From Emblems to Diagrams: Kepler's New Pictorial Language of Scientific Representation

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Kepler's treatise on optics of 1604 furnished, along with technical solutions to problems in medieval perspective, a new mathematically-based visual language for the observation of nature. This language, based on Kepler's theory of retinal pictures, ascribed a new role to geometrical diagrams. This paper examines Kepler's pictorial language against the backdrop of alchemical emblems that flourished in and around the court of Rudolf II in Prague. It highlights the cultural context in which Kepler's optics was immersed, and the way in which Kepler attempted to demarcate his new science from other modes of the investigation of nature.

1. INTRODUCTION: THE PLINIAN FRAMEWORK: FINE LINES AND ABSTRACT IDEAS

In his *Natural History* Pliny the Elder (ca. 23–79 CE) supplies an outline of the significance and power of painting through several stories and comments. He tells, for instance, of the Greek painter Apelles, who traveled to visit Protogenes, another famous painter, in Rhodes. When Apelles arrived there, Protogenes was not in his studio, but in his place an old woman watched over a "panel of considerable size on the easel."[1] Apelles decided to leave his mark and painted "an extremely fine line in color across the panel." When Protogenes returned to his studio, he recognized Apelles as the only painter who could have painted such an exquisite line. In return Protogenes

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[1]The story is in Pliny the Elder, 1976, 120–23 (*Naturalis Historiae* 35, §81–83). This celebrated story has received many interpretations through the years; one may note especially the following: Gombrich; Waal; Elkins, 1995.

"drew still a finer line." Coming back, Apelles was "ashamed to be beaten, cut the lines with another in a third color, leaving no more room for any further display of minute work." The result was a panel that "had nothing else on its surface except lines, which eluded the sight."[2]

Another anecdote from Pliny tells of two painters, Zeuxis and Parrhasius. Zeuxis had painted grapes so deceptively that birds came down to peck at them. Parrhasius challenged him and invited Zeuxis to his studio to show him his own work. When Zeuxis eagerly tried to lift the curtain from the panel, he found it was not real, but a painting of a curtain.[3] A final anecdote from Pliny describes an attempt to introduce pictures into ancient Greek botany: "[Some] Greek writers... adopted a most attractive method [in botany]... which has done little more than prove the remarkable difficulties that attended it. It was their plan to delineate the various plants in colors, and then to add in writing a description of their properties. Pictures, however, are very apt to mislead... it is not enough for each plant to be painted at one period only of its life, since it alters its appearance with the fourfold changes of the year."[4]

In these stories Pliny sets the domain of pictures vacillating between the perfect mimesis of phenomenal reality — as an illusion, for instance, that baffles the senses — and the domain of abstract ideas, where perfect geometrical lines exist. Painting may aspire to either of these, but, as Pliny's third comment suggests, its power is limited. Pliny asserts that pictures cannot become a vehicle for conveying true universal knowledge since they are always connected to the accidental particularity of corporeal bodies. In this middle ground, a painted line may aspire to the one-dimensionality of a geometrical line, but it can never become one. The painted line can only imitate a true geometrical line. The painted picture can create, as if by magic, a perfect deception, but only of a particular accident. It cannot convey or recreate the essence of a physical object.[5]

These stories set the field for the late sixteenth- and early seventeenth-century debates on pictorial representation in general, and on the relation between pictorial and scientific knowledge in particular.[6] These polemics were part and parcel of an in-depth reexamination of the foundations of

[2]Pliny the Elder, 1976, 120–23 (*Naturalis Historiae* 35, §81–83).

[3]Ibid., 108–11 (*Naturalis Historiae* 35, §65).

[4]Pliny the Elder, 1980, 7:140–41 (*Naturalis Historiae* 25, §8). Translation amended.

[5]See, for instance, Erasmus's celebration of Dürer and his ability, compared only to Apelles, "to depict what cannot be depicted": Panofsky, 1951, 37. For general classifications of images and discussion of their relation to knowledge, see Franklin; Elkins, 1999.

[6]These debates are evident in the fate of the Academia dei Lincei: see esp. Freedberg. In recent years there has been a fast-growing literature concerning the role of pictures, diagrams,

human and divine knowledge, which included not only epistemological issues, but explicitly involved the problem of the representation of knowledge and of the world. These questions are concerned with a crucial question of the emerging new science: in what sense had the new science transformed the world into a picture, that is, in what sense was the world transformed into a knowable representation? How were the new means of representation to be manipulated in order to produce new knowledge? Could such a manipulation create new objects in the world? These were vital matters, especially in demarcating the autonomous field of scientific knowledge from other forms and practices that involved the production and application of visual knowledge in early modern European culture.

Throughout the sixteenth century, scholars, painters, alchemists, and theoreticians of art challenged this Plinian way of thinking of geometrical lines and pictorial representation.[7] Their attempt was to reshuffle the new pictorial means, such as perspective, in order to form a scientific language, constituted from visible signs, that not only represented human knowledge and the physical world, but could also affect physical processes. This attempt was made, however, still within an Aristotelian paradigm that conceived a geometrical line as an abstraction of a concrete, corporeal line (in the Aristotelian sense, a geometrical line is a line drawn ever more finely). This supposition, being at the core of sixteenth-century theories of representation, preserved an unbridgeable dichotomy between concrete appearances and the realm of knowledge.[8]

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and other visual images in the formation and dissemination of scientific knowledge: see Edgerton; and Mahoney's critical answer to Edgerton's thesis. See also Kemp; Kusukawa. Several recent volumes are dedicated to the uses of images in early modern science: for example, see Lefevre; Lefevre, Renn, and Schoepflin — both of which emphasize the cognitive-practical role of images. *Transmitting Knowledge* concentrates on the rhetorical role of images and the way images were mobilized in order to persuade and to distribute knowledge in early modern Europe. For a more general view of the intricate relationship of the visual arts and the sciences, see Jones and Galison. Renaissance mnemonic techniques were a further application of images to the production of knowledge: see Yates, 1996; Bolzoni; Heimann-Seelbach; Farago.

[7]See Barocchi for the different comments of theoreticians such as Pino, Francesco de San Gallo, and others. The technique of perspectivist painting responded to Alberti's demand at the opening of his *De pictura* "to set [mathematical entities] up as visible" ("sub aspectu rem positam esse volumus"): Alberti, 36–37. Yet perspectivist painting also emphasized the precarious nature of visual experience and the uncertainty involved in visual knowledge. For a general analysis of the epistemological vicissitude of the Renaissance theory of art, see Summers, 1981, esp. 41–55, 103–43, 230–33; Summers, 1987; Elkins, 1994.

[8]For Aristotle's treatment of the status of geometrical lines, see Aristotle, 1:330–31 (*Physics* B2 193b23–194a12); ibid., 2:1703–05 (*Metaphysics* M3 1077b18–1078a31). This topic is much debated in recent philosophical literature concerning Aristotle's philosophy of

In his treatise on optics of 1604, Johannes Kepler (1571–1630), the court mathematician of Rudolf II (1552–1612), directly tackled the problem of the pictorial representation of the physical world, and contrived a new pictorial language that transcended the dichotomy, inherent in Pliny's stories, between universal forms and concrete appearances.[9] In order to accomplish this, Kepler had to confront alternatives for the depiction and transmission of visual knowledge. One of the more salient contenders in the context of the Rudolfine court was the rich literature of emblems, especially alchemical emblems, which offered fantastic pictures as the vehicle to transgress the boundaries of forbidden knowledge by means of a transmutation of the human gaze. Set against this literature, certain aspects of Kepler's optical analysis of pictures and diagrams emerge as direct responses to the epistemological problems addressed by such pictorial experimentation. Reading Kepler's notions of the role of mathematical diagrams and his optical theory of retinal pictures as a response to the same epistemological problems addressed by this tradition of alchemical emblems will accentuate the role of his new theory of observation in his scheme of scientific knowledge.

2. Mathematical Symbols in the Alchemical Emblem

The aspiration of the literature of emblems was to challenge the gap between human mental construction, which aspired to the realm of eternal forms, and ever-changing physical reality. It attempted to accomplish this through paradoxical games that conflated different levels of interpretation with different systems of sensory experience.[10] Such sensory games reached their mature form in the famous treatises on alchemical emblems by Heinrich Khunrath (ca. 1560–1605) and Michael Maier (1568–1622), associated with the court of Rudolph II. As Alciati notes, emblems aim "to pierce the soul, to nourish the eye, to fill what is empty with meaning, and to give the power of speech to what is mute."[11] Whereas emblems usually elucidate and clarify the written epigram, the alchemical emblem emphasizes the function of the emblem as a means to decipher reality. The

mathematics: see Mueller, 1970 and 2006; Gaukroger; Lear; Cleary; Hussey. For the hold these Aristotelian ideas had on late medieval and Renaissance scientific thought, see Laird; Chen-Morris, 2001.

