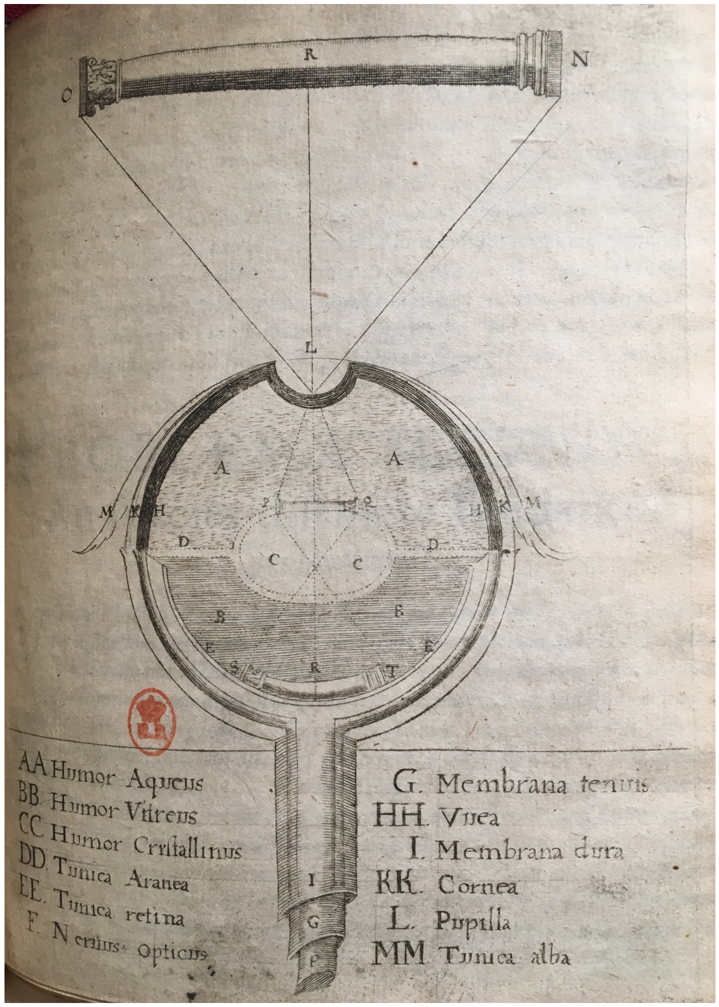

Image 3.7 — Image of eye with double refraction, both in the pupil and crystalline humor
Valentin Kunitsch, *Assertiones ex universa philosophia*; *item Problemata optica visu* (1630).
Courtesy Bibliothèque Nationale de France

One Jesuit who addressed the confused image was Niccolo Cabeo (1586-1650), who discussed Scheiner's optics in his *Meteorologia*. Within the work Cabeo is mainly interested in the rules of refraction, such that the eye and the telescope would operate similarly. When

[353] Bettini "Apiaria VI," in *Apiaria* 1:41: Sed controversiam auserunt experimenta praesertim apud nostrum Scheinerum non solum in libro minore de oculo, sed etiam in tomo maiore de maculis solaribus.

addressing the anatomy of the eye and the inverted image, as explained by Scheiner, Cabeo suggested that the inverted image resulted in a "confused vision" with the rays reversing within the center of the eye. To aid in his explanation, Cabeo discusses a dissection in an animal, like Scheiner. The animal in question, however, was a lamb, not a cow as Scheiner explained, suggesting that Cabeo either performed his own dissection or at least had a separate source of information apart from Scheiner for the inverted species. Either way, even though Cabeo found the inverted image odd, he did not find any difficulty with it because, despite such inversion, the "image of the object is all in all."[354] And, according to Cabeo, the importance of the entirety of the object being contained within the inverted image avoids the possibility of illusion, or as he says, "fantastical figments."[355]

Scheiner himself recognized the oddity of the inverted image, referring to it as according to "God's wisdom."[356] Another Jesuit, Mario Bettini, referred to it as "by the Author of Nature's providence," (although he included two occasions of refraction within the eye to cause the image to be positioned correctly)[357] Yet, despite the surprise that this was how vision occurred, the important point that these authors recognize needed to be maintained was that the totality of the visual object was still possessed within the totality of the retinal image. As noted in Chapter

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[354] Meteorologica, 3: 117: imaginea obiecti esse totam in toto.

[355] Nicolo Cabeo, *In quatuor libros meteorologicorum Aristotelis commentaria, Tomus Tertius* (Rome: the heirs of Franciscus Corbellettus, 1646) 3:117: radiationes non sunt figmenta phantastica, sed naturales specierum.

[356] Scheiner, *Oculus*, 162.

[357] Bettini, "Apiaria VI," in *Apiaria*, 1:46: Sciendum igitur a providentissimo Naturae Authore huic incommodo provisum esse, data oculo facilitate, quà eius humores, ac pellicular, presertim retina, pro libito, atq; usu animantis contringi, dilatari, protrudi, retrai possint, ut Anatomicorum, & Opticorum neotericorum authoritas, & experientia, & ratio ipsa docent.

Two, the theory of the visual species involved the visual pyramid, which provided the boundary within which the image scaled to the eye, but it simultaneously maintained the projection of visual species, each of which contained the qualities of the object from which they were projected. Thus, while the inverted image was odd—and for some problematic—because the inverted image nevertheless possessed the qualities of the object from which they were projected, it was not a problem which proved irreconcilable.

There is one notable aspect of Kepler's critique which most Jesuit authors skip over, and that is the Aristotelian problem. Due to its importance in Kepler's explanation of optics it is worthwhile considering it here.

The Jesuits and the Aristotelian Problem

Due to the importance of Kepler's critique of the Aristotelian problem, one might anticipate that the Jesuits would have been interested as well. However, the Jesuits do not address the problem in any noticeable way, and when they do, it is noticeable that they easily adopt Kepler's methods. This has already been shown in the way Christoph Scheiner explained the projection of light in the *Disquisitiones*, which explained that a light ray had as a fundamental aspect a point which was in some sense physical. Due to the importance of the Aristotelian problem within the more recent historiography of the Jesuits, as noted above, it is important to return to this question and give careful attention to the way one Jesuit addresses the problem, Athanasius Kircher (1601–1680).

In his *Ars magna lucis et umbrae* (1646), Kircher identifies the Aristotelian problem in Book II, Part I. It is here that Kircher explains the projection of light ("De actinobolismis seu radiationibus"). Although Kircher does not explicitly cite Kepler, the opening section is nearly entirely pulled from the opening section of Kepler's *Ad Vitellionem*, albeit in an abbreviated fashion. So, Kircher explains that light was itself the "image of his [God's] sacred Trinity," in language very reminiscent of Kepler.[358] Kircher's paraphrase, however, introduces several editorial changes, some of which prove interesting in the wider context of Kircher's argument. So, for instance, whereas in Kepler's *Ad Vitellionem*, he stated that the "point of the center is similar to the origin of the spherical,"[359] Kircher states that, "the point of the center is similar to the image of the spherical."[360] So, where Kepler had stated that the mathematical point of light was the "origin," Kircher clarifies the nature of the point saying that it was the "image" of sphericity. Similar to the analysis presented above, what Kircher does here is to use the same conceptualization of light within Kepler's optics, except he contends that in doing so one does not need to do away with the basic existence of the point—hence the "image."

Such a finely differentiated nuance comes to play an important role in the explanation of the Aristotelian problem, an analysis that occurs after Kircher explains how light projects through a circular aperture. In this earlier section he based his analysis on the projection of light rays, following Kepler; the luminous body is projected through the aperture based upon an infinity of pyramids issuing from the light source. After explaining this, he then analyzes the Aristotelian problem, which logically follows from his analysis of the circular aperture (and Kepler as well). As he concludes, the roundness of the projected image has to do with the overlapping apertures created by the projected light (as Kepler did). Yet, in his conclusion he

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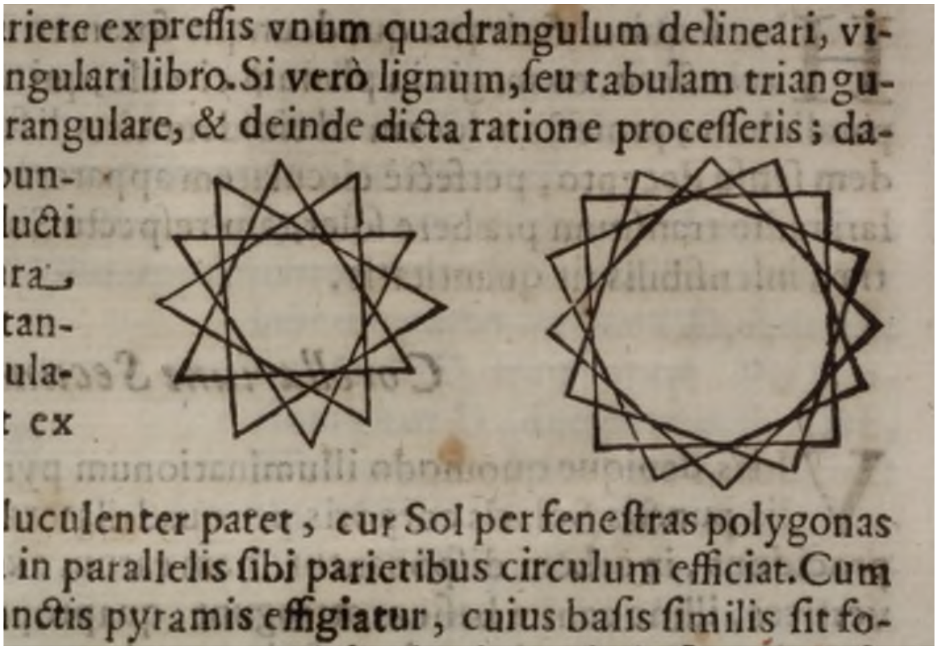
[358] Athanasius Kircher, *Ars magna lucis et umbrae* (Rome: Hermann Scheus, 1646), 108: sacrae suae Triadis imaginem. Cf. with Johannes Kepler, *Ad Vitellionem paralipomena* (Frankfurt: Claude Marne and the heirs of Jean Aubry, 1604), 6: adorandae suae Trinitatis imaginem.

[359] Kepler, *Ad Vitellionem*, 6: Centri punctum, est Sphaerici quaedam quasi origo.

[360] Kircher, *Ars magna lucis et umbrae*, 107: centri punctum est sphaerici quaedam quasi imago

states, “the rays are not lines of mathematics, but have some width, and consequently the points from which they consist are not mathematical but physical.”[361]



riete expreſſis vnum quadrangulum delineari, vi-
ngulari libro. Si verò lignum, ſeu tabulam triangu-
rangulare, & deinde dicta ratione proceſſeris; da-
un-
lucti
ra
tan-
ula-
ex
luculenter patet, cur Sol per feneſtras polygonas
in parallelis ſibi parietibus circulum efficiat. Cum
nctis pyramis effigiatur, cuius baſis ſimilis ſit fo-

Image 3.8 — Solution to Aristotelian Problem that shows how the overlapping apertures create a spherical projection
Kircher, *Ars magna lucis et umbrae* (1646), 118
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Earlier in this chapter it was explained that Kepler’s method of explaining the Aristotelian problem involved using a string, a book, and a polygon aperture. When explaining the Aristotelian problem, Kircher introduced a similar method of analysis, which he notes is borrowed from Kepler.[362] Conceptually the analysis of the string exercise within Kepler was not intended to portray a physical event. Yet, for Kircher, for whom the ray of light was itself

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361 Kircher, *Ars magna lucis et umbrae*, 117: radij non sint lineae mathematicae, sed aliqua latitudine praeditae, & consequenter puncta ex quibus constant, non mathematica, sed physica sint.

362 Kircher, *Ars magna Lucis et Umbra*, 118: Alteram huic ex Keplero adscribemus.

physical, the experiment with the book, string, and polygonal aperture not only shows how to solve Aristotle's problem, but also reinforces his theory that light had some width to it.[363] Thus it becomes apparent that Jesuit authors adopt Kepler's optics based upon the assumption that within a single ray of light, a physical point existed which could not be divided further and which provided the necessary physics to transmit the qualities of the object, and hence the entire object itself.

Throughout Kircher's explanation of the Aristotelian problem he does not mention Scheiner at all, or the *Oculus* or the *Rosa Ursina*. What he does include, however, are similar woodcuts to those included in the *Disquisitiones*, which demonstrate how light projects through a small aperture. The evidence further reinforces the importance of Scheiner's optical works within the translation of the new optics, particularly Kepler, into a form comprehensible by perspectivist optics.

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[363] Kircher, *Ars magna lucis et umbrae*, 118.

Actinobolismus Lucis. 125

Experimentum V.

De Sole.

LVcidum Solis corpus AB, per foramina C,D,E, in obscuro receptaculo GHKP, mittit tres conos radiosos CKL, DNM, EOP, æqualis potentiæ ob æqualia foramina C,D,E. Dico in communi concursu conorum lucem notabiliter augeri. Vnde segmentū OQL, omnibus tribus commune est lucidissimum, & splendore sesquialterū ad segmentum QRMO, & sese habet ad segmentū dictum, sicuti 2. ad 3. cum hoc ex duobus tantum radijs constet, alterum verò è tribus: triplum verò ad segmentū KCRM, quod est subduplum MOQR. vnde deduco, segmentum semper se habere ad radij simplicis splendorem, vti se numerus habet conorum, quorum est segmentum commune, ad vnitatem.

Experimentum VI.

De Igne.

ACcipe cylindrum cauum, in cuius conuexa superficie sint tria foramina A,B,C, è quorum regione statuantur tres faces accensæ quæ lumine suo traiecto in vnum locum interioris superficiei ED, colluceant, eritque lux ED, tripla lucis, quàm coni radiosi DIA, IBK, EKC, quisque per se habet: nam sicuti se habet 3. ad 1, ita lux DLE, ex tribus conis radiosis composita, ad conum KEC, vel DIA, & sicuti 2. ad 1. ita lux LKE, vel DLI ad DIA, vel EKC, simplex coni segmentum. Iterum vt 3. ad 2. ita lux DLE, ad segmenta DLI, vel ELK. at prior proportio est tripla, altera dupla, tertia sesquialtera: ergo lux intenditur iuxta multitudinem facum, posito, quod singulæ æqualem habeant à foraminibus distantiam, positisq; æqualium intensionum conis, communis concursus omnium in luce se habebit ad quamlibet illorum vt numerus omnium conorum ad vnitatem. Si verò communis concursus perforetur, & paulatim à se iterum coni diuergant, & suo lumine quisque allabatur in oppositum parietem MN, eritque MOP, & QNR, lunula ad segmentum PO, QR, vtrinque conuexum subdupla, horū autem vnumquodq; ad cōmune omnibus segmentū PR, subsequialterū.

Corol-

Image 3.9—Light projected through camera obscura, similar to those in *Disquisitiones*
Kircher, *Ars magna lucis et umbrae* (1646), 125.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Aside from providing one with an account of the psychology of how sight occurs such that the aspects seen in the world were believed real and not illusory, the importance of Scheiner's optical synthesis may be seen in the way it came to be used for its theological significance, in understanding the Eucharist, a final point that is important to consider in understanding how the members of the Society absorbed the new optics.

The Optics of the Eucharist

Within the history of science, there has been considerable attention given to the physics of the Eucharist. And indeed, Jesuits discussed on the topic prominently, particularly in the second half of the seventeenth century.[364] However, what has been given far less attention is the optics of the Eucharist, an issue which takes center stage in the first half of the seventeenth century, during the Thirty Years War. Because for believers the encounter with the Eucharist was a visual occurrence as well, as the Priest raised the sacraments into the air, it was not only important to maintain the substance of the Eucharist (which was an important matter of debate since the 1520s, near the beginning of the Reformation), but equally that the congregants would encounter the real presence in the bread and the wine—optically.

One of the leading Jesuit theologians of the seventeenth century, Cornelius a Lapide (1567–1637), included within his 1638 *Commentary on the Four Gospels*, an analogy about how the real presence of the Eucharist was able to be perceived, drawing upon the role of a mirror in optical theory. What is important to notice is the way in which Lapide's explanation is quite similar to Scheiner. Like Scheiner's explanation that the totality of an image is seen through a single ray, Lapide similarly identifies how a single ray explains the universality of the Eucharist. This reinforces an important use of optical theory to maintain the visual species, and in the process uphold a view of the Eucharist in opposition to the Protestants.

The relevant part of Lapide's commentary is his explanation of Matthew 26:26, on the Last Supper. In the passage, which occurs just before the death of Jesus, Jesus states the following: "Take eat; this is my body." The meaning of this phrase was hotly contested in the

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[364] For a helpful overview see Marcus Hellyer, *Catholic Physics: Jesuit Natural Philosophy in Early Modern Germany* (Notre Dame Ind.: University of Notre Dame Press, 2005), 90–113.

sixteenth and seventeenth century, as the precise nature of the body and blood of the sacraments was among the prominent issues around which the Reformation took shape. Lapide himself points toward this in his commentary, as he references the doctrinal decision that developed at the Council of Trent, in Session 22, where the doctrine of transubstantiation was affirmed.[365]

Among the aspects that the Council of Trent affirmed in its articulation of the transubstantiation of the Eucharist was the adoption of Aristotelian physics to explain the separation of the accidents and the substance of the bread and the wine within the Eucharist. According to Catholic doctrine, whereas the Eucharist kept the accidental qualities of bread and wine, its substance changed into the body and blood of Christ. It is for this reason that historical scholarship has focused on the way the changing theories of physics related to the Eucharist. Such issues will be given more consideration in Chapter Five below, where the physics of the Eucharist became an important issue for the Jesuits amidst the Air Pump experiments of the 1640s.

What has received far less attention is the optics of the Eucharist, an issue which Lapide addresses:

> Take, therefore, an analogy of this case by way of demonstration—from the eye and a mirror. For both a mirror and a small eye receive into themselves the whole quantity of the very greatest things, not only men, but houses, temples, trees, mountains, &c., and clearly reproduce and represent them whole. Why then should not a small host, by God's power, set forth the whole Christ? You will say that in the eye and in the mirror what takes place is done in a spiritual manner, by means of optical or visual species. I reply, in like manner the Body of Christ in the Eucharist assumes a spiritual mode of existence, so that, as a spirit, it should be spiritually in the very small portion of the host. Let us add this, that the objective species themselves are not spiritual in such a sense as that they are not really natural and physical, yes, corporeal, entities. For they inhabit a body, such as the air. And of these things we see that very many, and as it were an infinite number, are received and comprehended in a mirror and in the eye. If all this constantly takes place in a natural manner, with respect to the species received by the eye, much more can the

[365] Cornelius a Lapide, *Commentarii in IV. Evangelia, Tomus Primus* (Leiden: Jacob and Petrus Prost, 1638), 472.

> omnipotence of God do the same thing supernaturally in respect to the Body of Christ, miraculously in the Eucharist.[366]

What is of immediate importance is the way that Lapide appeals to the experience of a mirror and the way that a mirror receives the entirety of an object, such as a tree, in the same way an eye receives the entirety of an object.[367] The use of mirrors in explaining the species also places Lapide firmly within the perspectivist tradition. Within the perspectivist optical tradition the experience of a mirror was often used to justify the existence of the visual species. For instance, one need only look into a mirror to see the species projected. So, Book II of John Pecham's *Perspectiva communis* (1270s), Proposition 5 states the following: "Light and color reflected from mirrors manifest to the eye the objects of which they are the species."[368] In the propositions immediately surrounding Proposition 5 Pecham provides ample explanation as to how the species changes with respect to various mirrors—whether dimmed, pyramidal, or concave—but at no point does he question the species's existence. It is undoubtedly following

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366 Cornelius a Lapide, *Commentarii in IV. Evangelia, Tomus Primus* (Leiden: Sumpt. Iacobi & Petri Prost., 1638), 473. Accipe ergo huius rei analogicam quasi demonstrationem, primò physicam, secundò mathematicam. Physica est in speculo & in oculo. Tam enim speculum quàm oculus exiguus in se recipiunt integram quantitatem maximorum non tantùm hominum, sed & domorum, templorum, arborum, montium &c. eámque integram clarè referunt & repraesentāt: Quidni ergo parvus hostia, Deo agente, totum exhibeat Christum? Dices, hoc in oculo & speculo fieri spiritualiter per species intentionales opticas, sive visivas. Resp. Pari modo Christi corpus in Eucharistia accipit spiritalem modum existendi, vt quasi spiritus spiritualiter sit in puncto hostiae. Adde ipsas species intentionales, non ita esse spirituales, quin revera sint entitates naturales & physicae, imò corporeae: inhaerent enim corpori, scilicet aëri, harum tamen plurimas, & quasi infinitas videmus simul in speculo & oculo recipi, & comprehendi. Si hoc quotidie sit naturaliter in speciebus oculo receptis, multò magis idem facere potest omnipotentia Dei supernaturaliter, in corpore Christi per miraculum in Eucharistia.

367 Like Lapide, the Jesuit Cabeo references the image within a mirror and how that provides a way to explain how the totality of Christ's body or blood may be in the bread and the wine. Cabeo, Meterology, 1:86.

368 Pecham, *John Pecham and the Science of Optics*, 161.

similar lines of reasoning that Aguilonius stated "therefore what is seen in a mirror is a species."[369]

So Lapide is simultaneously making two claims here. First, the entire physical entity of the host is the actual body of Christ. This angle of analysis is typical within the historiography as the "Physics of the Eucharist," and is also related to Lapide's third argument in the commentary, which is on rarefaction and condensation.[370] The more surprising and under explored aspect is the second point. When one sees the physical host then they see the actual body of Christ. Such an explanation is apt on account of the way that the Eucharist within Catholic religious services was primarily a visual event, and the Jesuits had given particular importance to the role of the visual within the process.[371] Perspectivist optical theory supplied an important explanation for how the viewing congregants encounter the real presence in the Eucharist. It is important to note, then, that Lapide's language is reminiscent of the perspectivist tradition—"an infinite number" of species. Within such a context, then, it is even more important that Scheiner maintained fidelity to the perspectivist tradition in his explanation as to how the species is preserved through the projection of light and how the retina receives them.

Lapide's explanation here in the biblical commentary is suggestive of the importance of optics within the period of the Reformation. That encounters with mirrors provided an apt analogy to reinforce a fundamental aspect of the faith, such as the Eucharist, draws attention to an under-explored aspect of the history of optics, namely its theological and Eucharistic

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[369] Aguilonius, *Opticorum libri sex*, 52: Ergo quod in specula cernitur species est.

[370] On the Physics of the Eucharist, see Hellyer, *Catholic Physics*, 90–113.

[371] On the elaborate techniques the Jesuits employed to present the Eucharist, see Joseph Imorde, "Visualising the Eucharist: Theoretical Problems," in *Le Monde Est Une Peinture,* ed. Oy-Marra and Remmert, 109–126.

significance.[372] While it was the case that the Aristotelian pyramid was the formative way in which vision occurred, it is equally the case that the theory of the visual species introduced a way for the singular ray and quality of color to both be able to be projected and comprehended by the faithful. It also demonstrates why optical explanations provided an important confessional tool within early modern Catholic Europe.

There is some indication that Scheiner's explanation could have circulated as a way of improving upon explanations of the Eucharist provided within perspectivist optics. It was already noted above in the explanation of the disputation in Lithuania, that Scheiner's optics not only circulated alongside Aguilonius's optics to improve areas where Aguilonius was deficient, but also as an important aid in the explanation of the Eucharist. Similarly, in 1670, the Jesuit Zacharia Traber published the work, *Nervus opticus*, which serves as a useful example as to how much of the perspectivist optical theory perpetuated up into the end of the seventeenth century, since the text was reprinted in 1690. The book includes one of the last full-page engravings within a Jesuit book which depicts light for its theological meaning. The text itself is full of engravings, many of which are borrowed from Kircher's *Ars magna* (1646). In Book I of the work, in a section just after the explanation of the eye and the visual species within it, where Traber is explaining how the many species come together in a singular point to represent the entirety of the object: "the individual points are together in the whole eye."[373] Immediately after explaining this, Traber then explains how based upon the same understanding one is able to

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[372] That optics provided an important context for the Eucharist is reinforced based upon the importance that optics had within the theological and Eucharistic thought of John Wyclif, Heather Phillips, "John Wyclif and the Optics of the Eucharist," *Studies in Church History. Subsidia* 5 (1987): 245–58.

