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# LEAST ATTRACTIVE?
## Aristotelian Presuppositions to Explain Magnetic Movements


### Abstract

Since Antiquity, scholars have sought to explain the cause of magnetic 'attraction' through diverse theories, which raised questions as to whether the magnet attracts iron or vice versa, or if both entities play equal roles. Aristotle himself avoided the notorious question of how magnetic attraction works: his commentators and critics made good for this lacuna. Medieval theories predominantly posited that iron moved towards the magnet for teleological reasons. Medical and alchemical authors in turn emphasized the magnet's active attraction of iron, while only a minority believed in the iron's active attraction of the stone. The seventeenth century saw William Gilbert establish an account of reciprocal attraction between the iron and the magnet. These causal representations, rather than being empirically grounded, were often rooted in natural-philosophical or metaphysical assumptions, especially Aristotle's causal principle of motion. A fierce controversy about the 'correct' account of the causal roles in magnetic attraction grounded, prepared and partly overshadowed the debates on how to explain magnetism. This article will shed light on this little-known controversy. It offers a more balanced account of the tacit and salient impact of Aristotelian natural philosophy by providing a framework that enabled different theories to contradict each other – until even this framework dissolved during the seventeenth century.



### Keywords

Aristotelian Natural Philosophy, Magnetic Attraction, Aristotelian Paradigm of Causation, Averroes, William Gilbert



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## *1. Introduction*

Birds of a feather flock together. Since Antiquity, maybe even longer, the relationship between a magnet and iron has been considered as an instance of sympathy.[1] These two natural substances seem to have some connection, as they – *prima facie* – attract each other and stick together. The first naturalists, magicians, and physicians writing on the magnet were not primarily concerned about a complex understanding of what was really going on between magnet and iron. For them, it sufficed to marvel at the observation that certain natural objects stand in a fixed relationship to each other – that they fit into a web of sympathy and antipathy.[2]

In ancient natural philosophy, more theoretical reflections on the concept of attraction or movement of magnet and iron emerged with the Presocratics.[3] According to Aristotle, Thales assumed a soul in the magnet, with the help of which it seemingly would move itself to the iron. Magnetic attraction here is deferred to a superior principle, i.e. a soul being the cause of the magnet's movement.[4] Plato criticized common perception and stated that magnets actually do not attract iron.[5] In line with some pre-Socratics he explained magnetic attraction away by subscribing to material and mechanistic principles.[6] The 'avoidance of a vacuum' (*fuga vacui*) or the collisions and movements of atoms thus made attraction, at the theoretical level, an illusory phenomenon that could be reduced to invisible mechanics underlying the visible effects.[7] However, Aristotle himself avoided the notorious question of how magnetic attraction works.[8] His commentators and critics made good for this lacuna, after all.

In fact, Aristotle, or rather, Aristotelian natural philosophy, defined – for a large part – the conceptual framework against which the question of

[1] See Sander (2020) chap. 8.1.3.2.2. This article closely follows, and partly translates, research of Sander (2020) pp. 606-22.
[2] See Lehoux (2003).
[3] See Radl (1988).
[4] See Sander (2020) chap. 8.1.3.2.4.1. See Aristotle, *De an.* 405a19-21.
[5] See Sander (2020) p. 701. See Plato, *Tim.* 80.
[6] See Sander (2020) chap. 8.1.3.2.8.1.
[7] See *ibid.*, p. 621.
[8] See Sander (2023a).

how magnets work was discussed, even by critics. While there was much disagreement of how to exactly explain magnetic attraction – or a movement so-perceived –, a certain web of metaphysical assumptions or distinctions was not as heavily contested until the premodern era: For example, action-at-a-distance was rarely argued for in the natural realm and most philosophers took up a distinction between an active and a passive role in causation.

The metaphysics of causation within the history of Aristotelian philosophy have not escaped scholars' attention, and several studies have shown how much of an (often hidden) Aristotelian metaphysical skeleton laid below the muscles of non or even anti-Aristotelian accounts.[9] Yet, the absence of an authoritative Aristotelian account of magnetism, and the somewhat fuzzy assumption of 'occult qualities' to account for it, have largely blurred the actual Aristotelian embedding informing the diverse pool of premodern accounts of magnetism.[10] Those already mentioned occult qualities, often ascribed to allegedly Aristotelian accounts, are one specific *explanans* for the *explanandum* 'magnetic attraction'. However, several if not the majority of scholars generally took, e.g., for granted that the iron is moved to the iron (being altered by the quality), including the critics of occult qualities. Such a claim or belief can be considered a causal representation – an underpinning of specific causal explanations, such as by 'occult qualities' or atoms. These more fundamental causal representations were to some degree deeply Aristotelian in subscribing to active and passive causal roles, for taking causes to be fundamental to the domain of natural philosophy, and for holding logic, natural language, and 'common-sense' observation as apt point of departures of the natural philosophical investigation. To some degree, this changed in the seventeenth century, in different ways. This article will tell part of this well-known story by way of one concrete example: causal representations of explanatory theories of magnetism from Aristotle to the rise of Cartesianism.

