

# The Formation of Nothing, Or Kepler's Visual Economy of Science

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Draft Version

In his 1596 *Mysterium cosmographicum*, the young Kepler predicts the reaction of his critics against his speculations on how platonic solids determine planetary orbits:

I shall have the physicists against me because I have deduced the natural properties of the planets from immaterial things and mathematical figures, and furthermore because I dare to investigate the origin of the orbits out of bare (*nuda*) imaginary cross sections.<sup>1</sup>

Kepler describes his critics sitting pensively, like Dürer's melancholic angel, pondering at a row of platonic solids lying in front of them, wondering how such imaginary constructs can supply scientific explanation to real physical bodies. At first glance this assumed criticism is an extrapolation of the traditional Aristotelian principle of *metabasis*. According to this principle one cannot "prove anything by crossing from another genus (*metabasis eis allo genos*) – e.g. something geometrical by arithmetic."<sup>2</sup> The word *imaginatio*, however, signify that a shift occurs in the meaning of the admonition against *metabasis*. Aristotle's criticism of the application of mathematics to physical phenomena was founded on his claim that the mind separates mathematical entities from material objects it senses. Although this is a mental operation, the existence and truth of such mathematical entities is dependant on external, physical and corporeal bodies. The observer of a physical, three-dimensional object creates an image of such an object in his imagination and this image is the substratum and the ontological anchor of any further intellectualization.

Kepler's imagining stresses the autonomous existence of such entities especially with regard to their application to natural phenomena.

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<sup>1</sup> Kepler, Johannes. *Mysterium Cosmographicum: The Secret of the Universe*. Trans. A. M. Duncan, introduction and commentary by E. J. Aiton. New York: Abaris Books, 1981, chap. XI, p. 122 [translation amended].

<sup>2</sup> Posterior Analytics, bk I, ch. 7, 75a38; in *The Complete Works of Aristotle*, p. 122. For extensive discussions of this theme see: W. Roy Laird, "Robert Grosseteste on the Intermediate Sciences," in *Traditio* 43 (1987), 147-169, and his "Galileo and the Mixed Sciences," in *Method and Order in Renaissance Philosophy of Nature: The Aristotle Commentary Tradition* (eds.) D. A. Di Liscia, E. Kessler, and Ch. Metheun, 1997 253-270.

In explaining natural phenomena one is condemned to limit the inquiry to visible features. Maestlin, Kepler's teacher and mentor, attempted to legitimize the application of mathematics to a study of the heavens. His move consisted in qualifying astronomical research, contending that this concerns only apparent motions and not the real motions of the heavenly bodies. In 1582 Maestlin affirmed that "Principally, astronomy deals with the heavenly bodies." Yet, Maestlin continued and emphasized that astronomy's business was not with the real physical motions of these bodies but "So as to catalog, measure and investigate the causes of their apparent motions." This emphasis on apparent motions allows Maestlin to turn astronomy into a mathematical science :

It is plainly a composite [science] in itself. For it is properly subjected to be an object or matter of physics: mathematics, truly, is separated, as Geometry and Arithmetic, evidently supply it with demonstration as if with a form. Indeed, apparent motions are not demonstrated physically, but are demonstrated according to mathematical reason.<sup>4</sup>

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<sup>3</sup> Aristotle, *Physics*, Bk. 2, 194a 10-11, trans., R. P. Hardie and R. K. Gaye, in *The Complete Works of Aristotle*, (ed.) J. Barnes (Princeton, New Jersey: Princeton University Press, 1984), vol. 1, p. 331. For a discussion of the status of geometrical lines in optics see: Chen-Morris, Raz D. "Optics, Imagination, and the Construction of Scientific Observation in Kepler's New Science." *The Monist* 84, 2001: 453-86.

<sup>4</sup> Maestlin, M. *De astronomiae principalibus et primis fundamentis disputatio*. Heidelberg, 1582, fol A2<sup>v</sup> Ipsam ergo compositam esse patet. Physicae enim propter obiectum seu materiam subiacet: Mathematica vero secretior, videlicet Geometria & Arithmetica suppeditant ei demonstrationes velut formam. Apparentia enim motuum non physicis, sed mathematicis rationibus demonstrantur. Quoted in Methuen, Charlotte. *Kepler's Tübingen: Stimulus to a Theological Mathematics*. [St. Andrews Studies in Reformation History] Aldershot: Ashgate, 1998, p. 192.

In trying to keep within the set boundaries of the sciences Maestlin ends up with a very epistemologically narrow definition of astronomy. Mathematics, like in Thomas Aquinas, supplies merely the formal cause. Sense experience yields only apparent motions of the heavenly bodies, and therefore the mathematical formal cause is applied not to a genuine and direct sense experience of the natural phenomena, but as an imaginary construct to indirect and dubious apparent motions. A few years later, in 1599, another Italian commentator - Lodovico Carbone, will bring these arguments to their extreme form, arguing that in astronomy one demonstrates either through appearances without determining whether they are causes or not, or through false premises (such as eccentrics and epicycles) assumed merely to save appearances.<sup>5</sup>

In the Aristotelian context of *De anima*, the imagination is where a synthesis of sensual data is given a coherent shape. Since the imagination does not rely, however, on special sensibles (like each of the five senses) but attempts to combine them and determine what the perceived object is, the imagination is liable to errors and to the production of false images. This quality of the imagination requires the control of the soul's faculty of rational judgment. The flaw of the imagination faculty meant that those mental concepts, such as mathematical entities, are far removed from the reality of the physical world. Thus, for instance, Nicole Oresme, in his commentary on Aristotle's *Politics*, remarked concerning the possibility of a universal empire:

"If everyone wished to avoid war and to obey one sovereign who could always understand every matter, and judge it well and properly order everything ... it would be a splendid thing, as it seems. But in fact this is like the fiction of the poet, or the speculation of the mathematician (ymaginacion mathematicque). For as I have said earlier the world is not run by hypothesis. It must be taken as it is ... and taking it as it is by nature, it scarcely seems possible that anyone could be a sovereign (universal) monarch and last for very long."<sup>6</sup>

Mathematical hypotheses are ideal cases, but their application toward an understanding of the world (be it the natural or the political world) is dubious. The mental production of mathematical images, abstracted from matter by the imagination, is liable to errors and is to be considered true only

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<sup>5</sup> See further discussions on the classification of the sciences in late 16<sup>th</sup> century Italian context in: Mikkeli, Heikki. "The Foundation of an Autonomous Natural Philosophy: Zabarella on the Classification of Arts and Sciences," in *Method and Order in Renaissance Philosophy of Nature: The Aristotle Commentary Tradition* (eds.) D. A. Di Liscia, E. Kessler, and Ch. Metheun, 1997, 211-228, and his *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences*, Helsinki, 1992.

<sup>6</sup> Quoted and translated in. Babbit, S. M. "Nicole Oresme: The Limits of Imagination." *Mediaevalia* 10 (1984) p.63.

under the strict rules of definition and deduction. Mathematical sciences can discover universal principles of beauty and order, but their relevance for the knowledge of concrete objects and events is controversial. However, like comedy, which applies general understanding concerning the nature of man to hypothetical events, mathematics is less convincing than physics, which takes as its subject matter concrete events and objects (as in the tragedy). Mathematics can thus supply ideal cases but when compared to "nature as it is," it is like poetic fiction or political ideals never truly fulfilled or implemented in reality.

This critique was only one side in late medieval reevaluation of the role of the imagination in general and of mathematics in particular, in acquiring knowledge. In as much as the imagination can produce images of things never perceived by the senses, it can furnish the mind with foundations for the investigation of invisible and super-sensory entities. Dante in Canto XVII exclaims:

O thou, Imagination, that dost steal us  
So from external things sometimes, that man perceives not,  
Although around may sound a thousand trumpets,

Who moveth thee, if sense impels thee not?  
Moves thee a light, which in the heaven takes form,  
By self, or by a will that downward guides it.<sup>7</sup>

Dante stresses that the imagination is severed from its ties to any external sensory experience:

And hereupon my mind was so withdrawn  
Within itself, that from without there came  
Nothing that then might be received by it.<sup>8</sup>

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<sup>7</sup> O imaginativa che ne rube  
talvolta si` di fuor, ch'om non s'accorge  
perche' dintorno suonin mille tube,  
  
chi move te, se 'l senso non ti porge?  
Moveti lume che nel ciel s'informa,  
per se' o per voler che giu` lo scorge.

In the Renaissance this quality of the imagination began to occupy a much more prominent place among the faculties of the soul. Gianfrancesco Pico della Mirandola in his *De imaginatione* (1501) argued that fantasy as a derivative of *phaos* (light) is the bridge between matter and mind. Fantasy (or imagination) is like sense in that it perceives the particular, corporeal and present; but "it is superior to sense in that, with no external stimulus, it yet produces images, not only present, but also past and future, and even such as cannot be brought to light by nature."<sup>9</sup> Juan Luis Vives reaffirm this view and declares that fantasy is "prodigiously unrestrained and free; it can form, reform, combine, link together and separate; it can blend together the most distant objects or keep apart the most intimately connected objects."<sup>10</sup>

The power of the imagination to view and observe what is not present to normal human sight was compared to artificial instruments of observation, and especially to lenses. Savonarola, in his sermon on the art of dying of 1496, argues that in order to comprehend something one must form a phantasm in the imagination. These phantasms are "the eyeglasses of the intellect." Just as eyeglasses mediate visible objects, so the imagination mediates true knowledge; and just as one needs clear lenses for observation so one needs a well ordered imagination. As opaque lenses distort visual data so the imagination governed by human passions can distort the truth. In order to control the imagination one has to form strong images that attract the imagination and move the human soul towards the Godhead.

The strength of the fantasy moves man even against reason... If lustful things come into your fantasy, you will immediately be moved to evil. If you wish to do good and sun evil, make a strong *fantasia* of death. These are the eyeglasses I am telling you about.<sup>11</sup>

The notion that the imagination operates like a lens won great circularity in the 16<sup>th</sup> century. At the center of Naldini's allegory of dreams in the studiolo

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<sup>8</sup> e qui fu la mia mente si` ristretta

dentro da se', che di fuor non venia

cosa che fosse allor da lei ricetta.

<sup>9</sup> Gianfrancesco Pico della Mirandola *on the Imagination*. The Latin text with an Introduction, an English translation, and notes by Harry Caplan. [Cornell Studies in English], Vol. XVI. Yale University Press, 1930, pp. 30-31.

<sup>10</sup> Vives, Juan Luis. *De anima et vita*. Ed. M. sancipriano, Turin, 1959, pp. 32-3.