[373] Traber, *Nervus opticus*, 47: singula puncta simul esse in toto oculo.

understand how the entire body of Christ may be within a singular host. "As also the mystery of faith in the body of Christ, in which the whole body is in the whole host, and the whole body in each part."[374] To establish his point, Traber notes Scheiner's *Rosa Ursina*, Book 2, Chapter 26, where Scheiner is explaining how the eye works, by way of analogy with the telescope.[375] Due to the fact that Traber locates his explanation in the context of vision, it is apparent that he is making a similar point as Lapide. Optics supplies both an explanation as to why the entire host is the actual body of Christ. But it also explains how seeing a single point on the host is the same as encountering the real presence in the host.

Thus, while Scheiner's book is often read as a tool for explaining the eye, the telescope, and as a compromise of sorts, within this context, it is important to see how it circulated as an important tool of confessionalization amidst the unstable visual culture of the Reformation as well as early modern optical theory.

Conclusion

This chapter has argued that the members of the Jesuit Order easily adopted the new optics into their own tradition of optics and image formation. Among the reasons that they were able to accomplish this so easily pertained to the importance of the multiplication of the species and the way in which this theory provided the justification for the way in which a single ray and point possessed the entire essence of the visual object. One of the surprising claims made, which is absent from the historiography, is that the basic framework of this theory may be found in the

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[374] Traber, *Nervus opticus*, 47: sicut & mysterio fidei in corpore Christi, quod totem est in tota hostia, & votum in qualibet parte.

[375] Traber, *Nervus opticus*, 47; Cf. Christoph Scheiner, *Rosa Ursina*, 116–20.

medieval perspectivist tradition, particularly in Ibn al-Haytham and Roger Bacon. Thus, the refracted species within the eye and their subsequent projection upon the retina could be consistent within Aristotelian natural philosophy and perspectivist optics.

This chapter also showed that such a suggestion was consistent not only with mathematical and philosophical theory, but equally so within the understanding of the artistic and material world. Whereas Chapter One commented on how Aguilonius had argued against the visual species interrelating to the discipline of art, it was noted in this chapter that the projected species on the retina left this as a possibility, most notably demonstrated in Scheiner's application of the species within the explanation of the pantograph.

In addition to the theoretical explanations provided, the chapter also drew attention to the way optical theory was woven within confessional practice. This was suggested in the interrelationship between the emperor Ferdinand's authority and the explanation of optics in the frontispiece included with Scheiner's *Oculus*. More significant than this, however, is the way optical theory and Eucharistic theology came to be connected. This connection is undoubtedly on account of the importance of perspectivist optics in the medieval past and its close association with Aristotelian natural philosophy. That such an analogy proved important further reinforces the way in which optics shaped the confessional activity of many members of the Jesuit Order.

CHAPTER FOUR
THE SERIOUS JOKES OF MAGIA OPTICS

"I said, therefore, [magic is] whatever is marvelous and exceeding the common sense and understanding of people."
—Gaspar Schott, 1657[376]

In 1646 the Jesuit Athanasius Kircher explained an optical technique whereby one could imaginatively enact the Ascension of Jesus, the biblical event from Acts 1 where Jesus departs earth for heaven. As he explains, by placing a hollow cylindrical mirror over a picture of Jesus, one can recreate the movement of Jesus into the air. This optical trick, known as casting "images in the air," was included in his Roman museum, popularized by his students, and even remembered in David Brewster's *Letters on Natural Magic* (1832) as an important early modern visual trick.[377]

Why might Kircher, a devout Jesuit, have utilized such an optical trick to project something so sacred to the Catholic tradition—the Ascension of Jesus? This is among the driving questions that this chapter explores as it locates the interest in optical illusions among certain prominent members of the Society of Jesus, particularly Mario Bettini (1582–1657), Athanasius Kircher (1602–1680), and Gaspar Schott (1608–1666). In the case of Kircher's ascending Jesus, while it might be the case that such a selection was on account of the widespread role of sacred and religious imagery among Catholics, what this chapter will show is that the rhetorical and intellectual merit of the trick was enhanced on account of the ludicrousness—causing Jesus to

[376] Gaspar Schott, *Magia universalis*, 1:18: Dixi denique, mira, & communem hominum sensum ac captum excedentia.

[377] Schott, *Magia universalis*, 1:337; Georgio de Sepi, *Romani Collegii Societatis Jesu Musaeum celeberrimum* (Amsterdam: Janssonio-Waesbergiana, 1678), 39; David Brewster, *Letters on Natural Magic, Addressed to Sir Walter Scott* (London: John Murray, 1832), 92.

ascend—and all of this enhanced by the interest in religious imagery. It was because of the imagery's sacredness that the trick was able to deliver its rhetorical meaning, an intellectual move which found resonance within the wider culture of early modern natural magic and the way in which seemingly absurd intellectual jokes provided important philosophical commentary.[378]

The goal of the chapter, however, is more than reaffirming the rhetorical techniques that particular Jesuit mathematicians employed. It aims to locate the response of these Jesuit authors to the seeming crisis in visual and optical theory introduced by optical illusions, a crisis parallel to the more intellectual one addressed in Chapter Three. As argued in Chapter Three, Jesuit authors developed an optical tradition which was able to easily incorporate the new optics of the seventeenth century. Among the reasons that they were able to do this was the adaptation of the theory of the multiplication of species to emerging optical theories, such as that of Johannes Kepler. At the same time that these efforts were accomplished, largely by Christoph Scheiner, other Jesuits worked to engage a much broader and widespread culture of optical illusions, doing so in a similar fashion as Scheiner—to maintain fidelity to perspectivist optics and Aristotelianism more broadly. Bettini, Kircher, and Schott provide an important perspective on the degree to which illusions proved problematic, and they also provide an opportunity to consider important aspects of the way in which confessional interests shaped the investigation of optics.

Since the middle of the twentieth century historians have worked to locate the role of optical illusions within early modern science and culture. In the pioneering work of such authors

[378] On this point see Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150-1750* (New York: Zone Book, 1998).

as Jurgis Baltrušaitis, the development of optical illusions, particularly anamorphic illusions, criticized the over-simplistic representations of the transformation of linear perspective in the sixteenth and seventeenth centuries.[379] Rather than locate the transformation of linear perspective as the ever-increasing rationalization of sight, Baltrušaitis demonstrated that the underlying interest in anamorphosis showed that coincident to the rationalization of sight was an increased interest in adopting occult sensibilities by demonstrating visual doubt. Similar interest in these parallel developments, both the over systematization of sight as well as the deconstruction of visual reality, was made popular through the cultural and visual analyses of Martin Jay.[380] Within Jay's analysis of early modern visuality, the Jesuits themselves become key characters as they come to represent the style of "baroque" with its interest in illusion. Yet, for all the successes of these approaches, nobody has analyzed how the optical illusions fit within their intellectual optical and visual tradition, as identified in the preceding chapters. This chapter aims to fill this gap in the literature.[381]

This chapter operates off the assumption that perspectivist optics and optical illusions, particularly anamorphoses, do not represent two distinct cultures, but existed in tandem, a historiographical perspective raised by Lyle Massey and followed by Stuart Clark. What Massey showed, and what Clark borrowed at key places, is the way in which the tricks of optics existed

[379] Baltrušaitis, *Anamorphic Art*; Jurgis Baltrušaitis, *Anamorfosi, O Thaumaturgus Opticus,* trans. Piero Bertolucci (Milan, Italy: Adelphi, 2004).

[380] Jay, "Scopic Regimes of Modernity," in *Vision and Visuality*, 3–28; Martin Jay, *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought* (Berkeley: University of California Press, 1993).

[381] This might be because most scholars who study them are interested in perspective art or visual culture more abstractly. For instance they feature prominently in Kemp, *The Science of Art*.

in tandem with the intellectual efforts of early modern opticians. As they contend, optical illusions created an important context out of which the new optics of the seventeenth century emerged.[382] The information analyzed in this chapter will differ from such sentiments, particularly that of Stuart Clark, in one important respect. Rather than arguing that the broader culture of optical illusions possessed an unintended consequence of bringing about the demise of perspectivist optics, a point that is implicit in Massey's understanding of the role of illusions in Descartes's optical thought and which Clark seems to use for the entirety of the early modern period, this chapter will argue that for the Jesuits optical illusions did not prove problematic. Instead, cloaked in the rhetoric of natural magic, optical illusions provided a cultural and intellectual boundary marker between those who could see and those who could not.[383] To suggest that the adoption of optical illusions on the part of the Jesuits induced a demise of perspectivist optics is to frame the transformation of optics according to the standard Scientific Revolution narrative, and fails to appreciate the trajectory that certain prominent Jesuits took.

In the hands of Jesuit mathematicians, optical illusions were serious jokes. While this observation is not new and has been articulated by many different historians, what has not been appreciated is the interpretive role that optical jokes play in understanding the response to the seeming optical and visual crisis by members of the Society of Jesus. What will be shown is that

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[382] Massey, *Picturing Space, Displacing Bodies*; Clark, *Vanities of the Eye*.

[383] With respect to the Jesuits Stuart Clark states "But while not intending to question representational theories of vision in any serious way—on the contrary, while depending on these theories for the very idea of the visual paradox itself, and the impact of specific visual marvels—their tireless elaboration of cases where visual sense impressions were manipulated to the point where they bore no resemblance to what was being perceived showed just how unworkable the inherited theories might become." In this section, however, he utilizes Massey's interpretation of Descartes as a heuristic for the entirety of early modern optical culture; Clark, *Vanities of the Eye*, 110.

serious jokes possessed rules of intelligibility that could accommodate seeming intellectual contradictions. This was especially the case for serious natural magic jokes, the intelligibility of which could easily escape the sensibility of the commoner. By appealing to such a rhetorical motif, Jesuit authors do not necessarily bring about the unintended end to Aristotelian natural philosophy, even though it might appear as such to contemporary philosophy or to retrospective analyses of their argumentation.

Before addressing the notion of serious optical joke among the members of the Society of Jesus it is important to consider the importance of natural magic among the Jesuits, which was a significant impetus for their engagement with optical illusions and for the construction of serious optical jokes.

The Jesuits and Natural Magic

Natural magic proved to be an important social and cultural category for the transmission of early modern scientific knowledge. Because it addressed topics which were not traditionally associated with Aristotelian natural philosophy, but were of wide social intrigue, natural magic produced analysis of topics which would not have otherwise received attention.[384]

For the Jesuits, their cultural mission motivated their engagement in topics of magic. More than creators of Catholic Orthodoxy and defenders of Aristotelian natural philosophy, the Jesuits used education and learning to engage the youth of early modern Europe, and did so in such a way that the popular topics at the time were molded into the curriculum. An implication of this was that the explanation of magic, and in particular, the delineation of licit magic from

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[384] Wayne Shumaker, *Natural Magic and Modern Science: Four Treatises, 1590-1657* (Binghamton N.Y.: Center for Medieval and Early Renaissance Studies State University of New York, 1989).

illicit magic proved an important pedagogical and cultural activity that members of the Jesuit Order across a multitude of disciplines and regions specified as an important cultural task of their mission.

For instance, one of the most prominent Jesuit theologians and natural philosophers of the sixteenth century, Benito Pereira, wrote a book at the end of the sixteenth century, *De magia, de observatione somniorum, et de divinatione astrologica* (1598). In this book he actively sought to bring the topics of magic into an ordered system for the purposes of instruction within the Jesuit colleges. Pereira had been one of the chief objectors to the recognition of mathematics as a legitimate scientific subject, and yet in this work he legitimizes the role of the mathematical sciences as a means toward delineating the natural and knowable forms of magic—the "natural magic"—from those that are unknowable and incomprehensible. In his organization there were three types of natural magic: Things knowable by humans; the activity of God and Angels; and things caused by demons.[385] Yet, despite his inclusion of God and the preternatural among the causes of natural magic, the rest of the book nevertheless demonstrates Pereria's goal, that is the identification of the ways human reason could be used to explain hidden characteristics of nature. Among Pereira's goals was to demonstrate the importance of teaching magic within Jesuit colleges across Europe with the goal of countering superstitions.[386]

The inclusion of the divine and preternatural among the categories of natural magic were by no means uniform. For instance, Matthias Mairhofer, a Jesuit professor of theology and philosophy at Ingolstadt stated the following in 1581

[385] Benito Pereira, *De magia, de observatione somniorum, et de divinatione astrologica* (Cologne: Joannes Gymnicus, 1598), 11.

[386] Cristiano Casalini, *Benet Perera and Early Jesuit Pedagogy: Human Knowledge Freedom Superstition* (Rome: Anicia, 2016), 191–192.

> We apply true and natural causes to the production of rare and strange effects…since the application has its basis in the principles of natural philosophy, it follows that natural magic is subordinated to natural philosophy. Which means that, concerning the application of causes, it is for natural philosophers to decide how far the nature of the causes agrees or disagreed [with the intended effects].[387]

In the decade after the formalization of the Jesuit *Ratio studiorum*, the document outlining the educational structure of the various Jesuit colleges, the Jesuit educational theoretician Antonio Possevino provided a commentary on the *Ratio* in his *Bibliotheca selecta*. While the *Ratio* had outlined the curriculum which was intended to unify the various Jesuit colleges across diverse geographies, the *Bibliotheca selecta* had a much more ambitious perspective of commenting on the morals and merits of various educational efforts in such a way that it sought to inculcate a particular cultural perspective on education fitting with the religious goals of the Society of Jesus.[388] It is very evident that Possevino believed the pedagogical goals of the Society could create a moral culture. While the *Ratio* has received much more attention within the historiography, the circulation of the *Bibliotheca selecta* was of a noticeably similar impact.

Towards the beginning of the work Possevino states "Someone who is silent about the false things that have improperly inserted themselves among the true sciences, abandons culture."[389] Immediately following this Possevino lists the process that he has in mind, which entails, among other things, the separation of the licit from the illicit forms of magic. A much

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[387] Stuart Clark, *Thinking with Demons: The Idea of Witchcraft in Early Modern Europe* (Oxford, UK: Oxford University Press, 1999), 226.

[388] Koen Vermeir, "Historicizing Culture: A Revaluation of Early Modern Science and Culture," in *Cultures Without Culturalism: The Making of Scientific Knowledge*, ed. Karine Chemla and Fox Keller (Durham: Duke University Press, 2017), 227–49.

[389] Possevino, *Bibliotheca selecta*, 2:37: At & culturae deest qui reticet, quae falsae sese inter veras scientias improbe immiscuerunt.

stronger appeal than that included in Benito Pereira's text above, what Possevino is stating is that the act of pedagogical instruction, and hence the act of cultural transmission on the part of the members of the Society of Jesus, involves the engagement with magic and the delineation of licit from illicit magic; or to put another way, the identification of natural magic from demonic inspired forms of magic.

The history of the Society of Jesus throughout the seventeenth century involves the adoption of the pedagogical and cultural vision of those like Pereira and Possevino as many mathematicians of the Society used their particular theological and cultural framework to engage the broader European community. Such engagement came not only from mathematicians and scientists, which was to be anticipated, but also from pastors and theologians. The historian Bernard Barthet, in his study of Jesuit theologians in France in the seventeenth and eighteenth centuries, demonstrates that by the second half of the seventeenth century natural magic even came to be appropriated by certain Jesuits as of important pastoral significance, as it provided an intellectual form of communication within which one could comment on the sensitivity of the soul and the transmission of spiritual knowledge.[390]

Yet it was quite apparent that among those members of the Jesuits who could gain the most from the serious engagement with natural magic were the mathematicians. As identified in the previous chapters, one of the questions among the members of the Society between the sixteenth and seventeenth centuries involved the identification as to the scientific and philosophical merits of mathematics. In his recent study of the development of the "mathematicus" among the Society of Jesus, the historian Michael Gorman contends that many

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[390] Bernard Barthet, *Science, Histoire et Thématiques Ésotériques chez les Jésuites en France (1680-1764)* (Pessac: Presses universitaires de Bordeaux, 2012).

members capitalized on the boundary between licit and illicit magic to articulate the importance of mathematical knowledge. Thus, it is for this reason that many mathematical treatises show the small angelic figures of the Putti creating mathematical figures, and why many Jesuit authors contrast their mathematical knowledge with the preternatural.[391] Two books already discussed in this dissertation, Aguilonius's *Opticorum* and Christoph Scheiner's *Pantographice* both use the Putti in their presentation of mathematical knowledge. And as will be shown in later sections of this chapter, many Jesuit authors explicitly contrast their mathematical knowledge with that of the preternatural to improve the rhetorical appeal of mathematics.

Image 4.1 — Dissection of eye by Putti
Aguilonius, *Opticorum libri sex* (1613), Book I engraving
Courtesy of The Linda Hall Library of Science, Engineering & Technology

391 Particularly the chapter "Between the Demonic and the Miraculous," in Gorman, *The Scientific Counter-Revolution*, 197–248.

For the purposes of this dissertation, the identification of optical magic (*magia optica*) among the members of the Society of Jesus began in the sixteenth century, one of the earliest examples being in Benito Pereira's work on magic.[392] What Pereira intends to identify is the proper forms of licit magic and those that are illicit. Optical magic was among the licit forms. Similarly, the Jesuit intellectual Martin Del Rio, whose *Disquisitiones magicae* was widely read and used by both Protestants and Catholics alike, identifies various popular forms of vision within the magical traditions, such as the "fascination of the eyes" mentioned in Chapter Two. Immediately after this he addresses the nature of natural magic, within which mathematics was one of the tools utilized to create such magical feats.[393]

Serious Optical Jokes

The first chapter explained the way in which optical illusions became prominent in the period because of their close relationship to perspectivist optics. The intrigue in the way the eye could be tricked played upon expectations for what perspectivist optics implied, namely the maintenance of the visual species and the defense of visual experience itself. Optical illusions drew attention not only for the practicality of the feat itself, such as casting images into the air, the reformation or deformation of images, or anamorphic projections, but also because it made one aware of the subtle presuppositions one held for the way that sight occurred. One of the curiosities of the sixteenth and seventeenth centuries, as Paula Findlen identified and as

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[392] Pereira, *De Magia*, 54.

[393] Martino Del Rio, *Disquisitionum magicarum libri sex*, *Tomos Primus* (Lyon: John Pillehotte, 1612), 17–28; On the broader importance of Del Rio, see P. G. Maxwell-Stuart, "Introduction," in Martin Del Rio, *Investigations into Magic*, trans. P. G. Maxwell-Stuart (Manchester: Manchester University Press, 2000) 8–9.

explained in Chapter One is the way in which early moderns utilized the category of "scientific joke," to communicate about contentious scientific subjects. As Findlen states, its goal was "an attempt to reconcile ancient philosophies with new ways of seeing."[394] In the context of the Jesuit intellectuals, what natural magic allowed them to do was to incorporate new knowledge, while at the same time maintaining fidelity to the Aristotelian framework. And, notably, such an interest in optical illusions involved more than Jesuit mathematicians alone.

The Jesuits' interest in serious optical jokes also came to be incorporated in their religious festivals, which often incorporated art, emblems, and on occasion the use of mirrors and other optical tools to incite visual wonder.[395] At the feast of the canonization of Saint Ignatius of Loyola and Francis Xavier at the Jesuit college in Poitiers, in 1622, an emblem was hung upon a pyramid at the center of the courtyard, with two mirrors positioned on either side. The picture upon the emblem was intended to be an emblematic optical illusion, where the meaning of the image depended upon the angle with which one looked at it. When one looked toward one mirror, reflected in the mirror was a picture of Jesus. When one looked at the other mirror, the image reflected was that of Saint Ignatius.[396] Such a prominent public optical demonstration shows how sophisticated optical techniques existed within the broader Catholic visual culture of the Jesuits, such as in the commemoration of Saint Ignatius Loyola here.

A similar trick was performed at another Jesuit college, in the French city of Pont-à-

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394 Paula Findlen, "Jokes of Nature and Jokes of Knowledge: The Playfulness of Scientific Discourse in Early Modern Europe," *Renaissance Quarterly* 43, no. 2 (1990): 295.

395 Joseph Imorde, "Visualising the Eucharist," in *Le monde est une peinture*, 109–26; Mia M. Mochizuki, "Jesuit Visual Culture in a Machine Age," in *The Oxford Handbook of the Jesuits*, ed. Ines G. Županov Oxford University Press, 2018), 1–35.

396 Rosa De Marco, "From Parts to Wholes and Back Again : Emblems in French Jesuit Festivals (1622-1623)," *Volume 2. Von Zentrum und Peripherie der Emblematik.* (2017), 857-858.

Mousson, on the occasion of the defense of mathematical theses in 1622, which similarly coincided with the canonization of Ignatius and Xavier. The theses themselves covered a wide range of topics, such as studies on the inclined plane, burning mirrors, as well as anamorphic projections. Within the theses the authors proudly claim their ability to project anything within a mirror, a similar anamorphic trick of wide interest in the seventeenth century. These mathematical theses attracted the attention of many in the 1620s, and their optical claims were used by Gabriel Naudé (1600–1653), who was not himself a Jesuit, to defend the medieval intellectual Roger Bacon from suspicions of black magic. In his explanation, Naudé appealed to the overlap between the work of the Jesuits in the early seventeenth-century and Roger Bacon.

> For being such a great mathematician as one can see, as much by the treatises and the instruments of [Bacon's] own invention sent to Pope Clement IV as by those two books of his, published just a decade ago, on perspective and mirrors, we can well believe that he managed to do many extraordinary things with this knowledge. The underlying causes being unknown to the common people — who were then much more primitive and barbarous than those of today — they could not help being associated with magic. And yet I believe he will always be supported by learned men, and above all by the Most Reverend Fathers of the Society of Jesus, who have not neglected to mention in the Theses in Mathematics that were defended in Pont-à-Mousson in 1622 on the day of the Canonization of Saints Ignatius and Xavier, that it was possible for a man well-schooled in optics and catoptrics — as Roger Bacon undoubtedly was — "if given any object whatsoever, to show anything at all in the mirror, as for example a mountain from an atom, a swine's or ass's head from a human's, or an elephant from a hair.[397]

The Jesuits' adoption of optical illusions also proved quite important in their missional endeavors. In addition to this, Jean-Baptiste Du Halde (1674–1743), a French Jesuit who chronicled many activities of the Jesuits in the seventeenth century, explains the way in which, through the expertise of Pere Grimaldi, the Jesuits were able to introduce the anamorphic optical illusions on the hallways. As he explains,

They made upon the four walls four human figures, every one being of the same length as

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[397] Quoted in Eileen Reeves, *Galileo's Glassworks: The Telescope and the Mirror* (Cambridge, MA: Harvard University Press, 2008), 119–120.

> the wall, which was fifty foot: As he had perfectly observed the optick rules, there was nothing seen on the front but mountains, forests, chases, and other things of this nature; but at a certain point they perceived the figure of a man well made and well-proportioned[398]

Du Halde also explains the way in which Jesuit authors created several catoptrical tricks, such as the magic lantern, to attract the attention of the Ming court. Thus, from these examples, those of religious festivals as well as those of the Jesuit missionary endeavor in China, it is clear that when Jesuit mathematicians engaged the topics of optical illusions it was not merely to demonstrate the utility of mathematics, but equally so, to support the much wider visual culture, in which images and the delineation between true and false visions were significant religions questions—thus, they ultimately had the goal of confessionalization. In the case of Du Halde's comments on the Jesuit mission to China, the optical tricks were undoubtedly aimed to allow the Jesuits to win favor at the Ming court, and hence further their mission in China.[399] Thus the need to use the serious jokes of optical illusions, while within the realm of the mathematician, was of a much wider interest than merely the mathematicians.

As explained in the previous chapters the members of the Society of Jesus adopted perspectivist optics, with its support of Aristotelian natural philosophy, as its generalized understanding of optics, and particularly vision. These intellectual commitments shaped their understanding of the visible, everyday world, such as how one can see and make intelligible any visual experience, as well as more serious topics in the early modern period, such as the visual encounter with the Eucharist. The incorporation into *perspectiva* of mirrors and lenses of all

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[398] Jean-Baptiste Du Halde, *The General History of China, Volume the Third*, trans. R. Brookes (London: John Watts, 1739), 73.

[399] On the role of Jesuit mathematics and science in China, see Florence Hsia, *Sojourners in a Strange Land: Jesuits and Their Scientific Missions in Late Imperial China* (Chicago: University of Chicago Press, 2009).

shapes and sizes introduced new questions and experiences which demanded explanation. The juxtaposition of the inherited visual tradition and the newfound optical and visual abilities induced widespread intellectual jokes within the early modern context. And, in an ironic twist, many members of the Jesuit Order led the way in instigating such visual jokes, the intellectual and philosophical implications of which were not readily realized along the way.

As one might anticipate, such optical jokes often led to questions about the preternatural. So, for instance many of the Jesuit authors utilized the occasion of the camera obscura to demonstrate that it was not demons that were projected, but normal images.