[9] See, e.g., Feingold (2003); Garber (1992); Leijenhorst, Lüthy and Thijssen (2002); Wallace (1981). There are a plethora of studies, this volume included, that show how much Aristotelian philosophy shaped philosophical and scientific thought in the early modern period.

[10] See Sander (2023b). This publication studies the acceptance, criticism, and transformation of the concept of 'occult qualities' in explaining magnetism in depth. Respective assessments below in this article are based on this study.

Focusing on this longue durée reveals that the Aristotelian paradigm of causation, its fundamental metaphysics of causation undergirding hylemorphism and qualitative change, was employed even for non-Aristotelian accounts of magnetic attraction. It provided a syntax of causation, even if matter, form, and qualities were abolished by many in the course of the scientific transformations of the seventeenth century. To put in a nutshell, the Aristotelian causal model, also applied to magnetic attraction, was based on active and passive roles, an agent and its object. This model could work for all sorts of specific explanations, but eventually was contested by another model, proposing causal reciprocity, mutuality, or symmetry.

## *2. Six Ways to Look at Magnetic Attraction*

Any view of magnetic attraction as a particular form of attraction or motion already implies far-reaching causal assumptions about what happens, from the point of view of natural philosophy, when iron and magnet are brought into spatial proximity. What is actually observed here? How is it best described? What attracts what? Or are both objects being attracted equally by each other? Is it even an attraction at all? For most premodern – pre-Hume – natural philosophers, these questions were not to be decided empirically, but are primarily rooted in a theoretical understanding of 'attraction'. This does not primarily relate to the *explanans*, but more importantly to the *explanandum*. Answering these questions required an abstractly defined conception of the actual phenomenon to be explained. To explain *how* something works implies to have an idea of this *something*, most importantly a mapping to causal roles.

To be sure, any answer to these first-order questions of causation already may provide a partial answer to the actual causal question of the 'how?'. The relation of the causal *relata* 'iron' and 'magnet' thus co-determined the causal representation of the object of explanation, which was explained by various theories. Two theories, which seem very similar in terms of their natural philosophical explanatory principles, can explain two actually quite different causal representations of the same phenomenon. Conversely, one single causal representation can also be explained by two very

different theories. This logical variance goes some way to enable both the great variety of premodern magnetism theories and the fierce controversies that this entailed.[11] To study this controversy, the two levels – representation and explanation – have to be logically distinguished, although they have not always been explicitly distinguished as two levels by the actors' themselves.

From a bird's eye view on these premodern debates about causal representations of magnetism, the below abstract typology can serve as a helpful instrument for grouping and relating historical theories to each other. Essentially, authors between late Antiquity and the early modern period argue for six possible modes of causation:

I. The magnet actively attracts the iron.
II. The iron actively attracts the magnet.
III. The magnet and iron attract each other.
IV. The magnet and iron come together.
V. The magnet moves to the iron.
VI. The iron moves to the magnet.

It goes without saying that even within these six modes there is still plenty of scope for different understandings of the causal relations. For example, purely mechanistic accounts of attraction, in which attraction is nothing else than the pushing of material particles, in fact reduced Modes 1 to 3 to options 4 to 6. While the very concept of attraction is superfluous for ancient atomists and early moderns inspired by them, as we shall see, they nonetheless did opt for Modes 4 to 6. They needed a causal model in their metaphysics, too!

Modes 4 to 6, on the other hand, concern the issue of self-movement.[12] The fundamental background to this problem, at least since Late Antiquity, has been a principle of Aristotelian physics: "Everything that is moved is moved by something else" (*omne quod movetur ab alio movetur*).[13] For most natural philosophers, this principle had an axiomatic character and therefore

[11] Whether the causal representation is a consequence or prerequisite of a certain explanatory theory is disputable but also of less importance here.
[12] See also Gill and Lennox (1994).
[13] See esp. Hesse (2005) p. 64; Lohrmann (2008) p. 230; Pines (1961); Sarnowsky (2007) p. 123; Weisheipl (1965).

prompted them to account for apparent self-movements, such as the movement of the elements to their natural location, by involving an internal complexity within the subject of movement to ensure a proper distinction between the mover and the thing moved.[14] A self-movement *per se* was usually attributed exclusively to living beings, with the soul, the intellect, the will, etc., being a mover. A self-movement *per accidens* however applied to inanimate things, such as iron, which was accordingly moved to the magnet by the iron's own form or some other disposition. In the common Aristotelian account, the purpose of such movement was considered a final cause, not only triggering, but strictly causing a movement per accidens. Hence, the iron, once moved to the magnet, was not endowed with some sort of mental intention but acted on behalf of its telos, written into its substantial form and corresponding to the form of the magnet. Vitalist accounts however extended this self-movement even further but considering magnets as quasi-living substances, moving to the iron on their own. While this might require some reconciliation with the Aristotelian axiom for apparent self-movements mentioned above, proponents of this vitalist account often simply ignored it, outrunning any Aristotelian constraints of metaphysics.

