‘Borders,’ ‘leaps’ and ‘orbs of virtue:’ Francis Bacon’s extension-related concepts

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Abstract

Francis Bacon’s natural philosophy contains a whole series of interconnected concepts related to extension, such as “borders,” “leaps” and “orbs of virtue”. These Baconian concepts are still not fully understood and are in need of a detailed analysis. They do not derive from a general conception of (homogeneous) space, and are not explainable in terms of parts of matter and aggregates. Instead, they are somewhat mysteriously defined in terms of limits and boundaries of action. This article offers a contextual investigation of Bacon’s extension relating concepts. I show that in adopting a particular strategy of deriving spatial properties and extension related concepts from a theory of action and force, Bacon follows in the footsteps of Gilbert’s magnetic philosophy. However, in contrast to the more traditional approaches of William Gilbert, Giovan Battista della Porta and Johannes Kepler, Bacon strips his extension-related concepts from any natural philosophical content and argues for a methodologically driven approach, leading to operational definitions.

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Introduction

Francis Bacon's natural philosophy contains a whole series of interconnected concepts related to extension. Such concepts as "limits," "borders," "leaps," "measures of space," and "orbs of virtue" abound in Bacon's explanations of the structure of the universe,[1] body-body interactions, local motion, action-at-a-distance, etc. [2] They do not derive from a general conception of (homogeneous) space, because Bacon does not have such a conception. They are not explainable in terms of parts of matter and aggregates of such "parts" of matter, because Bacon is generally not favourable to corpuscular explanations. Instead, his extension-related concepts express limits and boundaries of action; as well as limits and bounda-

[1] For Bacon, the universe is made of regions and layers endowed with dissimilar properties. Change mostly happens (and is especially easier to see) at the "borders" between these regions (OFB VI 123ff; 145, 149, 177). On Bacon's cosmology see (Rees 1975b, 1975a, 1996; Manzo 2006). On the relative stability of the regions and the activity at the borders see OFB VI 137, 145. See also (Rees 1979, 204). These "natural borders" are sometimes described in terms of "leaps." Thus, Bacon claims that there are great leaps from the region of the air to the region of the Moon, and similarly there is an enormous leap [*saltus*] from the heaven of the Moon to the heaven of the stars;" (OFB VI 177).

[2] For Bacon, each individual body contains spirits, or pneumatics, endowed with "the appetite and faculty of constantly generating, multiplying and spreading themselves in all directions […] of mutually attacking and invading one another" (OFB VI 231). More generally, bodies exhibit virtues operating by contact, but also at a distance (OFB XI 369); also, most bodies emits both tangible and pneumatic effluvia (SEH II 643-645).

ries of perception. More precisely, his general claim is that there are such natural limits and boundaries in nature; that

> […] virtues and motions of things operate and work over distances which are neither indefinite nor random, but finite and certain, so that in the particular natures under investigation to grasp and take these distances into account, is of the greatest importance for practice. [3]

Consequently, the role of the investigator of nature is to discover these natural boundaries and limits, these specific "orbs of virtue," for all the "virtues and motions of things."

My purpose in this article is to offer a contextual investigation into the questions and challenges raised by this way of thinking. I show that in developing some of his extension-related concepts, Bacon follows the strategy developed by Gilbert and other proponents of a magnetic philosophy to define, describe and chart "orbs of virtue," i.e., the space "effused" and organized by a certain magnetic virtue. In the first part of the paper I attempt to reconstruct the problematic background of Gilbert's attempt to devise a "science of the orb themselves,"[4] and its sequel in Kepler's endeavours to generalize it from the case of magnetism to central force. In the second part of the paper I deal with Bacon's attempts to generalize and operationalize the "orbs of virtue." I show that, in contrast to Della Porta, Gilbert

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[3] OFB XI 369.
[4] (Gilbert 1893, 304, 1600, 205).

and Kepler, Francis Bacon's attempt was to disentangle the natural philosophical content from the operational content of this concept I claim that Bacon's definitions of "orbs of virtue" as "measures of space"[5] and "limits of perception"[6] successfully avoid all questions concerning the nature of action and perception and their respective mechanisms of operation. Instead, they are general, operational definitions, embedded into a sophisticated strategy of experimental inquiry.

The "orbs of virtue" in magnetic philosophy: natural philosophical and operational aspects

Scholars have already noted that in devising the notion of "orbs of virtue" Bacon borrowed a natural philosophical concept already formulated by Gianbattista della Porta and William Gilbert, and he generalized it, so that

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[5] In the ANN, Bacon proposes an inquiry into the "measure of distance or the orb of virtue [*mensura spatij, sive the orbe virtutis*]; this is the distance which the powers of bodies may travel to, stop at, build up and die down from." OFB XIII 211.

[6] The same ANN contains a second definition of the orbs of virtue, in terms of "the distance that perception reaches to;" OFB XIII 195. I discuss Bacon's definition of "perception" in the second part of this paper.

it extends beyond mere magnetism, to all natural virtues and actions. [7] However, the details of Bacon's strategy were never subjected to a thorough scrutiny. This is partly due to the realization that there is a certain degree of latitude and confusion in how Della Porta and Gilbert used this term. A thorough history of the natural philosophical significations of the "orbs of virtue" for the proponents of magnetic philosophy still waits to be written.

The purpose of this section is to set the background for a more thorough investigation into Bacon's strategy of generalization and clarification. I begin by discussing the problems encountered by various attempts to give a natural philosophical significance to this concept. Then, I address the challenges and difficulties facing Gilbert's attempt to construct a "science of the orbs themselves."

Terms like "sphere of influence," "sphere of activity," "orbs of effluvia," and "orbs of virtue" abound in sixteenth century; they are usually employed to express the belief in a radiative nature of bodies. Giovan Battista Della Porta claims that bodies radiate "beams of virtue;" which means that they can act at certain distances upon similar objects, with a force often described in terms of concord, "love" and sympathy. Magnetic attraction is a special form of this more general sympathetic attraction.[8] Each

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[7] (Rees 1979; Kelly 1965). On the sphere of activity and the orb of virtue before and after Gilbert see (Ugaglia 2006; Parigi 2011; Pumfrey 2002; Hesse 1960a, 1960b).

[8] Della Porta describes a radiative process in which the magnetic virtue emanates within a certain orb of virtue. See (Porta 1658, 199, 203). Porta's explanation of magnetic coition is formulated in terms of an "active" and a passive form

magnet has a sphere of activity, or orb of virtue; and within that sphere, it can impart some of its virtue to other magnets, or to pieces of iron. The magnetic force spreads in space in very much the same manner in which light spreads around a light-source; it decreases with the distance, and the limits to which this emanations can extend determine "the orb of virtue."[9] Della Porta's explanations of magnetic attraction are not specific to magnetic attraction; they can be easily generalized to other forms of sympathies.[10] Meanwhile, Della Porta's treatment of the "sphere of activity" has a distinct operational feature: he is less interested in the natural philosophical mechanism of magnetic activity than in questions regarding the possible ways of extending the given sphere of activity of one magnet.