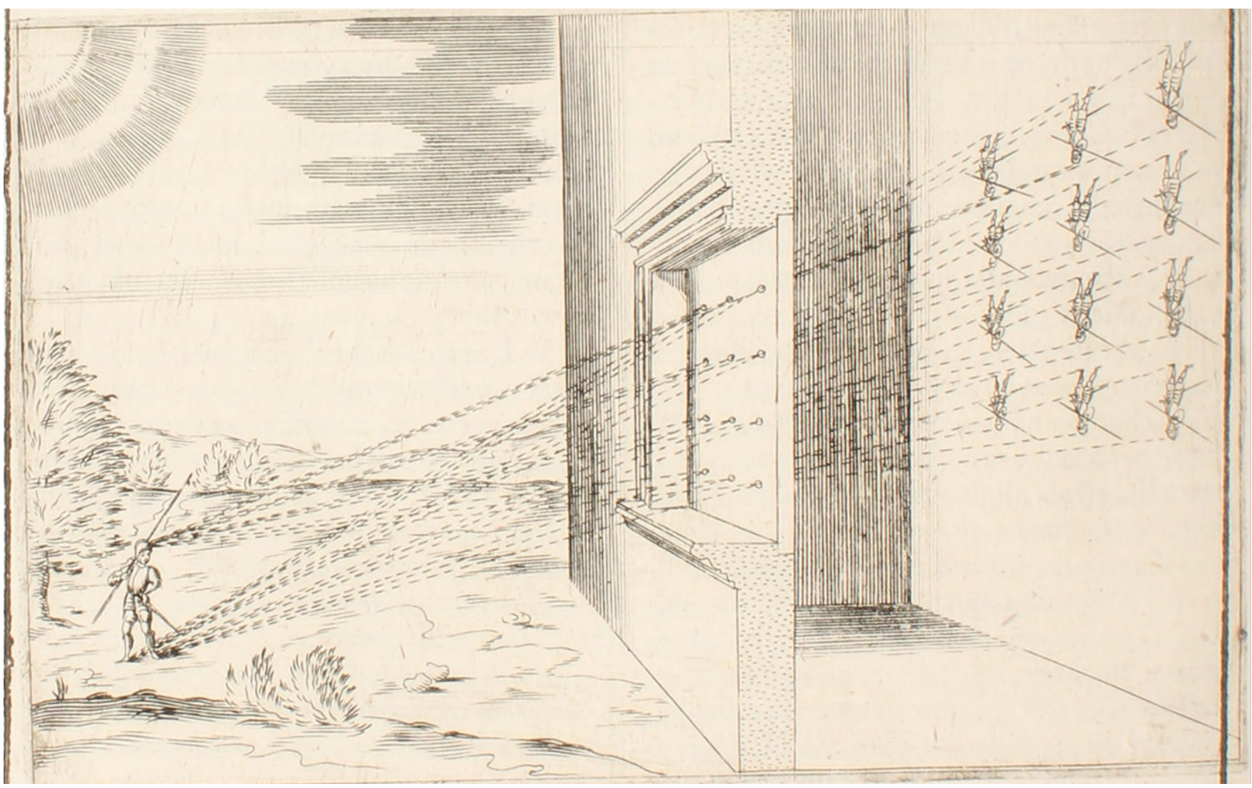

Image 4.2 — Camera obscura
Bettini, "Apiarium VI," in *Apiaria* (1642), 1:38
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Like other Jesuit authors at the time, Bettini explicitly contrasts his explanation of the camera obscura in Image 4.2 with the popularized understanding of Della Porta, who was mentioned in Chapter One, and who (falsely according to Bettini) claimed to be able to project a demon into the air.

In addition to the camera obscura, many Jesuit authors were interested in mastering the reflection in mirrors of all different shapes, particularly cylindrical mirrors. Tricks known as anamorphoses (as well as the "reformation" and "deformation" of images) provided not only an important occasion for demonstrating mathematical prowess, but also an opportunity to comment on popular visual uncertainties at the time. Image 4.3, taken from Gaspar Schott's *Magia universalis* (1657), shows a popular anamorphosis. In this example it teaches one how to construct an anamorphosis using a cylindrical mirror in which Figure II would be projected upon a mirror placed in the center of Figure III.

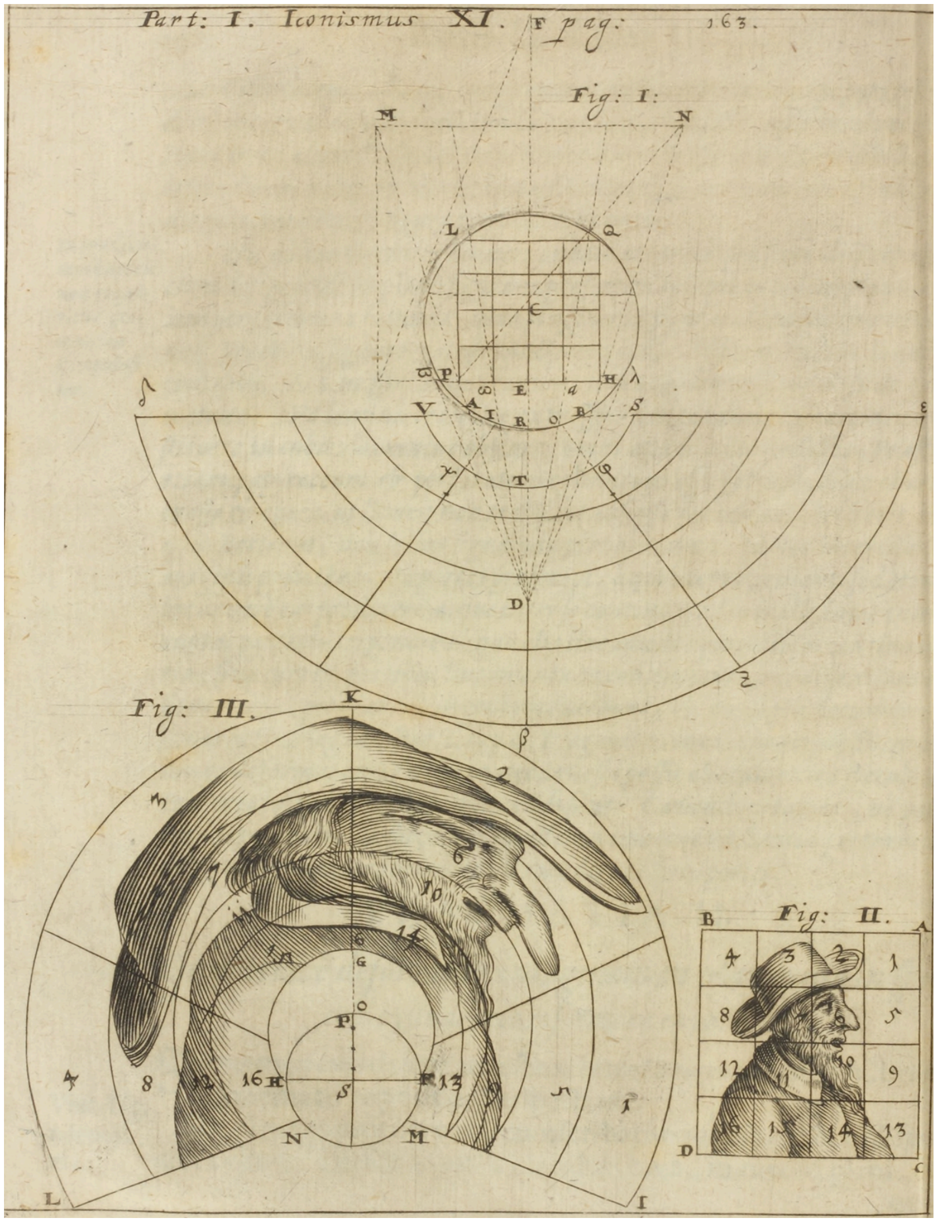

Image 4.3 — Image of anamorphosis with cylindrical mirror
Gaspar Schott, *Magia universalis* (1657–1659), 1:163
Courtesy of The Linda Hall Library of Science, Engineering & Technology

When looking at the Jesuit books on optics it is evident that they were deeply influenced by another Catholic Order, the Minims, who were quite large in the seventeenth century.[400] In

[400] P. Whitmore, *The Order of Minims in Seventeenth Century France* (The Hague: Martinus Nijhoff, 1967).

particular, the Minim Jean Francois Niceron (1613–1646), who composed *La perspective curieuse* (1638) and *Thaumaturgis optics* (1646), and was mentioned in Chapter One, exerted a tremendous influence on the Jesuit interest in optical illusions. One need only look at the optical works of Athanasius Kircher or Gaspar Schott, or read other works, such as those of Nicholas Zucchi, to see the reproduction of images and concepts from Niceron within these Jesuit works, albeit reframed within the particularities of their context. For instance, the conical forms of anamorphosis in which an image was transcribed onto a cone such that it was intelligible from a single visual point when one was looking straight at the image, was an optical trick that derived from multiple steps within Niceron's work and which he popularized in the 1630s. The image itself was of a man (Image 4.4). The same trick among the Jesuits, both Kircher and Schott, was not a man but a two-headed eagle, the heraldic emblem of the Hapsburgs (Image 4.5). Such a transformation of the content of the image is a reminder that the confessionalization of optics among the Jesuits involved not merely the theoretical dimensions, but also the pictures themselves, and in this case the representation of the Hapsburgs and their importance in the Catholic Counter Reformation.

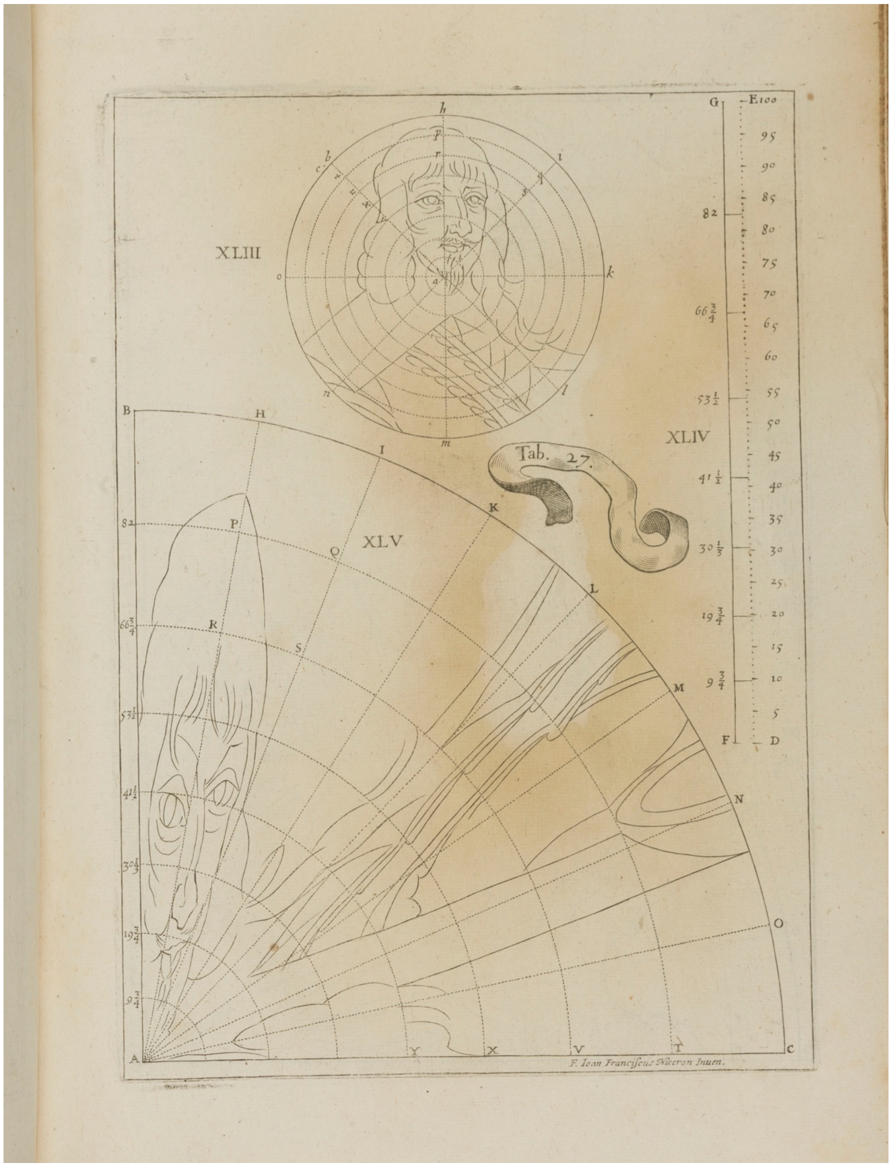

Image 4.4 — Conical Anamorphosis
Niceron, *La perspective curieuse* (1663), table 27.
Image courtesy of the History of Science Collections, University of Oklahoma Libraries

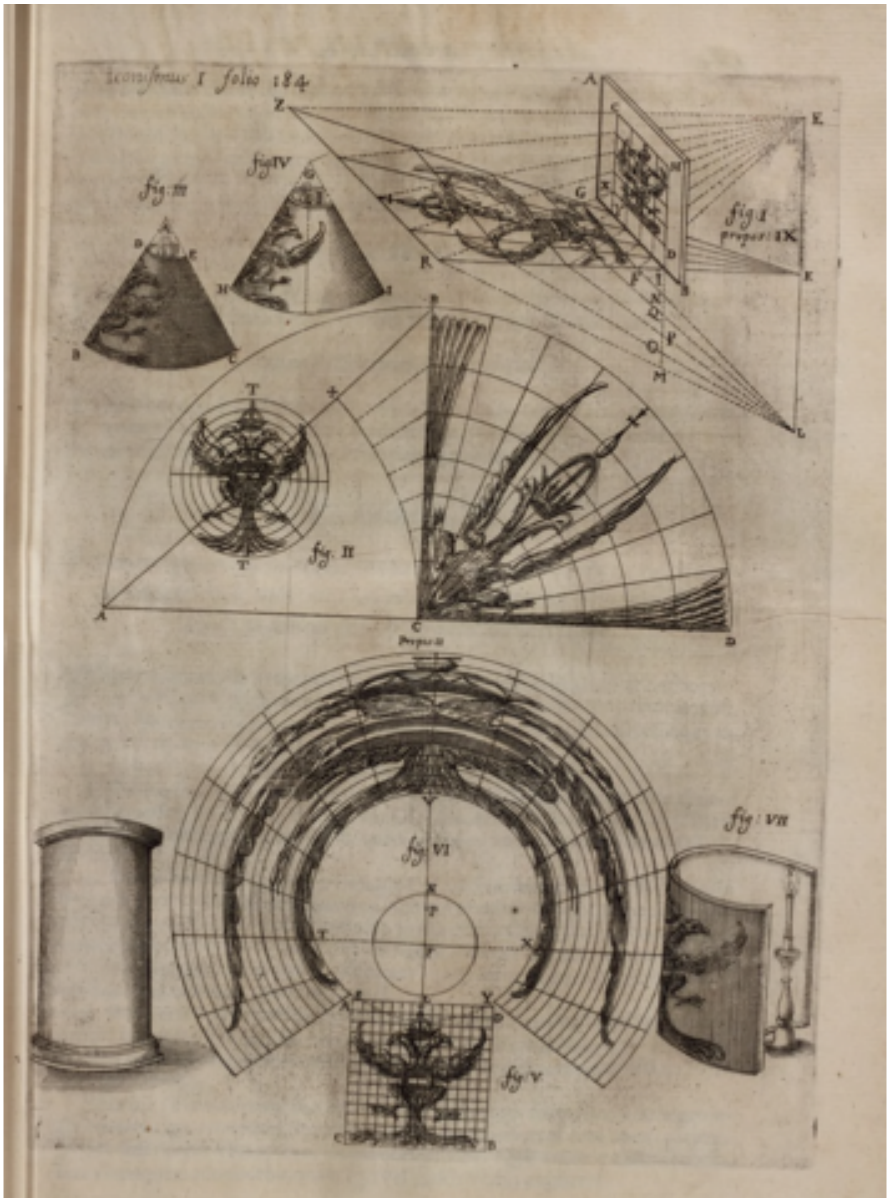

Image 4.5 — Conical Anamorphosis
Kircher, *Ars magna lucis et umbrae* (1646), 184.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Kircher himself credits the influence of Niceron and in the process employs the term "anamorphosis,"—which is likely the first use of the phrase by a Jesuit author.[401] Such a flow of

[401] Kircher, *Ars magna lucis et umbrae*, 185. There is a strong historiographical tradition to identify Gaspar Schott has employing the phrase "anamorphosis" first. However, Kircher clearly does so in his *Ars magna*. See Kircher, *Ars magna lucis et umbrae*, 184. As an example of the

interest in anamorphosis, from France to Italy, parallels other interests in anamorphosis from France to Italy in the middle of the seventeenth century.[402] The projected images in Niceron's anamorphoses, and thus those included in the Jesuits' works, were often images of the preternatural or other pictures of visual deception, such as monstrous women (which played upon the perception that witches worked by way of optical illusions), all of which were clear indications of the participation of anamorphoses within early modern cultures of serious jokes.[403]

One notable difference with the Jesuits' engagement with such traditions of optical illusions and those of others, such as Niceron, is the detailed explanations that the Jesuits provided for the explanation not only of the way in which an image could be deformed and reformed, but also for the way in which it provided an important occasion to analyze the implications of such illusions for the understanding of vision. The book by the Italian Jesuit Nicholas Zucchi, *Optica philosophia* (1652-1656) exemplifies this aspect quite well.

Zucchi was a friend of Johannes Kepler and had allowed him to borrow a telescope when Kepler struggled financially. His two-volume work on optics, which features an engraving by the Counter-Reformation artist Bernini in the book, exemplifies his work on light and image formation over the course of his life. Whereas the first volume, published in 1652, focused on light and the relationship between light and color, the second volume, published in 1656 deals almost entirely with the way the eye works and its relation to image forming mirrors. Among the

misidentification of Schott as coining the neologism "anamorphosis," see Massey, *Picturing Space*, 20.

[402] Susana Gómez López, "The Encounter of the Emblematic Tradition With Optics. The Anamorphic Elephant of Simon Vouet.," *Nuncius* 31, no. 2 (2016): 288–331.

[403] Nicholas Zucchi interprets one of Niceron's images as portraying a monstrous woman, a term which suggests that Niceron intended one of his illusions to engage the rhetoric of the "bloody mirror" and its association with witchcraft. See Zucchi, *Optica philosophia, Pars altera*, 2:200.

issues which Zucchi tackles in volume two is the topic of the reformation and deformation of images and the way in which the image appears from a "single point." In a subtle recognition of the role of the visual pyramid in the maintenance of vision, what Zucchi implies by the reference to the "single point" is the way in which anamorphosis may be integrated within the theory of perspectivist optics and its insistence that optics occurs through the visual pyramid.

At the same time, throughout both volumes of the book Zucchi repeatedly refers to the way in which the image formed is an "appearance" rather than a "species," perhaps on account of his uncertainty as to the philosophical nature of the image seen.[404] Such a subtlety in language is likely on account of the way Zucchi engaged the problem of vision not merely as an abstract connotation, but through the medium of optical devices, which necessarily creates all sorts of philosophical confusion and leads one to wonder, particularly in the context of anamorphic projections, whether the object seen was the one distorted or the one projected in the mirror. Such philosophical ambiguity is why at the conclusion of Zucchi's book he manipulates the Pauline adage of "seeing face to face" to apply to the role of optical devices: "now we see through means prepared by a divine art."[405]

From these examples it becomes clear that the serious jokes of optics were an important concern for many members of the Jesuit Order. Optical illusions were a performative encounter, which were enjoyable apart from their specific philosophical explanation, although as will be shown in the work of Mario Bettini, Athanasius Kircher, and Gaspar Schott, the task of explaining the philosophy of such illusions proved an important and necessary task for the

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[404] He mentions the "species visibiles" only rarely, such as in Niccolò Zucchi, *Optica philosophiae, experimentis et ratione, pars prima* (Leiden: Guilleimum Barbier, 1652), 1:177.

[405] Zucchi, *Optica philosophia, pars altera* 2:371: nunc videmus per media Divina arte praeparata.

mathematician.

Mario Bettini

Bettini was born February 6, 1582. Although he achieved mathematical renown in the first part of the seventeenth-century, even anonymously publishing a treatise in contrast to Galileo's *Sidereus nuncius*, he did not publish any materials personally until he was in his sixties, and even then used the prestige and renown of his fellow Jesuit Grienberger, whom he referred to as the "other Archimedes of our time" to help justify the legitimacy of his mathematical skill.[406] Such a comment, likely intended to aggrandize the perceived mathematical perception of Bettini since Grienberger was a well-respected Jesuit mathematician at the time, also serves to locate Bettini as a participant within the Jesuit mathematical culture, a rhetorical move which the historian Michael Gorman has noted was often used in Jesuit mathematical works. The point was to demonstrate one's continuity alongside their fellow Jesuits, rather than their radical difference.[407]

During his lifetime, Bettini completed two important publications. The first publication, an elaborate two-volume folio, *Apiaria universae philosophiae mathematicae* (Beehives of the whole of mathematical philosophy), was published in 1642, and dedicated to Holy Roman Emperor Ferdinand III.[408] The second, a much less elaborate three-volume quarto, *Aerarium*

[406] Bettini, "Lectori," in *Apiaria*, 1:C2r: Qui nostri aevi alter Archimedes.

[407] See the chapter "Mathematics and Modesty: The Problematic of Christoph Grienberger," in Gorman, *The Scientific Counter-Revolution*, 41–84.

[408] Tthe book was prepared in the 1630s, but that its publication was held up on account of the lack of an acceptable patron; Michael Gorman, "Mathematics and Modesty in the Society of Jesus," in *The New Science and Jesuit Science*, ed. Mordechai Feingold, 4.

philosophiae mathematicae (Treasury of mathematical philosophy), was published in 1648. Of the two publications, it is the *Apiaria* that provides the best representation of his thoughts on optics and visual theory. Among many important features, the book represents Bettini's moral approach to optics, as well as mathematics more broadly, as the frontispiece indicates his position as a "moral philosopher". As he states in the third section of the *Lectori*, the study of mathematics provides a natural progression to the topics of morality and theology.[409] In fact, he explicitly utilized a religious term, "purgatoria" to explain what happens to one's mind through the study of mathematics.[410]

To understand Bettini's understanding as to the relationship between mathematics, vision, and optics, one turns to Apiaria five through seven. It is clear that Bettini identifies his work as belonging among the known Jesuit optical sources at the time. For instance, he cites many of the usual Jesuit authorities, such as Christoph Scheiner, Aguilonius, and Villalpando. He also cites Maurolyco as the authority for his explanation of light as it pertains to refraction.[411] One of the more striking aspects of Bettini's book, which was briefly mentioned in Chapter three, is the disagreement that Bettini has with Scheiner's understanding of the way the eye works. Because of the importance of avoiding the "confused" vision of the inverted image on the retina, Bettini supplies a refraction within the Crystalline Humor which would restore the image to its normal orientation. Such a point he justifies based upon Andreas Vesalius's explanation of the eye as

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409 Bettini, "Lectori," in *Apiaria*, 1:C3r.

410 Bettini, "Lectori," in *Apiaria*, vol. 1, C3r. On the application of Bettini's mathematics to geology, see Luzzini, Francesco. "Description, Analogy, Symbolism, Faith. Jesuit Science and Iconography in the Early Modern Debate on the Origin of Springs." *Acque Sotterranee. Italian Journal of Groundwater* (2016): 66.

411 Bettini, "Apiarium VII," in *Apiaria*, 1:39.

well as the presumed refraction that would have occurred within the aqueous substance of the crystalline humor.

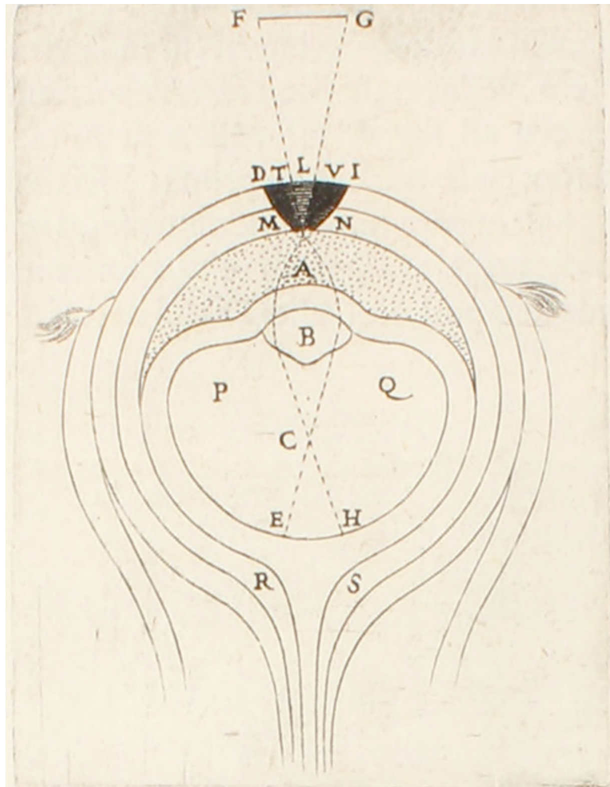

Image 4.6 — Anatomy of the Eye
Mario Bettini, "Apiarium VI," in *Apiaria* (1642), 1:41
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Similar to the other Jesuits he locates the significance of perspectivist optics within the tradition of *De Anima*, affirming its role in maintaining the visual species, but on the other hand also emphasizing the role that mathematics played in the explanation of the process.[412] So, for instance, he explains that refraction through a lens projects a species rectilinearly.[413] This in itself is not surprising, since he has no problem accepting the refracted species within the eye itself.