[9]Kepler, 1604; *Ad Vitellionem parlipomena* is vol. 2 of Kepler, 1937–. Translation in Kepler, 2000. Unless otherwise noted, all translations are from Kepler, 2000.

[10]For the emblematic tradition in early modern Europe, see Praz; Ashworth, 1990; Manning; Watson. See Pinkus for a postmodern interpretation of early modern emblems.

[11]Alciati, A1^{v} ("ad lectorem").

alchemical emblem's main purpose is to indicate how to unveil corporeal reality and to unearth its significance.[12] In sketching the role of visual images of geometry in such alchemical emblems, special consideration will be given to a short passage from Robert Fludd's *Utriusque cosmi maioris scilicet et minoris. . . historia*. Though Fludd (1574–1637) was not in direct contact with the court in Prague, he shared the spiritual aspirations of this intellectual circle. In the passage he supplies a possible key for the theory of visual cognition that underlies these emblems and their epistemological agenda.[13]

The emblem was a focal point for different kinds of knowledge from different sources. As a verbal expression, a puzzle, and a picture, it enabled the reader to bridge gaps and inconsistencies in different textual traditions. The emblem enabled the concentration of a web of analogies, associations, and implications of different elements of the universe. In emblematic thinking, to know something is not merely to conceive it as a phenomenon. One can fully recognize something only through its diverse meanings, through the aphoristic wisdom embedded in it, and the different textual contexts in which it appears. The alchemical emblem attempted to combine in a single picture the transmission of knowledge, the explanation of its hidden meaning, and the potency of the image to create magical effects in the physical world as well as in the human psyche.[14] The emblem produced

[12]Stoichita, 163–65.

[13]The most conspicuous treatise of alchemical emblems associated with Rudolf's court was Khunrath, which had already won imperial approval and privilege in 1598. Michael Maier, who served as Rudolf II's personal physician, published most of his alchemical treatises in the years immediately following Rudolf's death. Yet, as Evans, 206, comments, "the labour of inventing and preparing [these books] must have occupied him through his Prague years." Fludd and Maier shared not only the same Paracelsian and Rosicrucian sentiments, as well as the same publisher, De Bry in Frankfurt, but also probably met during Maier's frequent trips to England. Maier dedicated his first publication to Sir William Paddy, King James's physician and Fludd's friend: see Yates, 1972, 80–82; Evans, 205–06; Tilton, esp. 27–28, 87–112. Some scholars have cast doubts about a personal connection between Maier and Fludd: see Figala and Neumann, 45; Moran, 107–08.

[14]I use the word *magical* in the way Kepler mockingly applies it to describing the images produced in a camera obscura. Kepler, 1937–, 11:338 (translation in Kepler, 2003, 57–58), describes a "magical ceremony" (*magica ceremonia*) and a "magical rite" he performed using the camera obscura to reveal hidden messages to his baffled visitors: see also Chen-Morris, 2005, 238–39. The reader of an alchemical emblem (as a unique subgenre of emblematic literature) is supposed to perform the same rite. Looking through the emblematic device — and, in Maier's case, also singing the epigrams — the reader is able to decipher the message hidden in the fantastic image. A further function of the emblematic image was probably thought to be, as with Dee's *Monas Hieroglyphica*, to capture cosmic powers and apply them to the production of certain effects: see Josten.

this effect by suggesting initially a fictive, yet rigid, spatial arrangement that combined a dramatic action within a schematic setting. It further emphasized its paradoxical appearance by combining visible signs with verbal puzzles and auditory experience (the emblem's text was sometimes meant to be read aloud or sung), thus displaying different and only artificially connected sensory systems.[15] This paradoxical effect allowed the emblems to guide the reader to simultaneously different (and usually contradictory) levels of meaning.[16] Lastly, the alchemical emblem applied mathematical symbols as a means to combine a sense of actual calculation with allegorical revelation (usually as a mnemonic device) and a demand to see visible signs as pointing towards higher, ideal realities.

The reader of alchemical emblems has to recognize each natural object by the metaphorical element contained within it, as a symbol for spiritual and supersensual ideas that constitute the divine realms of the universe. As an example, I present here some emblems from Michael Maier's *Atalanta fugiens* of 1617.[17] Maier characterizes his treatise as "Partly adapted to the eyes and the intellect, with copper etchings, and added sentences, epigrams and notes, partly [adapted] to the ears and to the recreation of the soul with less than fifty musical fugues in three voices... to be seen, read, meditated, understood, judged, sung, and listened with particular pleasure."[18]

Maier's intention is the paradoxical combination of solitary contemplation and sensuous pleasure. As a visual device, the engraving opens up for the reader a treasure of texts, which in any other way would seem contradictory, or as initiating an endless stream of different interpretations. The

[15]The fundamental differentiation between sensory systems is set in Aristotle: see Aristotle, 1:665 (*De anima*, 2.6.7–25.). For a treatment of this subject in the context of medieval theology, see Chidester.

[16]Recent research on the literature of emblems emphasizes that "words are simply there to explain the picture": Bath, 20; see also Daly. Accordingly, emblems are seen as part of a rhetorical exposition, and their paradoxical, oxymoronic character is uneasily admitted as a "tension or fracture in the Renaissance discourse of emblematics," as "hesitations and instabilities" (Bath, 153), or as a sort of "scandal" (ibid., 159). Alchemical emblems, however, challenge these assertions as they embrace paradoxical reasoning as a cornerstone in an attempt to go beyond human rhetoric and linguistic exposition.

[17]In my interpretation and translation of the following citations I follow De Jong, unless specified otherwise. For a recent treatment of alchemical emblems, see Adams and Linden. For Jungian interpretations of Maier's alchemical emblems, see Szulakowska; Tilton. For the interaction between alchemy and the visual arts, see P. H. Smith, esp. 129–51.

[18]Maier, 1617a (frontispiece): "Accommodata partim oculis & intellectui, figuris cupro incisis, adjectisque sententiis, Epigrammatis & notis, partim auribus & recreationi animi plus minus 50 Fugis Musicalibus trium Vocum... singulari jucunditate videnda, legenda, meditanda, intelligenda, dijudicanda, canenda & audienda." Author's translation.

engraving, together with the aphorism and the enigmatic verse, enables the reader to overcome the gap between the two systems of representation, to integrate sensual experience and to guide the mind to a truth that is situated beyond visual experience, beyond the obscure ancient texts in which this truth was initially revealed. The emblem makes it possible for the contemplative spectator to awaken mnemonic powers, not in order to induce fantasies of the sensual and material realm, but to "rise into that garden where roses of philosophy bloom."[19]

An additional element of the emblem is the place and role of mathematical symbols, especially those concerned with perspective.[20] In late sixteenth-century art theory, perspective became an arcane and secret subject: a complicated, somewhat obscure, and highly mathematized domain. Perspective also earned negative associations, notably an association with saturnine humors. However, it kept certain an ambiguity: the "corridor space" of perspective suggests both the infinity of death as well as of the eternity of God.[21]

A somewhat different symbolic meaning is attached to perspective in alchemical emblems. For instance, in an engraving of the magus room in Heinrich Khunrath's *Amphitheatrum sapientiae* from 1609 (fig. 1), a hall is depicted in strict one-point perspective.[22] This method of depiction creates the illusion of progressing from the musical instruments and measuring devices in the foreground to the alchemical furnace, then to the magus, who kneels in front of an altar within a majestic tent, where, with the help of geometrical diagrams and combinations of Hebrew letters, he aspires toward enlightenment. Finally, the spectator's gaze is directed toward a window that opens onto a void. The same kind of perspectival image occurs in the picture of the gate leading to the doors of the amphitheater of eternal wisdom (fig. 2). A tunnel is depicted in a one-point perspectival grid, directing the spectator's gaze from a world of visible light to an invisible world illuminated by a mysterious source.

A similar structure of perspective appears in Maier's treatise in emblem 8 (fig. 3). Here, in the background of a highly theatrical scene, in the back wall of the theater's closed space, a vestibule depicted in one-point

[19]Maier 1617a, 117 (emblem 27).

[20]For the role of perspective in Khunrath's and Maier's emblems, I follow Szulakwska.

[21]Elkins, 1994, 166–76. For the association of geometry in general and of perspective in particular with melancholy, see also Klibansky, Panofsky, and Saxl, 317–38.

[22]*Amphitheatrum Sapientiae Aeternae* was first published at Hamburg in 1595, but then made more widely available in an expanded edition published a few years after the author's death in Hanau in 1609.