By contrast, William Gilbert's *De magnete* begins with the natural philosophical explanations of magnetic attraction in terms of matter theory and within the larger framework of a magnetic cosmology. He divides bodies into electrics and magnetics:[11] electrics emanate spheres of effluvia,

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of sympathy: the magnetic virtue excites a response in other magnets (because of similitude of substance) and iron (which has some form of passive or potential magnetic virtue). As a result, attracted bodies "run" towards the attractive, "to meet it, to be embraced by it (Porta 1658, 201). For a discussion of Porta's descriptions of magnetism see (Kodera 2014). .

[9] (Porta 1658, 199). See also (Porta 1589, 305)

[10] This is how some of Della Porta's medicines are supposed to work. See Book 8, (Porta 1658)

[11] As it has been shown, Gilbert attempted to construct a comprehensive, "cosmological" theory on the basis of this division. Gilbert also claims that there are only two kinds of attraction, magnetic and electric. (Gilbert 1893, 170). On Gilbert's cosmology, see (Freudenthal 1983). For a more general discussion of Gilbert's theory in context see (Hesse 1960a, 1960b).

a material medium responsible for various forms of attractive effects.[12] By contrast, the propagation of magnetic virtue is a form of action-at-a distance; it does not require a medium, and permeates through matter without material contact.[13] Magnetic virtue does not reside in space -- there are no orbs of "permanent essential virtue spread through the air"[14] – but is constitutive for each magnet, for which it defines fixed points (the poles), directions of spatial organization (the magnetic axis, but also directions such as "away" from the magnet and "towards" the magnet) and other symmetries.[15] Although keeping the analogy between magnetism and the emission of light, Gilbert also claims that magnetic virtue travels "much faster" than light, i.e. becomes manifest quasi-instantaneously, within the "orb of virtue" of a magnet, in places where other magnetic bodies are present.[16]

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[12] The distinction between electrics and magnetics is done in terms of matter theory: electric bodies are those containing "humours;" while magnetics contain "earth." Both electrics and magnetics have attractive powers, but the mechanisms of attraction are different. In the case of electrics, material effluvia produce attractive effects. (Gilbert 1893, 340). See (Pumfrey 1989, 48). See also (Pumfrey 1987, 92 ff). On the discussion of the difference between virtues propagated through effluvia and the propagation of magnetic virtue, see (Gilbert 1893, 107 ff).

[13] (Gilbert 1893, 123-124). See also (Henry 2001). In *De mundo* Gilbert claims that the orbs of effluvia around planets are small, while the interstellar spaces are void. Light and magnetic virtue can "travel" through empty space. See *De mundo* Book II Chapters 25-27. (Gilbert 1651, 212-214).

[14] (Gilbert 1893, 123)

[15] More on the ways in which magnetic virtue is constitutive of spatial organization in the next section.

[16] (Gilbert 1893, 123). For Gilbert, the nature of magnetism is similar with that of the (animal) soul. Like soul, magnetic virtue is a specific, active form of a body, possessing natural motion. It can exist in a dormant form in iron and steel, and in a more actualized, perfect form, in magnets, magnetized iron and in the celestial bodies. Gilbert's model is the world soul or the celestial intelligences of the planets; each great globes has its own "soul" (animate force/vigour), those of the Sun and stars being "superior" to those of smaller globes. See (Gilbert 1893, 308).

Meanwhile, Gilbert uses the emanationist language to describe how magnetic virtue is "effused" throughout each orb of virtue; how "in all globes the effused forms reach out and are projected in a sphere all round," and how the soul-like magnetic powers of each celestial globe "extend an unending action, quick, definite, constant, directive, motive, imperant, harmonious, through the whole mass of matter."[17] Effects somewhat similar happen in laboratory conditions; and Gilbert explains magnetic interaction in terms of a step-by-step process. When a bar of iron is brought in the orb of virtue of the *terrella*, its dormant magnetic virtue is first "awakened," then "endures," and "by its very act gives back the force again." [18] At the second step, the newly magnetized object "orients" itself within the orb of virtue of the *terrella*, rotating until it becomes "well disposed" with respect to it.[19] It is only in the third instance that attraction (or, in Gilbert's term "coition") manifests itself. The strength of coition varies with the distance,[20] the quality of magnetic substance, the particular geometry of the

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[17] (Gilbert 1893, 308-309, 311). Similarly, Gilbert claims that the Sun has the power to incite motion in the celestial globes, causing them "to advance in their courses […] by sending forth the energies of his spheres." (Gilbert 1893, 333). Although it is usually said that Gilbert only acknowledges the cosmological implications of his magnetic philosophy in book VI of *De magnete*, there are numerous passages throughout the other books as well, which ascribe celestial motions to magnetic energy and talk about the "law of the whole," or about the "ordering and planning of the universe and the earth." See (Gilbert 1600, 41, 44). For a discussion of Gilbert's "cosmic magnetic field" see (Miller 2014).

[18] (Gilbert 1893, 150-151)

[19] (Gilbert 1893, 130). See also (Gilbert 1600, 82).

[20] See for example (Gilbert 1893, 161-163). Gilbert distinguishes clearly between the variation of the "strength" of coition (which strongly decreases with the

magnet,[21] and the particular configuration (and geometry) of matter in which the magnet is placed. Because, for Gilbert, anything that contains solid matter is, at least, potentially magnetic, most magnets are already in the orb of virtue of other magnets, as well as in the larger, all-encompassing orb of virtue of the Earth.[22] As a result, their magnetic virtue is often "altered, changed, incited, renewed and driven out;" [23] but can be also strengthened and multiplied. Gilbert is particularly interested in the experimental investigation of particular situations of magnetic union.

> Pieces of iron in the presence of a loadstone, though not in contact with it, come together, eagerly seek and seize one another, and when in conjunction

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distance) and the variation of the direction, orientation and rotation in the magnetic field, which have more complex forms of variation. See (Georgescu 2014).

[21] On the dependence of the strength of attraction on the qualities of matter see (Gilbert 1893, 167-169). However, the more important variable seems to be the geometry of the magnet, which determines both the geometry of the orb and the strength of attraction. For example, elongated magnet "attracts best at the vertex" (Gilbert 1893, 122).

[22] (Gilbert 1893, 136): "[…] here on earth, naught can be held aloof from the magnetic control of the earth and the loadstone and all magnetic bodies are brought into orderly array by the supreme terrene form, and loadstone and iron sympathize with loadstone though solid bodies stand between." See also (Gilbert 1893, 212-213). Gilbert claims that "the matter of the entire orb conspire, produces verticity in bodies" (Gilbert 1893, 216). Thus, one standard procedure for fabricating a magnet recommended by Gilbert and his followers is to heat up a piece of clay and cool it down oriented in the lines of the Earth's magnetic field.

[23] (Gilbert 1893, 209). Gilbert discusses in Book III many examples of multiple magnetic interactions, showing how changes in vorticity occur, or how magnetic power can be renewed, diminished and lost as a result of these interactions. These kinds of loss of magnetic powers do not happen in magnets, however, because in the loadstone force is "innate" and "inhere more closely, nor do they easily retire from their ancient seats." (Gilbert 1893, 209)

> are, as it were, glued together. Iron dust or iron reduced to a powder, packed in paper tubes, and placed on the meridian of a loadstone or merely brought near it, coalesces into one mass, and in an instant the many particles come together and combine: and the multitude of united grains act on a piece of iron and attracts it, as though they formed but one continuous rod if iron, and take the north and south direction when laid on a loadstone.[24]

Magnetic union creates a solid bond between bodies, and it is produced by an attraction stronger than mere coition. If two pieces of iron are placed in the orb of virtue of a loadstone,

> […] likeness of substance becomes decisive and iron gives itself up to iron, and the two pieces are united by their most like (identical) and homogeneous forces. This is effected not only by coition, but by a firmer union.[25]

Incidentally, it is this stronger bond of magnetic union which explains how "the foundations of the earth are conjoined, connected, held together magnetically."[26]

Thus, Gilbert's investigations disclose the complexity of magnetic interactions. He shows that magnetic philosophy has to deal with a number

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[24] (Gilbert 1893, 142).