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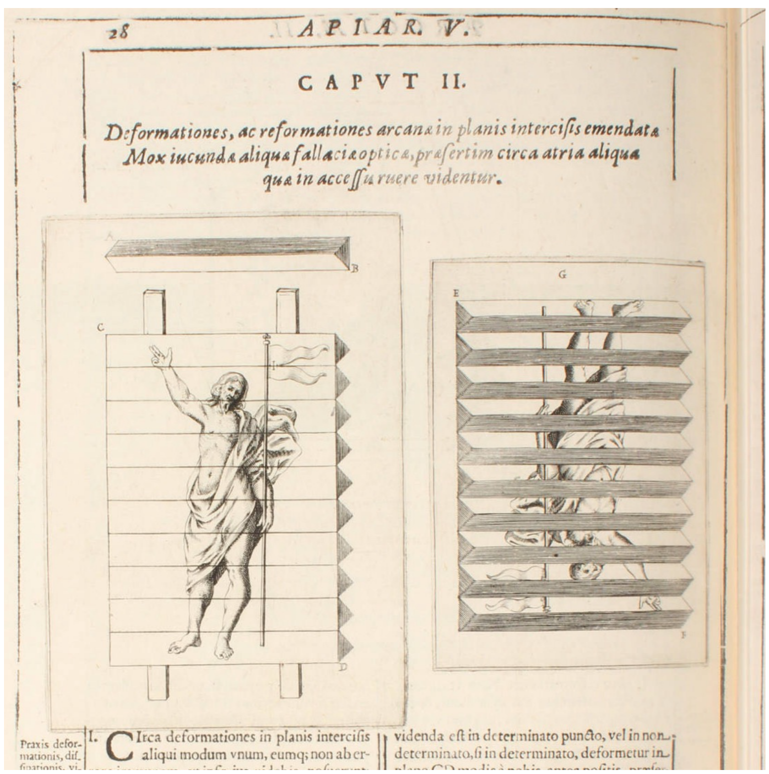
[412] Bettini, "Apiarium VI," in *Apiaria*, 1:45.

[413] Bettini, "Apiarium V," in *Apiaria*, 1:30.

The most surprising explanation of the relationship between optical illusions and perspectivist optics involves one particular trick in a section titled the “Reformation and Deformation” of the eyes, in Apiari VI, Chapter Two. In this particular section of Bettini’s book he is explaining a type of anamorphosis utilizing elongated prisms. As he explains, one should line up the prisms and then turn them over such that one side of the prisms are flat. Then, one should produce a picture on the flat side of the prisms, such as is pictured in the left side of the image below. Then one should rotate all the images such that the side of the prisms with the image on them are not in alignment but are separated, hence “deformed,” as in the right side of the image below.


28 APIAR. V.

CAPVT II.

Deformationes, ac reformationes arcanæ in planis intercisis emendatæ Mox iucundæ aliquæ fallaciæ opticæ, præsertim circa atria aliqua quæ in accessu ruere videntur.

Praxis defor-mationis, dis-

1. Circa deformationes in planis intercisis aliqui modum vnum, eumq; non aber-

videnda est in determinato puncto, vel in non determinato, si in determinato, deformetur in

Image 4.7 — Visual illusions with prisms
Mario Bettini, “Apiarium V,” in *Apiaria* (1642), 1:28
Courtesy of The Linda Hall Library of Science, Engineering & Technology

After this, one should place a mirror at an oblique angle at the end of one of the prisms, like the image below.

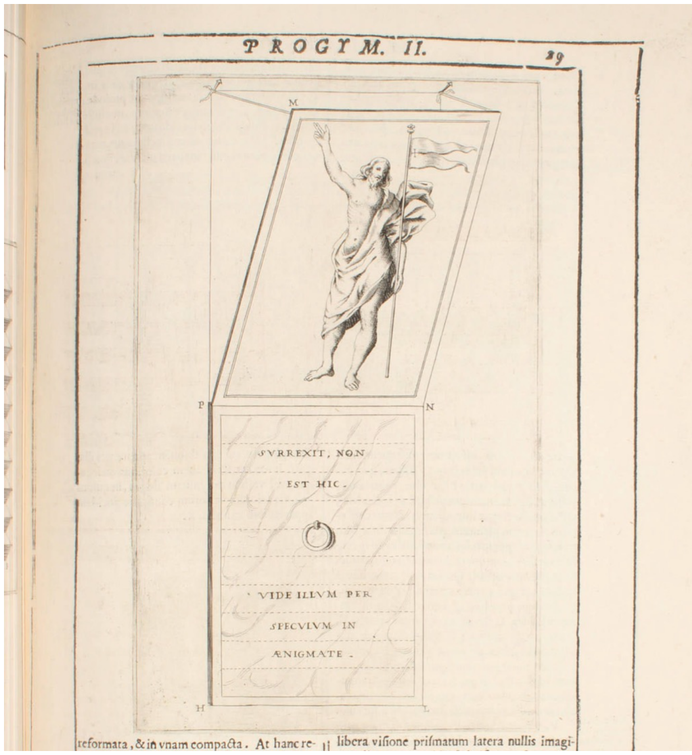


Image 4.8 — Resurrection of Jesus in the mirror
Mario Bettini, "Apiarium V," in *Apiaria* (1642), 1:29
Courtesy of The Linda Hall Library of Science, Engineering & Technology

When one looks at the image from the appropriate angle, position G in the image on the right above, one is able to see the reformed image. The effect of this, as Bettini explains, is the production of the "intentional species," at the proper reflection point in the mirror. The term 'intentional species' which showed up in Chapter Two and Three, was the term which signified how knowledge of the material world was able to be transformed into immaterial intelligibility.[414] In Chapter Three, the point conveyed through the term "intentional species" was

[414] Dennis L. Sepper, "Species, Intentional," in *The Cambridge Descartes Lexicon*, ed. L. Nolan (Cambridge: Cambridge University Press, 2015), 690–692.

the fact that the actual object was able to be wholly seen within the eye. Here, borrowing the same language, Bettini conveys the fact that from one perspective—from one point—the image is made intelligible. What Bettini does here, then, is to borrow the framework of perspectivist optics and apply it to the tricks of optics to suggest that knowledge of the thing seen is still possible, albeit when viewed according to the secret of the image.

On the back side of the prisms with the deformed image, Bettini suggests the following inscription be included: "He has risen, he is not here. See through a darkened mirror."[415] The phrase itself is a blending from the Bible from Matthew 28:6 and 1 Corinthians 13:10. The latter passage, 1 Corinthians 13, includes the section that is among the most widely cited about optics, since it includes the phrase by St. Paul, "see through a mirror dimly." What is more interesting is the former passage, Matthew 28:6, because it refers to the Ascension of Jesus. Like Kircher's utilization of the Ascension of Jesus as the content of his optical trick of casting images into the air, so also does Bettini in this particular passage of the reformation and deformation of images. This aspect, paired alongside the fact that Bettini specifically includes the phrase "intentional species," strongly suggests that Bettini realizes he is treading on uncertain visual waters. While he does not clearly explain his underlying philosophical point, it nevertheless is evident that what Bettini aims to do is to locate the optical joke within this broader philosophical tradition. The serious joke of the resurrection, paired with the importance of unveiling the optical trick, indicates that Bettini aims to reinforce the way in which optical tricks do not in themselves undermine the received theory of optics.

Nevertheless, despite such intentionality in this optical trick, there are other indications

[415] Bettini, "Apiarium V," in *Apiaria*, 1:30: Surrexit, non est hic: vide illum per speculum in anigmate.

that Bettini equivocates the meaning of "species," "simulacrum," and "picture," in his explanation. The clearest location where this happens is in the section where Bettini explains the refraction of the image within the eye. To do this he uses an analogy from a camera obscura with a double-sided lens. Yet, in his explanation he explains that the projected image is a "simulacrum," a "picture," as well as a "species."[416] While such an explanation might indicate the way in which Bettini is uncertain as to the ontology of the object seen, it might also be the case that Bettini employs a similar line of reasoning as Aguilonius, whom we encountered in Chapter Two. In that chapter it was explained that for Aguilonius, the most important aspect in understanding the projected image was that it represented the object itself, regardless of the overlapping terms. It could be that Bettini is doing something similar here. Regardless of that point, however, such an equivocation reinforces the point that Bettini had in the previous optical illusion, where he purposely employed the phrase "intentional species." As Bettini's fellow Jesuit Zucchi had realized, locating optical illusions within the traditional perspectivist system was difficult.

Athanasius Kircher

A slightly younger contemporary of Mario Bettini was Athanasius Kircher. Kircher was a polymath who not only developed acuity in science but equally so linguistics.[417] He was influential in the development of the scientific tradition at the Roman Museum during the middle part of the seventeenth century, but developed his renown early on especially for his ability in

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[416] Bettini, "Apiarium VI," in *Apiaria*, 1:34–35.

[417] Paula Findlen, "The Last Man Who Knew Everything…or Did He?" in *Athanasius Kircher: The Last Man Who Knew Everything*, ed. Paula Findlen (New York: Routledge, 2004), 11–12.

optics.[418] In 1632 Kircher transferred to Avignon to teach at the Jesuit College there, and demonstrated his expertise and adeptness in optics and mathematics. His first published book, the *Primitiae gnomonicae catoptricae*, was on the topic of sundials. Yet, a cursory analysis of the book clearly demonstrates Kircher's interest in optics, as many of the sundials are integrated into catoptrics. It is also notable throughout his later *Ars magna*, when discussing catoptrics he often references sundials as an example of a general principle. The *Primitiae* was published in 1635 and dedicated to the city council of Avignon and to Claudius Sylvester, the city's property assessor. In it he demonstrates his ability as an exquisite sundial creator, which during the time was of much importance in the context of natural magic.[419]

That optics played an essential role in Kircher's own self-presentation may be noticed by the print history of his main work on optics, the *Ars magna lucis et umbrae*. At the time the book received its approval for printing from the Jesuit censors, Marin Mersenne arrived in Rome with a copy of his *Harmonie universelle* to test Kircher's scientific acumen and to project his own identity as a rival to Kircher's status.[420] Kircher's publisher Ludovico Grignani realized in the publication of *Ars magna lucis et umbrae* that it would be important to publicize Kircher as an important intellectual. Consequently at the back of most copies of the *Ars magna* there was a list indicating the seven books of Kircher's that were already published, as well as an additional

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[418] One of the most helpful overview is Findlen, ed. *Athanasius Kircher: The Last Man Who Knew Everything*; For more attention on his scientific works see John Edward Fletcher, *A Study of the Life and Works of Athanasius Kircher, 'Germanus Incrediblus': With a Selection of His Unpublished Correspondence and an Annotated Translation of His Autobiography* (Leiden: Brill, 2011).

[419] Ulrike Feist, "The Reflection Sundial At Palazzo Spada in Rome: The Mirror as Instrument, Symbol, and Metaphor," in *The Mirror in Medieval and Early Modern Cultures Specular Reflections*, ed. Nancy Frelick, (Turnhout, Belgium: Brepols, 2016), 271–286.

[420] Findlen, "The Last Man Who Knew Everything," in *Athanasius Kircher*, ed. Findlen, 23.

eight being prepared as well as eight translations he had produced. This aspect is important to note, as it helps us to see that involved in the reception and distribution of Kircher's *Ars magna* was not only his ideas and presentation of his optical development, but it also occurred at an important attempt to promote his scientific work.[421]

The *Ars magna* was first published in 1646 and republished in 1671.[422] In the *Ad lectorem*, Kircher relates that the *Ars magna lucis et umbrae* is divided into 10 books to correspond to the 10 Zephiroth of the Kabbalah.[423] Kircher also refers to it as the *Harmonia Decachordi*, the harmonious ten strings. Immediately following the table of contents Kircher gives an indication as to the inspiration for the ten strings: Psalm 134 "for you, God, we play on a ten-stringed lute."[424] Such aspects reinforce the hermetic ideology that was so common within Kircher's scientific works. As Michael Gorman has shown, woven throughout all Kircher's scientific works—whether astronomy, optics, horology, chronology, or his work on magnetism—was the articulation that the science he was recovering was that of a lost, ancient knowledge. As such, the significance of Kircher's scientific works was as much for its rhetorical significance in the way he used the hermetic tradition to vouchsafe it, as it is for any specific

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[421] At the time of the publication of the *Ars magna* Kircher also travelled throughout Europe and pitched his own "solution" to the famous geometrical problem, the quadrature of a circle. Yet, according to Paula Findlen many intellectuals throughout Europe found this method laughable; Findlen, "The Last Man Who Knew Everything," in *Athanasius Kircher*, ed. Findlen, 27.

[422] The engravings in the 1671 publication are keyed for the 1646 edition. However, the printer took the time to make the corrections based upon the errata at the end of the 1646. There are two main differences between the two books. First, the large foldout sundial plate in the middle of the book has been reconstructed in the 1671 edition. Second, Kircher goes to length in the 1671 edition to defend his identity as the creator of the magic lantern.

[423] Athanasius Kircher, "Lectori," in *Ars magna*, 2.

[424] Kircher, *Ars magna*, Table of Contents: In decachordo psalterio psallam tibi.

scientific contribution he made.[425]

The rhetorical role of recovering ancient knowledge is also featured on the frontispiece of Kircher's book, which blends the religious, the metaphorical, and the classical. The sun, which is a symbol of Phoebus-Apollo and Hermes as well as of God, Christ, and Angels in Christianity, and the moon, which is Phoebe, the Virgin Mary, Artemis-Diana, and Athena-Minerva, are flanked by a two-headed eagle and peacock, which is a symbol of the Hapsburgs and optics.[426]

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425 Gorman, *The Scientific Counter-Revolution*, 168–196.

426 Koen Vermeir, "Athanasius Kircher's Magical Instruments: An Essay on science, religion and Applied Metaphysics." *Studies in History and Philosophy of Science Part A* 38, no. 2 (2007): 376.

Image 4.9 — Frontispiece featuring several optical tricks
Athanasius Kircher, *Ars magna lucis et umbrae* (1646), frontispiece.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

One of the immediate observations from the frontispiece is the role of reflection and refraction in the projection of such ancient knowledge. Reflection is most noticeably seen in the reflection of light from the sun off the moon as well as in the cave, and refraction is produced through the passage of light through the telescope with the “sensus.” The incorporation of the four types of knowledge—sacred authority, reason, profane authority, and the senses—is inspired not only by traditional Catholic thought and practice, but also quite likely intended to imitate the work on optics by Christoph Scheiner, the *Rosa Ursina* (1630).[427] Due to the importance of Scheiner's *Rosa Ursina* in establishing a path forward for Jesuits amidst the new optics, the similarity of the frontispieces demonstrates how Kircher's book built upon the tradition laid out by Scheiner.

In terms of content Kircher's book has a natural progression, from the basics of light and vision at the beginning, to explanations of illusions and the metaphysics of optics towards the end. The first two books cover the theoretical topics oftentimes associated with optics, light, shadow, colors, radiation the structure of the sun, moon, and planets. Books three thru six deal with clocks, astrolabes, and horoscopes. Books seven and eight focus on 'reflected' and 'refracted' astronomy. Book 9 discusses the instruments involved with studying heights. And Book 10 deals with the 'magic' of light and shadow. All of this is then followed by a metaphysical epilogue.[428] For the purposes of understanding how Kircher engages the culture of optics it is important to consider sections at the beginning of the book and those toward the end.

Kircher's theory of light, optics, and vision, as he explains in Book two, follows many traditional patterns of explanation. For instance, he upholds the basic theory of the visual species and the distinction between "lux" and "lumen." In providing such an explanation Kircher incorporates a similar woodcut as had previously been used in the disputation Christoph Scheiner

[427] Volker R. Remmert, *Picturing the Scientific Revolution,* trans. Ben Kern (Philadelphia: Saint Josephs University Press, 2011), 70–71.

[428] On the role of the often-overlooked epilogue, see Koen Vermeir, "Athanasius Kirchers Magical Instruments: An Essay on Science, Religion and Applied Metaphysics," *Studies in History and Philosophy of Science Part A* 38, no. 2 (2007): 363–400.

supervised, the *Disquisitio* (1614), which was discussed in the previous chapter.[429] The top image from the *Disquisitio* was pictured in Image 3.2 above, the second one is pictured below alongside the same images from Kircher's book. This observation reinforces the importance of the *Disquisitio* within the formation of the explanation of optics and vision among the members of the Society of Jesus in the middle of the seventeenth century.

Actinobolismus Lucis. 125

Experimentum V.

De Sole.

LVcidum Solis corpus AB, per foramina C,D,E, in obſcuro receptaculo GHKP, mittit tres conos radioſos CKL, DNM, EOP, æqualis potentiæ ob æqualia foramina C,D,E. Dico in communi concurſu conorum lucem notabiliter augeri. Vnde ſegmentũ OQL, omnibus tribus commune eſt lucidiſſimum, & ſplendore ſeſquialterũ ad ſegmentum QRMO, & ſeſe habet ad ſegmentũ dictum, ſicuti 2. ad 3. cum hoc ex duobus tantum radijs conſtet, alterum verò è tribus: triplum verò ad ſegmentũ KCRM, quod eſt ſubduplum MOQR. vnde deduco, ſegmentum ſemper ſe habere ad radij ſimplicis ſplendorem, vti ſe numerus habet conorum, quorum eſt ſegmentum commune, ad vnitatem.

Experimentum VI.

De Igne.

ACcipe cylindrum cauum, in cuius conuexa ſuperficie ſint tria foramina A, B, C, è quorum regione ſtatuantur tres faces accenſæ quæ lumine ſuo traiecto in vnum locum interioris ſuperficiei ED, colluceant, eritque lux ED, tripla lucis, quàm coni radioſi DIA, IBK, EKC, quiſque per ſe habet; nam ſicuti ſe habet 3. ad 1., ita lux DLE, ex tribus conis radioſis compoſita, ad conum KEC, vel DIA, & ſicuti 2. ad 1. ita lux LKE, vel DLI ad DIA, vel EKC, ſimplex coni ſegmentum. Iterum vt 3. ad 2. ita lux DLE, ad ſegmenta DLI, vel ELK. at prior proportio eſt tripla, altera dupla, tertia ſeſquialtera: ergo lux intenditur iuxta multitudinem facum, poſito, quod ſingulæ æqualem habeant à foraminibus diſtantiam, poſitiſq; æqualium intenſionum conis, communis concurſus omnium in luce ſe habebit ad quamlibet illorum vt numerus omnium conorum ad vnitatem. Si verò communis concurſus perforetur, & paulatim à ſe iterum coni diuergant, & ſuo lumine quiſque allabatur in oppoſitum parietem MN, eritque MOP, & QNR, lunula ad ſegmentum PO, QR, vtrinque conuexum ſubdupla; horũ autem vnumquodq; ad cõmune omnibus ſegmentũ PR, ſubſequialterũ.

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Image 4.10 — Engraving of light projected through a camera obscura
Athanasius Kircher, *Ars magna lucis et umbrae* (1646), 125.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

[429] One will notice there are a few minor differences, for instance Kircher's does not depict the projection of light into a box or dark room, as Locher's seems to indicate

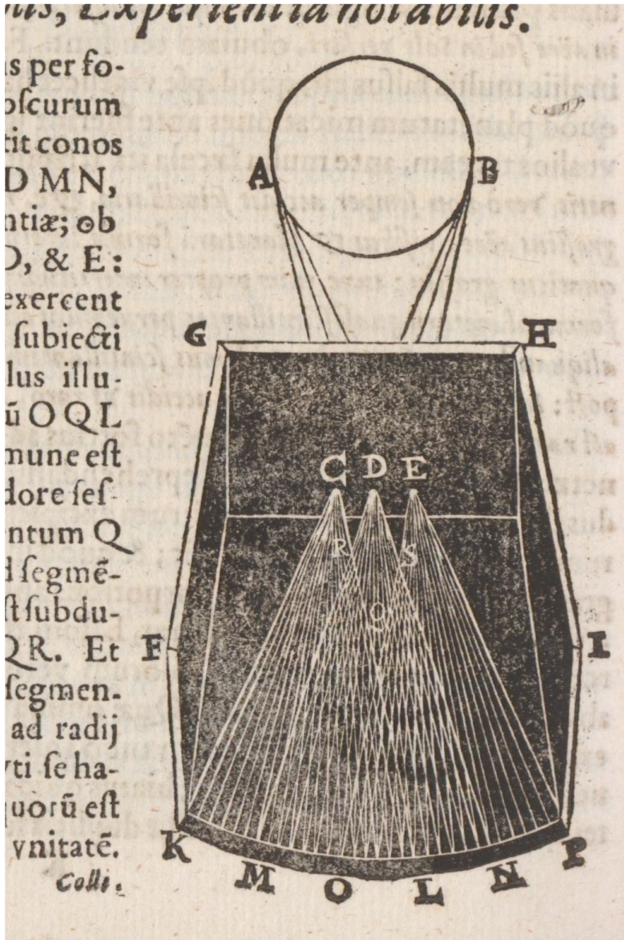

Image 4.11 — The image from the *Disquisitions* is similar to the top image from Kircher
Georgius Locher, *Disquisitiones mathematica*e (1614), 72
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Similar to Bettini in the previous section, among the importance of image projection for Kircher is the way in which it is able to demonstrate the “infinity of species,” which he does through a demonstration with a camera obscura. Fitting the genre of early modern natural magic, included in Kircher’s camera obscura is the projection of the image of a demon. In the demonstration Kircher explains how one could project any object, whether demon, cross, or sundial, through a tiny aperture on the side of a hollow column. The object would then be projected and inverted within the column, as pictured below. He also states that it was clear from this that a transparent medium would be full of the visible object's species.[430] Such a comment was a logical extension of perspectivist optics applied to the camera obscura—if a species could project through one aperture, then theoretically it could project through any aperture. It is worth noting that Kircher explicitly refers to this as a "joke" (ludicra) which is an indication of the explanatory power that he perceived optics to possess.[431]


lupina pelle, vel cauda, manicis, calceisque vngularis; tum is foris meditabundus eo obambulat loco, ex quo suus & color, & figura per vitreum orbem in conclaue transfundi potest. Rebus ita callide comparatis, silentium seuerius indicitur, quasi quispiam proditurus sit è machina Deus. Hic pallere alij, alij sudare metu rei euenturæ. Profertur chartacea tabula, qua opposita lumini, mox Dæmonis obambulantis speciei simulacrum cernunt timidi, intuentur, contemplantur. Ita rudes illi

homines, vt citatus Author, vt vmbram videant Histrionis, operam perdunt, & pecuniam, nihilo profecto infantibus doctiores, qui credunt signa omnia aliena. Lucr. Satyr. lib. 10.

Viuere, & esse homines.

Corollarium Secundum.

Ex his patet, quòd quæcunque de luminis huc vsque actinobolismo dicta sunt, de colorum quoque radiatione sint intelligenda: Sicutienim in lucis

Image 4.12 — Camera obscura experiment
Athanasius Kircher, *Ars magna lucis et umbrae* (1646), 129.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

430 Kircher, *Ars magna lucis et umbrae*, 130: Hinc patet quoque diaphanum quodvis plenum esse infinitis speciebus rerum visibilium.
431 Kircher, *Ars magna lucis et umbrae*, 129.