These and many other theory-specific conundrums are best analyzed in the light of these individual theories and will thus be largely ignored in the following. The main take-away from this for this article rather is that one and the same phenomenon could be represented in different causal conceptions. This phenomenon is the spatial movement to be observed when magnet and iron are brought into spatial proximity to each other.

In describing this phenomenon, however, the English (this article's language) and Latin (the dominant language of the sources) languages already implicitly define important causal assumptions that must be kept in mind.[15] The verb 'to attract' (*attrahere*) is semantically bivalent, so it usually demands a direct object. This linguistically defines subject and object as *agens* and *patiens*, even if it is used reflexively in the plural ('A and B attract each other').[16] The

[14] The principle thus resembles the assumption largely shared by modern analytical philosophers that causality is not reflexive.

[15] See also Johnson (2010).

[16] In German, unlike in Latin or English, the verb 'bewegen' is necessarily reflexive under certain conditions: in German 'A bewegt sich zu B', while in Latin or English it is 'A movet

verbal syntagma 'to unite (with something)' (*sibi unire*) and the nominal syntagma 'bilateral union' (*unio utriusque*) imply yet another view. These expressions semantically necessarily imply reciprocity, without a causal effect on anything else being presupposed. However, a latent asymmetric relation is often connoted, since the unification can be initiated by one of the *relata*, with the subject occurring in the singular: 'A unites with B'. The lexeme 'to come together' or 'to join' (*coire* or *coitio*) plays a particularly important role. Semantically and grammatically, these expressions tend strongly to demand a subject in the plural (verb) or a genitive object in the plural (noun). In addition, it is grammatically impossible for the lexeme to have an object as a verb and a *genitivus obiectivus* as a noun. Unlike a simple movement, the path of movement for such a join is not determined by direction, that is, A and B usually do not 'join at C'.

The Latin sources examined here use the whole repertoire of these expressions to describe the same phenomenon or event. For the sake of linguistic simplicity, however, the term 'magnetic attraction' will be used throughout this article, although this formulation is actually already the result of a certain causal representation. The following description mostly follows the chronology of the controversy instead of the six modes. This helps illustrate that the development of different causal representations is historically a discursive product. Most actors did not explicitly opt for any of the modes – they presumed these modes, often quite tacitly.

### *3. Ancient and Medieval Background*

Aristotle's theory of motion famously distinguishes between the eternal, circular motion of the celestial bodies and the perpendicular, linear motion of the sublunar world.[17] Among the linear movements, he distinguishes between the natural movements of the elements and four 'violent' forms of movement, that is, motions caused by something external: Pushing, pulling,

ad B' or 'A moves to B'. The fact that the subject's movement affects 'itself' is therefore implied in German, but not necessarily presupposed in natural philosophy.

[17] Cf. Cohen (1994); Falcon (2005) pp. 55-84; Kosman (1969); Machamer (1978); Wallace (1978). See also Sander (2020) chap. 7.3.3.1 and 8.1.2.2.

carrying and turning (*pulsio, tractio, vectio, vertigo*).[18] He does not explicitly classify magnetic attraction in this typology. While one might assume that it could be classified as a form of pulling, this would be inaccurate, as he understands it to mean mechanical pulling, such as when a horse pulls a carriage.[19] Aristotle occasionally mentions other forms of attraction, such as attraction caused by 'heat' – but nowhere in his work does he address magnetic attraction as *explanandum*.[20]

A particularly influential natural-philosophical definition of the concept of attraction has been developed in the medical context – most importantly by Galen – where magnetic attraction is explicitly considered as an example of attraction. Galen acknowledged attraction by suction, i.e. by avoidance of a vacuum.[21] However, he moreover assumed an attraction, which was brought about by a so-called 'natural faculty' (*facultas naturalis*).[22] This attraction he related to a certain 'relationship of qualities' between what was attractive and what was attracted. Being an important theoretical building block, especially in Galen's physiology and pharmacology he explained, for example, how the bodily parts could attract its proper food stuff or how certain drugs could attract corresponding body juices.[23] It is important that Galen defended his concept of attraction against authors who did not concede any 'real' attraction in nature, such as the atomistic theory of magnetic attraction, which ultimately reduces it to the collision of atoms.[24] Galen assumed the magnet as an *agens* to attract a *patiens*, i.e. iron: "The magnet is somewhat stronger, so that it is more suitable for attracting than for being attracted" (ἀλλ' ἰσχυροτέρα πώς ἐστιν, ὡς ἕλκειν μᾶλλον ἢ ἕλκεσθαι ἕλκεσθαι / *verum fortior est quodammodo, ut attrahere sit aptior, quam attrahi*).[25] Galen's account is therefore an exponent of Mode I in the scheme outlined above, and his legacy is bifold.