[25] (Gilbert 1893, 150-151)

[26] (Gilbert 1893, 142). Magnetic union is not only a property of loadstone and iron but seems to be a much more widespread property. For example, Gilbert gives an example of grafting: if a branch is cut into two halfs, one cannot graft another branch on the upper part, but only on the lower part. This is because, Gilbert claims, "the vegetative force […] tends in a fixed direction." (Gilbert 1893, 200)

of forces and motions;[27] as well as with complex spatial configurations. One of Gilbert's attempts to clarify the matters is to multiply the orbs and spheres of activity, by distinguish between a smaller orb of coition, and a larger orb of virtue. This allows him to classify magnetic attraction and magnetic disposition according to their range of action; magnetic union and coition happen within the smaller, orb of coition, while disposition, orientation and rotation take place within the larger orb of virtue. However, the difference between the two orbs is not merely one of dimension, but also one of symmetry. Magnetic attraction has a radial symmetry; and the orb of coition is spherically diffused. By contrast, the orb of virtue has a much more complex symmetry; it has fixed points and a definite direction (the nord-south axis); and magnetic orientation and "verticity" have different strength and directions at various points within this orb of virtue.[28]

In fact, the symmetry and spatial organization of the orb of virtue is so complex that it has led Gilbert to the understanding that magnetic philosophy needs to provide a "science of the spheres themselves" [*novam & admirabilem … orbium ipsorum scientiam*],"[29] i.e., a description of the ge-

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[27] Gilbert distinguishes between four different magnetic motions: coition (attraction, verticity, declination and magnetic dip.

[28] (Gilbert 1893, 125). Gilbert claims that the poles of a magnet are fixed (within the orb of virtue); they are said to be "the citadel, the judgment seat of the whole region." (Gilbert 1893, 131). They are said to be "reference points of direction and of position." (Gilbert 1893, 129).

[29] (Gilbert 1893, 304, 1600, 205).

ometry, symmetries and the transmission of magnetic powers within the orbs of virtue.[30]

Spatial organization: limits, orientation and symmetries

For Gilbert, each orb of virtue has a particular geometry and a determinate structure, partly dependent on the geometry of the magnet,[31] partly due to the "strength" of magnetic vigour and the ways in which it is "effused" around the magnet.[32] One of the main aims of *De magnete* is to map these orbs of virtue, at least in relatively simple case of a spherical magnet.[33] The way to do this is with the help of a small magnetic needle

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[30] Laura Georgescu is claiming in a recent paper that Gilbert's main contribution to the development of magnetic philosophy lies in shifting the interest from the phenomenon of attraction to the orientation in space, spatial distribution and symmetries. See Georgescu (draft).

[31] The geometry of the orb of virtue corresponds to the geometry of the magnet; orbs are only spherical around spherical magnets; they are oriented according to the magnet's axis and have, similarly "fixed poles." In the case of the Earth, Gilbert emphasizes time and again, that poles and the magnetic axis are "permanent, and fixed, and natural." (Gilbert 1893, 67).

[32] For example, an elongated magnet creates an elongated orb and concentrates the magnetic forces at the poles. As a result, Gilbert claims, "the force supplied by other parts [of the magnet] […] are better massed and united, and thus united they are stronger and greater."(Gilbert 1893, 131). See also (Miller 2014, 74).

[33] David Marshall Miller has suggested that Gilbert replaced the traditional spherical representation of space with a "geographical representation" of space and that this geographical framework is essential for understanding Gilbert's descriptions and explanations of magnetic phenomena. However, unlike the geographer spatial representation, Gilbert's geographical representation corresponds to the physical properties of the magnet and its surrounding space. The magnet "sets" and "defines" the spatial properties of the orb of virtue. As Marshall has convinc-

which, placed in different points around the magnet, is led to "follow" the directing force of the magnetic virtue, disclosing borders, limits, directions and hidden symmetries of the orb. In Book VI of *De magnete*, Gilbert generalizes his findings; first, to the orb of virtue of the Earth and then to the universe as a whole. He claims, for example, that the Earth's axis of rotation points always in the same direction (towards the Ursa Minor) and that, if it were deflected from this direction, it would naturally return to this former orientation.[34] However, this direction is not a general direction in space; it is not established by the pre-existing geometry of celestial orbs. Quite on the contrary; the direction of the Earth's magnetic axis is determined by the "forces […] implanted in the earth."[35] These "forces" and virtues of each magnet are "poured forth and diffused beyond their superficies spherically, the form being exalted above the bounds of corporeal nature."[36] In this way, properties of the solid, magnetic bodies are extended to the orbs, while the shape and structure of the orb is indicative of the direction and strength of magnetic motions.[37]

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ingly shown, Gilbert is using this particular spatial (geographical) representation to discuss limits and symmetries of the orb of virtue. (Miller 2014, 70-73).

[34] See also the passages of Book III, (Gilbert 1893, 180-181).

[35] (Gilbert 1893, 329). Gilbert also claims that the revolution of the Earth around the sun is determine by the same "innate energy," plus a law of necessity which is responsible for the cosmic harmony of planetary motions. (Gilbert 1893, 333)

[36] (Gilbert 1893, 304).

[37] For example, an elongated magnet creates an elongated orb and concentrates the magnetic forces at the poles. As a result, Gilbert claims, "the force supplied by other parts [of the magnet] […] are better massed and united, and thus united they are stronger and greater."(Gilbert 1893, 131). See also (Miller 2014, 74).

For small spherical magnets (Gilbert's *terrellae*), the result of this process of mapping is a spherical "oriented" space, endowed with a complex symmetries.[38] For example, Gilbert claims that at various distances along the same radii, the magnetic needle has the same orientation. He also claims, against Della Porta, that the center of the magnetic movements is not at the poles, but in the center of the magnet (or the center of the earth), while disposition and orientation are governed by their relation with the Nord-South axis. This means that, at various points within the orb of virtue, the magnetic needle is both attracted (towards the center of the magnet), and "controlled," disposed and "rotated,"[39] according to the inner directions (and symmetries) of the orb itself, i.e., towards the poles of the magnet.[40] The strength of attraction decreases along the radius of the orb of virtue; but at each point along the same radius, the directive power maintains the same direction.[41] In Gilbert's terms:

> […] everywhere at equal distances from the centre or from the convex circumference, just as at one point it seems to attract in a right line, so at

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[38] For details of Gilbert's construction and reasoning see (Georgescu 2014).

[39] See for example (Gilbert 1893, 150-151). Gilbert claims that the force of attraction (coition) emanates "from the whole mass" of the magnet. In this way, the magnetic attraction has a radial symmetry. Meanwhile, the rotation and orientation towards the poles are directed by a different kind of symmetry. The two superposed symmetries are describing the spatial distribution (orientation) around a magnet.