<sup>11</sup> Savonarola, G. *Predica dell'arte del ben morire*. Florence, 1496 [fac. Berlin, 1926, unpaginated]. Quoted in Summers, David. *Michelangelo and the language of Art*. Princeton, NJ Princeton University Press, 198, pp.114-15.

of Francesco de' Medici appears the feminine figure of Aurora holding a large spherical object. A careful examination of this object reveals it is a huge lens.<sup>12</sup> The figure of Aurora embodies those moments at dawn, when according to classical tradition one can envision dreams of truth. These dreams, which allow a glimpse of the mysteries of the world, however, are not clear. The fogs that surround the slumbering mind obstruct the dreams to decipher the riddles and grasp the message concealed in the vision. The danger is that the dreamer would glide over the visionary wings into the abyss of madness. The dreamer is prone to losing the ability to differentiate between imaginary apparitions springing from his desires and passions, and the divine message concealed in the dream's symbolic language. Francesco de Medici's ambition was to find a way to have the ability to observe clearly through the veils of illusion and to perceive the divine truth masked by the dream. The lens as an artificial means, a human-made object, replaces the incompetent natural eye, as the tool to achieve this super-sensory perception of truth clouded in fantasy. In order to comprehend the inner content formed in the imagination, one has to filter them through artificial instruments shaped by the imagination. This paradoxical method seems only to distance one's inner fantasies away from external, physical reality. The lens, instead of reducing the fantastical mental image to a concrete sensible appearance, only accentuates the non-existent nature of these apparitions and specters.

It is this problem of accommodating imaginary constructs with reality, of finding a common measure between inner artificial pictures and external sensory phenomena that haunts Kepler. The old Aristotelian *metabasis* demarcating mathematics and physics had acquired new significance. Late Renaissance science perceives this Aristotelian principle as a dichotomy between artificial constructs and natural phenomena, between human inner imaginations and external corporeal motions. The traditional distrust in human sensory knowledge was complemented by apprehension over the creative power of human imagination. In this way, interpretations of sensory data are likely to be further distorted by one's inner fantasies. How can one vouchsafe that one's inner speculations are true reflections of the truth? This is the same anxiety that troubles Richard II in his cell at Pomfret Castle:

I have been studying how I may compare  
This prison where I live unto the world:  
And for because the world is populous,  
And here is not a creature but myself,

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<sup>12</sup> Hamburg, Harvey. "Naldini's *Allegory of Dreams* in the Studiolo of Francesco de' Medici." *Sixteenth Century Journal* XXVII/3 (1996), pp. 679-704.

I cannot do it. Yet I'll hammer it out.<sup>13</sup>

Shakespeare captures the main epistemological discontent of late 16th century thought: One can know only oneself, yet that same self is silent and invisible, beyond language and sensory experience. No matter for how long one is to observe the world and speculate over it, the true causes that govern it and its motions will remain beyond human reach.

Man can not declare and express them in wordes. Some man doth neyther geve rest unto his eyes by daye nor by night, and yet can he neither fynde the cause nor the reason of Gods workes, yea the more he laboreth to seeke it, so much the lesse shall he fynde it?<sup>14</sup>

The attempt to capture the invisible causes that govern the universe is beyond human language and human senses, thus it is in the domain of the imagination to figure the "reason of God's workes." King Lear is Shakespeare's protagonist in investigating such invisible nonentities as "Love" and "Nothing". Lear begins his inquiry with the assumption that man is the measure of all things, and thus human linguistic means are adequate in capturing the unknown and imperceptible realms. When Cordelia admits that all she can say in answering her father's demand to measure her love is nothing, all that Lear can suggest to her is to "mend your speech a little."

In one of the subsidiary scenes, the Earl of Gloucester gives a clue as to how one can observe Nothing. His bastard son Edmond pretends to hide a letter incriminating his brother the legitimate heir to the Earl of Gloucester inquires "what paper were you reading?" and Edmund replies: "Nothing, my lord." On this answer the Earl marvels:

No? What needed then that terrible dispatch of it into your pocket? *The quality of nothing hath not such need to hide itself. Let's see. Come, if it be nothing, I shall not need spectacles.*<sup>15</sup>

Gloucester, with this double negation, discloses the truth. In order to observe what is unobservable, that is nothing, one actually needs lenses, as artificial means that go beyond the capability of human senses. Towards the end of the play as Lear carries in his arms the body of Cordelia the power of artificial lenses and mirrors is fully revealed. Lear cries out "Howl, howl, howl!" and protests against the shortcoming of human language to reflect his feeling and of the human eye to see reality, stressing the first vowel in the shape of a zero:

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<sup>13</sup> Shakespeare, William. *Richard II*. Act V, Scene v, lines 1-5.

<sup>14</sup> Pope Innocent III, *The mirror of mans lyfe Plainely describing, what weake mouldre we are made of: what miseries we are subiect unto: howe vncertaine this life is: and what shal be our ende*. Englished by H. Kirton. , Imprinted at London : By Henry Bynneman, 1576., ch. 10

<sup>15</sup> Shakespeare, William. *King Lear*. Act I, Scene II, lines 33-36.

O, you are men of stones: Had I your tongues and eyes, I'd use them so that heaven's vault should crack.