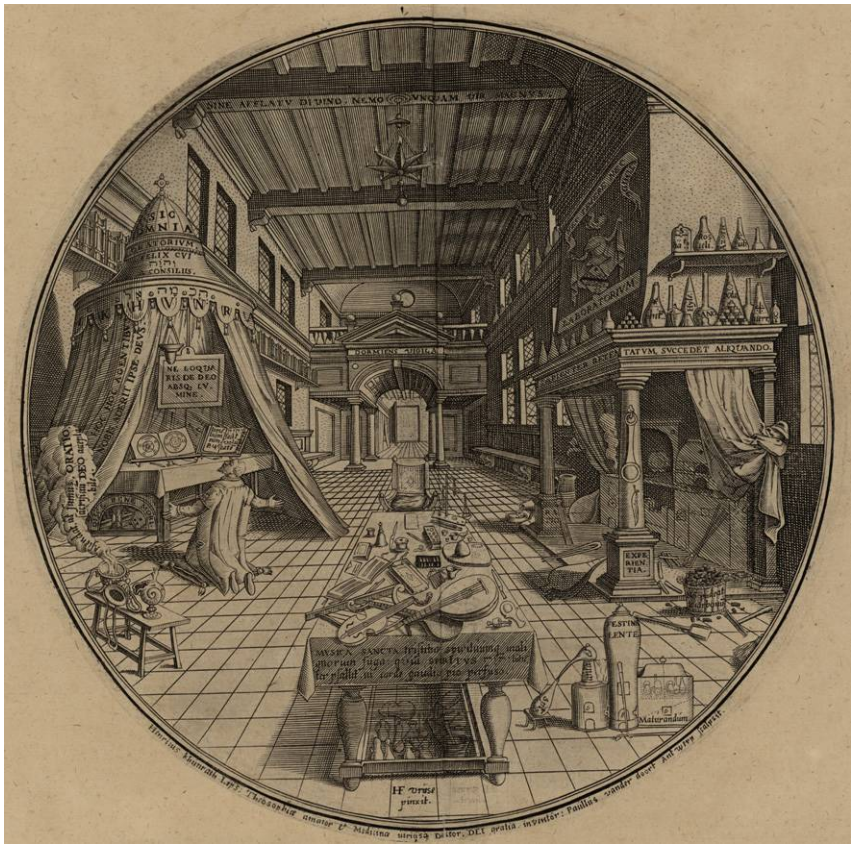

FIGURE 1. *Alchemist's Laboratory*, in Heinrich Khunrath, *Amphitheatrum sapientiae aeternae* . . . Hanau, 1609. Courtesy of the Gershom Scholem Library, Jerusalem National University Library.

perspective leads to an empty area visible only to the mind's eye. The motto for this engraving reads "Take the egg and pierce it with a fiery sword."[23] The epigram continues and develops the allegory: the egg is a source from which, through the combined help of Vulcan and Mars, a bird would rise that will conquer the realm of fire and metals. [24] As with the other emblems, the same kind of complicated web of associations and allegories is knitted here, leading from Greek mythology to Christian allegories and alchemical

[23]Maier, 1617a, 41 (emblem 8): "Accipe ovum & igneo percute gladio."

[24]Ibid.: "Est avis in mundo sublimior omnibus, Ovum / Cujus ut inquiras, cura sit una tibi. / Albumen luteum circumdat molle vitellum, / Ignito (ceu mos) cautus id ense petas; / Vulcano Mars addat opem; pullaster & inde / Exortus, ferri victor & ignis erit."

FIGURE 2. *Portae amphiteatrum sapientiae aeternae*, in Heinrich Khunrath, *Amphitheatrum sapientiae aeternae* . . . Hanau, 1609. Courtesy of the Gershom Scholem Library, Jerusalem National University Library.

symbols that deal mainly with the transmutation of metals. The alchemical process, according to the emblem and the discourse appended to it, is portrayed in analogy to other processes of transformation: from an egg to a mature bird, from the womb to an adult human, and, especially, from the Virgin's womb to divine perfection. The alchemist's task is to follow these processes in his attempt to realize perfect control over nature. The perspectival vestibule guides the reader from the material and sensual gaze to a different kind of gaze, a perfected one structured according to perfect mathematical proportions. This gaze will be made possible when the egg is cracked open in the material theater from which the magus embarks on his way after supreme wisdom. Accordingly, the meaning of the vestibule drawn in perspective is the transformation of human cognitive processes and the shift to another form of consciousness and awareness, which exists on a separate level of reality.

FIGURE 3. Emblem 8 in Michael Maier, *Atalanta fugiens*. Oppenheim, 1618. Courtesy of the Huntington Library, RB 600059.

However, mathematical symbols acquired additional meanings in the emblematic world. For instance, in emblem 21 of *Atalanta fugiens* (fig. 4), the motto commands: "Make a circle out of a man and a woman, out of this a square, out of this a triangle, make a circle and you will have the Philosophers' stone."[25] The epigram develops further the symbolic nature of the geometrical shapes:

> Make a circle out of a man and a woman,
> From which a quadrangular body arises with equal sides,
> Derive from it a triangle, which is in contact on all sides with a round sphere:
> Then the Stone will have come into existence.
> If such a great thing is not immediately clear in your mind
> Then know that you will understand everything, if you understand the theory of Geometry.[26]

Maier asserts that geometrical shapes and their manipulation acquire new significance: the squaring of the circle is a symbol of the unification of contraries. The shapes themselves acquire a dimension of sexual identity and difference that the magus aspires to transcend. One of the means the magus can apply is the activation of images and their combination, a process that will bring about harmony in the universe; vice versa, processes in the universe, like the creation of a suprasexual being — as in the words of St. Paul, a being "no longer male and female" (Galatians 3:28) — will cause the squaring of a circle. Maier follows here a tradition of astral magic that took geometrical shapes as a means to mobilize astral forces to produce terrestrial effects.[27] The association between the geometrical shape and the natural object is not a quantitative representation but a qualitative analogy. In other words, the geometrical figure itself becomes an emblem that concentrates within itself a web of verbal — that is, textual — associations.[28]

Following the above examples, one can point to two main uses of mathematics within the emblematic world: initially, mathematical entities are conceived as both causing and symbolizing the metamorphoses of the

[25]Ibid., 93 (emblem 21) : "Fac ex mare & foemina circulum, inde quadrangulum, hinc triangulum, fac circulum & habebis lap. Philosophorum."

[26]Ibid.: "Foemina masque unus fiat tibi circulus, ex quo / Surgat, habens aequum forma quadrata latus. / Hinc Trigonum ducas, omni qui parte rotundam / In Sphaeram redet: Tum Lapis ortus erit. / Si res tanta tuae non mox venit ob via menti, / Dogma Geometrae si capis, omne facies."

[27]Cf. Agrippa, esp. 253–55 (2.23), and 69–70 (1.34); see also Josten.

[28]Zur Shalev has suggested to me that the outer circle with crumbling bricks and plaster creates an image with the appearance of a world map. For the association of maps and emblems in early modern cartography, see Nuti.

FIGURE 4. Emblem 21 in Michael Maier, *Atalanta fugiens*. Oppenheim, 1618. Courtesy of the Huntington Library, RB 600059.

so-called magical gaze. The magus's vision moves from the perception of the material world to the conception of a different realm arranged according to pure proportions. These proportions guide the contemplative eye to a higher sphere of being.[29] The other use of mathematical entities fixes them as symbols of hermetic processes that cause the unification of contraries, or as talismans that concentrate in them the powers of the universe — this is usually the case in Renaissance theories of astrology. This utilization of mathematical symbols aims at influencing the material world itself. It is the use of the knowledge acquired through the first process for the transformation and salvation of the visible realm. The square and circle are abstract entities and their meaning is not easily recollected. Thus one's understanding of these geometrical figures must go beyond their quantitative aspect. Recollecting the essence of geometric shapes will lead to the understanding that a square is not a mere theoretical quantity, but actually a symbol for the chemical qualities of the four elements. The circle is not merely a visual shape, but the symbol of the simple body. Thus, the process described in the emblem is not just the squaring of the circle, which Maier claims the natural philosophers knew, but an alchemical process in which the four elements are transformed into three: body, spirit, and soul.[30] These in turn correspond to the three primary colors: the earth, or material body, is black (the color of Saturn), the spirit is water and appears in the whiteness of the moon, and the soul, like the air, is the yellow of the sun. The triangle must be transformed into a circle, which is unity, and its color is red. This is the process through which a woman turns into a man to become unity. In such a way, the numbers are perfected by One that is "rest and eternal peace."[31] Through the contemplation of these analogous processes the initiate will advance toward true enlightenment.

The alchemist perceives the natural world to have deteriorated from its initial divine grace and perfection.[32] Nature has been corrupted, and has

[29]See Yates, 1969, esp. 42–79.

[30]See Maier, 1617a, 94–96.

[31]Ibid. These three elements correspond to John Dee's conception of three grades in the advent of the initiate towards perfection and wisdom. The realm of *pneumaticus* (the spiritual) is divided into three levels. Leading from the *philosophos*, associated with the element of water, and having a "taste of the fundamental truths of natural knowledge," the *sophos* follows: this second grade is associated with the element of air. He explores the "celestial influences" and "the reasons for the rise, condition, and the decline of other things." The last is the *adeptiuus*, who is associated with the element of fire and aspires to explore "the supernatural virtues and metaphysical influences." See Josten, 114–21; Clulee, 81–82.