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[18] See Aristotle, *Phys.* VII 2.243a. On this see also Wardy (2007) p. 127.
[19] Cf. Maier (1943) p. 174. See also Sander (2020) p. 614 n. 120.
[20] See Furley (1983) p. 90.
[21] See Brunn (1967) pp. 108-9, fn. 2; Galen (1916) p. 318; Meyer-Steineg (1913) pp. 443-4.
[22] See Sander (2020) chap. 4.2.1.1.1. See also Hankinson (1998) pp. 395-400.
[23] See Sander (2020) chap. 8.1.3.2.5.1.
[24] See *ibid*., chap. 8.1.3.2.8.1.
[25] This is explicitly stated in Galen (1561) p. 198; Radl (1988) p. 73. See Galen (1821) vol. XI, p. 612. See also Sander (2020) chap. 4.2.1.1. In a similar way, the kidney attracts a certain

On the one hand, Avicenna proposed in his *Canon* an influential tripartite division of types of attraction that is clearly inspired by Galen:[26] attraction by 'heat' (*calore*), e.g, when a burning oil lamp attracts the oil, by 'filling the vacuum' (*implendo vacuum*), as with a water pump, but also an attraction by 'attractive power' (*virtute attractiva*).[27] His example of the latter form of attraction is the magnet with its attraction of iron. Avicenna's commentators interpreted this 'attractive power', which at this point was probably closely related to Galen's concept of *facultas*, as a 'specific form' or 'occult property' (*forma specifica sive proprietas occulta*).[28] This medical idea of active attraction by a non-mechanistic principle, established to a large extent by Galen, remained influential in the Middle Ages. Ugo Benzi, for example, expressly emphasizes with Galen: "The magnet attracts the iron and not vice versa" (*magnes attrahit ferrum et non e converso*).[29]

Galen's contemporary Alexander of Aphrodisias, on the other hand, seems to criticize this conception in the *Quaestiones* attributed to him.[30] He rejects the comparison between magnetic attraction and the physiological attraction of organs. The latter also attract what lies between them, whereas the magnet does not attract any medium, but only the iron.[31] Alexander then points out that the living being is apparently attracted to its food. However,

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part of the blood or a certain drug attracts the body fluid that suits it. Cf. McVaugh (2012); Temkin (1977).

[26] See Avicenna (1522) fol. 22*v*. See esp. Weill-Parot (2013) pp. 371-94. On Avicenna's conception of attraction, see Goddu (1985).

[27] Avicenna notes that some philosophers reduced the attraction of 'heat' to the attraction of 'filling the vacuum'.

[28] Cf. Jacopo da Forlì and Avicenna (1547) fol. 62*r*. See Sander (2020) chap. 8.1.3.2.3 and 8.1.3.2.5.1. On Galen and Avicenna's concept of (magnetic) attraction, cf. also Costeo and Avicenna (1589) pp. 495-523; Luiz (1540) fols. 10*v*, 15*v*; Marcellus and Aristotle (1508) fols. 51*r*-52*r*. See also Siraisi (1981) p. 162. For Avicenna, however, the explanation implicit in Galen that attraction is related to the relationship of qualities between *agens* and *patiens* does not play a role. See Cardano (1548) p. 20.

[29] See Benzi and Avicenna (1485) fol. 37*v*. See also Sander (2020) chap. 4.2.1.2. Similarly in Jacopo da Forlì and Avicenna (1547) fol. 90*v*. Forlì also mentions Averroes's position (cf. *ibid*., fol. 218*r*). See also Taddeo Alderotti and Siraisi (1981) pp. 179-82.

[30] See Alexander of Aphrodisias (1548) p. 128, (1892) pp. 73-74, (2014) p. 31; Radl (1988) p. 84. See also Alexander of Aphrodisias and Aristotle (2011) pp. 131, 143. For Alexander's criticism of Galen, cf. in particular Al-Hasan ibn Musa al-Nawbakhti and Aristotle (2015) pp. 168-73; Pines (1961).

[31] See Sander (2021).

the living being actually moves toward its food because of its need for food.[32] In the same way, the iron is moved to the magnet: not by force emanating from the magnet, but because the iron lacks something that the magnet possesses.[33] Alexander can easily accept this being moved to something for lack of or striving for something, even in inanimate things. This theory's background lies in Aristotelian teleological causality.[34] Alexander's position represents Mode VI.

Alexander's position was, most influentially, taken up by Averroes.[35] Averroes presented Alexander's position in his Middle Commentary on *Physica* (1170), but despite some translations, Latin readers paid far less attention to this comment than to his Great Commentary (1186).[36] In that much-read commentary, Averroes takes on Alexander's position without mentioning his name.[37] Averroes, as well as Alexander himself, deal with the

[32] The text seems to be corrupt in this passage, as shown by Radl (1988) p. 86.

[33] Alexander seems to think of the elementary qualities of the two substances. Cf. Sander (2020) chap. 8.1.3.2.5.2.

[34] See *ibid.*, chap. 8.1.3.2.5.

[35] On Averroes's knowledge of Alexander, see for instance Glasner (2009) p. 159 n. 110. It seems that Alexander has taken up this resolution of the magnetic attraction as motion of the iron to the magnet again in his commentary on the *Physica* of Aristotle, which is largely lost today. See also the commentary by Simplicius in Radl (1988) p. 121. This is also pointed out by Dandino and Aristotle (1610) p. 439.