However, neither the human eye nor human language can penetrate the heavens to come face to face with the mystical Nothing (the Kabalistic *Ayin*) that governs life and death. In order to penetrate into these depths of nothingness Lear needs artificial means of observation:

I know when one is dead and when one is alive; she's dead as earth. Lend me a looking-glass; if that her breath will mist or stain the stones, why, then she lives.<sup>16</sup>

The only way to observe breath, that is, an almost invisible nothingness and simultaneously the essential sign of life, is to manipulate it through the application of mirrors, the device that produces false images and distorted reflections.

Kepler picks this line of investigation and turns it into a new science. Kepler aspires by means of this new science to capture and measure the "moving soul and infinite motion" that emanates from the sun moving the planets.<sup>17</sup> This moving soul is what Dante asserted to be "that lofty fantasy...the Love which moves the sun and the other stars." In a sense Kepler seeks to quantify "love" in the same way as King Lear. At the core of Kepler's research program are imaginary mathematical entities and artificial instruments of observation. Yet in order for these to produce scientific knowledge, Kepler has to reduce the visible corporeal world into a theatre of nothing. In the preface to his magisterial work on optics Kepler declares that in observing the celestial bodies "we consider nothing but their image," and this image is reduced to "light and shadow" on the one hand, and to "shape and quantity" on the other hand. These quantifiable illuminations are *mise en scène* of "this theatre of the world" and are signs suitable to the "human minds, likenesses of God", assisting them in their investigations after deeper meaning. The way, however, in which humans can perceive these signs, is principally as shadows and deficiencies, that is, as no-thing that captures true knowledge of the world.

"Now, one may consider, that all the rest of Astronomy is closely associated with the motion of the Sun and the important assistance given us by the Moon, participating in the days just as in the nights, when all other means failed us: it is believed rightly that universal astronomy is born from this obscurity of the luminaries. Just as these darknesses may be the eyes of the astronomers, these defects may be a rich source for doctrines, and

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<sup>16</sup> *Ibid.* Act V, Scene III, lines 259-264.

<sup>17</sup> "Deinde, in Sole est anima movens et motus infinitus, in mobilibus decrementum motus duplex primo inaequalitas reditus, quam causatur amplitudo orbium inaequalis, etsi vigor motus esset idem in omnibus orbibus, 2. Sed jam ille vigor motus, (ut in opticis lux) quo longius a fonte est, hoc debilior est" *GW*, vol. 13, Nr. 22, p. 32.

these "stains" may illustrate the most precise pictures on the mortal mind. O most excelled and commendable argument for all the nations about the glory of the shadow." <sup>18</sup>

The only way to capture these images and shadows is by applying *camera obscura* as a micro-theatre of light and shadow. The *camera* assists the astronomer in avoiding "the inadequacy of the eyes" and is the only "sure procedure... for measuring something that happens in the sky."<sup>19</sup> Within the darkness of the *camera* the astronomer can "accomplish... what is completely impossible in clear light." The eye cannot measure shadows as it is attracted to the strong light of the luminaries and to their visible effects, whereas within the *camera* one observe and measure the shapes and figures created by a ray of light coming through a window onto a wall. The stains of light on the wall were considered in late Renaissance culture as figments of the imagination. Leonardo da Vinci prescribed them as stimulation for the artistic invention.

I remind you that it is worth your while to stop sometimes in order to look at the stains on walls, or... clouds... or similar things, in which, if you consider them well, you will find marvelous inventions... because in confused things the *ingegno* is stimulated to new things. <sup>20</sup>

Yet for Erasmus these stains on the wall are no mere playful invention of the human imagination but are representations of nothing as he explains in his *Adagia*:

"Clouds upon a Wall. In a letter to his son, Gregorius, Ausonius used the phrase 'clouds upon a wall' for something most similar to nothing or a dream; 'have you ever seen a cloud painted upon a wall?' he says. [By this] he indicates that the subject (*lemma*) of the poem subjoined to this letter is trifling and empty; for, a cloud is too unsubstantial to be expressed by colors."<sup>21</sup>

In producing the visible and corporeal world as an insubstantial shape on a wall Kepler can apply to it mathematical measurements circumventing the Aristotelian admonition against *metabasis*. Furthermore, Kepler not only reduces corporeal objects to shadows and images on the wall but defines the light as the agent that produces these stains on the wall as a two-dimensional, non-corporeal entity, for "light has no matter, weight, or resistance."<sup>22</sup> Further

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<sup>18</sup> Kepler, Johannes. *Ad Vitellionem paralipomena, quibus astronomiae pars optica traditor*. Francofurti, 1604, p.16.

<sup>19</sup> *Ibid.* p. 39

<sup>20</sup> Leonardo da Vinci, *Treatise on Painting*. Ed. A. P. McMahon. Princeton, 1956, 2 vols. p. 76.

<sup>21</sup> Erasmus, *Adagia*, p. 405, 2nd Chilias, 4<sup>th</sup> Centuria, no. XXXVIII. Quted and discussed in Panofsky, Erwin. "'Nebulae in Pariete': Notes on Erasmus' Eulogy on Dürer." *Journal of the Warburg and Courtauld Institutes* 14, 1951:34-41.