[40] In modern terms, Gilbert maps separately the strength and the direction of the magnetic field.

[41] (Gilbert 1893, 151). Gilbert claims that, in principles, "forces are the same on the same parallel," at least unless there are no variations produced by the "inequalities" of the magnet.

> another it can control and rotate the needle, provided only that the loadstone be of not unequal power.[42]

Thus, the orb of virtue contains concentric spherical surfaces where the strength of magnetic attraction has the same value, while magnetic disposition differ from one point to the next.[43] However, Gilbert claims that this variation of direction is not random but "continuous," so that if a magnetic needle is moved on any spherical surface inside of the orb of virtue, it "rotates completely twice, in one circuit around his center, like an epicycle around his center."[44]

A more thorough discussion of Gilbert's views on such inbuilt symmetries is beyond the scope of the present paper. For my purpose it suffices to have shown that there is in Gilbert a constant preoccupation for a "science of orbs themselves;" i.e., for an attempt to show how the emanation of magnetic virtue is constitutive of a spatial distribution and spatial symmetries around each magnet. Discovering the symmetries of this "spherically effused magnetic vigor" leads to the discovery of the properties of physical

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[42] (Gilbert 1893, 150).

[43] (Gilbert 1893, 151). Gilbert claims that, in principles, "forces are the same on the same parallel," at least unless there are no variations produced by the "inequalities" of the magnet.

[44] (Gilbert 1893, 307). It is not clear how is this particular property derived from Gilbert's empirical construction or from his "diagrammatic reasoning." Here, most probably, considerations of symmetry play a more important part in Gilbert's reasoning than empirical considerations. Most probably, Gilbert's reasoning is motivated by his interest in planetary motion.

space, such as direction, situation, orientation etc.;[45] at least, in the case of an isolated magnet. However, as we have already seen, in Gilbert's magnetic cosmology there are hardly such things as isolated magnets. When mutual influences are taken into consideration, Gilbert's theory is confronted with insurmountable difficulties, as I will show in the next section.

Perception, collaboration and benevolence: natural philosophical difficulties of the "science of the orbs themselves"

Gilbert's magnets are not isolated bodies. Magnetic needles, iron bars or artificially devised *terrellae* are already disposed and oriented towards each other, as well as within the larger orb of virtue of the Earth. Since a magnetic substance is very common, orbs of virtues are practically everywhere. And this extends to the universe as a whole:[46] Gilbert does not ex-

[45] Although magnetic virtue propagates spherically through space, the magnetic action is oriented along (or parallel) to the magnetic axis. For a discussion of Gilbert's "oriented space" see (Miller 2014, 99-100; 103-105).

[46] Some scholars have attempted to limit Gilbert's magnetic philosophy to the Earth, claiming that one can separate book VI from the rest. This type of interpretation was widespread amongst Gilbert's own contemporaries and is nicely exemplified in the debate between John Barlow and Mark Ridley. See (Barlow 1616) and (Ridley 1613, 1617). In fact, Gilbert's cosmology is not limited to book VI; statements regarding the cosmological significance of magnetism abound. And Gilbert often refers to the "ordering and planning of the universe and the earth," (Gilbert 1600, 44) or to the fact that magnetic planetary globes take position (are ordered) in the universe according to a "law of the whole" [*totius normam*.] (Gilbert 1600, 41). For a more general discussion of Gilbert's magnetic cosmology in terms of a "cosmic magnetic field" see (Miller 2014, 66-71).

clude the possibility of mutual magnetic influences among planets, claims the existence of an universal, active virtue, effused by the Sun; [47] and raises the issues of a cosmic "orb of orbs," and a direction "common to the whole universe."[48]

Explaining these complex mutual interactions poses a number of problems. First, it led Gilbert to appeal to concepts such as the "collaboration" between magnets, the "general benevolence" [*benevolentia*] among like substances, and a common good of the Universe. [49] Second, in order to explain individual behavior of magnetic globes, Gilbert had to introduce supplementary concepts, such as "perception," "imagination," and "judgment." [50] His planets are endowed with souls and have both an "impulse of

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[47] See for example (Gilbert 1893, 332-333). Also, Gilbert claims that all planets are in the "orb of influence" of the Sun. It is not entirely clear from this context whether this is the magnetic orb, or the orb of virtue of Sun's light. But the Sun is said to be "the chief inciter of action in nature," and the cause of planetary motions. (Gilbert 1893, 333, 1600, 224), while planets are said to be situated "within the sphere of Sun's forces," (Gilbert 1893, 344).

[48] (Gilbert 1893, 308-309): "[…] each homogenic part tends to its own globe and inclines in the direction common to the whole world, and in all globes the effused forms reach out and are projected in a sphere all round, and have their own bounds – hence the order and regularity of all the motions and revolutions of the planets, and their circuits." In a similar passage in which he describes the orientation of Earth's magnetic axis, Gilbert proposes a "primary soul" (of the world). (Gilbert 1893, 329).

[49] See for example (Gilbert 1893, 310-311). "Therefore the bodies of the globes, as being the foremost parts of the universe, to the end they might be in themselves as in their state endure, had need of souls to be conjoined to them, for else there were neither life, nor prime act, nor movement, nor unition, nor order, nor coherence, nor *conactus*, nor *sympathia*, nor any generation, nor alternation of seasons, and no propagation; but all were in confusion and the entire world lapse into chaos, and, in fine, the earth were void and dead and without any use."

[50] (Gilbert 1893, 311-312).

self-preservation," and a capacity to "perceive" and recognize a common good, in order to act accordingly.[51]

Moreover, vitalist concepts are not reserved for the planets only. All magnetic bodies are ultimately animated by "mutual love" and "undying good-will" to bring about "the true and genuine conformance of magnetic bodies in nature."[52] In terms of particular interactions, this is spelled out as a form of mutual collaboration towards a common good:

> The weaker loadstones are refreshed by the stronger ones, and the less vigorous bring no damage to the more vigorous. Yet a strong loadstone exterts more attraction in another strong one than in one that is feeble, for a vigorous stone contributes forceful action, and itself hastes, flies to the other, and solicits it vehemently; accordingly there is cooperation, and a clearer and stronger cohesion.[53]

One can take all these vitalist concepts to be the result of Gilbert's prior, metaphysical commitments. My suggestion is to regard them as resulting from Gilbert's attempts to solve the problem of mutual, body-body interaction.

The case of the Earth-Moon system is representative of the difficulties Gilbert runs into when attempting to describe mutual interactions in the

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[51] (Gilbert 1893, 308-309, 1600, 210). See also (Gilbert 1893, 329).

[52] (Gilbert 1893, 186). He also seem to claim that there is a "natural position" of magnets within the orb of virtue of the Earth, as well as a more "constant and permanent station and position in the system of nature." (Gilbert 1893, 182-183).