[32]See Croll, 1659, B2 ("Preface to the Reader"); Croll, 1657, esp. 131–39. See also Hannaway; Webster, esp. 48–71; Tilton, esp. 78–79 and 183–89.

disintegrated as a result of original sin. This lapsed natural state is not limited only to the sublunar realm: many philosophers during the sixteenth century watched with anxiety how decay and corruption spread to the eternal heavenly bodies. Alchemists and hermetic philosophers saw in this state of affairs an urgent call for an extreme effort to save the universe. Maier, following Paracelsus and other alchemical theoreticians, conceived the transmutation of metals as a salvation of their primary divine nature. The task of the alchemist was to retrieve these memories of the divine creator's act, which are locked within fallen matter. The process Maier describes takes place on two analogous levels, in the human mind and in physical nature. Contemplating emblematical scenes initiates a mnemonic process whereby the human mind dissociates itself from the material world to gaze instead on spiritual and divine essences. The human contemplator searches for divine sparks that were imprisoned in the material realm of bodily passions, and attempts to reunite them with their divine origin. This process is complemented by the alchemical transmutation of metals, whereby debased metals are transformed back to their noble essence. These two processes are connected, each reflecting the other. The alchemist experiments with fire in the material realm to inspire and induce the mental processes, and vice versa. Thus the salvation of nature will take place simultaneously with an apocalyptic salvation of the human race.

The alchemical emblems addressed the Aristotelian gap between the realm of concrete visual signs and the realm of universal concepts by turning this gap into a paradox, into serious play.[33] The visual image is set in order to overcome the loss of Adamic language, together with the deep wisdom associated with it that allowed words to penetrate the hidden corners of the universe. The visual image enables putting the different texts side by side: the Bible together with the Platonic dialogues, the Hermetic texts together with Aristotelian speculations or with Paracelsian treatises. It combines the meaning of the various textual traditions, and produces a coherent and unified truth. The emblem thereby disconnects memory from normal sensual experience and the external world, and enables it to begin its travel after the resurrection of lost knowledge. This becomes possible through the fantastic nature of the visual image. Although it is a sensuous image it depicts unusual occurrences that transform natural phenomena into playful puzzles. Yet in this play the serious conclusions are always ephemeral, always hinting that things are not what they seem, and that any serious truth

[33]For some initial treatments of serious play in early modern Europe, see Barolsky; Colie; Findlen, 1990; Gordon; Kaufmann, 1990.

arrived at will evaporate immediately in front of the frustrated gaze of the sinful human mind.

3. Emblems and Intellectual Vision in Robert Fludd

In order to understand this ambiguity of the emblem as a mnemonic device, on the one hand, and as pointing beyond memory to the source of divine wisdom, on the other, one has to look into the psychological system of vision as Fludd presents it. Overlooking it may foster a misunderstanding of Fluddian rhetoric, with the false assumption that Fluddian science envisions a protoempiricist scientific method.

In the second volume of his monumental work dealing with the history of the microcosm, Fludd gives an idiosyncratic account of the triple division of the soul's vision. This account combines a strange mixture of Neoplatonic, Hermetic, and Aristotelian psychology. The first stage in the soul's visual perception is the corporeal vision that perceives the colors and dimensions of external bodies.[34] The soul needs this corporeal dimension, since otherwise it is unable to perceive external physical reality due to itself being an invisible spiritual substance. The second type of vision discerns the spiritual images of corporeal bodies. Although these images originate from material bodies, Fludd names them spiritual because they do not possess a corporeal body. Furthermore, these images are created by an occult power. This occult power enables the external bodies to express themselves in the same manner as images are produced in a mirror.[35] The third type of vision is the intellectual vision, which aims at a realm beyond the physical world and perceives the truth itself.

Fludd's next step is to put these three types in an ordered hierarchy according to their cognitive value. In contrast to Aristotle in the *De anima*, who assumes the perception of the special objects of each of the senses to be infallible, Fludd declares that the material sense of vision itself is responsible for errors of perception in the soul.[36] Fludd gives different topical examples of visual errors, from sailors who imagine the shore to withdraw, to the stick

[34]The discussion of the tripartite division of the soul is in Fludd, 2:204.

[35]Ibid.: "Therefore, the soul is seized in this way by some occult and spiritual power, as the similitudes of the body are portrayed in place of the body, just as one would see in a mirror." All translations of this work are by the author.

[36]Aristotle, 1:665 (*De anima*, bk. 2, 6:418a14–18): "Each sense has one kind of object which it discerns, and never errs in reporting that.... Such objects are what we call the special objects of this or that sense." Fludd, 2:204: "Indeed, so often the soul is deceived and led astray by corporeal vision . . . the sense is deceived concerning the true and specific object, since what seems to appear in fantasy, it believes to be the effect of the body itself."

that appears to be broken in the water. Fludd concludes this section by denigrating vision as a prime deceiver of the soul: "On the contrary, inasmuch as vision is the most excellent among all the other senses, it is mostly deceived."[37] All these matters are treated in the science of optics; however, for Fludd, optics does not seem to solve the problems concerned with visual deception but only to trace the problems and the extent of visual illusions in daily human experience. Fludd then rejects the Aristotelian definition of special objects of sense, and locates the visual distortions in the eye itself and not in the judgment of the soul. Moreover, the soul can adjust (as well as produce) these distortions by using the science of optics and perspective.

According to Fludd, the power residing in the more spiritual elements of the soul is greater than in the senses concerned with material reality as such. Therefore, the distortions produced in the spiritual parts are more potent and have more lasting effects. These distortions not only cause the soul to fail, but also bring suffering and aggravation.[38] The principle that guides and shapes these effects is that the second type of vision is concerned not with the things in themselves but with their similitude, and the mind perceives these simulacra as in a polished mirror. However, these images are not only the product of things in themselves but are their reflection, the image of these things exerted from the unreliable external senses.[39] It is through this type of vision that one discerns the three-dimensional outlines of the corporeal world, which is the place where the images of the celestial bodies and of the zodiac are constructed. Fludd, however, is careful to emphasize the difference between this spiritual vision and the intellectual vision. The latter can never err and is always contemplating higher realities such as "God, the rational mind and intellectual reason, the cardinal virtues, chastity, piety and whatever else of this kind"; whereas through the former type of vision one sometimes acquires correct perceptions and sometimes wrong ones. Thus the spiritual vision sometimes agitates the soul and sometimes brings it to tranquillity.

The main cause for this problematic state of affairs is that the spirit is not a body, but participates in bodily qualities either by being the form and similitude of the body, or by participating in the nature of the lower and material kind of light. While one is sleeping, the more agitating effects of

[37]Fludd, 2:204: "Immo vero inter omnes alios sensus maxime visus, quamvis praestantissimus, decipitur."

[38]Ibid.: "Concerning the second grade of the vision of the soul, that is in the imagination or phantasy... in these the soul seems sometimes beguiled, suffering and aggravated."

[39]Ibid., 205–06.

the spiritual imagination are revealed in sexual dreams and nocturnal emissions of semen.[40] Although it may have some cognitive value, the imagination is more dangerous and false than the external senses because it can move the flesh while the normal inhibitions are weakened in sleep. Thus even chaste and religiously-minded people are not protected against its evil temptations.[41] For if the soul adheres to the superior mind then its vision is turned to more mental and intellectual pursuits. However, when the soul is subjected more to the sensual elements of cognition it employs more of its inferior vision. If one attempts to gaze at the truth, one must first release the middle spirit from its corporeal temptations. Fludd implies the means for liberating the soul from the grip of material passions in his discussion of dreams. While for the most part dreams, the hallucinations of the madman, and daydreams are just reenactments of daily material desires, there are certain kinds of dreams in which one is not viewing external and material bodies but the spiritual content of the soul itself. In this kind of internal vision the soul perceives not those simulacra it received from external bodies, but inspects its own inner forms in themselves. In order to achieve this kind of vision, Fludd testifies that he contemplates remarkable emblems (*admiratio insigni*) that bring him to amazement and wonder. This vision is disconnected from the material corporeal vision: "Yet, whatever the nature of that vision is, it is for certain not corporeal. For no [corporeal] body produces those images in the spirit. Nor has it this power to shape something spiritual; but the spirit by itself presents it in its own wonderful speed, as one might expect of [something] spiritual, intellectual, or rational."[42]

According to Fludd, the material eye can only produce meaningless visual impressions; it gazes at the passing ephemeral reality and receives its shadowy impressions, which become pictures in the internal eye of the spirit, where fantasies retain the content of one's memory. However, as long as this pictorial content is associated with the external world, it has

[40]Ibid., 206–07: "Whence, often the images of corporeal things are present in a dream so distinctly, just as the body itself appear when one is awake, so much so that it is not possible to distinguish between the vision of those who sleep and the true cogitations of those who are awake, as [those who are sleeping] are moved by the always present flesh, and against their usual conduct, and the accepted mores, they see themselves mating, and what naturally is accumulated, is emitted through the genitals; and indeed the physicians name this action 'nightly pollution.'"