<sup>22</sup> Kepler, *op. cit.* Chapter I, proposition 3, p. 8.

more the ray of light is but a representation of its motion and thus has no material reality: "the ray is not in the transparent... but there was [a ray], or almost was."<sup>23</sup> Kepler asserts that the non-corporeal geometrical line can express and represent motion, "since motion cannot keep the one thing that is complete about it, its past".<sup>24</sup> Light is the purest embodiment of motion as it penetrates the transparent medium and collides with dense surfaces "without matter or the dimension of solidity."<sup>25</sup>

Kepler's analysis of refraction, for instance, compares the motion of light to oars penetrating the surface of the water and to theories of a balance. He can separate the element of motion from the mobile and turn geometrical lines into representations of possible paths within a geometrical model (either a circle in case of a balance, or a *tabula*<sup>26</sup> in case of oars penetrating a stream). The perpendicular, drawn within that model, is a limiting case: in the case of the balance, the perpendicular is drawn to the centre of the balance and to the centre of the circle it describes. This perpendicular is the limit for the ascent or descent of the arms of the balance; in the case of the oars, it is that line to which the oars deflect in case of an inclined violent motion of the river; in the case of light, the density of the medium limits the dispersion of light. The oblique ray cannot proceed in the same direction, nor can it be deflected in a direction further away from a perpendicular ray emanating from the same source. Thus, an oblique ray must be refracted from its point of incidence somewhere between the path of a ray perpendicularly passing the denser medium and the continuation of its original oblique path (i.e., it will be refracted toward the perpendicular).

Although the outlines of Kepler's explanation are not different from the medieval perspectivists' theory of refraction, the ontological significance of Kepler's scheme is radically different. The perpendicular line, in Kepler's explanation, does not stand for any concrete ray of light but represents a possible path that may be described by the passage of light (that is, by the motion of two-dimensional surfaces). Geometrical lines can represent all

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<sup>23</sup> *Ibid.* p. 40.

<sup>24</sup> Kepler, Johannes. *Strena, seu De nive sexangula* (Frankfurt, 1611). English translation as *A new Year's Gift, or On the Six-Cornered Snowflake*. Ed. and trans. Colin Hardie (Oxford: Clarendon Press, 1966), p. 5.

<sup>25</sup> "...sine tamen materia aut soliditatis dimensione" (Kepler, *GW*, vol. 2, pp.27-28)

<sup>26</sup> William Donahue translated it as "a panel" and rightly remarks that "Kepler evidently wished to use a term not usual in geometry, to remind the reader this is a physical surface and not a geometrical plane." (Kepler, Johannes. *Optics: Paralipomena to Witelo and Optical Part of Astronomy*. Trans. And notes by W. H. Donahue. Santa Fe, New Mexico: Green Lion Press, 2000, p. 33, n.41)

physical motions. The peculiar aspect of light is that its motion can be described with no reference to matter, since light is an incorporeal being. The tendency of the refracted ray of light toward the perpendicular is neither because of an innate virtue of light or of perpendicular lines, nor because of any diminution in the quantity of light in the oblique ray. The only part played by the perpendicular is its being a limiting case of direct radiation. The perpendicular line in an optical analysis is neither a concrete body, nor a hypothetical heuristic sign, nor an ideal entity existing in some super-sensual realm but is the representation of geometrical necessities operating within the material world itself:

These actions are not an intelligent application of form, or a consideration of a final cause, but material conditions limited by their own geometrical necessities.<sup>27</sup>

Kepler's conception of geometrical physics is more than mere Renaissance Platonism. Kepler's geometry does not constitute a separate realm, but is created by the actions and passions of the physical world itself. The natural world does not aspire to imitate and imperfectly fulfil some ideal Divine plan. On the contrary, despite its blind and material motions, the natural world somehow directly and exactly represents the Divine archetypes to the human eyes and intellect. On the other hand, geometrical entities are determinant factors of physical motions. This is not restricted to such defined geometrical bodies and shapes as the perpendicular but consists also of indefinite entities such as a point at infinity. In a parabola, for instance, "one focus [...] 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." This focus at infinity determines in parabolic mirrors the parallel flow of rays originating from it.<sup>28</sup>

One can sketch Kepler's main principles of his new visual economy:

A. In order for truly mathematical account of physical phenomena, one is to apply instruments of observation to reduce these phenomena to insubstantial, yet perfectly measurable, shadows and stains of light.

B. Motion is not a qualitative process of change defined by its beginning and end points, but as the vanishing continuum produced by the mobile.

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<sup>27</sup> Atqui haec opera non sunt formae consilio utentis aut finem respicientis, sed materiae suis Geometricis necessitatibus astrictae" (Kepler, *Ad Vitellionem*, ch.3, prop. XVI, p. 71).

<sup>28</sup> Field, J.V. "Two Mathematical Inventions in Kepler's 'Ad Vitellionem paralipomena'," *Studies in History and Philosophy of Science*, 17, 1986: 449-68.

C. Geometrical lines and points must be considered not as hypothetical devices or as aesthetic factors. They are embedded in the physical material realm determining its possible motions. A point at infinity is not merely a geometrical playful speculation but can be considered as a real cause in determining the path taken by light in a parabolic mirror.