Similar to Christoph Scheiner, Kircher situates the explanation of visual rays and of the visual species within the nexus of early modern artistic construction, most notably when he addresses optical illusions. Following his explanation of the anatomy of the eye, Kircher addresses various topics relating to anamorphoses and how looking at images from different angles produces different visualized images. Naturally, to explain such experiences Kircher turns toward art to explain. Rather than adopt the pantograph, however, Kircher incorporates the "planum mesopticum," which is a very idiosyncratic term for Kircher.[432] The device, pictured below, was a tool like Scheiner's pantograph, in which one was able to draw a picture more accurately in proper proportion. What one would do is to look through the hole at point G to maintain a consistent line of sight, and then copy what was seen at the proper locations on the canvas stretched within the parallel grid. To make the drawing more precise, one could stretch a string from the object drawn to the picture of it. Among his interesting points is that this device demonstrates the reality of the "visual ray" or the "visual species" (which Kircher seems to equate), all of which is a natural and logical progression from the projection of images and the way in which the anatomy of the eye operates.[433] So, the device itself, reinforces the existence of the species as based upon a singular point and line, aspects which were axiomatic in Scheiner's explanation of vision.

[432] Kirsti Andersen, *The Geometry of an Art: The History of the Mathematical Theory of Perspective From Alberti to Monge* (New York: Springer, 2007), 611.

[433] Kircher, *Ars magna lucis et umbrae*, 172.

Image 4.13 — Depiction of artistic device mesopticom
Athanasius Kircher, *Ars magna lucis et umbrae* (1646), 171.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

This device is also important for Kircher to justify the trustworthiness of visual illusions in the second part of Book ten where he discusses the representation of "prodigious things."[434] It is within this book that Kircher includes the optical trick with the Ascension of Jesus that received so much notoriety on into the nineteenth century. Analyzing Kircher's optical theory in these sections reveal important aspects as to how he understands the role of visual theory in explaining optical illusions.

[434] Kircher, *Ars magna lucis et umbrae*, 799: Magia parastatica, sive de repreaesentationibus rerum prodigiosis.

In the first section on "representations of the air," he begins by identifying the true images in the air—portents by God, such as armies in the sky; meteorological phenomena, such as halos, comets, and crosses; various effects from light, as well as the rainbow.[435] Kircher had already discussed the rainbow and various meteorological phenomena in other sections of the work, and so it is not important for him to establish such principles here. Such explanations of the rainbow, which occur in Book 1, do not differ significantly from traditional perspectivist optical theory in which the coloration of the rainbow is based on reflection of light within the clouds.[436] It is noticeable that the Jesuits were active in the seventeenth century in supporting the defense of rainbows as solely involving the reflection of light, and not in any way involving refraction, an explanation which began to develop during the first decades of the seventeenth century.[437]

Kircher's interest in this section, though, does not pertain to such natural phenomena as rainbows. His goal is to identify the boundary between the miraculous and the natural. To accomplish such a delineation he works systematically through several reports of images cast into the air, demonstrating why certain of them should be considered natural and not demonic or miraculous.

One prominent example pertains to apparitions from the coastal Italian town of Reggio Calabria. Kircher includes a letter from a Jesuit in the area which details several odd images in the air, which the local inhabitants had come to refer to as Morgana. It was well known in this region that various images could suddenly appear in the sky, such as armies, palaces, castles, or

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[435] Kircher, *Ars magna lucis et umbrae,* 800.

[436] Kircher, *Ars magna lucis et umbrae*, 73–74.

[437] Galeatio Mariscotto, *De Iride disputatio optica* (Rome: Jacobus Mascardi, 1612).

even demons.[438] Kircher, however, is quick to explain the various images as being caused either by particularities of the geography (reflective rocks), as well as coalescing of vapors, and reflective clouds.[439] Conceivably, due to the notoriety of the Morgana apparitions, Kircher then analyzes similar images in the air from diverse Jesuit missions: Mauritania, South America, and India. While he is not outright denying the activity of demons to create images, he nevertheless desires to show that "various spectra are not always the illusion of demons."[440] The importance of such an understanding as Kircher identifies is that it helps one to identify the "idols," within these various Jesuit missionary contexts, an identification rife with religious and theological significance as he indicates that the understanding of optics provides an avenue as an apologetic for true religion.[441]

After this he analyzes various representations in nature, such as stones, rocks, or other objects that appear to have crucifixes, the Virgin Mary, or other religious images within them. In this context Kircher returns to the importance of the Mesopticum, as pictured above, so that "it will give an image similar to that object."[442] Among the reasons that Kircher appeals to this device is the way in which it enables one to recreate such images, even those that might be at oblique angles. His example of such an image existing at an oblique angle is an anthropomorphic mountainside that looks like a man's face when turned to the side. Immediately following the

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[438] Kircher, *Ars magna lucis et umbrae*, 800–801.

[439] Kircher, *Ars magna lucis et umbrae*, 802.

[440] Kircher, *Ars magna lucis et umbrae*, 803; varia spectra non semper diaboli esse illusiones.

[441] Kircher, *Ars magna lucis et umbrae*, 803; idolum. Throughout the *Ars magna*, Kircher reserves the word "idolum" for false images.

[442] Kircher, *Ars magna lucis et umbrae*, 809: obiectum dabit imaginem similem illi.

chapter in which he explains how one identifies and recreates images in nature with the Mesopticum, he then explains the way in which one is able to project images with the camera obscura. In the first, one can create a simulacrum, in the second, one can see a species and then transfer such an image onto a paper and thus create a simulacrum.

Within the flow of the section it is difficult not to wonder whether or not Kircher intends to draw a comparison between objects imagined in nature, such as the anthropomorphic land (the center image in Image 4.14 below), and those projected in the camera obscura. Similar to the anthropomorphic land, which is only intelligible when flipped ninety degrees, a species in a camera obscura is made intelligible by also rotating. That such a comparison is warranted may be noticed by the way the imagery of both are included on the same page, an aspect preserved in Gaspar Schott's *Magia universalis*.[443] Such a juxtaposition would naturally make one wonder, what is the difference between a rotated image of a mountainside and a rotated image projected within a camera obscura. But the juxtaposition, left implied, is itself an aspect of the rhetoric of a serious joke. Like the reorientation of the image within the camera obscura and thus within the eye, so also is the reoriented image of the mountainside. Vision may be maintained as long as one approaches it with the proper perspective—or, fitting with the genre of natural magic, if one is led by the wise and is not confused by the common understandings. The nature of vision, with its confused image, provided an emblematic experience itself through which to justify the importance of the mathematician who could resolve such confused vision.

[443] Kircher, *Ars magna lucis et umbrae*, 806.

Image 4.14 — Depiction of camera obscura
Athanasius Kircher, *Ars magna lucis et umbrae*, 807.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

Thus, Kircher's goal in the section on "representations in the air" was to use the knowledge of optics, especially optics informed by seventeenth-century meteorology, to counter popular explanations of image representation. While not categorically denying the possibility that certain images are the product of divine or preternatural activity, he nevertheless uses his scientific prowess to pose questions about the nature of visual experience. Such a context proves helpful in understanding Kircher's explanation of the Ascension of Jesus, an optical trick which not only reveals Kircher's interest in optical illusions but also reinforces the role of serious jokes among the members of the Order since its content matter was anything but funny.

The Ascension of Jesus

It is in Part III of the tenth book that Kircher handles the Ascension of Jesus, in a section that deals specifically with the tricks of catoptrics. In this section he uses the trick of the Ascension of Jesus to counter a widely popular type of trick at the time known as casting images into the air. This particular trick was mentioned in Chapter One as it was also the optical trick that incited the criticism of Johannes Kepler against the natural magician Della Porta. It is clear from the wider context of the Jesuits, however, that Kircher's explanation of images in the air had to present itself carefully. Certain Jesuit theologians and natural philosophers incorporate into their various literature how the cases of images that miraculously appeared in the sky itself.[444] Whereas Kircher sought to temper the widespread recognition of images being cast into the air as a divine or preternatural sign, he nevertheless could not categorically deny it, similar to the images in the air at Morgana and other locations discussed above.

[444] Cornelius Lapide (a theologian) and Nicholas Cabeo (a natural philosopher) demonstrate the way in which the issue was of widespread interest; Cornelius Lapide, *Commentaria in sacram scripturam, Tomos VIII*, ed. Xysto Riario Sfortiae (Naples: Magar, 1857), 88.
Nicholas Cabeo, *In libros meteorologicorum, Tomus Tertius*, 3:223–224; For further indication that "images in the air" was important for the Jesuits see Vermij, *Thinking on Earthquakes*, 105–111.

In this section Kircher aims to counter two quite popular types of casting images into the air, both of which used cylindrical mirrors. The first, which was expounded in Della Porta, involved a misidentification of an optical problem from the perspectivist tradition. In Book 5 of his *De aspectibus*, Ibn al-Haytham poses the following optical question. Provided a cylindrical mirror and two separate points residing outside of the mirror, and provided that the reflection occurs according to the rules of equal angles, such as the angles of incidence are equal, how does one find the point of reflection within the mirror. As the historian A. Mark Smith has shown, despite the relative simplicity of the problem, the actual solution, which al-Haytham provided, is quite complex. Throughout the seventeenth century many mathematicians and opticians actively worked to provide a simpler solution to "Alhazen's Problem" (using the latin West's name for Ibn al-Haytham). The transmission of the optical problem came through many of the other perspectivists, with the thirteenth-century *Perspectiva* by Witello being one of the most important. One of the most articulate answers to the problem within the century occurred through the work of Christiaan Huygens who in 1669 proposed a much simpler solution than that of Ibn al-Haytham.[445] The reformation of the problem in the work of Witelo was the most common adaption of it. This reformulation occurred in Book 7, Proposition 60, where it states the following: "it is possible to set up a convex cylindrical or conical mirror in such a way that someone looking [into it] can see the image of the particular object that is out of sight [floating] in the air outside the mirror."[446]

Essentially following Ibn al-Haytham's solution, Witello adopts a complex series of

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[445] For more details, see A. Mark Smith, "Alhacen's Approach to 'Alhazen's Problem'," *Arabic Sciences and Philosophy* 18, no. 02 (2008): 143–163.

[446] Quoted in Sven Dupré, "Inside the Camera Obscura: Kepler's Experiment and Theory of Optical Imagery," *Early science and medicine* 13, no. 3 (2008), 225.

geometrical figures to explain how to find the reflection point from two defined points of vision. The precise solution is not important at the moment.[447] The important aspect to notice, however, is that it was widely believed in the sixteenth and seventeenth centuries that the perspectivist tradition provided an explanation as to how one was able to cast images into the air, such as what Della Porta says about the experiment.

It is this very textual tradition of casting images into the air that Kircher has in mind when he sets up his optical trick for the Ascension of Jesus, which is the conclusion to a two-part response that Kircher has to this trick of casting images into the air, which Kircher refers to as falsely being used by the impiety of Atheists.[448] Kircher follows an explanation for how the image would be "in the air," similar to what A. Mark Smith identifies. Utilizing a cylindrical mirror, Kircher explains that any image will be perceived as "in the air," provided the image was itself outside the vantage point of the viewer.

> We place a concave spherical mirror of whatever magnitude, and we place it such that it is parallel along the horizontal. Then put a visible object elsewhere from the region of the mirror and our eye, having been arranged in the line of reflection, will see straight ahead the thing erected in the air.[449]

The specific occasion for the Ascension of Jesus is only one occasion for this optical trick. In this trick Kircher suggests placing a flat picture of Jesus on a table, and then a hollow cylindrical mirror above it. When one looks at the mirror, what will become apparent is that

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[447] For a clearer explanation of Alhazen's context and its solution, see A Mark Smith, "Reflections on the Hockney-Falco Thesis: Optical Theory and Artistic Practice in the Fifteenth and Sixteenth Centuries," *Early Science and Medicine* 10, no. 2 (2005): 163–186.

[448] Kircher, *Ars magna*, 897.

[449] Kircher, *Ars magna*, 888: Accipimus speculum sphaericum concavum cuiuscunque magnitudinis, quod ita ponimus, ut situm habeat parallelum horizonti. Deinde e regione speculi alicubi ponatur obiectum visibile, quod oculus noster in linea reflexiones constitutus videbit prorsus in aere erectum.

Jesus appears in the "air" (albeit on the interior surface of the mirror) in a location other than where the original image was located. And due to the reorientation on the interior side of the mirror, it does have an effect of moving upward when one reproduces it.

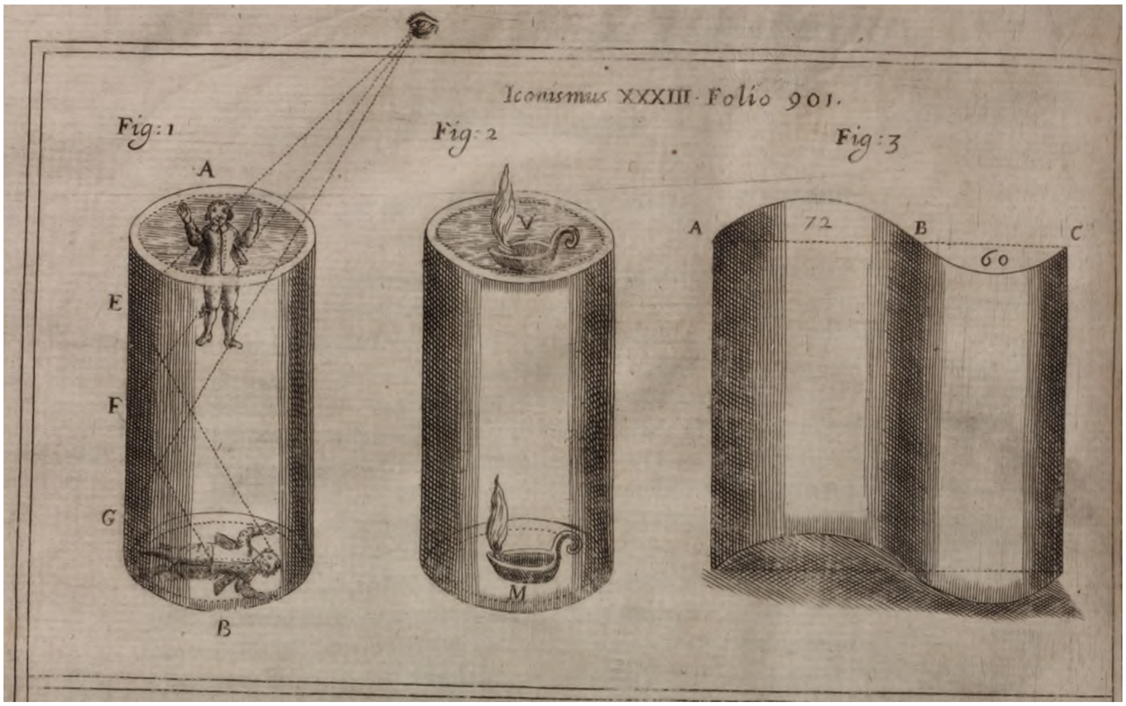

Image 4.15 — Optical trick to portray the Ascension of Jesus
Athanasius Kircher, *Ars magna lucis et umbrae* (1646), 901
Courtesy of The Linda Hall Library of Science, Engineering & Technology

As a summary of his entire excursus into the catoptrical images into the air, Kircher states that such a technique enables one to find the "species" or the "idol" of the image within the mirror itself. Thus, like the meteorological tricks above, Kircher uses the mathematics of optics to counter certain popular conceptions, such as the image in the air trick associated with Witelo noted above, of how one might project and produce visual species. But it also quite clearly demonstrates an important aspect of the Jesuit engagement with optical illusions: they oftentimes created serious optical jokes. The Ascension of Jesus was surely not anything to make light of, and yet it was the representation itself that Kircher selected to demystify a technique in wide circulation within early modern optical contexts.

For the theologian Benito Pereira as well as Martin del Rio and many other Jesuits, the observation of images in the air raised important philosophical and theological question. Records of signs of God's Providence, whether in images cast into the air, rainbows, or other miraculous signs were widely known at the time and oftentimes accepted in the sixteenth and seventeenth century as being theologically legitimate. At the same time, the natural magicians of the period had popularized natural magic to such an extent that it enabled one to turn an ordinary optical experiment, such as a cylindrical mirror and an image beyond sight, into a trick that could be leveraged toward debunking allegedly supernatural phenomena of the divine or preternatural. Kircher would have known this, and as a twist on its seriousness, it is why he used the occasion of the Ascension of Jesus as the topic of his trick. He demystified the unseen by appealing to a very serious theological topic for any Jesuit. It is undoubtedly the oddity that a Jesuit would recreate the Ascension of Jesus that this trick widely circulated into the nineteenth century as being a well-known trick by Kircher.

Gaspar Schott

A contemporary of Athansius Kircher, Gaspar Schott, was deeply inspired by Kircher's scientific and technological. Gaspar Schott was born in Bad Königshofen in 1606, entered the Society of Jesus in 1627, and then died in 1666 in Würzburg. Throughout his life he taught moral theology, mathematics, and natural philosophy, at Palermo, the Collegio Romano, and Würzburg. He also edited several works by Athanasius Kircher, and was the first Jesuit to publish on Otto von Guerike's air pump.[450] Among historians, there is some suggestion that Schott self-identified as a 'disciple' of Agrippa.[451]

An editor of some of Kircher's work, Schott published a comprehensive work on natural magic from the 1657-1659. Organized into four books, with an extended explanation as to the nature of natural magic, Gaspar Schott develops many of the themes in Bettini and Kircher. According to Schott's *Magia universalis*, magical optics was that part of the subject 'in which is examined whatever in this universal science is rare, hidden, prodigious, and paradoxical, and remote from the common notion and use of optics'."[452] While it is oftentimes commented that Schott's book is merely a reproduction of Kircher's there are a few clear differences when considering his first book on optics. One of the clearest is that Schott incorporates important sections not only from Kircher, but also from Bettini (who Kircher never cites).[453]

Schott also provides an important contextualization for the scientific works of Kircher and the importance of the Roman museum as well as the significance of science more broadly for the Jesuits. For instance, it is within Schott's book that one learns of the importance of Kircher's Roman museum in the conversion of Princess Christina of Sweden, the inclusion of which further reinforces the way in which many Jesuits cast the importance of their scientific works

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450 T. F. Mulcrone, "Schott, Gaspar (Kaspar)," in *Diccionario histórico de la Compañía de Jesús*, ed. Charles O'Neill, (Madrid: Universidad Pontifica Comillas), 3531–3532; S. Corradino, "Kircher, Athanasius," in *Diccionario histórico de la Compañía de Jesús*, 2196–2198.

451 Berthold Hub, "Aristotle's 'Bloody Mirror' and Natural Science in Medieval and Early Modern Europe," in *The Mirror in Medieval and Early Modern Cultures Specular Reflections*, ed. Nancy Frelick (Turnhout, Belgium: Brepols, 2016), 61.

452 Schott, *Magia universalis*, 1:15.

453 Schott, *Magia universalis*, 1:142.

within the context of the Thirty Years War.[454] In his section on optics Schott also notes that it was the Jesuits who were the earliest inventors of the telescope, noting a section from Cabeo's *Meteorologica* where Cabeo states that an early telescope was used by the Jesuits in the reading of the book of hours.[455] Whether this statement is true or not is beside the point. Instead, what is important to notice is the interest in locating the Society of Jesus as an important site of scientific development.

Throughout the works, Schott quite clearly evidences focused attempts to incorporate new technologies into principles of physics, a process which, similar to Kircher, he accomplishes through the epistemological category of natural magic. More so than Kircher, Schott spends significant amounts of text identifying the nature of natural magic, saying things like, "This form of magic not only aids, and perfects nature, as the other [mathematical disciplines] do, but clearly overcomes her.'[456] So alongside the presentation of an optical trick, such as an image flying into the air, a camera obscura, or an anamorphosis, Schott intends the reader to interpret the technological, and artificial contrivances alongside the definition of nature and its limitations. Whereas Kircher was often ambiguous as to the philosophical significance of certain experiments and their associated technologies, such as in the mesopticom analyzed above, Schott oftentimes adds an interpretation to add clarity to the philosophical ambiguity that could arise.

When it comes to explaining optics and the way in which vision works, Schott employs a

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[454] Schott, "Preface," in *Magia universalis*.

[455] Schott, *Magia universalis*, 1:27. Such a statement is also found in Cabeo.

[456] Quoted in Anthony Grafton, "Renaissance Histories of Art and Nature," in *The Artificial and the Natural: An Evolving Polarity*, eds. Bernadette Bensaude-Vincent and William R. Newman (Cambridge, MA: MIT Press, 2007), 201; Cf. Gaspar Schott, *Magia universalis, Volume Three* (Bamberg: Schönberg, 1677), 211.

variety of terms in a manner that suggests an equivocation. He affirms the visual species as the projection within the eye while at the same time indicating that this is sometimes referred to as the visual ray.[457] In another location when delineating between the intromission and extramission of visual rays Schott refers both to the way in which this represents a "species" as well as a "picture," an equivocation that does not necessarily deny the significance of the species but which nevertheless indicates that what was most important was the fact than an object could be represented, rather than its particular philosophical meaning.[458]

The clearest indication that Schott gives regarding the equivocation between the terminology involved in what was visually seen, occurs in a later section on catoptrics. Like Kircher, in this book Schott handles the various ways in which an image may be reflected in a mirror in such a way that makes the observer think they are encountering some sort of prodigy. So it is within this Book that Schott will eventually address the optical trick of the Ascension of Jesus that Kircher had identified. In the earlier sections where Schott presents the theory of catoptrics he clearly separates the species from the object in a mirror. As he states, "the object is in the mirror, the species are not seen in a mirror. You are able to see the object, but not where it is located."[459] More so than the previous authors analyzed in this chapter, what Schott recognizes here is the ambiguous identification of the image, whether the image is the one projected within the mirror or the one from which such a reformed image is derived. Important in his explanation is the fact that in looking at a mirror one does not see an "idol," but sees the object. Rather than try to determine where the species is located, Schott affirms the more important aspect, the

[457] Schott, *Magia universalis*, 1:68.

[458] Schott, *Magia universalis*, 1:86.

[459] Schott, *Magia universalis*, 1:253.

reformed "object" in the mirror is ultimately the goal of the trick.

Recall from the previous chapter that the theologian Lapide drew upon an analogy with a mirror to justify the existence of the visual species. It is within this context that many of the Jesuit authors operated. The role of the mathematicians was to use their skill to support certain philosophical interpretations. The equivocation of terminology among the Jesuit authors, particularly Kircher and Schott, suggests that they were not entirely sure where the boundaries were for their mathematical knowledge. Did it provide knowledge of the species? The picture? Something else? In the wake of such uncertainty they very subtly transitioned toward identifying their role as focused upon the maintenance of the visual object, sidestepping other more precise philosophical distinctions. This did not mean that it was not possible for one to still use the visual species, after all these authors utilize it with noticeable consistency. But that the goal was to support the understanding of the visualized object, a delineation which demonstrated their craft and the way in which it separated the wisdom of mathematics from the common comprehension. That the interpretation and experience of catoptrics separated the wise from the unwise may be noticed in one of Kircher's and Schott's more humorous optical machines, the catoptrical theatre.

Catoptric Cats

In Athanasius Kircher's museum there was an optical trick which allowed one to cast images into the air. The trick, titled *Theatrum Catoptricum*, was a display of mirrors in the form of an amphitheater, with individual mirrors surrounding the interior of the amphitheatre. The catoptrical theatre was a small theatre, positioned on a table, such that one could stand on the outside of the theatre and look into the image reflected. It is depicted in Figure VI below. As Kircher explains, one could place an object within the amphitheater and actually see the various “species” as they were projected in the mirrors. The Jesuit Georgius de Sepibus, who lived in Rome with Kircher and who catalogued the items within Kircher’s museum, says that what this particular experiment demonstrates is an “an infinite space.”[460] De Sepibus also says that in the catoptrical theatre “your eye, deluded by such a labyrinth, thinks it is within an infinite space and fields,” an aspect that is so “convincing” that it escapes the endless disputes introduced by the disputations of the physicists.[461] Among the rhetorical points that De Sepibus aims to articulate with respect to this particular trick is the contrast between the experiment with the catoptrical machine, which clearly demonstrates the nature of infinity and other abstract philosophical concepts, with the seeming infinity of discourse that may occur in a traditional scholastic disputation.[462]

[460] De Sepi, *Romani Collegii Societatis Jesu Musaeum celeberrimum*, 36: infinitum actu spatium.

[461] De Sepi, *Romani Collegii Societatis Jesu Musaeum celeberrimum*, 37: Ut oculus tuus tali labyrintho delusus in infinituum spacium, & campos protratum se lutet.

[462] Waddell, *Jesuit Science*, 112–116.