[41]Ibid., 207.

[42]Ibid., 208: "Qualiscunque tamen illa visorum natura sit, procul dubio corpus non est. Non enim corpora visa illas imagines in spiritu faciunt, nec eam vim habent, ut aliquid spirituale forment; sed ipse spiritus in seipso celeritate mira id praestat, utpote spiritualis, intellectualis atque rationalis."

dangerous implications. It excites the human imagination to false dreams and moves the human psyche mainly in the direction of sexual stimulation. Thus it moves one's mind away from its aspiration to wisdom and truth. The only way to turn the internal mind toward the superior domains of true wisdom is to arouse the spirit's inner content and to kindle the intellectual eye. This can be performed by refurnishing the theater of memory with pictures that have no origin in the external and sensual world. Although it has a sensory aspect, the emblem is a fantastic picture divorced from ordinary human experience that allows the spiritual eye to overcome sensual temptations and to turn toward intellectual contemplations of God.

Yet although the stakes were high, and the promise of the alchemical emblem was tempting, at the heart of this tradition was an epistemological obstacle. The gap between the concrete phenomenon and the realm of universal concepts was preserved. In bringing the particular and the universal ever so close, the serious play still left the spectator-reader of the emblem in uncertainty: had one glimpsed truth or just another level of allegory?

4. Kepler's Diagrams

Kepler encountered emblems on various occasions throughout his scientific career. He read books of emblems and gave serious consideration to the role of visual representations as a means for acquiring knowledge.[43] In his *Mysterium Cosmographicum* of 1596 Kepler had already supplied the reader with an impressive image of the heavenly globe constructed from the Platonic solids. The intention of this globe was to "direct the eyes to the central mystery of the cosmic machine."[44] This interest in visual representations persisted throughout his scientific career, always in an attempt to demarcate his own method for the utilization of images from artistic practices, on the one hand, and, especially, from the alchemists' application of visual imagery in their quest for knowledge, on the other.[45]

[43]See Kepler's handwritten comment concerning the emblem of a falling Icarus at the margins of Sanchez of Salamanca: "No one falls off the grassy plane of the earth while lying on one's back; Oh! So much emptiness surrounds human affairs!"

[44]Kepler, 1937–, 13:225 (Kepler to Michael Maestlin, 1/11 June 1598). For a more detailed discussion of Kepler's globe, its emblematic plan (a device to serve beverages to the courtiers), and its entertaining and playful intentions, see Mosley, esp. 202–09.

[45]See, for instance, L. P. Smith, 2:205–06, who relates an anecdote told by Sir John Wotton, ambassador of the English crown to the Holy Roman Empire: Kepler is reported to have emphasized that he drew his pictures "not as a painter, but as a mathematician." The issue of painters' practices is commented upon further in Kepler's correspondence with

In 1617 Kepler found himself in a direct polemic with the emblematic worldview of Robert Fludd and his alchemical-spiritual milieu. Kepler succinctly summarizes the differences: "In [Fludd's] work there are many pictures; in mine, mathematical diagrams keyed with letters. You may also note that he takes delight in the shadowy mysteries of things, while I strive to bring these same things, wrapped in obscurity, into the light of understanding.... The harmonies he aims to teach are mere symbols... poetic or rhetorical rather than philosophical or mathematical.... Following the celebrated axiom of Hermes, he makes *things above similar* or analogous *to things below*. But in order for this analogy to apply everywhere he must often drag things in by the hair so that they will apply on both sides. My view on analogies... is clear; they are apt to run into infinity."[46] What is new in Kepler's diagrams? What exactly is the difference, for instance, between Kepler's symbolically potent heavenly globe comprised of Platonic solids and Fludd's emblematic depiction of microcosms and macrocosms? What different ontological status did Kepler ascribe to his pictures, in contrast with those of Fludd and his milieu?

Both Fludd's emblems and Kepler's diagrams addressed the gap between knowable universals and concrete physical events. In order to surmount this gap and to disentangle his science from the multileveled interpretations of emblematic representations of the secrets of nature, Kepler had to redefine the epistemological status of pictures. Kepler is careful to distinguish true diagrams that are supposed to comprise an integral part of scientific reasoning from "pseudo" diagrams that serve a didactic or rhetorical purpose. In defending Brahe's diagram of parallax

Schickhardt: see Panofsky, 1927, 295–96; Frangenberg. For Kepler's debates with alchemists and Hermetic philosophers concerning visual representations, see, for instance, Kepler, 1937–, 16:154–65 (Kepler's letter to Joachim Tanckius, 12 May 1608); see also ibid., 4:245–46, for his *Tertius interveniens* (Frankfurt, 1610), where Kepler discusses the theory of signatures and comments that: "God Himself, since because of His supreme goodness He cannot remain without occupation, has therefore played with the signatures of things, and has represented Himself in the world; and so I sometimes wonder whether the whole of Nature and all the beauty of the Heavens is not symbolized in Geometry.... Just as God the Creator has played, so he has taught Nature, His image, to play, and indeed to play the same game that He has played before her." (Translation and further discussion in Walker, 55–56.) For a Jungian treatment of Kepler's 1617 polemic with Fludd, see Pauli; for further analysis, see Westman. See Pantin for the way Kepler applies images and figures rhetorically and didactically.

[46]Kepler, 1937–, 6:374 (appendix to book 5 of *Harmonices mundi*). Quoted in Copenhaver, 283.

calculations for the position of comets from Galileo's violent criticism, Kepler stresses that it was nothing but a "pseudodiagram."[47] Brahe's diagram was meant only as an explanatory illustration, and one cannot draw physical or mathematical conclusions from it. True diagrams are not simply visual illustrations artificially appended to corporeal reality, and they are not abstracted from it. On the contrary, Kepler turned the process of abstraction on its head, and with it the process by which mathematical entities originate.[48] Instead of the scholastic dictum that "nothing is in the intellect that was not first in the senses," Kepler declares that "Indeed, to the human mind . . . quantity is known by instinct, even if for this purpose it is deprived of all sensation. Of itself it understands a straight line, of itself an equal distance from a given point, of itself it forms for itself from these an image of a circle. . . . For the recognition of quantities, which is innate in the mind, dictates what the nature of the eye must be; and therefore, the eye has been made as it is because the mind is as it is, and not the other way around."[49] Kepler further asserts that a diagram is an expression of a priori principles, and that its role is to assist the mind in performing geometrical constructions: "Yet that construction is never drawn from sensible things in a diagram, though it is assisted by them; and it does not arise from the assembling of many individual sensible things into one axiom, but it is obtained a priori."[50]

Kepler's 1604 treatise on optics, *Ad Vitellionem paralipomena*, supplied the theoretical framework for the construction of such a priori diagrams and the legitimacy of their application to the physical world. This treatise heralded a new system of scientific observation, together with a new visual language to account for it mathematically. At the outset of his treatise Kepler declares: "I have not satisfied my soul with speculations of abstract Geometry, namely with pictures of what there is and what is not, to which the most famous geometers of today devote almost their entire time. But I

[47]Kepler, 1937–, 8:413; Kepler, 1625, 186: "διαγραμμα ψευδες," or "ψεδογραφημα." See also Kepler, 1937–, 8:309: "[T]his entire schema is to be seen as means for the understanding of this new demonstration, indeed not to deliver the true cause concerning this matter."

[48]For Kepler's critique of Aristotelian abstraction, see Chen-Morris, 2001. For other treatments of Kepler's philosophy, with an emphasis on his theory of archetypes, see Martens; for a more metaphysical treatment of Kepler's notion of vision, see von Samsonow.

[49]Kepler, 1997, 303–04 (*Harmonices Mundi,* pt. 4, chap. 1, in Kepler, 1937–, 6:222).

[50]Ibid.: "demonstratio vero illa ex sensibilibus diagrammatis nunquam habetur, etsi iis adiuvetur: nec ex collectionibus oritur multorum sensilium in unum Axioma, sed a priori comparatur."

have investigated the geometry that, by itself, expresses the body of the world following the traces of the Creator with sweat and heavy breath."[51]

Kepler aspired for the transformation of visual depiction into an exact representation of the motions of the universe. His visual images, optically produced, furnished the emergence of a new and coherent picture of the world, abandoning the claim for the creation of a transcendental reality. In discarding pictures "of what there is and what is not," Kepler probably had in mind the vast literature of alchemical emblems and mathematical mysticism so popular in and around the court of Rudolf II at the turn of the sixteenth century.[52] In place of such contrived and fantastical images, Kepler suggests his optics as the matrix that enables a priori diagrams to express "the body of the world" and to follow the "traces of the Creator."