Yet, Kepler has to face one further question: how can one guarantee that Nature is geometrical through and through; what vouchsafes that these procedures are not mere artificial hallucinations within the human mind. In order to confront these queries, Kepler has to assume that Nature herself is governed by a formative faculty corresponding to the human mind. Their function is to lead the mind in observing physical phenomena, both celestial and terrestrial, to recognize its own geometrical content. Physical bodies aspire to receive the perfect geometrical shape of an orb through their activity and effects. The manner in which physical bodies express themselves is incorporeal yet through its geometrical dimension the human mind can recognize and enjoy it. At the beginning of his Optics Kepler specifies the magnet as such non-material effect, but his aim was to present the whole natural world as suffused with this geometrically formative power. In a letter dated 10/11/1608 Kepler writes to David Fabricius:

"God has ordained certain animal faculties in this Earth, which are to be perceived as active in themselves in exuding vapours, assisting in a certain way the mind in perceiving geometrical beauty, or even discrete quantities. This is certainly that peculiar ordination of God: these faculties are Divine images, sensing the geometrical beauty, as God."<sup>29</sup>

Understanding these animal faculties that reside within the earthly matter supplies a powerful key to the mysteries of the universe. In fact, it provides Kepler with the true rules of the divine game:

"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."<sup>30</sup>

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<sup>29</sup> Johannes Kepler, *Ioannis Kepleri Astronomi Opera Omnia*, 8 vols., ed. Ch. Frisch, (Frankforti a. M. et Erlangae: Heyder et Zimmer, 1858-71), vol. 2, p. 357. Deum ordinasse facultates quasdam animales in his Terris, mentis quodammodo participes ad percipiendas geometricas pulchritudines, seu etiam quantitates discretas, quibus perceptis ipsae essent operosae in exsudandis vaporibus. Haec est igitur illa peculiaris Dei ordinatio, facultates illae sunt imagines Dei, percipientes geometricam pulchritudinem, ut Deum.

<sup>30</sup> "Dasz Gott selber/ da er wegen seiner allerhochsten gute nicht feyren konnen/ mit den *signaturis rerum* also gespielt/ und sich selbst in der Welt abgebildet habe:

As the divine game is incorporeal, Kepler's pawns have to evaporate to nothing while in play and reveal the bare grid of rules to his investigative mind. In 1611, just a few years after King Lear was first performed in London, Kepler attempted his own play with nothing. In a small treatise entitled *A New Year's Gift or On the Six-Cornered Snowflake* Kepler seeks an object that will be small enough to be considered nothing, yet would "give promise of a geometrical speculation," and could "excite the desire for invisible things." After considering and rejecting different minute things and animals, while crossing over Karlsbrücke in Prague Kepler found that a snowflake is "something smaller than any drop, yet with a pattern." Snowflakes are even better than clouds as representations of nothing<sup>31</sup>: they both evaporate almost immediately and 'melt into nothing', or "they are entangled in larger plumes." Better still, while snow is an earthly meteorological phenomenon it is associated with astronomical research as "it comes down from heaven and looks like a star." Contemplating the flakes with their six corners and feathered radii triggers Kepler's inquiry into Nature's formative faculty:

There must be some definite cause, why, whenever snow begins to fall, its initial formations invariably display the shape of a six-cornered starlet?

In order to answer this question Kepler has first to isolate the snowflake as a unique case. Other six-corner shapes in nature are formed with view to their utility. The honeycombs in the beehive and the seeds in the pomegranate are so arranged because of material necessity and not because of any aesthetic values or inner principles that guide the growth of the trees or the operations of the bee:

[Necessity in the material] excuse me from arguing at this point about the perfection, beauty, or dignity of the rhomboid, or from bestirring myself to conjure up, from a meditation on the shape that the bee builds, the inner nature of its diminutive soul. We would have to embark on something of the kind, if no utility in the shape had come to

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Also dasz es einer ausz meinem Gedancken ist/ Ob nicht die gantze Natur und alle himmlische zierligkeit/ in der *Geometria symbolisiert sey* ... Wie nun Gott der Schopffer gespielt/ also hat er auch die Natur/ als sein Ebenbild lehren spielen/ und zwar eben das Spiel/ das er jhr vorgespielet," Kepler, *GW*, IV, pp. 245-46, quoted and translated in D. P. Walker, "Kepler's Celestial Music," *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute; Leiden: E. J. Brill, 1978), pp. 55-6. For Kepler's sense of play see also Findlen, Paula. "Between Carnival and Lent: The Scientific Revolution at the Margins of Culture." *Configurations* 6, 1998: 243-267.

<sup>31</sup> Kepler quite explicitly rejects clouds as the embodiment of nothing. He initially approaches the addressee of his treatise and comments that "accept with unclouded brow this enrichment by nothing" and then plays down Aristophanes' "Clouds": "Away with that panderer to vulgar scorn and ignorance, Aristophanes; what need have I of Socrates, the theme of his play?"

light ... It is therefore superfluous to think about the inner principle of soul in this tree (pomegranate) that directs it to prefer the rhomboid.

An external factor, such as cold cannot be the cause of the vapor's particles assuming the six-cornered shape of snow. Neither can material necessity resulting from the clash of their inner heat with external cold be the cause. In that case the particles "can be arranged in two other ways consonant with their material." Kepler concludes that a solution will be formulated only if he manages to "bring to light a way for the internal heat to fix the drop of vapor on three diameters, in the shape of an octahedron, or at any rate in a six-sided shape, on which matter may accumulate by condensation." Kepler infers that the snowflake is formed over a "skeleton (so to say) of the octahedron with its three feathered diameters that intersect at right angles." This skeleton is the bare mathematical form that operates from within the plumed particles as "the formative power" that resides in the center "disseminates itself equally in all dimensions." This formation is not random but is part of the "creator's design... preserved in the wonderful nature of animal faculties." The formative faculty within the Earth expresses itself by exuding vapors. In the case of shaping snowflakes this formative faculty operates with no obvious purpose and thus reveals itself in its pure form:

"Formative reason does not act only for a purpose, but also to adorn. It does not strive to fashion only natural bodies, but is in the habit also of playing with the passing moment."