[53] (Gilbert 1893, 147-148). See also (Gilbert 1893, 186): "Magnetic bodies seek formal unity, and do not so much regard their own mass;" and (Gilbert 1893, 344).

physical universe.[54] Both Earth and Moon are magnetic globes; they have a natural circular motion. This natural, circular magnetic motion of the Moon is hindered by its presence in the Earth's orb of virtue; and thus the Moon is "the prisoner to the Earth," tied magnetically to it.[55] Meanwhile, if Moon does not spontaneously rotate around its axis, it does revolve around the Earth; and this happens, according to Gilbert, because of its own celestial energy and power. The Moon's motion results from two impulses: its own magnetic energy and its perception of the Earth's orb of virtue and willingness to "collaborate" with it. Meanwhile, the Moon also exerts "astral influences" upon the Earth; these exercise, for example, a form of attraction upon terrestrial waters, producing tides. However, according to Gilbert's own theory of magnetic interaction, this is not possible. The Moon's orb of virtue is smaller than the Earth's, and her orb of coition is smaller still. Thus, Gilbert's suggestion is that Moon-Earth attraction is a combination of magnetic and electric interaction, i.e., that the Earth is within the Moon's orb of *effluvia*. Electric effluvia travel from the Moon towards the earth and exercise a form of attraction upon Earth's (electric) waters.[56] Thus, what looks like a mutual attraction between the Earth and the Moon is, in fact, the result of a complex interplay between electrics, on one hand (water and the electric component of Moon's mat-

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[54] Significantly, this case is not treated in *De magnete* but in Gilbert's unpublished *De mundo*.

[55] This is why, according to Gilbert, Moon always turn the same face toward the Earth; (Gilbert 1651, 186-187).

[56] Water, in Gilbert's theory, is among the electrics, and so it is air or atmospheric vapors. The problem with this explanation is that one has to suppose that material effluvia extend all the way to the Moon which is, of course, a serious problem. See (Freudenthal 1983, 31-33).

ter), and magnetics, on the other.[57] Meanwhile, it is clear that these effects cannot be neatly separated; in *De mundo,* Gilbert also claims that "the Earth colludes with the Moon," and that that "the effused lunar powers" and "the Earth's magnetic virtues," "unite in a joint action," and "act in unison."[58] Moreover, he claims that the respective powers of the Moon and Earth can be "increased" by the influence of the Sun, i.e., by effluvia, powers and virtues coming from the Sun. Similarly, in *De magnete*, references to planetary and astral influences abound, and it seems to be left open whether they refer to light, magnetic virtues or other effluvia. They can be taken to express the same general, theoretical difficulties to describe mutual influences in terms of properties of orbs, or orbs-within-orbs.

To conclude: one way to understand Gilbert's introduction of concepts such as "perception," and "collaboration" is to see them as a response to the abovementioned difficulties. In order to describe the mutual body-body interaction, Gilbert assigns "perception" and "intellection" to the magnetic souls of the planets. This is what allows smaller magnetic bodies to orient themselves within complex situations (such as orbs-within-orbs) in a way so as to "give way" to stronger magnets, but also to "collaborate," or to

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[57] Gilbert claims, in *De mundo*, that there are orbs of effluvia around every planet, i.e., that each planet has a natural magnetic motion and a natural sphere of activity. This, each planet is composed of a mixture of electric humors and magnetic "earth." See (Gilbert 1651, 109)

[58] (Gilbert 1651, 187). See also (Pumfrey 1987, 51ff).

follow the common good.[59] This also allows planetary soul to receive effused celestial virtues which can add or subtract from their own powers.

Gilbert was not alone in facing such difficulties. One can recognize the same problems in Kepler's attempt to place a "celestial rooftop upon Gilbert's magnetic philosophy."[60] In the *Astronomia nova*, Kepler follows Gilbert in distinguishing the orienting power of the magnetic force,-- what he calls the directing force of the Sun,-- from the mere attractive force of magnets. By claiming that the sun acts "like a magnetic body,"[61] Kepler claims, in fact, that: (1) The Sun is itself in a (magnetic) motion of spontaneous rotation;[62] (2) the Sun's orb of virtue organizes the space around it, contributing to the orientation and motion of surrounding planets;[63] (3) this

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[59] At least for the motions of the celestial globes, Gilbert claims that "connate in them are reason, knowledge, science, judgment."(Gilbert 1893, 312). (Gilbert 1893, 344).

[60] Kepler's letter to Georg Brengger, 30 November 1607, JKGW vxi 86.

[61] A lot has been written on the status of Kepler's analogy. For the purpose of the present paper, it is less important whether Kepler really states that the Sun is a magnet or that the anima motrix is a species of the same genus as magnetic force. In both cases, the types of conceptual difficulties he is facing are very similar with Gilbert's own difficulties in explaining the mutual magnetic interaction. For a discussion see (Barker and Goldstein 2001, 109-110), (Voelkel 2001, 237 ff).

[62] One of the most clear statement of this point can be found in the letter to Maestlin, March 5 1605, KGW vol. XV 172. The Sun is said to be a "circularly magnetic body," rotating "in its place [by virtue of a *facultas animalis* already found in Plato], whereby it carries around its *oribis virtutis* with it." In the same letter, Kepler emphasizes the fact that Sun's magnetic virtue is not attractive but "directive," organizing the space around the Sun in such a way that the planets are moved "more slowly" or "more quickly" according to their position in the orb of virtue.

[63] See KGW III 355. The Sun does not "attract" planets, but has only a "directing force [*vis directoria*]." In addition, this directing force acts within the plane of

spatial organization and directive force is ascribed to Sun's "immateriate species," which, however, are imagined as a sort of magnetic filaments, or fibers.[64]

This re-configuration of the notion of "orb of virtue" leaves open most of Gilbert's own problems regarding the mutual effects of magnetism (and gravitation).[65] First and foremost, it leaves open the problem of the accord between the Sun's magnetic virtue and the respective magnetic virtue of each planet. Kepler's suggested solution is very similar to Gilbert's: namely, he distinguishes between the motive power (of the Sun) and the perceptive faculty (of the planet). Following Gilbert, he deems them both magnetic;[66] however, the two powers refer to two very different motions. The spontaneous rotation of the sun "generates" an already organized and oriented space, in which planets are disposed, and directed. The magnetic intellective faculty of each planet "perceives" the properties of this orb of virtue, and tends to react accordingly.[67] However, in this attempt, the magnetic faculty of each planet is hindered by its own, animate faculty "which

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the ecliptic. It is worth emphasizing that, for Kepler, both magnetic and gravitational attraction always take place in the orb of virtue.

[64] Kepler, AN 176; KGW III 355. For a discussion on Kepler's immateriate species see (Rabin 2005; Dupré 2012)

[65] For a more general discussion see (Krafft 1991).

[66] The planet's libration is the effect of its own magnetic faculty; however, Kepler agrees that this is a complex motion and he ascribes it to the planet's capacity to perceive the angular size of the sun and thus, to know its distance from it and to regulate its own motion. See (Voelkel 2001, 179).

[67] Kepler AN 276.

is designed to keep the magnetic axis in line."[68] As a result, Kepler sees the resulting motion of a planet as the result of an inner "battle," or a "wrestling match" between two faculties of the planet's soul: the animate faculty and the perceptive, magnetic faculty.[69]

To conclude: the natural philosophical concept of the "orb of virtue" faces insurmountable difficulties in both Gilbert's magnetic philosophy and Kepler's celestial physics. In both cases, the response to the attempt to distinguish between kinds of interactions leads to the multiplication of orbs. In both cases, the challenge to define mutual interactions leads to the introduction of supplementary concepts such as "perception," "passive magnetic faculty," collaboration etc. And in both cases there is a clash between a spherically diffused central force and another kind of interaction, constitutive for an oriented space. Thus, natural philosophical difficulties plague the attempts to give operational definitions to the orbs and their extension-related elements.