This is neatly exemplified in Kepler's treatment of the conic sections in *Ad Vitellionem* (fig. 5). In Apollonius's classical treatment of conic sections (ca. 200 BCE), each curve is constructed separately from a visible concrete cone.[53] Kepler's treatment is the first to depart from such a cone and to present a unified system of the sections and their property.[54] Kepler considers the sections not as abstractions of specific sectionings of a specific cone, but emphasizes the analogical relation between them. He begins his exposition with no geometrical constructions of specific cones, but with a quick inventory of the different possible cones. Then he specifies the five species of sections of the cones, emphasizing that the characteristics of these sections are independent of the specific kind of cone they bisect.[55] This enables Kepler to present the reader with an a priori system of conic sections, where the value of each of its different elements is internally determined and interrelated to the other elements.[56] In this system the age-old ontological dichotomy between the basic species of lines, the straight and

[51]Kepler, 1937–, 2:10 (dedicatory letter): "Neque animum explevi speculationibus Geometriae abstractae, picturis scilicet και των οντων και των μη οντων in quibus pene solis hodie celeberrimi Geometrarum aetatem transigunt: sed Geometriam per ipsa expressa Mundi corpora, Creatoris vestigia cum sudore et anhelitu secutus, indagaui." Author's translation.

[52]The target of this remark might have been Giordano Bruno's *Articuli adversus mathematicos*. In the dedication to Rudolf II, Bruno insists upon the study of the vestiges or footprints left by nature through a set of contrived geometrical constructions. For the intellectual ambiance at the Rudolphine court in Prague, see especially Evans; Kaufmann, 1988. For a general survey of the role of emblematic representation in the context of the Habsburg court of the seventeenth century, see Ashworth, 1991.

[53]See Fried and Unguru.

[54]See Davis; Field.

[55]The sections of all these, regardless of kind, fall into five species.

[56]Here I follow Klein, esp. 121–23.

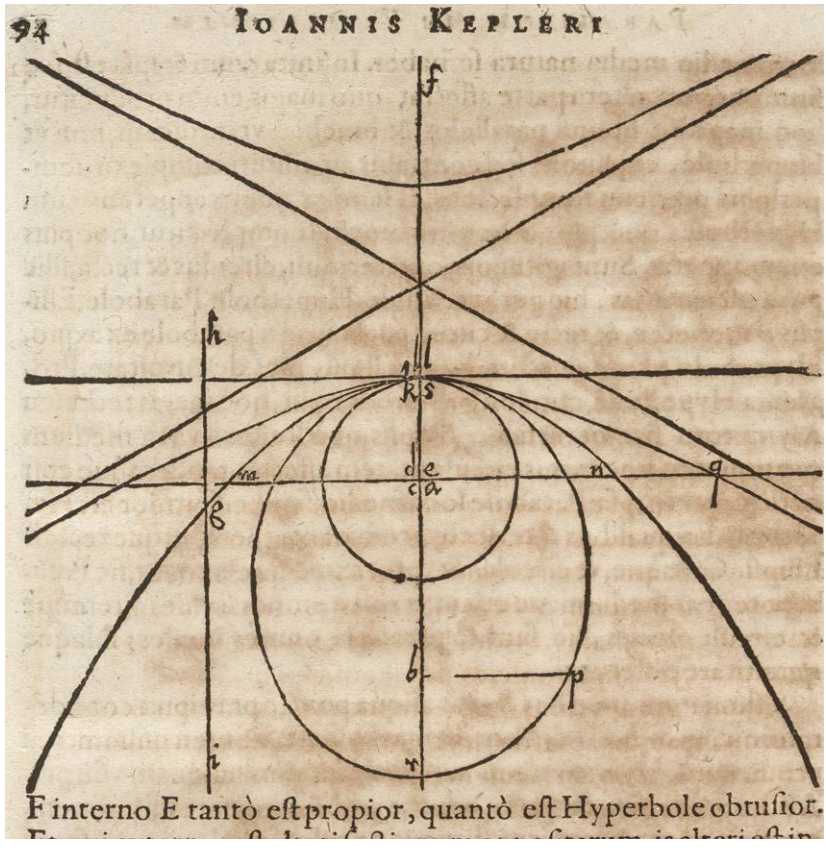

FIGURE 5. Kepler's system of conics. Ch. 4, p. 94 in *Ad Vitellionem paralipomena*. Frankfurt, 1604. Courtesy of the Huntington Library, RB 487000.347.

the curved, collapses.[57] Through systematic and self-regulating transformations, Kepler unifies these contradictory elements into one geometrical continuum: "For the line on the surface of a cone established by a section is either straight, or a circle, or a parabola or hyperbola or ellipse... there exist among these lines the following order, by reason of their properties: it passes from the straight line through an infinity of hyperbolas to the parabola, and thence through an infinity of ellipses to the circle."[58]

[57]See Plato, 827 (*Republic* 10, 602c); Aristotle, 2:1559 (*Metaphysics*, A, 986a22–26), Aristotle's mentioning of the Pythagorean dichotomy of the straight and the curved. See also ibid., 1:119 (*Posterior Analytics* 1, 73b19–24); Proclus, 84–92.

[58]Kepler, 1937–, 2:90 (translation in Kepler, 2000, 107).

The straight line is nothing more than an infinitely stretched hyperbola, and a circle is but an obtuse ellipse: "For the most obtuse of all hyperbolas is a straight line; the most acute a parabola. Likewise, the most acute of all ellipses is a parabola; the most obtuse, a circle... Therefore, the opposite limits are the circle and the straight line: the former is pure curvedness, the latter pure straightness. The hyperbola, parabola, and ellipse are placed in between, and participate in the straight and the curved, the parabola equally, the hyperbola in more of the straightness, and the ellipse in more of the curvedness."[59]

Kepler, however, is unable to establish this system of interrelated elements on firm geometrical grounds.[60] Discarding Apollonius's "cone-based" generation of the different kinds of curves, Kepler is unable to suggest the quantitative reasons for his system, and all he has to fall back on are qualitative analogies. Kepler celebrates these analogies as "the most faithful teachers" that assist the scientist in exposing the "hidden secrets of nature."[61] Yet he knows that these analogies cannot deliver a geometrical proof for his system. Kepler puts forward instead a physical analogy, emphasizing the role of the conic sections in the analysis of curved mirrors that focus the rays of the sun. His description of the *foci* (probably a linguistic invention of Kepler) transforms the physical points into geometrical terms. Kepler explains how the single focus of the circle and the two foci of the ellipse are related, and continues: "In a parabola one focus D is within the section, the other is to be supposed on the axis, either outside or inside the section, removed at an infinite distance from the former one, so that a line HG or IG drawn from that hidden focus to any point of the section G is parallel to the axis DK."[62]

Kepler can now complete his system of analogies: "It follows by analogy that, for the straight line, the focus (as we will use the term, in relation to the straight line, without precedent, to complete the analogy) in both cases coincides with the line itself, so that there is only one focus, as for the circle. Then in the circle the focus is at the center itself — the point furthest from the circumference — in the ellipse it is less far from the circumference, and

[59]Kepler, 2000, 107.

[60]Ibid., 106, where Kepler presents his own analysis of the conics in the following way: "However, because the consideration of the section is difficult, because it is too little pursued, it would be good to say a few words about it in a mechanical, analogical, and popular vein. Geometers, be indulgent!"

[61]Kepler, 1937–, 2:92 (translation in Kepler, 2000, 109).

[62]Kepler, 2000, 108.

in the parabola much less, in the end being the minimum distance away: that is, it falls on the line itself."[63]

Kepler's method for the construction of conic sections, and the a priori reasoning that brought this system into being, are not enough to make it meaningful.[64] This system becomes meaningful only if the mind is able to recognize these curves in the movements of the physical world, that is, as a surface that would turn into parallels all the rays of light falling upon it and would describe a pattern of the angles of refraction. Kepler is looking for a geometrical surface that will have an exact physical meaning. Yet he has to admit that mechanics shows that a physical surface of this kind only resembles a hyperbola, and that "it is a little more acute than the hyperbola itself near the vertex." Dissatisfied, he concludes his attempt to measure refractions in setting a challenge to his reader: "When you shall have acquired perfect knowledge of this surface by some procedure, know that you have achieved something great in mechanics."[65]

5. KEPLER'S PICTURES

Kepler's new conception of light as a principle of physical motion, and not as an emanation from the realm of ideas, supplied him with the grounds for a thorough critique of the emblematic pictorial language of late sixteenth-century alchemy. Emblems attempted to bridge the gap between abstract ideas and concrete appearances through a paradoxical application of a sensuous picture that will lead the spectator to experience an intellectual and spiritual truth. Playing with fantastic and paradoxical pictures was meant to assist the spectator in disengaging his mind from mundane reality, leading him to contemplate higher spiritual realities. Kepler, however, not only transformed geometrical entities into a representation of motion, but set to

[63]Kepler, 1937–, 2:92: "Sequitur ergo per analogiam, vt in recta linea vterque focus (ita loquimur de recta, sine vsu, tantum ad analogiam complendam) coincidat in ipsam rectam: sitque vnus vt in circulo. In circulo igitur focus in ipso centro est, longissime recedens a circumferentia proxima, in Ellipsi iam minus recedit, et in Parabole multo minus, tandem in recta focus minimum ab ipsa recedit, hoc est, in ipsam incidit."