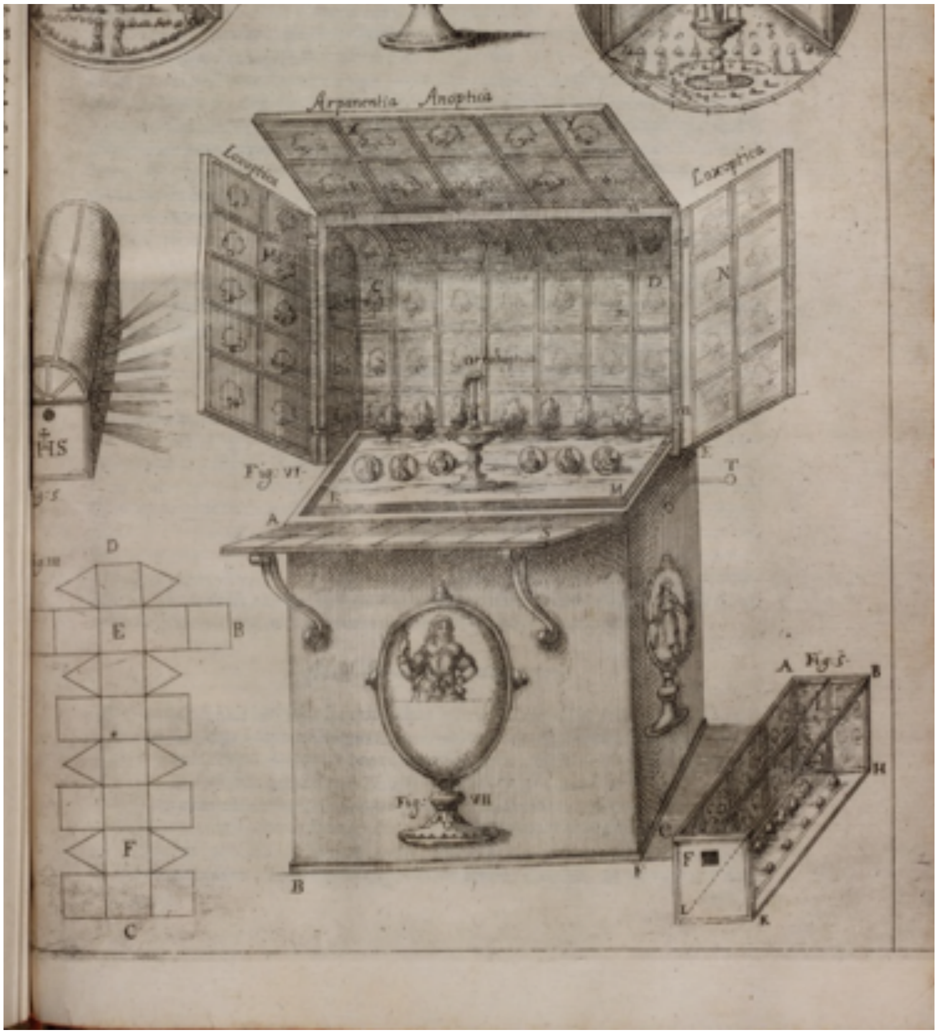

Image 4.16 — Theatrum Catoptricum
Kircher, *Ars magna lucis et umbrae* (1646), 892.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

If one limits their analysis of this machine to De Sepibus, however, one misses an important feature of this machine—the particular objects that Kircher would include in the machine, whether a tree, rock, piece of bread, or even a cat. As Kircher narrates in his *Ars magna* if one places a live cat within the theater one will notice many antics:

> While the cat sees himself to be surrounded by an innumerable multitude of cats, and he values them to be real, it can with difficulty be said how many jokes the cat exhibits in this theatre, while he sometimes attempts to follow the other cats, sometimes to entice them with his tail, sometimes attempts a kiss with its own mirror image, than attempts to

> break through the obstacles in any manner attacking with his claws, so great is its desire that he may be joined together with those other cats. It declares so clearly with various voices, and miserable cries as indication of his various affections, of indignation, rage, jealously, love and desire. It may be said similarly with respect to other animals.[463]

Besides the humorous experience of watching a cat within the theatre, Kircher is trying to claim something much more about the nature of catoptrics, the visual species, and human interaction. Visual perception involved one's disposition. When considering a similar account of the cats' interaction with the optical theatre provided by Kircher's contemporary Gaspar Schott, the contemporary historian Michael Gorman argues that what Kircher and Schott intend to convey through this device and the experience is that the act of optics was itself an act of civilizing (or de-civilizing). Gorman's argument follows the research of Robert Darnton on the torment of Parisian cats, who suggested that the act of tormenting cats was an exercise of class distinction and superiority. Although in this situation Kircher is not slaughtering the cats, he is similarly, suggesting that the catoptric machine (and his optical machines more broadly) create a form of control. They cause the cat to respond with respect to its innate instinct—or as Gorman puts it, the cat's "passions."[464] Just as the cat acts according to its instincts, so also do humans. Thus, the *Theatrum Catoptricum*, and many of Kircher's other mathematical machines, were intended to train individuals' desires—or as Gorman contends, to civilize.[465]

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463 Kircher, *Ars magna lucis et umbrae*, 894: dum enim innumerabili sese hinc inde Cattorum multitudine stipatum videt, verosque esse putat, dici vix potest, quantum iocorum in hoc theatro exhibeat cattus; dum illas nunc assequi conatur, modo cauda abbladiri, nunc oscula proprio simulacro figere, iam obstacula omnibus modis effringere, nunc unguibus impetere; quanto denique desiderio illis coniungi desideret; voce varia, & miserabili gemitu variorum affectuum, indignationis, rabiei, zelotypiae, desiderij, amoris indice, satis declarat. Idem de caeteris animalibus dicendum.

464 Gorman, *The Scientific Counter-Revolution*, 221.

465 Gorman, *The Scientific Counter-Revolution*, 224.

If one uses Gorman's assessment of the *Theatrum Catoptricum* as representative of the Jesuits, natural magic, and optical illusions more broadly, then what one may argue is that the degree to which one understood the illusion had to do with their own disposition. If one believed in the existence of the visual species, they could be seen easily enough reflected within the mirrors. Armies could even be cast into the sky, which is the trick that Kircher includes just before that of the cat on the theatre stage. Yet the believability of it depended on something other than that of mathematical proof or even mechanistic instrumentation. It depended on one's own passions and how one responded to such illusions. To reinforce this idea it may be noticed that throughout Kircher's *Ars magna* he returns on occasion to the question as to what forms an individual's imagination, whether it be the influence of the mother on the fetus or whether it is determined by one's temperament, whether melancholic or sanguine.[466] In that regard, the response of the cat to the machine is very much driven by the cat's disposition.

Conclusion

Regarding whether the production of optical illusions by members of the Society of Jesus contributed to the demise of their Aristotelian natural philosophy, as Stuart Clark and Lyle Massey contend, one may turn toward Gorman's analysis for insight. The rhetorical argument built within Bettini, Kircher, Schott, and many other Jesuits wasn't that the amassing of optical illusions brought about an end to their Aristotelian natural philosophy, but that it was only the wise who could understand. This was the rhetorical role of natural magic among the members of the Society of Jesus, and it was the role of a serious optical joke. It wasn't merely smoke and mirrors, but rather, in some real sense their engagement with optical illusions preserved an

[466] As one example see Kircher, *Ars magna lucis et umbrae*, 521.

underlying Aristotelianism. Whether or not this was philosophically coherent, at least by contemporary standards or by the standards imposed by Descartes or other theories of knowledge in the seventeenth century is not relevant to the issue. Rather, relying upon the social and intellectual construction of serious optical jokes, the members of the Jesuit Order advocate for the maintenance of the important philosophical aspects of perspectivist optics, especially those which preserve the important components of their Aristotelian natural philosophy.

A second observation may also be gleaned from this chapter. Bettini, Kircher, and Schott used the identification of a single point—whether from the reformed image of an anamorphosis such as with Bettini, or from Kircher's artistic device—to reinforce the existence and maintenance of the visual species. So, similar to the analysis of Scheiner in Chapter Three, the fact that an optical illusion was intelligible from a single point was interpreted along the same lines as standard perspectivist optics in which it was a single point which sustained an intelligible visual encounter. Whether or not such explanations were philosophically rigorous or beyond criticism from contemporaries was not important in its explanation. What was significant was demonstrating the possibility of optical illusions being in accord with perspectivist optics. By demystifying the various tricks of the eye it became possible to maintain visual truthfulness. This activity, which weaves together both art and science in the middle of the seventeenth century, also counters claims for the separation of the two subjects during the period under investigation. Such an element reinforces a recent trend within the history of early modern optics in which the practice and theory of optics become intertwined together.[467] Rather, what is important to notice

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[467] Sven Dupré, ed. *Perspective as Practice*. Such a work intended to critique the overt reliance on symbolism within perspective, characteristic of Erwin Panofsky as well as the focus on theory along, such as in the work of David Lindberg. Erwin Panofsky, *Perspective as Symbolic Form,* trans. Christopher S. Wood (New York : Cambridge, Mass.: Zone Books; Distributed by the MIT Press, 1991); David C Lindberg, *Theories of Vision From Al-Kindi to Kepler* (Chicago:

is that such explanations were deemed useful for mathematicians in their support of a mathematically informed philosophy of optics.

University of Chicago Press, 1976).

CHAPTER FIVE
THE CONFESSIONALIZATION OF LIGHT

"I see that I will not be able to publish my study on colors…because of the rigorous orders made."
—Orazio Grassi, 1652[468]

The focus of optics among members of the Society of Jesus underwent a transformation in the second half of the seventeenth century. Whereas the inherited perspectivist optics with its close allegiance to Aristotelian natural philosophy possessed as a fundamental goal the explanation of sight, by the seventeenth century it is noticeable that many Jesuit authors pursued lines of explanation regarding the nature of light, irrespective of its utility in explaining sight. As the current historiography attests, such a transformation of optics from 'sight' to 'light' is not something unique to the members of the Society of Jesus, but was an interest much more broadly held by many early modern opticians.[469] Thus, the fact that many members of the Jesuit Order shifted their attention to light is not a new or significant observation.

As this chapter argues, the shift from sight to light was a confessionalized process—important philosophical and institutional aspects of the Jesuits shaped the way many members explained the nature of light. Aspects of confessionalized optics have already been identified in the preceding chapters. In the intermingling of optical theory and religious and political identity, the selection of images for optical experiments, as well as in the explanation of the Eucharist, it was noted that these topics illustrate the way in which members of the Society of Jesus adapted

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[468] Statement made by the Jesuit Orazio Grassi, quoted in Mordechai Feingold, "Jesuits: Savants," in *Jesuit Science and the Republic of Letters*, ed. Mordechai Feingold (Cambridge, MA: MIT Press, 2003), 21.

[469] Smith, *From Sight to Light*.

optical theory in ways that cohered with their Counter-Reformational identity. Many of these interests were not unique to the Jesuits but were indicative of the broader sensibilities in visual culture absorbed by the Jesuits as part of the Catholic Counter Reformation. So, while this study has focused on the way in which confessional interests came to be commingled with optical theory, it should be noted that certain topics in the preceding chapters would have overlapped with other Catholic Orders in the early modern period.

The transformation of optics into a study of 'light' fits the overall trend of confessionalization, but it is here that one may find the Jesuits at times parting ways from other Catholic Orders, suggesting that the explanation of light was a much more identifiable 'Jesuit' feature. The impetus for this was experimentation with the barometer and the air pump which forced one to either say that light was a substance, as some Catholics did, or to say the experiment was not clear and that it required reason to understand the seemingly inexplainable—the position nearly all Jesuits took. Understanding the way in which the Jesuits developed their explanations of light provides an occasion to understand the fundamental shifts occurring with respect to the boundaries of optics among the members of the Society of Jesus, and to do so in such a way to appreciate the complexities of early modern confessionalization. Rather than understanding such aspects as detrimental, or potentially restricting optics in the seventeenth century, this chapter aims to use the occasion of those experiments to explain the response of the Jesuits as an aspect of confessionalization. Such a heuristic not only traces the path many members carved in response to the changing concepts of optics in the middle of the seventeenth century, but it is consistent with the preceding chapters, in which the Jesuits are used as an alternative story to the prevailing narratives of the Scientific Revolution. Before addressing important aspects of the transformation of optics from 'sight' to 'light' among the Jesuits, it is important to first clarify why light was a topic of confessionalization.

Confessionalization and the nature of light

Optics, and the explanation of light more broadly, came to be connected to important aspects of confessionalization in the early modern period. Because prior to the early modern period optics had as its goal the explanation of sight, and cognition itself, the categories and optical terms show up at interesting points within the rhetoric of the Reformation and Counter Reformation. For instance, in 1553 the future Bishop of Gloucester, Richard Cheyney (1513–1579), in a speech before the assembled lords in London, said, "What could it mean…for them to ride forty miles during the day and 'not be able to say at night, that they saw their horses all the day, but only the colour of their horses' or for Christ not to have seen Nathaniel under the fig-tree but only 'the colour of him'?"[470]

Cheyney, an Anglican priest, was the first Elizabethan bishop of Gloucester and an outspoken advocate of Protestantism. The broader context of his speech was his refutation of the Catholic doctrine of the Eucharist, pointing out the illogicality of saying they saw not the actual bread and the wine after the consecration, but only the color of the bread and the wine, as the strict explanation of the Catholic doctrine of transubstantiation implies.[471] It is notable, then, that Cheyney's critique is couched within the language of perspectivist optics and Aristotelian natural philosophy. His exaggerated point argues the ludicrousness of this theory of vision and how, according to the principles of perspectivist optics, one cannot say that they actually see anything in itself.

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[470] Quoted in Clark, *Vanities of the Eye,* 184.

[471] Clark, *Vanities of the Eye*, 184.

The Jesuits, who maintained the traditional views of optics, would have been among the targets of Cheyney's. And so, as the philosophical curriculum progressed throughout the seventeenth century, it would have been philosophically important for Jesuit authors to uphold perspectivist optics because of its theological significance in the confessional debates. Various aspects of this have already been discussed in previous chapters, particularly Chapter Three, in which the experience of mirrors provided a persuasive demonstration for the reality of the visual species, and as a consequence supported the Catholic doctrine of the Eucharist. More broadly in that chapter it was noted that the Jesuits largely adopted Kepler's optical theory, albeit with slight modifications. What is yet to be clarified is how the Jesuits interacted with shifting theories of light, an important feature of Kepler's optics which did not contribute to as fundamental optical reform for the Jesuits as it did for Kepler.

One of the earliest explanations of the nature of light within a Jesuit text comes at the end of the sixteenth century as they were establishing their philosophical curriculum, in chapter seven of the Coimbran commentary on Aristotle's *De Coelo*. The text itself evaluates the degree to which light (lux) was a material composition and the degree to which it was of divine origin. The author's insistence on the instantaneous propagation of light and his differentiation between celestial and terrestrial light ultimately negates the suggestion that light could be a material substance. Among the points used to negate this idea is the fact that if light were a material substance then celestial bodies would eventually be extinguished.[472] From this it is clear that the nature of light followed from philosophical ideas in Aristotelian natural philosophy, and that the nature of light is a necessary tool without which vision itself is incomprehensible.

[472] *Commentarii College Conimbricensis, In quatuor libros De Coelo* (Cologne: Lazari Zetzeneri, 1599), 313–340.

A similar point may be noticed in the fourth book of Christoph Scheiner's *Rosa Ursina*, where he responds to various criticisms regarding his cosmological conceptions, such as the fluid heavens, and responds to a question as to whether "light is real." Towards the beginning of the section he responds to a question "whether light might appear to the eyes in abstract."[473] The point he wishes to address is whether or not it is possible to see light without an object to be seen. His response to it involves the role of light in making the Eucharist visible, which is to be expected, but also generally the role of light in making anything in creation visible and thus knowable (cognoscit). Scheiner's response is very traditional according to Aristotelian natural philosophy, as explained in Chapter One, with the delineation between the two types of light, both lux and lumen. What is intriguing in his response, however, is the way in which he implies the axiomatic status of light as something which is logically necessary for visual knowledge itself. Light must exist in order for vision to occur. Such a statement naturally follows from the perspectivist theory of optics, since the encounter between the eye and the object necessitates the movement of the species through a medium rendered transparent by lumen, which itself could not be a substance. Very broadly, then, Scheiner was not being creative in such an explanation of light but was reiterating a similar perspective as laid out in the Coimbran commentary on Aristotle.

From these few examples it is possible to see the uniform commitment to the standard view of light within key texts at important stages of the Jesuit intellectual development. And, even though certain Jesuits began to experiment with light, such as with burning mirrors, the explanations are nevertheless uniform in that light was not a substance. In parallel fashion, and with implications for the explanation of light, Jesuit mathematicians also adamantly supported

[473] Scheiner, *Rosa Ursina*, 614: An lux in abstracto oculis pateat?

the continuum and opposed the indivisibles. The continuum as it related to perspectivist optics, was the medium rendered transparent by lumen between the eye and the object which allowed for actual sensation between the eye and the object. The indivisibles, or atomism, introduced theories of matter which allowed for small light particles and which implicated the whole existence of the continuum. Both of these topics, the continuum and the indivisibles, were topics discussed in both physics as well as mathematics, and which raised problems for the Aristotelian informed perspectivist optics that the Jesuits maintained, and for the transubstantiation view of the Eucharist.[474] In 1606, 1613, and 1615, certain Jesuit Revisores (censors) outlawed the philosophical view that the continuum was composed of finite parts, and thus an atomistic view of the continuum, because it was contrary to acceptable philosophical instruction.[475]

It is for these reasons and others that optics proved such an important topic for the Jesuits, and motivated confessionalized responses. At the middle of the seventeenth century one experiment challenged the axiomatic status of optics, using the air pump and barometer. The barometer and the air pump suggested that light was a substance, and not an accident. Since light was shown to exist in an evacuated space, it could not be an accident; after all, the evacuated space contained nothing of which it could be an accident. Sometime between 1641 and 1643 the Italian intellectual Paul Causato performed an experiment with the barometer for the French Minim Emmanuel Maignan and the Jesuits Athanasius Kircher and Nicholas Zucchi. Inverting a glass tube filled with mercury in a mercury bath, what they saw at the top of the tube was evacuated space without the mercury, and yet light remained. According to Aristotelian theories

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[474] For a background of the whole topic, see Amir Alexander, *Infinitesimal: How a Dangerous Mathematical Theory Shaped the Modern World* (New York: Scientific American, 2015); Catholic Physics, 47-48; Phillips, “John Wyclif and the Optics of the Eucharist,” 245–258.

[475] Alexander, *Infinitesimal*, 121–122.

of light, this was impossible.[476]

In response to this the Jesuits Kircher and Zucchi as well as some of their fellow confreres adamantly opposed the idea that this experiment determined that light was a substance. The Minim Maignan as well as his friend the Capuchin Valeriano Magni came to recognize this as demonstrating that light was indeed a substance. While Magni himself was not blind to the philosophical difficulty of the experiment. His treatise *De Luce mentium et eius imagine* (1643), reads as an extended treatise on the way one may maintain cognition in the absence of Aristotelian views of light. He nevertheless repeatedly attacked the Jesuits in his later scientific works for their repeated insistence that light was an accident.[477] In a book he published in the 1660s, while he was in the midst of his dispute with the Jesuits, he even complained that the Jesuit mathematicians, such as Kircher and Scheiner, are able to create any meaning from any topic, a statement which undoubtedly refers to the way they would utilize natural magic to manipulate the philosophical meaning of a mathematical topic.[478] Each side developed their own experiments to support their view, most notably with Kircher attaching a bell within the evacuated space to demonstrate the existence of air based upon the presence of sound.[479]

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[476] On the interpretation of the Minim Maignan to the barometer experiment, see Gorman, *The Scientific Counter-Revolution*, 127–128.

[477] Valeriano Magni, *De Luce mentium et eius imagine* (Antwerp: Hieronymus Verdussen, 1643).

[478] Valeriano Magni, *Christiana et catholica defensio adversus Societatem Jesu* (1661), 103–106.

[479] What is significant to note, as Michael Gorman shows, is the way the dynamics between Magni and the Jesuits reveal significant aspects of European politics in the aftermath of the Thirty Years' War, the most notable moment being when Pope Alexander VII imprisoned Magni in Vienna for his explicit and consistent criticism of the Jesuits and the barometer. In Gorman's assessment, what this episode indicates is the way in which the philosophical expositions of the continuum, the topic of which impinged on the nature of light, threatened the institutional position of the Jesuits in seventeenth century Europe, particularly at a moment when the

From this it becomes clear that maintaining the traditional Aristotelian theory of light was the main goal of the Jesuits. It should be noted that alongside this certain other Jesuits questioned how biblical passages affected the explanation of light — such as God within the pillar of fire from the book of Exodus or God (conceivably) within the fiery furnace from the book of Daniel — but biblical texts do not provide significant frameworks for explaining the nature of light or its religious significance.[480] By and large, the biblical texts appealed to within the optical texts, as well as select others found within this study, either referred to light for its metaphorical significance or used the biblical texts to support the already established theories of Aristotelian natural philosophy and so was not a textual source to challenge the accepted theories of light.

Provided the importance of maintaining the traditional Aristotelian view of light, it is important to consider what strategies the Jesuits used to uphold this view of light. One of the more interesting ones is the way certain Jesuits used the explanation of magnetism to maintain the nature of light.

Light and Magnetism

One unexpected part of the transformation of light among the members of the Society of Jesus, is that it was communicated in relationship to the nature of magnetism. Magnetism in the early modern period involved practical, philosophical, and rhetorical importance. Practically, it was important because of the issue of magnetic declination—or the variations of the magnetic

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hegemony the Jesuits had established in the first half of the seventeenth century began to decline; Gorman, *The Scientific Counter-Revolution*, 127–141.

[480] For the significance of the Exodus account on the nature of light see Aguilonius, *Opticorum libri sex*, 421–422; for the importance of God in the fiery furnace see Libert Fromondo, *Meteorologicorum libri sex* (Antwerp: Plantin, 1627), 82.

compass—and the way in which the resolution of the magnetic declination problem proved important for establishing political boundaries, such as the oversea boundary dispute between Spain and Portugal in 1494 which led to the Treaty of Tordesillas. Magnetism also involved important scientific questions difficult to determine and captured the attention of many in the sixteenth century. For instance, there was widespread dispute as to the source of the magnet's power. Ficino located it in Ursa Minor; Cardano within a star in Ursa Minor's tail; and Francesco Maurolyco thought that there might even be an island on the pole toward which the needles pointed.[481] While these theories ultimately proved unattractive for many, largely on account of the influence of William Gilbert's *De Magnete* (1600) which argued that the earth itself was the source of magnetism, they ultimately created a context in which magnetism was of widespread popular interest in the seventeenth century.[482] As a consequence the idea of magnetism in this period provided an attractive rhetorical platform for the articulation of philosophical ideas, such as has been noticed among the members of the Royal Society as well as the Mechanical Philosophers. What has not received enough attention is the way in which the members of the Society of Jesus also utilized magnetism to articulate important philosophical and scientific points, particularly the nature of light.[483]

Historical scholarship has known for some time about the influential role of William

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[481] Stephen Pumfrey, "O Tempora, O Magnes!: A Sociological Analysis of the Discovery of Secular Magnetic Variation in 1634." *British journal for the history of science* 46 (1989): 190–191.

[482] On the influence of Gilbert see Christoph Sander, "Magnetism in Renaissance Science," in *Encyclopedia of Renaissance Philosophy*, ed. Marco Sgarbi (Cham: Springer International Publishing, 2018), 1–6.

[483] The closest is Martha Baldwin, although she does not specifically address the interplay between magnetism and light, Martha Baldwin, "Magnetism and the Anti-Copernican Polemic," *Journal for the History of Astronomy* 16 (1985): 155–174.

Gilbert and Giambattista della Porta in the development of the science of magnetism. More recently, however, it has been determined that both Gilbert and Della Porta drew upon the work of the Jesuit Leonardi Garzoni (1543-92). While the Jesuits Niccolò Cabeo and Niccolò Zucchi both attest to the influence of Garzoni's magnetic investigations on Renaissance philosophers, notably Gilbert, Della Porta, and Paolo Sarpi, it has only been since the discovery of Garzoni's manuscript, *Due trattati sopra la natura, e le qualità della calamita*, in 2008 by Monica Ugaglia that it has been possible to ascertain the influence of Garzoni, and the Jesuits more broadly, upon early modern magnetism.[484]

As Ugaglia relates in her investigation of Garzoni's manuscript, while Garzoni draws upon a diverse array of sources, the two that provide the greatest influence are Petrus Peregrinus's *Letter* on the magnet, and the tradition of the perspectivists, notably Grosseteste's theory of light, John Pecham's *Perspectiva communis*, Henry of Langenstein, and Themo Judaeus.[485] Garzoni's explanation of magnetism utilizes the philosophical framework of the perspectivist tradition, particularly the way in which, similar to light, magnetism was a real quality, whose essence was carried virtually through the medium.[486] The philosophical question called the action-at-a-distance problem stands among the reasons that the Jesuits used magnetism to explain optics.