Francis Bacon's operational treatment of the orbs of virtue and the "measures of space"

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[68] Kepler AN 280; in addition, since the animate faculty of each planet is responsible for its tendency to rotate and preserve the direction of its axis, one can easily see that it is also a magnetic faculty, similar with the *anima motrix* of the sun. Thus, for Kepler, each celestial body has at least two magnetic faculties, one active, the other passive.

[69] AN 282. On Kepler's sources see (Regier 2014).

By contrast with Della Porta, Gilbert and Kepler, Bacon's way of dealing with the "orbs of virtue," is to disentangle completely the natural philosophical content from the operational content of this term. In what follows I show that one can distinguish two attempts to formulate an operational definition of the "orbs of virtue." The first is connected with a classificatory concern: Bacon repeatedly used the orbs of virtue as an instrument of classifying actions in terms of their range. This led him to discuss "natural limits," boundaries, borders and other extension-related questions in terms of a definition of "orbs" as "measures of space" for a given action. A second attempt to find an operational definition is in terms of a universal property of matter he calls "perception." However, unlike for Gilbert and Kepler, Bacon's perception is not a faculty of the planetary soul but a universal quality of matter. Again, Bacon circumvents the natural philosophical discussions on the nature and mechanisms of perception and merely classifies bodies as more or less perceptive, claiming that their range of their "perception" can be the subject of experimental investigation. This is precisely Bacon's second operational definition: orbs of virtue are the distances to which a certain perception extends. This definition opens the possibility of constructing "perceptive" instruments which can experimentally map the space around a certain body, determining its structure, its hidden limits and symmetries.

Classifying actions and the "measure of space"

Bacon claims that every natural virtue has its own, characteristic, "orb," which designates its range of action and the limits to which it can act, un-

der given circumstances. However, unlike Della Porta, Bacon does not conflate all effluvia under a generic term. He clearly distinguishes between different kinds of effluvia, either in terms of "subtlety," [70] or in terms of range, and mechanisms of interaction. For example, in *Sylva sylvarum*, Bacon discusses eight different types of effluvia, (he calls them "transmission of spirits"), extending from the "most corporeal," such as "odours" and "infections," to the "least corporeal," such as the astral "influxes" and the operations of sympathy. In between these extremes, Bacon arranges various types of attraction and "consent."[71] All these actions, he claims, produce their effects at a distance, in ways too "subtle" to be fully understood.[72] Therefore, Bacon does not attempt to discuss and classify them in terms of their respective mechanisms of propagation. Instead, he proposes a classification based on two parameters: the range of action, and the role played by the intervening media. Some of the eight types of effluvia are short ranged; others can act at considerable distances. In some cases, the action is strongly depending on the intervening medium (as in the case of light and sound). In some other cases, "emissions of spirits and immateriate powers and virtues," "work by the universal configuration and sympathy of the world:"

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[70] "Subtlety" is a technical term in Bacon's vocabulary; it describes the multiple and complex ways in which the fundamental processes taking place in nature escape the senses. See for example OFB XI 211, 347, SEH II 602. For a discussion see (Rees 1980) and (Jalobeanu 2015a).

[71] SEH II 602.

[72] It is tempting to read Bacon's types of effluvia in corpuscular terms, and his classification as one of substances made of increasingly smaller corpuscles. However, this is not Bacon's definition of subtlety. Subtlety refers to perception; it is a generic name for describing the multiple and complex ways in which fundamental processes taking place in nature escape the senses. See OFB XI 347.

> Of this kind is (as we suppose) the working of the load-stone, which is by consent with the globe of the earth: of this kind is the motion of gravity, which is by consent of dense bodies to the globe of the earth: of this kind is some disposition of bodies to rotation, and particularly from east to west: of which kind we conceive the main float and refloat of the sea is, which is by consent of the universe, as part of the diurnal motion. These immateriate virtues have this property differing from others; that the diversity of the medium hindered them not; but they pass through all mediums; yet at determinate distances.[73]

Thus, from the perspective of the investigator, the major difference between the "materiate" and "immateriate" powers and virtues is that the latter can be investigated without taking into consideration the action of the intervening media in widening or shortening the range of action.[74] By contrast, electric action and other forms of sympathy work depend on the medium in which bodies are placed; [75] and that means that by operating on the medium, the investigator can obtain a wider-ranged action, or a less powerful attractive effect.[76]

Similar classifications of actions and virtues in terms of their range of action can be found in *Novum organum* and *Abecedarium novum naturae*. In *Novum organum,* Bacon proposes a tripartite classification of virtues:

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[73] SEH II 644.

[74] In *Sylva Sylvarum* Bacon extensively discusses the role of such intervening media, such as the air, in the transmission of odours and diseases. He is also interested in natural magic tricks of extending the "natural range" of human imagination. More experiments on the role of the media in electric attractions can be found in (Bacon 1679, 140-151).

[75] Sympathetic attraction comprise "the attraction in gold of the spirit of quicksilver;" "the attraction of heat at distance, and that of fire to naphta; and that of some herbs of water, though at distance; and divers others." See SEH II 644.

[76] See also (Bacon 1679, 150-151).

some operate by contact, others at small distances,[77] and others at large and very large distances. In each case, regardless of the actual mechanism of interaction, the range of action, or the "orb of virtue," is determinate.

> […] virtues and motions of things operate and work over distances which are neither indefinite nor random, but finite and certain.[78]

Thus, Bacon claims that there are "natural limits" and orbs of virtue, not only for magnetic and gravitational virtues, but for every each action, virtue and motion. The same tripartite classification is applied, in the *Abecedarium novum naturae*, to simple motions. Bacon distinguishes wide-range motions, whose orb of virtue is the "sphere of the universe," from middle and short-ranged motions.[79]

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[77] Bacon's list of short-ranged actions contains quite diverse items: instances of electric attraction, but also "bubbles" in water, "merging when they come together." Instances of action-at-a-distance properly speaking comprise gravitation, magnetic attraction, but also the particular form of consent through which plants attract water, even at a distance etc. Bacon also opens the possibility of very long, cosmic "orbs of virtue" in case of magnetic disposition (orientation) and gravitational effects.

[78] OFB XI 369.

[79] OFB XIII 195; see also the next section. The unfinished *Filum labyrinthi sive Inquisitio legitima de motu* proposes another classification of simple motions in terms of categories such as space, time and alteration. SEH III 630; it is worth emphasizing that in this classification, the motions "with respect to space" cover very diverse tendencies of a body to avoid the void (*motus nexus*) to avoid interpenetration by other bodies (*motus plagae*); to keep within the limits of its own sphere (*motus libertatis*) and to change its sphere (*motus hyles migrantis, sive ad sphaeram novam*).