[64]Kepler's analysis of conic sections is a story of a failure both to mathematically establish an a priori system and to apply it to find "the causes for the magnitude of refraction": Kepler, 1937–, 2:110; see also Buchdahl. Yet this failure, while delineating the limits of Kepler's new science, exposes the essential features of his epistemology and scientific method: see Simon.

[65]Kepler, 2000, 123.

redefine the essence of a picture.[66] He aligned his new notion of the picture with a new theory of cognition, which reassigned the playing mode to the process of a serious inquiry aimed at discerning the physical truth.[67]

Kepler's redefinition of the picture appears in chapter 5 of *Ad Vitellionem paralipomena*: "Since hitherto an image has been a rational Being, now figures of objects that really exist on paper, or upon other screens, are called pictures."[68] In forming the figure of an object reflected in a mirror or refracted in water, the spectator's vision complements missing data by an act of inner calculation. This is why these images have no true existence. Kepler's definition attempts to preserve a dichotomy between pictures that are formed without any intervention on the part of human faculties, and those that are dependent on the human faculty of vision's own inept devices. This is Kepler's attempt to preserve the medieval differentiation between real optical effects, or *pictura*, and virtual ones, or *imago*. He defines *imago* as: "When an object itself is indeed perceived along with its colors and the parts of its figure, but in a position not its own, and occasionally endowed with quantities not its own, and with an inappropriate ratio of parts of its figure. Briefly, an image 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. The object is composed of the real form (*species*) of color or light and of intentional quantities."[69]

[66]See Malet. For other, somewhat different, analyses of Kepler's theory of vision, see Crombie; Straker, 1971; and especially Straker, 1976. For a critical response to Crombie and Straker's thesis, see Lindberg, 1985 and 1986.

[67]This coheres well with Clark, and his depiction of the ways early modern European culture rejected vision as a source of knowledge and de-rationalized sight. Maier and Fludd suggest fantastic pictures as a means to bypass the eyes. Kepler suggests mathematical analysis-*cum*-artificial instruments of observation — such as the camera obscura and, later, the telescope — to avoid "the inadequacies of the eyes": Kepler, 1937–, 2:39.

[68]Kepler, 1937–, 2:174: "Cum hactenus Imago fuerit Ens rationale, iam figurae rerum vere in papyro existentes, seu alio pariete, picturae dicantur." I have amended Donahue's translation (Kepler, 2000, 210) on two points: he translates *Ens rationale* as "Being of reason," which is somewhat vague and does not convey Kepler's attempt at an exact definition. I suggest that *rationale* should be taken as referring to ratios and their calculation. Secondly, Donahue translates *pariete* as "surface," and I suggest that "screen" is more appropriate in this context. For Kepler's differentiation between real pictures and images, see Malet.

[69]Kepler, 2000, 77. This is a reiteration of Pecham's definition of an image in a mirror: see Pecham, 170; see also A. M. Smith. For the meaning of *intentio* in the context of medieval theories of perspective, see Tachau, especially chap. 1. For *quantitas intentionalis*, see Oresme, 3–49.

The summation of Kepler's optical arguments, chapter 5 of *Ad Vitellionem paralipomena* begins by emphasizing and rehearsing the epistemological context of his optical discourse. "The astronomers place at the foundation [of their science] the diameters of the luminaries and the quantities of solar eclipses; now, some visual deception is produced, partly from the conduct of the observation, which we discussed in chapter 2, above [where Kepler discusses the formation of images in cameras obscura], partly from simple vision itself... as long as the latter is not dissipated, it would create considerable difficulties for the astronomers and diminish their judgment capacities. Therefore, the occasion of such errors in vision has to be investigated, and that according to the shape and functions of the eye itself."[70] The main part of the fifth chapter, dealing with human eyes and the sense of sight, is devoted not to anatomical data but to adjusting Kepler's optical theorems to a particular set of experiments. Kepler details the experimental context immediately after he summarizes his anatomical description of the eye's structure. The anatomical backdrop is utilized to isolate the two main components that produce the sensation of vision, the crystalline humor and the retina.

Kepler discusses two fundamental phenomena in this context: the appearance of a picture on paper, or any other sort of screen, placed behind a crystal ball or a glassy urinary flask filled with water set against a window in a room; and the disappearance of this picture when the eye is positioned where the paper was before. In other words, when placing a screen in a closed room behind a refracting object in front of a window, the light beaming through will project a picture of the outside on that same screen. When, however, the screen is removed and a human spectator — that is, a human eye — is placed where the screen had been standing, the picture will disappear and the spectator would see nothing. Kepler asserts that the main factors responsible for these phenomena are the refractions of rays of light and the convex shape of the glass globe filled with water.[71] In the following propositions he attempts to explicate these phenomena, and especially to delineate the psychological factors that determine the disappearance of pictures on paper, and the appearance of images on the surface of the ocular

[70]Kepler, 1937–, 2:143: "Dum diametri luminarium et quantitates Solis Eclipsium, fundamenti loco annotantur ad Astronomis: oritur aliqua visus deceptio, partim ab artificio obseruandi orts, quam supra cap. 2. Discussimus, partim ab ipso visu simplici: quae quoad non tollitur, plurimum negocii facessit artificibus, detrahitque artis existimationi. Erroris itaque in visu, occasio quaerenda est in ipsius oculi conformatione et functionibus." Author's translation.

[71]Ibid., 162. Author's translation.

lens — namely, the crystalline globe. Thus the presence of the eye transforms one's optical experience and turns a physical picture into a mere image. Kepler's first step is to explain the image as a psychological phenomenon dependent on the activity of the eye. Initially he proves that, following his catoptrical propositions, the geometrical locus of the image is between the eyes and the globe.[72] The problem arises as to why the eye sees the image on the surface of the globe, and not in that point where the picture had appeared before on the sheet of paper. The answer is that "there is no place in front of the ball or globe of water for the image of a thing hidden behind the ball."[73] The reasons for this are wholly dependent on the natural disposition of the eye.

Kepler defines three factors: physical and organic, functional, and psychological. The physical reason is defined in proposition two: "The sense of vision perceives with more difficulty the nearer [objects] than the remote ones."[74] Since the eyes tend to preserve their parallel position, any attempt to perceive a nearby object strains the eyes to turn and to contract toward it. The second factor is the natural disposition and function of the eyes to perceive light: "Vision is attracted by vividness, but it is hardly drawn to the fleeting and the feeble."[75] This disposition derives not only from experience, but also from the essential property that sight is moved by light. Thus, the stronger the light, the more agitated the eyes are. Therefore, the eyes follow the stronger illumination at the expense of the lesser-illuminated areas. The last factor is the ability of vision to actively create images. This ability is destroyed by strong light, which diverts the beholder from the supposed location of the image. Thus Kepler proves that the image cannot be seen between the eyes and the globe because the eyes are attracted to the illumination coming from the globe. Furthermore, this illumination will overpower and disperse the image.

This analysis leads Kepler to define the image as an entity that the sense of sight creates as an active agent. The human mind is forced to supplement the missing data that the sense of sight is unable to perceive, not because of the external environment, but on account of its own disposition. In these cases, the faculty of vision naturally constructs the mathematical ratios that

[72]Classical optics is comprised of three parts: optics itself, dealing with questions of perspective, the propagation of light, and so on; dioptrics, dealing with refraction; and catoptrics, dealing with reflecting surfaces such as mirrors.

[73]Kepler, 1937–, 2:164: "Ante pilam seu globum aquem nullus est locus imagini rei post pilam latitantis." Author's translation.

[74]Ibid., 163: "Visus ad multum propinqua aegrius respicit, quam ad remotiora." Author's translation.

[75]Ibid.: "Visus ad evidentia rapitur, tenuibus et vanescentibus maligne allicitur."

would inform visual reality and would present it coherently. Kepler provides an explicit case of such in his catoptrical discussion. Since the eyes cannot perceive the point of reflection (or refraction), the faculty of vision has to fill in the sensuous data and structure it geometrically. Kepler contends that this is the reason for one's perception of the image over a perpendicular line drawn from the object to the mirror. As he shows in the catoptrical part of the treatise, the perpendicular line is produced neither by the object nor by the form of the mirror's surface, but is in fact a mental construct: "For it makes no difference to the place of the image, what sort of mirror surface is placed opposite the object, since the proportions of the image being formed are all taken from that part of the mirror upon which are the two points of reflection of light to the two eyes. So it is at this part of the mirror, not at the actual perpendicular from the object, that the cause of the image's place being on that perpendicular lies. And so one should understand mentally the continuation of the pattern of the curvature that had created the reflection on the whole circumference, and above this imaginary sphere one should also draw a perpendicular from the object for defining the place of the image."[76]

For Kepler, illusions are not games played by nature in order to delude the human mind. In contrast to Fludd's sharp distinction between intellectual understanding and sensory experience, Kepler stresses the coherence of human perception. The limited nature of the human senses forces the mind to play and to invent the mathematical constructions that produce an intelligible visual reality. While an image is determined by the natural disposition of the human mind and of the human sense of sight to produce a coherent perception of reality, it depends for its particular appearance on a concrete set of physical circumstances.[77] The convergence between the mind's compulsion for mathematical regularity and the particular physical and psychological conditions causes the image to appear "confused and doubled." Hence the meanings of Kepler's terminology: *Ens rationale* and

[76]Kepler, 2000, 90.