Among the Jesuits who focused the most on magnetism was Athanasius Kircher. Kircher used the study and explanation of magnetism for strategic geographical mapping, reinforcing the

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[484] For instance Garzoni is mentioned here, Heinz Balmger, *Beiträge zur Geschichte des Erdmagnetismus* (Aarau: Sauerländer 1956), 253.

[485] Monica Ugaglia, "The Science of Magnetism Before Gilbert: Leonardo Garzoni's Treatise on the Loadstone," *Annals of Science* 63, no. 1 (2006), 68.

[486] Ugaglia, "The Science of Magnetism Before Gilbert," 69.

way that the Society of Jesus functioned like an organized scientific society during the seventeenth century. Kircher's interest and efforts with respect to magnetism are most clearly recognized in his efforts in coordinating the magnetic geography. During the 1630s and 1640s Kircher planned to carry out his "Geographical Plan" by utilizing the widespread networks of the Jesuit missionaries to reform geographical knowledge as well as resolve the practical problem of calculating longitude while at sea. Kircher knew the current knowledge of magnetic declination would not resolve the issue of longitude, an observation well know at the time. Yet, he believed that if he was able to acquire enough specific observations scattered throughout the globe, that he would figure out a way to use magnetic declination to calculate more accurately the precise longitudes.[487] A global Society provided him the opportunity to acquire such data points. Basic use of the sundial and compass were essential for any Jesuit engaged in missionary work, and so it was already necessary for missionaries to acquire the mathematical skill to record the data Kircher desired.[488]

Until recently the extent of the magnetic instruction among members of the Jesuit Order has been difficult to judge, largely because the work that Kircher had put into the magnetic map was stolen in 1650 and thus what survives are loose notes. However, the historian Augustín Udías has recently gathered the surviving notes sent to Kircher from Jesuits in their diverse contexts and mapped them across Europe, the Mediterranean, India, and China, throughout the Atlantic, as well as near the Cape of Good Hope. Through such a reconstruction and the corresponding history of the Jesuits who would have been involved within such a coordinated

[487] Agustín Udías, "Athanasius Kircher and Terrestrial Magnetism: The Magnetic Map," Journal of Jesuit Studies 7, no. 2 (2020), 172–174.

[488] John Michael Gorman, "The Angel and the Compass," in *Athanasius Kircher*, ed. Findlen, 239–259.

effort, what becomes evident is that the members of the Jesuit Order simultaneously used the globalization of their mission to map the magnetic declination as well as reform certain aspects of early modern mapmaking as well.[489]

The interrelationship between light and magnetism received its greatest recognition through the work of Athanasius Kircher. That Kircher adopted magnetism as an important intellectual topic may be noticed by the significant revisions he made to his publication on magnetism, *Magnes; sive, De arte magnetica*, first published in 1641, and then subsequently in 1643 and 1654. According to the historian Mark Waddell, the comparative revisions which Kircher made within the book indicate his care and interest in the nature of magnetism. In fact, in Waddell's estimation, Kircher created an entire worldview centered on magnetism and it was noticeable that many of his tricks in the Roman Museum depended on a magnet to deliver the prestige.[490] It should not be surprising, then, that when Kircher later wrote on light, in 1646, that he located the nature of light with respect to magnetism.

At key locations in his optical and magnetic works, Kircher makes jovial rhetorical appeals to the mysterious relationship between light and magnetism, a rhetorical move coherent within his Baroque context. As he states in the *Ad Lectorem* to his work on optics, the *Ars magna lucis et umbrae* (1646), part of the reason for the use of the word "great" pertains to its close linguistic proximity to the word for magnet, "magnes."[491] In Kircher's *Magnes* he identifies a *Catoptrica Magnetica*, in which, "by a certain disposition of mirrors, reflected and multiplied

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[489] Udías, "Athanasius Kircher and Terrestrial Magnetism," 166–184.

[490] Waddell, *Jesuit Science*, 119–135.

[491] Kircher, *Ars magna lucis et umbrae* (1646), Ad Lectorem.

images exhibit diverse and joyous spectacles of things caused by means of magnetic motion."[492] In a technique that reinforces the playful interplay Kircher pursued between light, optics, and magnetism, in Kircher's *Ars magnes* he explains how one may use hidden magnets to cause an object to move and that for the spectator the cause of the movement would be otherwise unknown. It involved catoptrics because one should place the statue within a catoptrical theatre, like the one described in Chapter Four of this dissertation. The effect is that one would see the images reflected in the mirrors, which are in themselves 'image in the air.' So, while the magnet was itself the hidden mechanism of the statue's movement, the spectator's imagination is drawn to the constantly shifting images in the mirrors, which in themselves reminded the viewer of "innumerable species of itself in fragments of the mirrors."[493]

Yet, for Kircher, the interrelationship between light and magnetism was more than a humorous comparison. It found expression through the Bologna stone. First discovered in 1603 near the town of Bologna, the stone was a luminescent rock that continued to shine radiantly at night after being exposed to the sun all day. The rock provided an important occasion for the study of the nature of light and was among the objects woven into early modern investigation of light. For some, such as Galileo, this suggested that light was itself a substance, composed of "atoms," since this rock seemed to absorb light, and yet it would wane throughout the day.[494] In his defense that the Bologna stone, and light more broadly, was not a substance, Kircher appeals to the magnet's nature to explain the stone's operation and in the process upholds the nature of

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[492] Kircher, *Ars magnes* (1643), 363: Qua certa speculorum dispositione imagines reflexae; & multiplicatae motu Magnetico varia iucundaque rerum exhibent spectacula.

[493] Kircher, *Ars magnes*, 364: innumeras sui species in speculorum fragmentis.

[494] Kircher, *Ars magna lucis et umbrae*, 27.

light as well. Just as the magnet emits a quality into iron, so also is light absorbed into the Bologna stone. As he notes, "indeed it [magnetic force] can be transferred from the magnet into the iron… similarly, this stone [the Bologna stone] draws the light by that reason."[495]

It is beside the point whether Kircher's explanation of light and magnetism proved persuasive at the time. What is important to notice is that Kircher readily borrows from the nature of magnetism to communicate the nature of light. Such a connection, as shown here, was not something idiosyncratic of Kircher but part of a much wider cultural and conceptual interest in links between light and magnetism on the part of the Jesuits. The nature of magnetism could be used as a way to defend the traditional nature of light. In Volume One of his *Optica philosophia* Zucchi identifies how his intention was never to publish his optical investigations, but that certain "recent" developments indicated the importance of publishing his work.[496] Although Zucchi does not explicitly mention the driving issue, one may infer from the wider context that it was the events of the barometer, air pump, and *the Ordinatio pro studiis* (discussed below) that motivated the publication of Zucchi's work.

Just prior to the publication of this book Zucchi had played a prominent role in the consolidation of the Jesuit opinion that the barometer and the air pump did not involve a vacuum. As Michael Gorman contends, Zucchi was the author of a very well-known anonymous letter in 1648 which had a wide circulation and which reinforced among his uncertain Jesuits the idea that these experiments did not demonstrate the existence of a vacuum. An interesting aspect in this letter is the description of various experiments he personally conducted in a cave, the

[495] Kircher, *Ars magna*, 27: etiam magneticam vim corpus esse; siquidem transferri potest ex Magnete in ferrum…hunc lapidem ea ratione lucem trahere.

[496] Zucchi, *Optica philosophia, pars prima* (1652), 7.

conclusions of which go against the interpretation that the barometer and air pump imply the existence of a vacuum.[497] The proximity of his letter with the publication of his book reinforce that a major philosophical doctrine he sought to counter was atomism.

It is even more important, then, to notice that when Zucchi explains why light does not imply atomism, he appeals to the nature of magnetism to do so. He does this first in Chapter Five, which addresses whether light is a "corpuscular substance." Among the issues he addresses in this chapter is whether the ability of magnets to attract iron filings implies the reality of corpuscularianism, as the filings possess an internal motion causing their movement toward the magnet. What Zucchi is quick to note is that this observation does not prove atomism. As he notes, magnetic philosophy itself explains that the filings are attracted to the magnet based upon "impression of the quality of magnetism."[498] In the following chapter, Zucchi then addresses the way in which the magnetic power is able to be diffused through all substances, similar to light.[499] Indeed, as Zucchi argues, the division of the magnet into its constituent parts only serves to confirm the existence of the magnet's qualities. By extension, the quality of light does not increase or decrease, but remains constant no matter the size of the light source.

Like Kircher, it is not important whether or not Zucchi's arguments were persuasive among their contemporaries. Rather, notice the way in which the explanation of magnetism and light existed in a symbiotic relationship among members of the Society of Jesus at a time when explanations of light underwent significant changes. While one might anticipate this coherence,

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[497] Gorman, *The Scientific Counter-Revolution*, 131–133.

[498] Zucchi, *Optica philosophia, pars prima*, 1:11–12: Ita sane, sed convincitur in Philosophia Magnetica, non nisi alteratione in iis facta per impressionem qualitatis magneticae, dicta ramenta provocare a magnete.

[499] Zucchi, *Optica philosophia, pars prima*, 1:13.

since the Jesuits subsumed physics to Aristotelianism and so it was believed that the core nature of light and magnetism overlapped, it is nevertheless important in the identification of the unique path that the Jesuits took in the confessionalization of light.

The particularities of confessionalization regarding light (and physics more broadly) are also noticeable in the way the Jesuits came to construct parameters around what could and could not be taught. While aspects of this began occurring in the earliest parts of the seventeenth century in the efforts of the Revisores, the most comprehensive of such efforts occurring through the *Ordinatio pro studiis superioribus*, a list of philosophical errors to be avoided both in teaching and publishing among the Jesuits. It is noticeable that certain aspects of it influenced the treatment of light among the members of the Society of Jesus.

The *Ordinatio pro studiis superioribus*

At the beginning of the seventeenth century, Jesuit theologians grew increasingly concerned about the consequences of new physical theories, including those on the nature of light. As described in the first chapter of this dissertation, the work of Kepler and its later adaptation by Descartes and others introduced a mechanical understanding of light and motion. In the process Descartes and others used "corpuscle," a term of wide usage at the time—even used in Christoph Scheiner's Oculus—though, Descartes and other mechanical philosophers certainly held different philosophical interpretations to the way the Jesuits used it.[500]

Suspicion of these potential erroneous doctrines culminated in 1651, when the Society of Jesus produced the *Ordinatio pro studiis superioribus*, which outlined the doctrines which were deemed unfit to be taught within the Jesuit colleges. The document developed out of

[500] Christoph Scheiner, *Oculus*, 233, writing with respect to the light of the stars.

philosophical and theological criticisms levied at the Jesuits in the 1640s and was intended as a way for the members of the Society to unify their instruction and avoid doctrinal error. It is a short text that merely lists the statements which are to be avoided. Yet, despite its brevity, it was a very authoritative document on the teaching and publishing of the Order in the second half of the seventeenth century.[501] When looking at the improper philosophical doctrines it is noticeable that the idea of indivisibles, whether atoms or corpuscles, was particularly problematic. For instance number 18 states that the following philosophical statement should be avoided: "An element is not composed from a material and formal (cause), but by atoms."[502]

While the Revisors' comments had been an early indicator as to the parameters being established within the philosophical curriculum, the *Ordinatio* provided a statement that had influence upon much more of the Jesuit intellectual culture. It is an important document of confessionalization as it shaped quite specifically the Jesuits' response and understanding of potentially contentious doctrines. So, for instance, when a notable Jesuit philosopher, Melchior Cornaeus, addressed many philosophical questions in his *Curriculum philosophiae peripatetic*ae (1657), he recognized that while he had previously openly taught certain doctrines as being true, the context of the 1651 *Ordinatio* required obedience.[503] The Jesuit Orazio Grassi, famous for debating Galileo over comets, made a similar statement with respect to light and color in 1652

> I see that I will not be able to publish my study on colors…because of the rigorous orders made . . . in these last General Congregations, in which ours are forbidden to teach many opinions, some of which are the substance of my treatise, and they claim to prohibit them

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[501] On the importance of the *Ordinatio* see the chapter by Michael Gorman "Discipline, Authority and Jesuit Censorship: From the Galileo Trial to the *Ordinatio Pro Studiis Superioribus*," in *The Scientific Counter-Revolution*, 85–124.

[502] Francesco Piccolomini, *Ordinatio pro studiis superioribus* (Rome, 1651), 24: Elementa non componuntur ex materia & forma, sed ex atomis.

[503] Hellyer, *Catholic Physics*, 50–51.

> not because they consider them bad and false, but because they are new and not ordinary. It will thus be necessary for me to sacrifice them to Holy Obedience, by which I will undoubtedly gain more than I would by publishing them.[504]

While it is not clear what precisely Grassi avoided with respect to his optical investigations, the important point to notice is that, as in the case of Cornaeus' *Curriculum philosophiae peripatetic*ae, the *Ordinatio* of 1651 created important philosophical boundaries on what was acceptable philosophical doctrine for the Jesuit authors to publish and to teach.

Such boundary drawing continued throughout the seventeenth century and shows up repeatedly throughout many Jesuit sources. One example was the *Theses mathematicae de geometría practica, mecánica, statica, geographia, optica*, defended at Lyon in 1675. These particular theses were well-illustrated, and provided a glimpse into the status and nature of mathematical instruction at an important Jesuit college. Regarding the nature of light, the theses declare that they follow Aristotle and not the Epicureans by declaring that light was a quality and not a body.[505] While the author did not explicitly address the *Ordinatio*, the particular emphasis on avoiding certain implications reflects the control that the *Ordinatio* sought to produce. The Revisores' work and the institution of the *Ordinatio* affected the investigation and presentation of the information among the members of the Jesuit Order. A further example is he optical work of the Jesuit Francesco Grimaldi.

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[504] Quoted in Mordechai Feingold, "Jesuits: Savants," in *Jesuit Science and the Republic of Letters*, ed. Feingold, 21.

[505] *Theses mathematicae de geometría practica, mecánica, statica, geographia, optica, propugnabuntur in Collegio Claromontano Societatis Iesu* (Clermont: Widow of Edmund Martin, 1675), 12.

Sic et Non: Fluid Light

While Zucchi articulated the role of magnetism in countering the principles of the mechanical philosophy with regard to optics, the Jesuit who demonstrated most clearly the actual importance of magnetism to understanding optics and the nature of light was Francesco Grimaldi (1618-63), in his 1665 *Physico-mathesis de lumine*.[506] As a member of the Society of Jesus Grimaldi was a student and collaborator of the Jesuit Giovanni Battista Riccioli, contributing both to the research and publication of Riccioli's *New Almagest*. In fact, the effusive eulogy that Riccioli appended to Grimaldi's posthumous *Physico-mathesis* makes one wonder whether Riccioli might have played an important role in the collection and publication of the work after Grimaldi's untimely death.[507] They also collaborated on the investigation of meridian lines in Italian Jesuit churches.[508]

John Heilbron in his book *The Sun in the Church*, describes European cathedrals that served as solar observatories where it was possible for one to chart the movement of the sun throughout the year, an issue that was important for establishing the date. Meridian lines were aligned within the cathedrals in such a way that a projected solar ray at noon would enable one to properly align the calendar. Heilbron draws attention to the way in which the observation of such solar rays during the 1650s actually demonstrated the validity of Keplerian Copernicanism, in the form of Kepler's astronomical tables, and in a surprising and public way.[509] Heilbron muses

[506] Francesco Grimaldi, *Physico-mathesis de lumine* (Bologna: Haeredis Victorij Benatij, 1665).

[507] Grimaldi, *Physico-mathesis de lumine*, located after the index at the end of the book.

[508] Michael John Gorman, "The Angel and the Compass," in *Athanasius Kircher*, ed. Findlen, 251–54.

[509] John L Heilbron, *The Sun in the Church: Cathedrals as Solar Observatories* (Cambridge, MA: Harvard University Press, 1999), 112.

whether Grimaldi could have developed his theory of the diffraction of light from the study of these solar rays, but this is not at all apparent in Grimaldi's book and would be unlikely due to the small size of the pinhole needed to cause light to be diffracted.[510]

Francesco Grimaldi's identification of light as a substance stands among the most memorable contributions to the history of optics among the Jesuits, as well as the wider European community. Even a century after the book's publication, the Jesuit Roger Boscovitch, who adopted many aspects of Isaac Newton's cosmology, pointed to the influence of Grimaldi within the Republic of Letters as well as the way it shaped Isaac Newton's own optics.[511] The print history of the work also provides evidence for the strategies that certain members employed as they sought to remain faithful to the philosophical parameters imposed by their Order while at the same time investigating newer scientific ideas.[512]

Prior to Grimaldi's book, optics (and consequently, light) was discussed according to three divisions: normal optics, catoptrics, and dioptrics. To this, Grimaldi added a fourth category, diffraction. As he explains in the opening pages of the book, Grimaldi had conducted experiments with light projected through a pinhole in an otherwise darkened room and noticed that as the light went through the hole, it bent. This motion, which Grimaldi identifies as "diffraction," is the reason that he entered the dangerous territory of explaining the nature of light because the implication of the diffracted light, as he saw it, was that light was a substance. The full title of the book provides a clear indication of how Grimaldi sought to explain the

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[510] Grimaldi, *Physico-mathesis de lumine*, 5.

[511] Boscovitch, *De lumine*, Preface.

[512] To date there is no detailed study of this book despite its importance among the Jesuits as well as the European community more broadly.

substantial nature of light:

> The two books of physico-mathesis of light, colors, and the rainbow. The first book puts forward new experiments, along with the reasons deduced from them in favor of the substantiality of light. In the second book, however, the arguments from the first are dissolved, and it is taught that the Peripatetic doctrine of the accidental nature of light can be held as probable.[513]

Grimaldi's books differ in length. Book one contains 475 pages, and book two is 60 pages. So, while the title implies that Grimaldi sought a style of reasoning of 'sic et non,' offering arguments from both sides in the shorter second book, perhaps similar to the response of the Jesuits after the condemnation of Copernicanism in 1616, the overwhelming attention is on the merits of light as a substance in the first book.[514] Identifying some of the important features of these arguments will reinforce the articulation of the substance of light by a prominent member of the Jesuit at the middle of the seventeenth century.

Grimaldi's *Physico-mathesis* provides one of the clearest examples of the influence of the *Ordinatio*. In Ugo Baldini's *Legem impone subactis*, which provides information on the Revisores Generals' influence on Jesuit publishing, he includes their assessment of Grimaldi's book:

> Proposition 42a signifies that colors, even those that are called permanent, are not themselves distinguished from light (lumine), and are not at all qualities. And proposition 14a teaches that the operation of the magnet consists in a substance effluvium that pervades all bodies… not at all in agreement with proposition 37a in the *Ordinatione pro Studiis*.[515]

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[513] Grimaldi, *Physico-mathesis de lumine*, Physico-mathesis de lumine coloribus, et iride. Liber primus qexaginta propositions continens, quibus ex novis quibusdam Experimentis deducuntur ea, quae videntur favere Opinioni aliquorum de substantialitate luminis, Dissolvenda tamen in 2. Libro, Eaque occasione multa traduntur de Coloribus Apparentibus, ac Permanentibus, & multa etiam demonstrantur de Iride.

[514] On Jesuit strategies of dealing with Copernicanism after the Condemnation of 1616 see Feingold, ed. *The New Science and Jesuit Science*.

[515] Reproduced in Ugo Baldini, *Legem Impone Subactis: Studi Su Filosofia E Scienza Dei*

These passages were revised prior to the book's publication and indicate the way in which the Revisores efforts, itself a form of confessionalization, shaped the production of the book itself.

Another important issue is the role that the *Ordinatio* and the Revisors General played in the production of Jesuit ideas on optics in the period after 1651. It is debatable whether the *Ordinatio* affected the final form of the book on account of the book's organization using 'sic et non'. Due to the overwhelming amount of content in Book I in contrast to that of Book II, it seems likely that Grimaldi intended the focus to be on the explanation for the way in which light was itself a substance (Book I) rather than the arguments against it (Book II).

In the opening section of the book, Grimaldi says that his recognition of diffraction was based upon his careful observation of how light projected through a small pinhole in a window shutter. What he noticed was that the penumbra, or the lightest part of the shadow, was larger than one might anticipate based upon the size of the hole. As a result he determined that one needed a new classification for the movement of light, beyond mere diffusion, reflection, or refraction—hence, his adoption of diffraction.[516] Thus, as Proposition two states: "light (lumen) appears to be a fluid fused very quickly through diaphanous bodies, and at least sometimes even undulating."[517] To justify his analogy with fluid Grimaldi adopts several different comparisons with the movement of water, such as the way water bends as it moves over objects. Those

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Gesuiti in Italia, 1540-1632 (Roma: Bulzoni Editore, 1992), 102–103: Propositione 42a significat colores, etiam qui appellantur permanentes, non distingui reipsa a luminò, nec proinde esse qualitates. Et propositione 14a docet operationem magneticam consistere in effluvio substantiali omnia corpora pervadente….minus consentanee ad propositione 37a in Ordinatione pro Studiis.

516 Grimaldi, *Physico-mathesis de lumine*, 1.

517 Grimaldi, *Physico-mathesis de lumine*, 12: Lumen videtur esse quid fluidum perquàm celerrimè, & saltem aliquando etiam undulatìm, fusum per corpora diaphanous.

comparisons are not very pertinent for this analysis, aside from his overwhelmingly novel idea, at least for a Jesuit at the time: light was a body.[518]

Grimaldi's text is a very lengthy analysis that includes many contemporary discussions pertaining to light. For instance, he addresses the topic of the barometer, noting that the evacuation of the fluid from the tube would cohere with his view that light was itself a fluid body. Explicitly citing the experiment of Paul Causato, Grimaldi contends that the fluid nature of light coheres with light occupying an area where mercury (which is a fluid) used to reside. The light that appears in the evacuated tube is separated off from the mercury itself. As he notes, the experiment shows light as "a fluid and transparent substance extracted from mercury."[519] He also includes many reports of exotic stones like the Bologna stone, one being the Mexican stone which the Jesuits there reported on. Like the case of the barometer tube, he demonstrates how his view of light as a fluid actually is supported by exotic stones.[520] While he clearly attempts to avoid identifying light as being an atom or a corpuscle—terms which he avoids—he nevertheless identifies it as the "smallest of particles."[521]

Throughout the work Grimaldi evidences the overlapping interest in light and magnetism that other Jesuits, such as Zucchi and Kircher, also display. For instance, he notes certain similarities between light and magnetism. Similar to the way in which magnets moving toward the pole had a non rectilinear movement, so also did light subject to diffraction. He also notes

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[518] A. Hall, *Beyond the Fringe: Diffraction as Seen By Grimaldi, Fabri, Hooke and Newton.* (London: Royal Society of London, 1990).

[519] Grimaldi, *Physico-mathesis de lumine*, 54: Substantia fluida & pellucida ab hydrargyro extracta.

[520] Grimaldi, *Physico-mathesis de lumine*, 388.

[521] Grimaldi, *Physico-mathesis de lumine*, 516.

that the fluid-like nature of light was similar to the effluvia, the substance thought to move out from the magnet. Within the course of his argument, however, the main goal of Grimaldi is to explain the way in which magnetism and light were both substances: “magnetic effluvium is some sort of substance.”[522] It is all the more telling then, that in the shorter Book 2, in which Grimaldi argues against his statements in Book I, he not only defends light against atomism, but he also defends magnetism against atomism.[523] Grimaldi’s account underscores the way in which the natures of light and magnetism were intertwined among the members of the Society of Jesus.

Grimaldi identifies potential objections to light as a substance in Book One and responds to them. Although advertised as a response to Book One, the shorter Book Two, does not seem as if it was intended as part of the original project, but was involved in the negotiation with the Revisores or Superiors to get the work published. The objections that Grimaldi posits in Book One provide more insight into the supposed objections to the theory of light as a substantial body. They cover topics such as the impact of fluid light on vision, the relationship between color and fluid light, hiddenness of the knowledge of the natural world and the impact of fluid light on the Eucharist.

Drawing upon the Council of Trent, Grimaldi mentions the influence of the distinction between the substance and accident in the identification of the Eucharist. He notes that the council never clarified the role of “color” within the substance and accident distinction. The significance of this point has to do with the prior objection, in which Grimaldi locates color as a sense within light, rather than the quality carried by light. While a subtle distinction, it nevertheless provides him an avenue through which to argue that the substance of the bread and

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[522] Grimaldi, *Physico-mathesis de lumine*, 59.