Thus, Bacon's first operational definition of the orbs of virtue is in terms of a *measure of space*. The "orb of virtue," he claims,

> […] is the distance which the powers of bodies may travel to, stop at, build up to and die down from - whether the operation occur by contact alone, or at a [greater or] lesser distance […].[80]

This operational definition provides the ground for a more accurate classification of actions and motions in terms of range. It also opens up the possibility of experimental investigations of these measures of space in particular circumstances. The experimental investigation of such measures of space is taken to reveal natural limits, "borders" and "boundaries" around particular bodies. Bacon claims that

> […] there is a kind of *No further* which varies according to the mass or quantity of bodies, or the strength and weakness of virtues, or the helps and hindrances of the media, all of which ought to come into the reckoning and to be noted down.[81]

In the experimental investigation of the orbs of virtue, one has to take into consideration three parameters: the "quantity" or bulk of the bodies involved, the "strength" of a given virtue, and the intervening action of the media. The experimental investigation aims to establish a correlation be-

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[80] OFB XIII 211-213.
[81] OFB XI 371.

tween these parameters in particular circumstances. Mark that, again, the actual mechanism of action is circumvented. What the experimenter attempts to do is map the space around a body, looking for how the effects of a particular action take place at various distances within the orb of virtue. In each case, the effects of the action are said to be "confined within the orb of its own virtue."[82]

In the light of all this, one can more easily understand Bacon's interest for borders and limits; his numerous examples of bodies changing their behavior when moving from one "orb" to another and his constant preoccupation to determine the "natural limits" and the range of action of each virtue. In his preface to the *Historia gravis & levis* Bacon clearly states that

> […] it is quite certain that a body is not affected except by another body, and that no local motion occurs which is not prompted either by the parts of the moving body itself; by adjacent bodies, be they contiguous or close at hand; or at least by ones within their orb of virtue.[83]

Thus, for Bacon, heavy bodies are not heavy because they tend towards the center of the earth; they are heavy because they happen to be in the orb of virtue of the Earth. The further away from the Earth, the less heavy they are; and at the borders of the Earth's orb of virtue, they would simply

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[82] OFB VI 157; OFB XI 317-319; OFB XI 329-331.

[83] OFB XII 133; *Historia gravis et levis* was one of the six natural histories Bacon planned to write in the last five years of his life. Its manuscript has not survived.

"hanging there like the Earth itself and not fall down at all."[84] By way of consequence, we can imagine similar limiting cases for each virtue. Hence, the experimental investigator can "map" the space around bodies for similar cases of strange behavior in bodies. Such "leaps" in the regular behavior of a body or another can mark the natural limits, or the orbs of virtue of a particular action, or motion.

Perception and "perceptive" instruments: mapping the orbs of virtue

The experimental determination of these "measures of space" is fraught with difficulties. Bodies are endowed with multiple virtues, each with its own orb. For example, Bacon criticizes Gilbert for over-simplifying "the matter of magnetic powers" by reducing the number of magnetic motions, and by confining them to the loadstone. [85] By contrast, Bacon claims that there are many more magnetic motions; [86] and that at least some of them

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[84] OFB XI 329. Bacon claims that this is the case of the lower comets, but also that of large clouds over the seas. See also OFB XI 317-319. Bacon also suggests various ideas of experiments attempting to find a quantitative relation between weight and the actual position in the orb of virtue. See SEH II 353-354.

[85] OFB XII 133.

[86] For example, a series of experiments in *Sylva sylvarum* attempt to determine four magnetic motions in the Moon: the "drawing forth of heat; the inducing of putrefaction; the increase of moisture; the exciting of the motions of spirits." (SEH

are universal, simple motions, that can be found in each body, tangible and pneumatic.[87] More generally, Bacon's appetitive metaphysics postulates that there are complex configurations of motions in each single body.[88]

> […] all bodies, by the manifold consent of things are also endowed with many motions, some ruling, others submitting, others again lying hidden unless excited; and there are no proper motions of things other than specific measures and modes of general motions.[89]

Each of these simple and composed motions has its own range of action, or "orb of virtue." In some cases, these orbs can be very large, no less than

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II 636). All these magnetic motions are instances of action-at-a-distance; and some of them are classified as instances of the "simple" magnetic motion. In addition, the Moon has the (magnetic) virtue to "lift up the waters," to "make moist bodies swell or inflate," etc. Bacon also mentions repeatedly the magnetic virtue of the Sun, which "holds" Venus and Mercury very close to the Sun's orbit. OFB XI 399. It is worth noting that in classifying magnetic phenomena, Bacon moves certain magnetic motions from one class of simple motions to another. See for example OFB XI 397-401; OFB XIII 197-198.

[87] Bacon uses the term "magnetic motion," or motion of congregation [*motum magneticum sive congregativum*]; or "great magnetic motions," for all mutual attractions where masses of matter are involved (bodies tending to unite with great masses of connaturals). See OFB VI 193; OFB XIII 195. This also extend to purely pneumatic matter, such as the celestial fire.

[88] Bacon's bodies are configurations of matter in motion; and he attempts to explain these perceptible motions in terms of a small, fixed number of simple motions. Bacon has various lists of such simple motions. There are interesting differences between one list and the other, both in terms of the number of simple motions and in terms of the actual description of one motion or another. On Bacon's doctrine of simple motions see (Manzo 2006; Rusu 2013; Weeks 2007; Jalobeanu 2015a).

[89] OFB VI 189.

the whole "sphere of the universe [*spheram universi*];"[90] this is the case of motions taking place by the "common bond of the system, or cosmical consent."[91] It is clear, especially from Bacon's earlier, unfinished texts, that he hoped to turn these estimative classifications into proper inquiries into the "nodes and spheres" of every motion, "the times and moments wherein motions work, and which is the more swift and which the more slow."[92] However, for such an investigation to work, one would need rules of composition of simple motions into sums of motions, as well as ways to compare the "strength" and weakness of various motions.[93] Bacon's abstract physics does not provide such general rules. [94]

On the other hand, his experimental program is suggesting a possible alternative direction for such an investigation. One can, in principle, begin with an experimental inquiry which attempts to map the space around a particular body, in the hope of determining certain natural borders and boundaries. The mark of such natural borders would be a "leap" in a variation of a particular property; or simply the change in the behavior

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[90] OFB XIII 195. The orb of virtue for this motion can also be very large. In *Novum organum* Bacon claims that this motion arise "from a certain harmony and consent of the world," a type of consent which manifest itself at distances greater than the orb of virtue of the Earth. This marks the particular place Bacon gives to verticity which, he claims is simply the way in which solid, "robust" bodies participate in the cosmic, diurnal motion of the universe (SEH V 455).

[91] OFB VI 193.

[92] SEH III 627.

[93] Bacon calls these rules "cannons of ascendency," and discusses some of them among the instances of special powers of the *Novum organum*. OFB XI 413-417.

[94] His ANN can be read as an unfinished, sketchy attempt to provide such rules of composition, with the intention of bridging the gap between his request of experimental investigation and what looks like a metaphysics of schematisms of matter and simple motions.

of an instrument that is "subtle" enough to "perceive" the border, or to register the leap. I suggest that this is the motivation behind Bacon's formulation of a second operational definition of the orb of virtue, as "the distance that perception reaches to."[95]

At first sight, Bacon's move looks deceptively similar to what we have seen in Gilbert and Kepler, i.e., introducing yet another natural philosophical concept in order to account for the apparently mutual character of magnetic (and gravitational) interactions. And indeed, Bacon introduces perception as a universal property of matter.