[36] For the translations, see also Hasse (2010). Two Hebrew translations (Zerahia ben Isaac ben Shealtiel Hen, Qalonymos ben Qalonymos) and three Latin translations (Vitalis Dactylomelos, Abraham de Balmes, Jacob Mantino) are known from the *Middle Commentary*. The seventh book of the commentary relevant here is not edited anywhere, since Mantino died too early to have his edition printed in its entirety. For the *Middle Commentary* see esp. Wolfson and Chasdaj Crescas (1929) p. 562.

[37] See Averroes and Aristotle (1962) fol. 315*r*: "Attractio autem, in qua attrahens est quiescens et attractum motum, non est attractio in rei veritate, sed attractum movetur ex se ad attrahens, ut perficiat se, ut lapis movetur ad inferius et ignis ad superius. Et similiter oportet hoc intelligere de motu ferri ad magnetem et nutrimenti ad membra [...] Nutrimenta vero non moventur ad nutriendum, nisi cum fuerint in quadam dispositione de nutrito, et similiter ferrum non movetur ad magnetem, nisi cum fuerit in aliqua qualitate de magnete. Et ideo quando magnes fricatur cum alleo, amittit virtutem. Nam ferrum non acquirit de lapide in illa dispositione qualitatem, per quam innatum est moveri per se ad lapidem. Et hoc manifestum est in ambra, quod attrahit paleam, quando calefit." See *ibid*., fol. 374*v*: "[...] et similis ferrum est quoquo modo de numero eorum, quae naturali moventur, cum non moventur a magnete, nisi per alterationem, quam acquirit, mediante aere a magnete. Et non quum complexio magnetis transmutatur, non attrahit; sicut accidit ei, quando confricatur cum alliis, et ut dicitur." For a textual variant, see also Rommevaux (2010) p. 623 n. 23.

concept of attraction from Aristotle's *Physica*.[38] Again, the Stagirite did not understand attraction (*tractus*) as a phenomenon such as magnetic attraction, but as mechanical pulling, as in a horse-drawn carriage. Accordingly, Averroes declares that in magnetic attraction one can speak only in the improper sense of 'attraction'. In fact, the iron is moved *ex se* or *per se* to the magnet, just as the food is moved to the body member. The iron has been modified by the magnet in such a way that it performs this movement by itself. This assumption, which is not found in Alexander's work, implies that the supposed attraction is a three-step transitive causal process: First, the magnet changes the medium, which in turn changes the iron, which then moves towards the magnet. He compares this with the kind of self-movement that occurs *per se* or *ex se* and also applies to the elements being moved to their natural place.[39]

Averroes's theory was accepted by the great majority of medieval philosophers, but formulated in various ways.[40] Hebrew authors also dealt with

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For some, the two quoted passages from Averroes' commentary contradict each other, e.g. Montanus (1587) p. 375. Cf. also Avicenna (2009) p. 188: "Unless, that is, that body emits to [the nature] a certain influence or power, and that influence and power are a certain principle that triggers the moved body to move naturally toward [the body], as in the case of the magnet and iron, in which case the motion is forced, not natural."

[38] Cf. also Maier (1943) p. 174: "Aristoteles und Averroes kennen keine attractio, sondern nur einen tractus, d.h. einen Zug im eigentlichen mechanischen Sinn des Worts, bei dem sich sowohl der Ziehende wie das Gezogene bewegen, also etwa der von einem Pferd gezogene Wagen. Hier ist natürlich der erforderliche Kontakt zwischen Beweger und Bewegtem vorhanden. Aber ein Analogon eines derartigen Vorgangs kommt für die Anziehung durch den natürlichen Ort nicht in Frage." See also Weill-Parot (2012) pp. 91-4.

[39] See Weisheipl (1965) p. 36: "Since this natural motion arises from the form, Averroes thinks that this intrinsic form is the immediate mover in natural motions. Consequently the natural movement of nonliving things is somewhat similar to self-movement in animals. But there is an essential difference: the animal soul is a self-mover *per se*, the natural form is a self-mover *per accidens*."

[40] See also Weill-Parot (2012). William of Ockham had a comparatively idiosyncratic interpretation, cf. Goddu (1984) p. 195; Weill-Parot (2012) p. 99. See also Albertus Magnus and Aristotle (1993) p. 523: "Est etiam adhuc advertendum, quod licet quaedam trahant, tamen non omnia quae aliquo modo trahuntur, dicuntur moveri motu tractionis. Sed aliquando moventur plus motu naturali eius quod trahitur, sicut nutrimentum movetur ad membra non motu membri, quod trahit ipsum, sicut locus trahit locatum, sed potius proprio motu, quia cum assimilatum est secundum aliquid membro, movetur ad ipsum sicut ad suum locum salvantem se in forma, quam recipit. Et hoc etiam modo grave movetur deorsum et leve movetur sursum. Et hoc etiam modo magnes movetur ad ferrum propter