In detecting the way nature follows the mathematical rules of play one can gather the causes of physical processes. The formative principle in nature, or its soul (*anima*), is geometrical and seeks to fulfil itself in the orderly shape of a regular body. The two basic regular solids are the cube, "which is the first born and the father of all the rest", and the octahedron, "his wife". Thus when cold breaks up the vapors the governing soul actively forms the parts in the shape of regular solids. The reason why these parts assume the shape of an octahedron is that under the attack of the cold front these vapors contract, and octahedron is the shape of gathering in.

If you remove from a cube its eight corners on equal sections and rearrange them to face inwards, you will produce precisely an octahedron. Also the cube spreads out into more corners, to wit, eight, but the octahedron into fewer, to wit, six.

The formative faculty resides in matter and operates like the human soul in imitating the Creator, playing with geometrical forms. These are not merely imaginary constructs but incorporeal causes that operate from within the material realm as active agents.

For the same faculty of soul which clothes the diamond within the earth in the form, which it furnishes from the innermost treasury of its nature, that of the octahedron, when it emerges from the earth in vapour, clothed with the same shape the snowflake which arises from that vapour.

Underneath the multicoloured physical reality are hidden skeletal mathematical figures and shapes. These are not part of the realm of platonic Ideas but are the constitutive elements of material shapes and their motion. The natural philosopher should not be deluded by external sensible qualities but strive to explore and reveal the "nothingness", those bare mathematical figures and proportions, that govern and form material reality. The human mind can know the world not as it appears to the senses but as it can be reduced to invisible geometrical components.

"Geometry ... passed over to Man along with the image of God; and was not in fact taken in through the eyes ... quantities possess constructibility not by virtue of the figures' passing before the eyes, *but in virtue of being clear to the eyes of the mind, in virtue not so much of having been abstracted from sensible things but of never having been associated with them.*"<sup>32</sup>

The Renaissance sense of melancholic contemplation of the ever widening gap between human inner abstract intellection and external corporeal phenomena is turned on its head. Instead of Dürer's melancholic angel contemplating artificial regular solids pondering over their physical reality, Kepler reduces the physical world to bare geometrical forms and their motions. Cold and heat in Kepler's analysis are not sensations but expansion and contraction, that is, motions and their direction. To know a snowflake is not to marvel like the Psalmist at its sensual similarity to wool, but to expose its skeleton of abstract geometrical structure. In concluding his "New Year's Gift" with the ironic "Nothing to follow", Kepler sets the outline of the Baroque answer to late Renaissance melancholic distress: scientific endeavor has to discard sensorial qualities and instead set its sight on "nothing". Descartes' mad melancholic persons "whose brains are so disordered and clouded by dark bilious vapors" are correct in distrusting their senses. No sensory criteria can establish a clear differentiation between wakeful states of mind and dreamy states and delusions. However, this calls not for a skeptical retreat but for a more nuanced control over one's imagination. When Kepler directed his telescope at the moon he reported to Matthias Bernegger:

, "An experiment with the telescope that I carried out recently, produced a marvelous sight, altogether remarkable: cities and walls, which were circular because of the shape of the *umbra*. What more should I say? Campanella wrote his *City of the Sun*. And if we were to write a *City of the Moon*? Wouldn't it be excellent to paint the cyclopean mores of our times in lively colors, but leave the earth behind and go to the moon, for the sake of prudence? But what is the good of such evasive action, since neither More in his *Utopia* nor Erasmus in his *Praise of Folly* were so well protected that they didn't have to defend

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<sup>32</sup> "Geometria... cum imagine Dei transivit in hominem: non demum per oculos introrsum est recepta! ...demonstrabilitas quantitibus insit, non quatenus figurae subjiciuntur oculis, sed quatenus mentis oculis patent, id est, quatenus non tam abstractae a sensibilibus, quam nunquam ijs concretae fuerunt" (*Ibid.* p. 223, translation, p. 304).

themselves? We must forsake the political tar pit and stay within the green and pleasant plains of philosophy."<sup>33</sup>

The images refracted by the telescopic lenses are like confused insubstantial stains or clouds upon a wall. These apparitions can lead the mind towards poetic ingenious inventions that can entertain, but cannot lead to true philosophy. In order to scientifically investigate celestial phenomena the astronomer has to discipline his imagination, expurgate its playful disposition to form novelties and direct it, through careful analysis and comparison at the true structure of physical reality. One has to mobilize the imagination, without which no scientific play can ensue, yet one should be careful not to be carried away, and search beyond the imaginary symbols and differentiate between false constructions and true causes.