[523] Grimaldi, *Physico-mathesis de lumine*, 533.

the wine could change, on account of the influence of color, even while the accident remains the same.[524] As he states, "the definition is not certain….whether among the accidents which are remaining, color is made as such before the consecration affects the substance of the bread or the intrinsic nature of the wine, and whether it is permanent as a form." Drawing upon the liturgy of the Jesuits, Grimaldi then turns toward a common prayer to identify the way in which the Jesuits themselves have used the language of "color" in their own hymn: "Through the world of wakened things: life and color dart." The point that he is raising is that color itself does not remain consistent.[525] The inclusion of the liturgical and symbolic elements in the explanation of how light was not a substance are important to notice, and remind one of the importance that many Jesuits gave to the symbolism of light explained in the Introduction to this chapter.

The final influence of Grimaldi's work is difficult to judge. It is noticeable that his fellow Jesuit, Honore Fabri borrows Grimaldi's explanation of light as a substance to argue that it coheres with his previously developed ideas of impetus and metaphysics, which he began formulating in 1648.[526] One of the clearest indications of the influence of Grimaldi's work, however, is in that of his fellow Jesuit, Claudes Dechales, who borrowed some of Grimaldi's explanation of the nature of light in his own explanation.

The color of orthodoxy

That magnetism, light, and color were interrelated together may be noticed by considering another of Grimaldi's fellow Jesuits, Claude Dechales. His book on mathematics

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[524] Grimaldi, *Physico-mathesis de lumine*, 406.

[525] Grimaldi, *Physico-mathesis de lumine*, 406.

[526] Honoré Fabri, *Dialogi physici* (Lyon: Antonius Molin, 1669), 1–5.

Cursus seu mundus mathematicus was first published in 1674 as a three-volume work, and then again as a four-volume work in 1690, with the second volume including sections with updated mathematical information. As a review in the *Philosophical Transactions* suggests, for the most part Dechales work was derivative, rather than original—"what the Author hath performed *beyond* others, and how much also he hath borrow'd *from* others without taking notice of his Benefactors, I must leave to the Intelligent and well-read Perusers of this Work to Judge."[527] So, Dechales's book is important not only for the information that he includes, but perhaps more importantly for the way it represents an important authority among the Jesuits at the middle of the seventeenth century.

Dechales's Volume Two provides his explanation of optics, occurring just after the section on navigation, which includes his most extensive treatment of magnetism. He organizes his treatment of optics according to four main categories—Optics, Perspective, Catoptrics, and then Dioptrics. Much of the text itself resembles previous Jesuit optical works. It begins with an analysis of the eye and its constituent parts (Optics), then considers anamorphosis and various tricks of the eye (Perspective), various issues relating to image reflection (Catoptrics), followed by a treatment of light refraction (Dioptrics).

For the purposes of understanding the interrelationship between light, optics, and magnetism, it is necessary to look in the Optics section, Book III, "On the Propagation of Light." In a digression on "opacity" and "transparency," Dechales addresses many of the questions surrounding issues regarding whether light is a quality or a substance. In the process he reaffirms most of the traditional stances regarding optics and light: light was a quality, not a body. He also provides numerous examples in which he defends the reality of the visual species, whether from

[527] Quoted in Shapiro, "Images: Real and Virtual, Projected and Perceived," 301-302, note 47.

mirrors, in water, or in air.[528] In explaining what light is, Dechales states that, similar to a magnet, common experience demonstrates that light (and magnetism) are qualities which act upon bodies and are not bodies themselves. He also claims that magnets, similar to light, emit effluvia in a spherical direction.[529] Despite important changes, this explanation, and the comparison of light to the nature of a magnet, remain essentially unchanged in the 1690 expanded version of Dechales's *Cursus seu mundus mathematicus*.

Eventually, in considering the nature of light, he considers Grimaldi's explanation that light was a perfect fluid "the smallest body part in which anything is able to be divided."[530] The point of the analysis is to use the understanding of light in air to maintain the way in which light could move like a fluid. To assess this possibility Dechales uses the example of mixing wine and water together. While wine itself is not penetrated by particles of water, the example nevertheless suggests how two substances might be combined. "There can be noticed no part of water that does not admit a particle of wine. This is seen in agreement with the transparency of air."[531] Following this, Dechales then considers the fluid-like movement of light through an aperture, the bending of which would be based on the crystalline nature of air.

It's quite clear that in this section Dechales is intending to address Grimaldi's text. In response, Dechales says that arguments for the substantial nature of light are not possible. After this he argues against the way in which air could either cause light to bend or explain the way

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[528] Dechales, *Cursus seu mundus mathematicus* (1674), 2:434.

[529] Dechales, *Cursus seu mundus mathematicus* (1674), 2:438.

[530] Dechales, *Cursus seu mundus mathematicus* (1674), 2:435: minutissimas partes corpus aliquod dividi potest.

[531] Dechales, *Cursus seu mundus mathematicus* (1674), 2:435: nulla notari possit pars aquae, quae vini patriculam non admittat, haec diaphaneitas aeri convenire videtur.

light could be a fluid. As one might expect Dechales also uses the discussion of the nature of light to reaffirm important aspects of the Eucharist. He does so in Book III of Optics, as well as in Book III of the Dioptrics. Both sections pertain to explain light, whether it is a fluid substance and whether light is comprised of colors. In the section on Dioptrics, Dechales affirms that light is an impression of color, albeit the impression of a quality. The language of 'impression' was one of the avenues that perspectivist optics used to express the real engagement of the species with the eye, explaining that the species impressed itself within the eye similar to an impression on a wax seal. In this section Dechales also goes to great length to avoid Cartesianism, and any indication that light might be a substance. As he notes, his own explanation maintains fidelity to the explanation of the Eucharist.[532]

Similar to the style of argumentation of Grimaldi, Dechales weighs one side of the argument and then responds with answers on the other side. While it is impossible to know what Dechales 'actually thought,' Dechales's weighing of the evidence nevertheless played an important role in the transmission of contemporary arguments with respect to light at a time when many Jesuits were not supposed to give much attention to the substantial nature of light. The strategies of "sic et non" as well being allowed to teach the existence of small particles, at least instrumentally, provided a mechanism through which many Jesuits could maintain their confessional loyalty while at the same participating in the intellectual discourse of early modern optics.

The analysis thus far in the chapter, however, has focused upon the way in which the Jesuits came to focus their attention on explaining the material status of light. As argued thus far, one of the reasons for the transition had to do with the encounter with the barometer and the air

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[532] Dechales, *Cursus seu mundus mathematicus* (1674), 2:711.

pump. One remaining questions, however, is what happened to the perspectivist expectation that optics should explain sight.

Virtual, Real, and Fictitious Images

Chapter Four addressed the way in which certain Jesuit authors addressed questions of the images in the air from the standpoint of an apologetic purpose. By demonstrating certain popular techniques that allowed one to cast images into the air, the Jesuit mathematician was able to naturalize what might otherwise have been considered to be supernatural. While this did not directly eliminate the necessity of relying upon supernatural explanations for visual experiences such as armies in the sky, it nevertheless aimed to create a context wherein the mathematician could project their ability and the power of mathematics to vouchsafe the trustworthiness of vision in the midst of widespread optical illusions.

While mathematicians were working to establish the reliability of vision they also resolved an important question that Keplerian optics had introduced on the location of images within three-dimensional space. Traditional perspectivist optics often focused on the perceived location of an image or object within three-dimensional space, largely because perspectivist optics could only account for perception. In the seventeenth-century as opticians studied refraction, they noticed that rays refracted through a glass lens served as a useful tool for locating the real position of an image or object, and went beyond the visual abilities of traditional perspectivist optics. Included within Johannes Kepler's optics was the recognition that an image and an object both projected their spatial location in the same way—by sending rays toward one's eye from their geometrical location. By the middle of the seventeenth-century most opticians explained this by using diagrams with rays and identifying "virtual images," "real images," and "fictitious images". Adopting many of the same basic geometric and optical tenets as their contemporaries, certain members of the Jesuit Order also utilized this technical vocabulary. Alan Shapiro first drew attention to this, although its significance may be better appreciated within the broader context of images in the air and the interests of the Jesuits and optics thus far established.[533]

Within perspectivist optics the study of image location occurred in the contexts of reflection within mirrors. Studying the reflection of the image within the mirror, which was a standard activity for understanding how images form and their spatial location, one was able to determine how images were perceived within geometrical space. A standard explanation for this involved analyzing the real and apparent location of an image reflected along a flat mirror. While the apparent location of the image was in the mirror, the real location involved the intersection of two straight lines. The first, the cathetus, was a straight line perpendicular to the mirror. The second was a straight line from the eye. The intersection of these two lines provided the actual geometrical location of the image in space (which would have been somewhere behind the mirror itself). One may see a mathematical example of this in Image 5.1. In this diagram, taken from Kepler's *Ad Vitellionem*. The image of point *a* viewed within the mirror *cf* from the vantage point of *b* is located at *e*, which is itself the intersection of the cathetus *ace*, and the ray extending "into the air" beyond the reflection point in the mirror, *bde*.

[533] Shapiro, "Images: Real and Virtual, Projected and Perceived," 270–312.

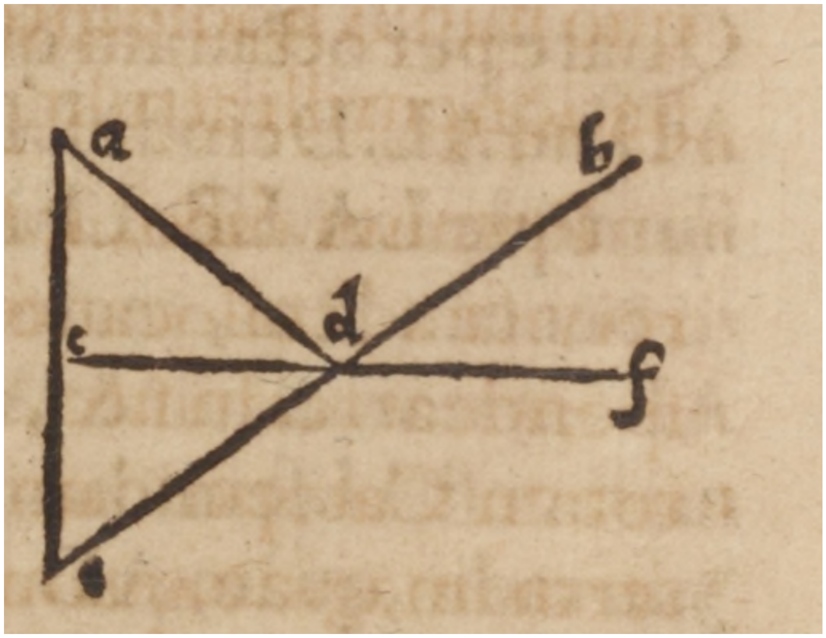

Image 5.1 — Example of locating an image according to perspectivist optics
Johannes Kepler, *Ad Vitellionem paralipomena* (1604), 56.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

In Kepler's interpretation of this he did away with the cathetus, and instead claimed that the location of the object would have been determined by pencil rays from the object, refracted through the eye, and then located on the retina. In this explanation, noted in previous chapters, Kepler separated the "image" in three-dimensional space, from the "picture" on the retina. Also involved in Kepler's understanding of vision was the realization that the beneficial rays from the object to the eye involve more than the straight rays between the object and the eye, as perspectivist theory had it, but included the oblique rays, since the refraction of the eye allowed for these rays to be useful. Kepler's illustration of how image formation and location occur according to pencil rays may be seen in Figure 5.2. In this diagram the rays from the object into the eye converge upon the focus psi (ψ).

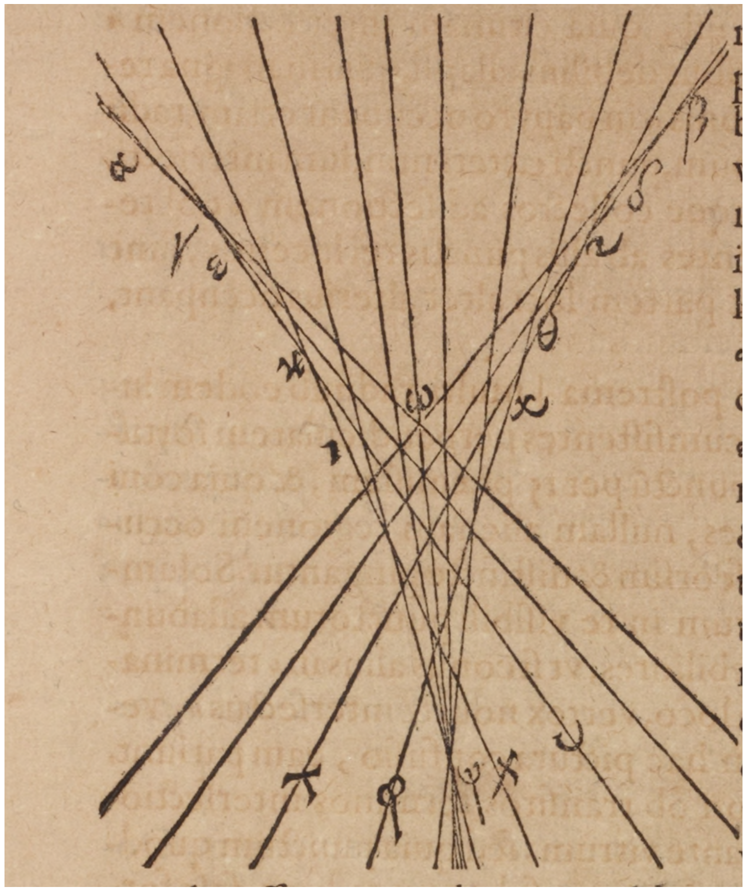

Image 5.2 — Depiction of image location according to the convergence of light rays
Kepler, *Ad Vitellionem paralipomena* (1604), 194.
Courtesy of The Linda Hall Library of Science, Engineering & Technology

As Alan Shapiro notes, in the middle of the seventeenth century this problem was resolved in the work of Roberval, an accomplished mathematician who posthumously published and bound together Marin Mersenne's *L'optique, et la catoptrique* (1651) which came to be later bound with the French minim, Jean Francois Niceron's *La perspective curieuse* (1638). Within his commentary on Mersenne's optical work, Roberval addresses the way in which the optical object exists in space as the product of rays converging or diverging from a point.[534] As Shapiro notes in passing, the particular question that Roberval was working on was the location of

[534] Shapiro, "Images: Real and Virtual, Projected and Perceived," 293.

"images in the air," the same ty question that the Jesuits addressed and was discussed in Chapter Four of this dissertation.

Although Roberval was not a Jesuit, the importance of his commentary, as well as his recognition as a practitioner of optics, was certainly not lost on the Jesuits, particularly those who addressed optical issues in the latter part of the seventeenth century. The Jesuits Eschinardi, Dechales, and the Cassini brothers (who were educated by the Jesuits) adopted Roberval's optical understanding. In the process, however, as Alan Shapiro notes, they developed several new terms to differentiate between the geometrical location of the image (and the solution to Kepler's dilemma) and the reflected image in the mirror—which was noted in chapter three as an important element in the explanation of sight according to perspectivist optics. Collectively what they develop are the terms "virtual," "fictitious" and "real" images, the first two referring to the location of the image within the mirror and the last the one within geometrical space.[535] When one remembers the importance that the theologian gave to images within a mirror as a way to substantiate the existence of the visual species, an aspect given attention at the end of chapter three, one may better appreciate why these authors retained terminology for the images located within a mirror.

Shapiro fails to connect the development of these terms with the background of the Jesuits' interest in the visual species, a context which is driving these terms. When explaining the visual species, Aguilonius in his *Opticorum libri sex* (1613) noted that the species was "virtual," attempting to avoid the oddities of the species being either the form or material of the object.[536] What is curious, however, is that later Jesuits, most notably Athanasius Kircher, quietly argue

[535] Shapiro, "Images: Real and Virtual, Projected and Perceived," 270–312.

[536] Aguilonius, *Opticorum libri sex*, 45.

that the visual species is formal and not virtual.[537] In contrast to Aguilonius, who composed a fairly typical scholastic book on optics, it would make sense that Kircher gave more attention to the shape of the species as being an important factor in maintaining the ontology of the species. After all, Kircher treated image reflection in mirrors at all sorts of angles, and so he was interested in explaining how the image reflections retained some resemblance to the actual object it represented. The use of "virtual" by Aguilonius is much more ambiguous, although it does not separate the nature of the species from the object it represents.

The incorporation of the language of "virtual" and "fictitious" by these mid seventeenth century Jesuits, at such an important moment in the transformation of Jesuit optics, suggests an important recognition on their part that this transition introduced odd questions about the relationship between the visualized object (understood as the reflection in the mirror) and the geometrical location from which it derived (Kepler's understanding). Their introduction of this terminological distinction is an important marker in the transformation of optics among the Jesuits, but also of the confessionalized nature of such a transformation, as the maintenance of the visual species was an important component in the negotiation of the relationship between mathematics and philosophy.

It is also worth noting that the transformation of the nature of image and vision was not near as contentious as the nature of light. For instance, Eschnardi was the first to popularize the explanation of the "fictitious image," among the Jesuits, and he did so without any concern whatsoever. In the same book, in a different location, he developed an argument that the barometer did not imply that light was a substance.[538] This distinction between two important

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[537] Kircher, *Ars magna lucis et umbrae* (1646), 125.

[538] Francesco Eschinardi, *Centuria problematum opticorum* (Rome: H. H. Corbelletti, 1666),

subjects is an important indication that the transformation of optics among the Jesuits occurred not "from sight to light," but commingled together. What this indicates is that, at least among the Jesuits, the transformation of optics from a subject being about sight to one about light, did not occur as the triumph of light over sight, but instead as the subtle modification of sight optics while all the interest and attention was given toward light.

Conclusion

The issues analyzed in this chapter are only a few (albeit a prominent few) of the issues relating to the transformation of optics and the theory of light among the Society of Jesus in the latter half of the seventeenth century. From these a few observations may be made. First, the fact that light became such an important topic of philosophical analysis meant, ironically enough, that Jesuit authors increasingly gave more and more attention to its explanation. A lot of this had to do with the confessional importance of light amidst the Counter Reformation. While certain aspects of this involved the Eucharist, it also, more importantly, was connected to the pedagogical doctrines outlined in the 1651 *Ordinatio*. The *Ordinatio* provided an important framework through which Jesuit authors shaped their optical explanation at a time when there was essentially no such thing as optics. While it meant that they often took a different path from the scientists commonly associated with the Scientific Revolution, their confessional considerations were not a hindrance to their participation in the scientific debates at the time. Confessional considerations were a form of social and political influence, not altogether dissimilar from the influences shaping the other more prominent figures within the

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127. The point he draws attention to is the various assumptions involved in the explanation that the vacuum implies that there is no substance there to which light is its accident.

historiography of early modern science.

Second, I have raised important issues regarding the transition from ‘sight’ to ‘light’ among the Society of Jesus. As noted in the Introduction and Chapter One of this dissertation, often the focal point of this transition is Johannes Kepler, yet I argue in Chapter Three, from the experience of the Jesuits, this was not the case. In Chapter Five chapter, I have shown that this transition among the Jesuits involved two issues. First, it involved increased attention to the nature of light, spurred on by the air pump and barometer. Second, it involved the adoption of a more sophisticated argument than was available within the perspectivist tradition about where a visual image is located within three-dimensional space. The story of how these two issues develop in the eighteenth century is yet to be written. They occur at the same time, and yet in an unrelated fashion. Their history among the Jesuits complicates the formerly simplistic image of how perspectivist optics transitions to modern optics, during the early modern period.

CONCLUSION

In the Introduction it was noted that this dissertation would explore why optics became such a prominent topic of investigation among the members of the Society of Jesus. Undoubtedly part of the reason for this is because most other intellectuals in early modern Europe were also investigating optics. In a sense, optics was the cutting edge of scientific research. Like many other Europeans, the exploration of this quickly changing topic and the quest to establish a new theory of optics (or to accommodate previous theories) provided an important stimulation for many prominent members of the Society of Jesus. And because optics possessed a performative capability, there was a certain interest on the part of many members of the Society of Jesus to capture the attention of the public. This was especially the case regarding the widespread interest in optical illusions by Jesuit mathematicians and non-mathematicians alike. But optics came to be important among members of the Society of Jesus for more than its popular appeal during the seventeenth century. It was an important topic because of the interrelationship between optics and confessional ideology within the Jesuits' Counter-Reformation interests. This last aspect proved especially important and its identification and explanation is the chief resultt of this study.

As this dissertation has shown, the confessional interests shaped the engagement of the Society of Jesus with early modern optics. This occurred in explicit ways, such as in the perpetuation of the visual species amidst Kepler's optics as well as in the explanation of light in the latter half of the seventeenth century. But it also occurred in subtle ways, as in the use of crosses, images of Mary, or the resurrection or ascension of Jesus in their optical experiments. Such aspects are important to note not only because they provide insight into the intellectual and visual culture of early modern Jesuits, but also because these aspects demonstrate how the category of confessionalization introduces a framework which helpfully reframes the "science and religion" discourse. It avoids questioning the degree to which religion was detrimental to science. Instead, confessionalization borrows from the religious and political realities of the early modern period and creates a fresh approach for the study of the Jesuits.

Alongside the interest in confessionalized optics, the dissertation also has drawn attention to important aspects of early modern optics that challenge parts of the prevailing historiography. For instance Kepler's optics, particularly the *Ad Vitellionem,* was not as significant at the start of the seventeenth century, at least among certain prominent members of the Society of Jesus, as the historiography assumes. While not intending to devalue the novelties of Kepler's optics, the dissertation showed how the Jesuits' integration of Kepler's optics into traditional perspectivism shows that the *Ad Vitellionem* was not perceived as the turning point that contemporary historians often make it. Instead, at least for the Jesuits, it was the air pump and the barometer which introduced the greatest challenge to perspectivist optics, and even then, there were strategies to obviate any perceived difficulties.

In addition to this, the Jesuits' encounter with early modern optics shows how the transition from "sight" to "light" was not necessarily the story of the latter simply replacing the former. Rather, light was a topic of utmost importance at the same time sight theory subtly shifted. The one, however, did not implicate the other. It was the air pump and barometer which shifted the focus to light, a move which was not dependent on the shifting of theories of sight.

Despite the importance of these observations, there remain prominent avenues of investigation that are worth pursuing further. The first is an explanation of how the confessionalized influences on optics disappeared. The particularities of optics that the Jesuits adopted eventually disappear. Explaining this process would be an important aspect of optics among the Jesuits. Undoubtedly it would involve more than the Jesuits themselves and would also consider not only changes in the theory of optics, but also developments in disciplinary practices, institutional dynamics within and beyond the Society of Jesus, as well as patterns of communication, since increasingly Jesuit authors sought to participate more fully in the republic of letters through their scientific work.

This transition would also likely address the Suppression of the Society of Jesus in 1773. Scientific explanation was among the tools Society members used to maintain their presence in the Pre-Suppression period, but it was quickly replaced in the aftermath of the Suppression. It is conceivable that optical theory both played a part in the maintenance of Jesuit (and Catholic) control in the eighteenth century, but was quickly replaced after the removal of the Society. It is also conceivable that the transformation of confessionalized optics among the Jesuits introduced subtle distinctions in the way early modern Catholics explained optics, and science more broadly. Aspects of this were alluded to in the way prominent Capuchins and Minims differed from the Jesuits regarding the nature of light. The way these dynamics continued to play out beginning in the second half of the seventeenth century has yet to receive analysis. It would be useful to have an account of the differences in science among various Catholic Orders. This might further the importance of confessionalization on the explanation of optics in the early modern period.

A final area that needs further exploration is the degree to which confessionalized optics was a phenomenon strictly within Europe, or whether it shaped and was shaped by the globalized identity of the Jesuits. Within the last decade historians have repeatedly demonstrated the significance of the global mission on various facets of the Society of Jesus.[539] In addition to this, historians have noted the way in which optical devices came to serve as colonizing devices in missionary endeavors.[540] Locating how the Jesuits might have used such instruments outside Europe, as well as how theories of sight or light might have shaped their missionary and cultural endeavors would be an important element in the explanation of confessionalized optics among the Jesuits. It would also be worthwhile to understand whether their globalized efforts had a reciprocal effect and shaped their engagement with European theories of optics.

All these questions emerge as worthy avenues of investigation once the argument of this dissertation is accepted, that "confessional" interests shaped the way the Society of Jesus engaged and explained early modern optics.

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[539] Luke Clossey, *Salvation and Globalization in the Early Jesuit Missions* (Cambridge: Cambridge University Press, 2008).

[540] For some examples, see Peter Erickson and Clark Hulse, eds. *Imaginary Conquests: European Material Technologies and the Colonial Mirror Stage* (Philadelphia: University of Pennsylvania Press, 2000).

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