Averroes.[41] Many of these debates, following Averroes, were revolving around the extent to which these forms of movement should be regarded as caused *ex se*, whether the magnet should be regarded as a final cause or as the cause of the qualitative alteration of iron, or whether its movement is caused solely by its now altered form.[42] The contingency of this causal relationship is nicely illustrated by a story in Albertus Magnus: some Dominican friar, he tells, observed a magnet in the possession of King Frederick II. This specimen however did not attract iron, but was in fact attracted by it (Mode II).[43] The monk was obviously able to clearly determine which substance was the

similitudinem formae, quam cum ferro habet, et ideo ferrum est locus eius. Et ideo cum impeditur vis illius similitudinis, ferrum non movetur ad magnetem nec e converso. Et ideo cum fricatur suco allii vel lapis vel ferrum, neutrum movetur ad alterum." See Thomas Aquinas and Aristotle (1954) p. 461: "Tertio quia ad hoc quod magnes attrahat ferrum, oportet prius ferrum liniri cum magnete, maxime si magnes sit parvus; quasi ex magnete aliquam virtutem ferrum accipiat ut ad eum moveatur. Sic igitur magnes attrahit ferrum non solum sicut finis, sed etiam sicut movens et alterans. Tertio modo dicitur aliquid attrahere, quia movet ad seipsum motu locali tantum. Et sic definitur hic tractio, prout unum corpus trahit alterum, ita quod trahens simul moveatur cum eo quod trahitur." See Jean Buridan and Aristotle (2010) p. 141: "De magnete dicendum est quod agit in ferrum, sed prius in medium aerem, ut dicit Commentator octavo Physicorum, ita quod aliquam qualitatem imprimit in aerem et multiplicatur impressio eius usque ad ferrum; et tunc ferrum perillam qualitatem sibi impressam est natum moveri ad magnetem propter aliquam convenientiam. Ita etiam conceditur quod sol agit in illa inferiora, sed prius naturaliter, licet non tempore, agit et multiplicat lumen in sphaeras caelestes sibi coniunctas; igitur tangit suum primum passum." See Nicole Oresme and Aristotle (2013) p. 733: "Respondetur sicut dicit Commentator, quod movetur ab intrinseco, videlicet a qualitate inducta in eo per ipsum magnetem, ita quod magnes alterat aerem usque ad ferrum, deinde ferrum." See also Rommevaux (2010) p. 624. Further examples can be seen in Robert Grosseteste (1912) vol. II, pp. 613-4; Walter Burley and Aristotle (1508) fols. 184*v*, 189*v*-190*r*, 191*v*, 218*r*, (1589) pp. 865-7. See also Nicholas of Cusa (1932-2014) vol. V, p. 33: "Nisi enim in ferro esset quaedam praegustatio naturalis ipsius magnetis, non moveretur plus ad magnetem quam ad alium lapidem." See also *ibid.*, vol. XVIII/2, p. 175: "Species seu forma magnetis trahit ad se ferrum, sed non nisi species a forma et virtute procedens mittatur ad ferrum. Postquam spiritus ille missus est ad ferrum ita, quod ibi maneat, tunc movetur ferrum."

[41] See in particular Langermann (2011) pp. 86-9; Wolfson and Chasdaj Crescas (1929) pp. 90-2, 253-7, 562-8.

[42] See Sander (2020) chap. 8.1.3.2.5 and 8.1.3.2.7.

[43] See Albertus Magnus (1890) p. 40: "Narravit mihi unus ex nostris sociis curiosus experimentator, quod vidit Fredericum Imperatorem habere magnetem, qui non traxit ferrum, sed ferrum vice versa traxit lapidem." See also Draelants (2011) p. 109.

attractive one and was astonished by the obvious reversal of the assumed asymmetric causal order.

Petrus Peregrinus, author of a landmark experimental treatise on the magnet in the thirteenth century, chose another representation.[44] He explains that between two magnets the stronger stone has the role of an *agens*, the weaker the role of a *patiens* (*in attractione lapis fortioris virtutis agens est, debilioris vero patiens*). According to the polarity of the magnet, the attraction occurs because the *agens* seeks to unite with the *patiens* (*agens intendit suum patiens sibi unire*). The south pole of a magnet thus attracts the north pole – but also vice versa (*meridionalis septemtrionalem attrahit et e converso*). On the one hand, the idea is unidirectional, in that one magnet is stronger than the other. However, this asymmetric causal relationship is opposed to polar symmetry: The two poles themselves have equal causal valence, i.e. both the north and south poles play an active role in the stronger stone. Peregrinus does not investigate the abstract relationship between magnet and iron, but speaks several times of the magnet "attracting" the iron (*attrahit*). Although Peregrinus thus retains the concept of attraction, the goal of attraction is determined by the concept of "unification".[45]

### *4. Early Modern Debates*

Several early modern authors were well-versed in Averroes's commentary, and frequently engaged with his causal theory.[46] Some even noticed that Averroes had followed Alexander's teaching.[47] Yet, Averroes's account was not merely accepted uncritically.[48] In his commentary on Galen, Fabius