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... 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. As in meteors, it is some active cause, capable of reason and Geometry that according to the rising aspect [a geometrical matter] in the heaven accommodates the modes and paroxysms of its operations, which is to excite the vapors of the subterranean humors, as they evaporate. The erroneous others support this by symbolization, expecting out of Saturn snow, out of Mars thunder, from Jupiter rain, and from Venus dew, out of Mercury wind, etc. But the Geometry of an aspect is an objective cause, moving the subterranean Arche to some impulse on account of which all the things mentioned, with no distinction, result - now this now that, according to the circumstances."<sup>34</sup>

In analysing celestial phenomena one should ignore the metaphorical and mythological significance of the heavenly bodies and their sensual qualities. All there really are in the sky are geometrical proportions and relations. In order to discover these geometrical aspects, one has to play, but this play has to be censured and meticulously adjusted to decipher the bare truth hidden underneath what appears to the senses in general and on the bodily eye in particular. Such disciplining of the imagination is exhibited in Kepler's posthumous treatise *Somnium*. The treatise narrates a fantastic dream of witchcraft and daemons, of ludicrous travel to the moon and back during eclipse on the shadows that fall on the moon and on the Earth respectively. Yet the aim of the story is to give "an argument in favor of the motion of the earth or rather a *refutation of the argument, based on sense perception, against the motion of the earth.*" [my emphasis]<sup>35</sup> In order to overcome one's

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<sup>33</sup> Kepler, *GW*, vol. 18, p. 143.

<sup>34</sup> *Ibid.*, vol.14, p.158.

<sup>35</sup> Kepler, Johannes. *Kepler's Somnium: The Dream or Posthumous Work on Lunar*

immediate sense perception the astronomer has to muster the power of the imagination, and so to prove Copernicanism Kepler suggests an imaginary point of view on the moon that would upset our normal perception and allow the invisible motion of the earth to be observed.

“Everyone screams that the motion of the heavenly bodies around the earth and the motionlessness of the earth are manifest to the eyes. To the eyes of the lunarians, I replay, it is manifest that our earth, their Volva, rotates, but their moon is motionless. If it be argued that the lunatic senses of my lunarian people are deceived, with equal right I answer that the terrestrial senses of the earth - dwellers are devoid of reason.”<sup>36</sup>

However, one cannot allow the imagination free reign, as chimeras and fantastic specters lure and attract the human mind to false games and the formation of distorted pictures of the world. In order to avoid these dangers Kepler adjuncts to his mythical narrative an extensive body of notes that direct the reader's mind beyond the immediate fantasy and to comprehend the astronomical truth disclosed within it.

The natural philosophers of the first decades of the 17<sup>th</sup> century relegated the imagination to the acquisition of knowledge. They no longer sought to suppress it but attempted to harness it in order to observe what the eye cannot see. If as Francis Bacon contends, "it is a false assertion that the sense of man is the measure of things"<sup>37</sup> then the imagination is needed to fathom a new measuring rod. The faculty of imagination, however, is traditionally associated with human passions that every so often lead it astray, producing sensual delusions. In order for the imagination to fulfill its role in the new scientific endeavor the passions must be regulated and supervised. Galileo blames his Jesuits adversaries for following "the strength of their passions", and for failing "to notice that the contradiction of geometry is the bald denial

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*Astronomy*, translated with a commentary by Edward Rosen (originally published by Madison, 1967; republished Mineolta, New York, 2003), 82. See also: Chen-Morris, Raz. "Shadows of Instruction: Optics and Classical Authorities in Kepler's *Somnium*." *Journal for the History of Ideas* 66:2, 2005:223-243. For a somewhat different interpretations of Kepler's *Somnium* see for instance: James J. Paxson, "Kepler's Allegory of Containment, the Making of Modern Astronomy, and the Semiotics of Mathematical Thought," *Intertexts* 3 (1999), 105-123; Elizabeth A. Spiller, "“To Depart from the Earth with such Writing”: Johannes Kepler's Dream of Reading Knowledge," *Renaissance and Reformation* 23 (1999), 5-28; and Swinford, Dean. *Through the Daemon's Gate: Kepler's Somnium, Medieval Dream Narratives, and the Polysemy of Allegorical Motives*. New York and London, 2006.

<sup>36</sup> Kepler, *Somnium*, 106.

<sup>37</sup> "Falso enim asseritur, Sensum humanum esse Mensuram rerum." Bacon, Francis. *Novum Organum* Aphorism XLI, In *Franciscy de Verulamio, summi Angliae cancellarij instauratio magna*. 1620, p. 57.

of truth."<sup>38</sup> One has to apply the faculty of imagination in order to perceive the world as a book in which "philosophy [is] written in the language of mathematics."<sup>39</sup> Yet the natural philosopher has to be vigilant and avoid being trapped in "the bounty of nature in producing her effects."<sup>40</sup> Early modern natural philosophers found in the *camera obscura* and the telescope the artificial scenes for disciplining human fantasy. Instead of "sensations, which... have no real existence,"<sup>41</sup> one can observe through these "spectacles" the true, yet unadorned, skeletal and bare geometrical discs and crescents of the planets. By concentrating the viewer's attention on shadows, light stains and ephemeral reflections and by adjusting the eye to a subsidiary role, the dangers and chimeras the passionate imagination is disposed to form are avoided. Reining the passions and attenuating the imagination reveal that the hidden and true shape of Nature is exactly the same as the geometrical figures the human mind contemplates. Scientific investigation does not require more powerful eyesight, but shunning of sensory experience altogether. Through artificial means the imagination is tamed and can be used to direct the mind's eye to know those bare and imaginary mathematical characters, and how they form the natural properties and paths of the corporeal world.

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<sup>38</sup> Galileo Galilei, *The Assayer*. In *The Controversy on the Comets of 1618*. Ed. And trans. By Stilman Drake and C. D. O'Malley. Philadelphia, 1960, p. 164.

<sup>39</sup> *Ibid.* p. 183.

<sup>40</sup> *Ibid.* p. 252.

<sup>41</sup> *Ibid.* p. 312.