> It is certain that all bodies whatsoever, though they have no sense, yet they have perception: for when one body is applied to another, there is a kind of election to embrace that which is agreeable, and to exclude or expel that which is ingrate: and whether the body be alterant or altered, evermore a perception precedeth operation; for else all bodies would be alike one to another. […] And this perception also is sometimes at distance, as well as upon the touch; as when the loadstone draweth iron; or flame fireth naphtha of Babylon, a great distance of. [96]

However, Bacon does not elaborate a natural philosophical explanation of perception. In most cases, he treats it as yet another operational concept to be applied in further experimental investigations. For example, his *Inquisitio de magnete* contains a series of experiments intended to prove that even if, by laboratory manipulations, one can destroy the active power of a

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[95] OFB XIII 195.
[96] SEH II 602.

magnet, its "passive power" of perception cannot be destroyed.[97] Thus, loadstone burned, or reduced to powder is still attracted by magnetized iron, appearing "to retain its passive virtue in some degree."[98] Perception is thus considered to be a fundamental property, prerequisite and preliminary to all action. This means that, each time a body is placed within the orb of another body, perception is the first "activated," and can be followed (or not) by action. Bodies can be more or less perceptive; and the detection and mapping of more subtle effluvia require very perceptive bodies.

Defining perception in this way allows a fully operational, experimental approach to body-body interaction. By placing suitable "perceptive" bodies close to one another one can detect various changes of behaviour. And since bodies are always acted upon by other bodies (either directly or through the emanation of subtle effluvia), one can consider that ensuing, observable motions arise as the result of a body's "labour for configuration relative to another body."[99] The motions thus observed can be manifold: attraction and repulsion, but also subtle, or less subtle changes of virtues.

This means that one can "map" the space around a given body by placing suitable "perceptive" bodies in certain configuration around it.

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[97] SEH V 403-305.

[98] SEH V 405.

[99] OFB VI 267: "For place has not power, and body is not acted upon save by body, and all the haste of a body which seems to be aimed at positioning itself somewhere, it longing and labour for configuration relative to another body, and not relative to a mere location or position." Bacon also claims that in addition to mutual motions there is a "cosmical" motion of rotation; but even that is a motion received "by consent" with the whole universe and not a self-motion properly speaking. See OFB VI 180-181.

Such bodies can perceive some of the borders, limits and boundaries of virtues and actions in the first body.

In practice, the experimenter meets with several different situations in this process of "mapping." The simplest situation is when the simple motion or the particular configuration of motions is already given. This is the case of "mapping" the variation of weight with distance.[100] Bacon claims that weight of a body decreases with hight and suggest a series of experiments intended to map this gradual decrease.[101] The case of magnetic virtue is slightly more complicated, because it involves at least three different simple motions (coition, verticity and the motion of situation).[102] Even more complex are the cases in which one does not know the prevailing configuration of motion. Bacon formulates an experimental investigation of this type in Century IX of *Sylva sylvarum*: a complex series of experiments intended to map "the inequalities of the air" in a given region. Without knowing what produce these inequalities, and without actually discussing what are these "inequalities of the air," the investigation attempts to find limits, borders and leaps in a given region with the help of very perceptive instruments, such as a weather glass or an improvised hy-

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[100] This is a simple situation because, in Bacon's view, motions of major congregation (the great magnetic motion) always prevail in competition with other motions. This is why one can investigate weight and the motion of gravity independently of any other motion. OFB XI 417.

[101] OFB XI 329; SEH II 353-354.

[102] Most of the time, any assessment of the orb of magnetic virtue has to take into consideration weight as well. Bacon usually gives examples where magnetic virtue "gives way" to gravitational attraction. However, in the *Inquisitio de magnete* there are also cases where the experimenter screens off the gravitational attraction in order to concentrate on either coition or verticity.

grometer.[103] These instruments are recording "changes" in the "inequalities of the air," and can be used to "map" a given region, for a given time. The recording of certain "leaps" in their behaviour of instruments is taken to be indicative of the discovery of natural limits and borders in nature. In this case, Bacon claims that the accuracy of this "mapping" depends primarily on the "subtlety" of the perception of the particular body used as an instrument.[104]

Again, one can read Bacon's introduction of "perception," and the associated strategy of determining boundaries, limits and leaps of the orbs of virtue as a generalization and operationalization of the same kind of concepts and questions one can find in Gilbert and Kepler. In contrast to his predecessors, however, Bacon strips completely such concepts from their natural philosophical context, anchoring them firmly in methodological formulations of laboratory procedures.

Conclusion

My purpose in this paper was to investigate Francis Bacon's particular strategy of defining extension-related concepts in terms of "limits" and

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[103] It is important to note that Bacon is not only interested in finding instruments that are "subtle" and "perceptive" enough, but also in devising and inventing them, i.e., using very perceptive bodies as instruments in a given situation. (Jalobeanu 2015b, 2013).

[104] The accuracy of mapping also depends on the application of the proper methodology of experimentation. (Jalobeanu 2015b, 2015a).

"borders" of action, i.e., "orbs of virtue." I have shown that, in formulating this kind of approach, Bacon was freely borrowing terms from magnetic philosophy and natural magic, building up on a series of questions and challenges already contained in Gilbert's proposal for a "science" of the "orbs of virtue." However, in his characteristic fashion, Bacon radically transformed both the meaning and the use of the borrowed concepts. I have shown that in his treatment of the "orbs of virtue," Bacon repeatedly circumvented all discussions about the nature and mechanisms of actions, and the nature and mechanisms of perception. Instead, he formulated abstract, operational definitions, in terms of "measures of space (distance)" to which an action can extend; and in terms of (spatial) limits of "perception." He used these two operational definitions to devise experimental strategies of investigation for detecting natural limits and borders of actions and virtues, and for the classification of the (unknown) actions and virtues in terms of their range. Clearly, Bacon's approach is more than a mere "generalization" of concepts borrowed from natural magic and magnetic philosophy. In many ways, it marks a conceptual breakthrough and opens up new possibilities of proper, quantitative measurement, in actual, experimental investigations.

Abbreviations

SEH	Bacon, Francis. 1857-74. *Works*, 14 vols. Edited by James Spedding, Robert Leslie Ellis and Douglas Denon Heath. London: Longman repr. Stuttgart-Bad Cannstatt: Frommann, 1961-63).
OFB IV	Bacon, Francis. 2000. *Advancement of Learning*, ed. by Michael Kiernan. Oxford: Oxford University Press.
OFB VI	Bacon, Francis. 1996. *Philosophical Studies c.1611-c.1619*, ed. by Graham Rees and Michael Edwards. Oxford: Oxford University Press.
OFB XI	Bacon, Francis. 2004. *The* Instauratio Magna *Part II*: Novum Organum *and Associated Texts*, ed. by a Graham Rees and Maria Wakely. Oxford: Oxford University Press.
OFB XII	Bacon, Francis. 2007. *The* Instauratio Magna Part III: Historia Naturalis et Experimentalis: Historia Ventorum *and* Historia Vitae et Mortis, ed. by Graham Rees and Maria Wakely. Oxford: Oxford University Press.
OFB XIII	Bacon, Francis. 2000. *The* Instauratio Magna: *Last Writings*, ed. by Graham Rees. Oxford: Oxford University Press.

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