[44] See Georgescu (2013) p. 88; Petrus Peregrinus (1995) pp. 74-8.
[45] See Sander (2020) chap. 8.1.3.2.5.1.
[46] Cf. Alvarus Thomas (2016) pp. 272-6; Graiff and Pomponazzi (1979) pp. 116-20. See also – deviating from Graiff's edition – another version of Pietro Pomonazzi's *Commentarii in Aristotelis octo physicorum libros* in the manuscript in Paris, Bibliothèque nationale de France, Lat. 6533, fols. 311*r*-314*r*. See also Nifo and Aristotle (1552) p. 240*v*: "Teneo igitur primam positionem quod motus ferri ad magnetem per se est alteratio quaedam intentionalis, quae non perficitur, nisi veniat ferrum ad magnetem, sed quoniam accidens ipsum distaret ab magnete, ideo per accidens movetur in loco."
[47] Bodin (1605) p. 244; Dandino and Aristotle (1610) p. 439; Pico della Mirandola (1520) p. 199*r*, (1573) p. 1247.
[48] See also Sander (2020) p. 188 n. 103.

Pacius (1597) inquires as to the cause of the movement of the iron.[49] The form of the iron is already predetermined to move the iron downwards according to the movement of the elements of gravity, rendering it incapable of exhibiting motion in an additional direction.[50] In addition, the iron would then have to be moved from a large distance in the direction of the magnet, which is not the case. Gerolamo Dandino (1610) explicitly concluded that, according to Averroes's theory, there is little evidence to support the concept of 'real' attraction at all.[51]

However, the claim that the magnet exerts an active attraction on the iron persisted, as evidenced by Pacius's case. This position remained attractive even beyond the context of Galen commentaries. Marsilio Ficino (1489) and those who espoused his views asserted that the magnet plays an active role in the process of attraction, given that it is ranked astrologically higher than iron.[52] In 1546, Georg Agricola dismissed Albert the Great's account of a magnet that was attracted *by* iron as so implausible that he chose to refrain from further comment on this and other purported properties of "fabulous stones."[53] For Agricola it was implicitly evident that the magnet attracts the iron and not vice versa.[54] Fortunio Affaitati (1549) addressed the question of why the magnet attracts iron, but not vice versa, in the context of Galen's account. The latter option was regarded as counterfactual.[55]

Andreas Libavius (1601) explained in the context of his alchemical, material theory that the magnet is the active part of attraction (*agens semper est magneticum, patiens vero ferreum*), and therefore attracts iron or another

[49] Pacius and Galen (1597) p. 170. On Pacius's own theory, see Sander (2020) chap. 8.1.3.2.6.
[50] This objection was already made in the Middle Ages by Ockham and others. Cf. Weill-Parot (2012) p. 99. See also Sander (2020) chap. 8.2.2.
[51] See Dandino and Aristotle (1610) p. 439: "Ex his omnibus facile intelligas, motum hunc minime attractionem appellandum esse, si accurate loqui velimus." See also Sander (2020) p. 188 n. 101.
[52] See Sander (2020) chap. 5.1.3.1.
[53] See Agricola (1546) p. 252: "quoniam vero nihil dicturus sum de lapidibus fabulosis, hic reliquo lapidem, quem a ferro trahi dicunt." See also Entzelt (1551) p. 176.
[54] Whether Agricola was familiar with Averroes's account remains unclear. On his scholastic sources,see Nobis and Fritscher (2002).
[55] See Affaitati (1549) pp. 23*r-v*.

magnet by emitting its *spiritus*.[56] The magnet would only move towards the iron by chance, namely if the iron were fixed. Daniel Sennert, Tommaso Campanella, Benedetto Ceruti, Andrea Chiocco and the Paracelsian Johann Agricola also took up this idea. Sennert (1624), who was acquainted with Libavius's theory, concludes that the cause of the attraction must be the magnet itself, rather than the iron (*caussam attractionis potius esse in magnete, quam in ferro*), given that the *spirtus* is able to escape from the unstable magnet but not from the solid iron.[57] Campanella (1635) also argues similarly that the 'spirituous' magnet draws iron and not vice versa (*Magnes enim spirituosus trahit ferrum, et non e contra*).[58] Active attraction here means emitting something that causes the attraction.

[56] Cf. Libavius (1601) p. 103: "Nos dicimus ad trahendum non sufficere cognationem spiritus ferri in magnete, cum eo qui est in ferro, sed in magnete esse spiritum magneticum bituminosum, cum spiritu tamen ferri commistum contemperatumque, ut ita magnes trahat vi bituminea certa ratione disposita, et affectat ergo ferri spiritum. Trahat vero teneatque etiam magnetem, quia huius spiritus cum ferreo societatem habet. Itaque agens semper est magneticum, patiens vero ferreum, quanquam ex accidente eveniat, ut immoto ferro magnes ad hoc transeat." See also *ibid*., p. 91: "ferrum, inquam, is trahit, et ferrum quoque; sequitur trahentem, non pro pondere in primis, sed pro virtutibus maxime nisi nimis id sit vastum fixumque cum deprehensum sit leviore Magnetem ponderosius adduxisse ferrum. Evenit autem etiam, ut ipse seipsum ad ferrum promoveat, si id pertinacius restiterit. Neque tamen ex omni parte trahit excellenter, sed maxime iuxta fluxum virtutis secundum lineam rectam." See, however, *ibid*., p. 97: "Ita solide probavimus sententiam nostram nimirum attractivam istam esse principaliter bituminis conspirantis cum principiis et elementis minerae ferrae, et ob hanc substantiam similem fieri mutuum amorem et allicientem simile quantum fieri potest". On Libavius's theory, see Sander (2020) chap. 2.2.2 and 8.1.3.2.8.2.