[77]A paper or screen does not respond to these effects of strong light or color. Therefore, the image is stabilized and appears over the paper or screen when it is positioned in the correct geometrical locus where the rays intersect. In this sense, the paper is a passive agent, and the appearance of the image is wholly determined by mathematical considerations. This does not hold for human perception. See Kepler, 1937–, 2:164: "But if you place a paper, say, if you insert a paper between the lens and the eye . . . now the image is not seen hanging in the air, but fixed on the paper. Because the paper strikes the eyes more clearly, it stabilizes them on the place of the image . . . the paper is seen principally, and the image secondarily. For not only mathematical dimensions create the image, but also and much more colors or illumination and physical causes." Author's translation.

Ens intentionale are intended to emphasize the active and inventive role vision plays in rationally producing an optical image. The difference between an image and a picture does not concern the process through which they are produced mathematically or physically, but only the psychological aspects that force the mind to actively complement its sensual data. In the case of the retinal picture, the human mind has no need to actively conjure the missing visual information. As the picture is symmetrically inverted, the mind only has to turn the inverted picture around its symmetrical center to get the exact upright depiction of visual reality. The picture is a passive product of the visual process, and this passivity secures its epistemological status as a true depiction of visual reality. Kepler writes:

Just as vision is not an action because of illumination's being an action, but is an effect contrary to an action, so also, in order that the places correspond, the recipients of the action must be directly opposite the acting things. Further, places are perfectly opposite when the same center forms the midpoint in all the lines of the oppositions, which was not going to occur if the picture had been erect. And so, in an inverted picture, even if from a universal perspective and with respect to some common line the right parts are transformed into the left, nevertheless the right parts of the object are perfectly opposed to the right parts of the picture, and the upper parts of the object to the upper parts of the picture (each in relation to itself), as well as concave to concave. Nor is there any fear that the sense of vision might err about the region.... Rather, it would have been in error had the picture been erect.... Therefore no absurdity is committed by the inversion of the picture.[78]

In the process of image formation, sensuous data is lacking or obstructed: the eye cannot perceive the point of reflection, or strong illumination erases other optical phenomena. However, in the formation of an optical picture all data external to the eye arrives at the retina. Moreover, since the picture preserves the mathematical arrangement of the visible object, there is no need for the mind to supplement it with imaginary geometrical constructs in order to produce a coherent perception of visual reality. The mathematical regularity of the inverted picture vouchsafes against any mistaken identification of place or area.

The medieval theorists defined *species* as the direct physical impression on the eye that travels along perpendicular lines to the crystalline humor.

[78]Kepler, 2000, 221. It is easier to turn an inverted picture (where up is down and right is left) to its correct position, than to reverse a mirror image (where down is down and up is up, but right is left) to its correct position. In the case of an inverted picture all lines from the visible object to the screen on which the picture appears pass through one central point.

They differentiated between *species* as physical effects and *species* as images that are imaginary constructs governed by geometrical laws of reflection and refraction. While still products of the human imagination, Kepler's images did not differ from pictures in their formative process, both being the result of refracted and reflected rays of light. The difference rests in the entirety of the visual data supplied by the process. In picture formation, all the reflections and refractions take place within the eye, thus preserving their geometrical arrangement, though still finally producing an inverted picture. In image formation, some data is missing and the intervention of the human imagination causes the final result to be a certain artificial entity, where things are not what they appear to be.

Keplerian internal imaging is responsible for visual distortions and errors. The mathematical arrangement supplied by the process of reflections and refractions of light and color within the eye can produce meaningful pictures of external reality. Kepler recognized the power of the human imagination to inform one's perception of reality. However, he aspired to limit this power and to supply the criteria for differentiating between real and false perceptions. Initially, he assumed that physical reality tends to express itself through geometrical figures and regularities. The human senses then respond to these geometrical forms, since these senses are formed according to the geometrical archetypes that reside in the human mind. Only when the human mind recognizes its own archetypal content in the sense data can the true knowledge of reality become possible. In other cases, when objects are perceived through reflecting or refracting surfaces, the visual data is incomplete and the mind enforces its own geometrical constructs in its perception of the world and thus creates chimeras and false images. Only a geometrical correspondence between physical reality — as it is represented by the geometrically governed propagation of light — and the mind's inner geometrical archetypes can create true knowledge. Any attempt to deny one of these components results in meaningless illusions. Therefore, while accepting the Platonic description of the mind as an inner painter, Kepler summons the painter to respond to the visual demands of the material, sensuous, and geometrically regulated world.[79]

Kepler's pictures are the products of refractions: they are not emanations from the visible object itself, but are produced by light as an external agent and colors, which are quanta of light hidden within the object's matter. Thus the retinal picture is a doubly mediated — that is, reflected — appearance of the visible object. The result of the visual process is an

[79]Plato, 1989, 1118 (*Philebus* 38b).

inverted and reversed picture of the external object: the parts on the right are now on the left and those at the top appear at the bottom. For medieval and Renaissance sensibilities, Kepler's retinal picture is a distortion on the verge of a chimera, a monstrous depiction of reality. What saves the retinal picture from absurdity is the geometrical regularity of the inversion of the retinal picture. The stable center, through which pass all the lines from the corresponding points on the object and on its inverted picture, limits the mind's ability to play with the sensuous data and thus guarantees one's visual knowledge. In a sense, Kepler's retinal picture is a sort of a serious joke: though it represents the world upside down, it allows one to perceive the truth. However, artistic jokes in the manner of Arcimboldo, or alchemical emblems, are human creations that suggest playful leaps between multiple levels of meaning and signification: their truth is hidden and evasive.[80] In contrast, Kepler's retinal pictures are natural creations and thus limit human creative playfulness — and, by their geometrical regularity, allow only one true depiction of visual reality. Kepler asserts that, unlike the human mind, "Nothing designated by Nature is wasted."[81] He differentiates between the realms of human creativity and natural truth. While the first produces illusions that are the result of epistemological uncertainty, the latter, when carefully analyzed, exhibits geometrical regularity and certitude.

As a fantastic image and as serious play, the alchemical emblem aims to turn the spectator's gaze away from mundane reality toward the invisible secrets of higher, more ethereal realms. Kepler turns the meaning of serious play on its head. Instead of a game that always exemplifies the gap between visible phenomena and the realm of knowledge, leaving the players wondering about several options for interpretation and meaning, Kepler's game results in one definite and clear solution: "I too play with symbols and have planned a little work, *Geometric Kabbala*, which is about the ideas of natural things in geometry; but I play in such a way that I do not forget that I am playing. For nothing is proved by symbols; no hidden thing is brought to light in natural philosophy through geometrical symbols, things already known are merely fitted [to them]; unless by sure reasons it can be demonstrated that they are not merely symbolic, but are descriptions of the ways in which the two things are connected and of the causes of these connections."[82]

[80]For Arcimboldo's serious jokes, see Kaufmann, 1990. For alchemists' notion of the serious game, see Maier, 1616 and 1617b.

[81]Kepler, 1937–, 2:144: "Natura enim nihil iacturae destinat." Author's translation.

[82]Ibid., 14:158: "Ludo quippe et ego Symbolis, et opusculum institui, Cabalam Geometricam, quae est de Ideis rerum Naturalium in Geometria: sed ita ludo, ut me ludere non obliuiscar. Nihil enim probatur Symbolis, nihil abstrusi eruitur in Naturali philosophia,

Keplerian pictures are means of acquiring knowledge because of their geometrical regularities. They are transformed into diagrams. Yet these diagrams are not abstractions from static corporeal bodies, but are representations of possible motions and the relation of these motions to physical bodies. A Keplerian line does not have to be ever finer in order to remind the observer of a true geometrical line. It only has to be accurately calculated so that it can convey the exact path of a possible motion of a physical body in space. By relegating the emanation of visual signs from a motionless corporeal reality — that is, by discarding the mimetic aspect of pictures — Kepler liberates scientific pictures to become exact human-made representations of disembodied motions.

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per Symbolas geometricas, tantum ante nota accommodantur: nisi certis rationibus euincatur, non tantum esse Symbolica sed esse descriptos connexionis rei utriusque modos et causas." For initial treatments of Kepler's notion of serious play, see Walker; Findlen; Chen-Morris, 2005.

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