[57] Cf. Sennert (1633) p. 434: "Ex quo alterum sequitur, causam attractionis potius esse in magnete, quam ferro. Ferrum enim iam fixum metallum est: Magnes vero nondum fixus est, ideoque vires suas et spiritus liberius emittere potest." See also Sander (2020) chap. 8.1.3.2.8.3.

[58] See Campanella (1635) p. 323. Campanella is not quite consistent in his position within his works, see also Sander (2020) pp. 617-8 n. 150. The same natural philosophical ideas are taken over by later authors. Cf. Ceruti and Chiocco (1622) p. 65: "Magnetem vim ferri attrahendi habere, propter cognationem quamdam, quae sit ei cum ferro." See also Sander (2020) chap. 8.1.3.2.8.2. See Agricola (1646) p. 199: "dieses ist die Ursach/ deß der Spiritus Magnetis et Martis eines ist/ und daß der Magnet das Eysen an sich ziehet/ und das Eysen nicht den Magnet/ ist die Ursach/ daß der Spiritus in dem Marte so hart verschlossen/ daß er seine Kräffte nicht erweisen kan/ hingegen ist der Magnet porosisch/ und gehet gerne auß ihm in seine Wirckung."

Authors such as Anselmus de Boodt (1609) and Ole Worm (1655), on the other hand, attributed the attraction to the magnet for the reason that it retained its forces when placed in iron filings.[59] Here, a seemingly empirical observation thus serves as an argument for the direction of the causal relationship. However, the same observation had been employed by Gerolamo Cardano in *De subtilitate* (1550) for a contrary causal representation of the magnetic phenomenon. Cardano's vitalist theory is not entirely clear in the relevant respect here, but he writes that the magnet desires iron as its food and is moved towards it (Mode V).[60] In his *De uno* (1561), Cardano revisits this topic and presents a comprehensive schematic of all potential causal relationships between the magnet and iron, categorizing them as either attractive or repulsive: magnet draws/repels iron, iron draws/repels magnet, magnet draws/repels another magnet, iron draws/repels iron.[61]

[59] See Boodt (1636) p. 442: "Ita ut non tam Magnes ferrum, quam ferrum Magnetem trahere videatur [...]. Verum verisimilius est Magnetem ferrum trahere, quam ferrum Magnetem, quia sepultus in scobe ferri Magnes vires suas conservat." Cf. Worm (1655) p. 62: "Unde dubitatum a multis, an Magnes ferrum, an vero ferrum Magnetem traheret. Probabilius certe Magnetem ferrum trahere, quia sepultus in scobe ferri Magnes vires suas conservat et auget: ferrum vero rubiginem contrahit et perit, quod sit quia puriorem et subtiliorem ferri partem ad se trahit, sibique unit."

[60] See Sander (2021). See Cardano (1560) p. 494: "Hoc ideo contingit, quoniam ferrum magnes ut pabulum desiderat; qui cum illud ad se trahere nequeat, ad ipsum mutata vice fertur." Cardano, however, ruled out that the magnet would align itself with the poles, since it was too heavy to do so. Therefore the iron needle is needed, since it can be turned more easily. See *ibid.*: "Cum vero ob gravitatem nequeat seipsum movere, ferro affricatum movet illud in aequilibrio positum ob facilitatem; et etiam quoniam principium est quoddam naturale, nihil seipsum movere. Ergo cum duae sint partes, ferrum quod a boreali tangitur, cuspidem illam ad boream dirigit; quod si australem contingat, ad austrum etiam impellitur, non ad boream." Isaac Beeckman also seems to assume that the magnet moves towards the iron, cf. Sander (2020) chap. 8.1.3.2.8.3.

[61] Cf. Cardano (1663) vol. I, 283.

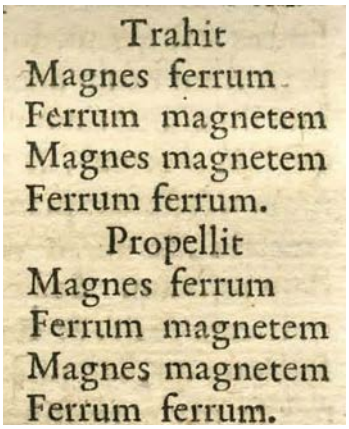


*Figure 1*: Syntax of magnetic attraction and repulsion according to Cardano (1663) vol. I, p. 283. Source: Torino, Biblioteca provinciale dei Frati Minori Cappuccini, MD.55.122 (online).

Cardano places magnetic attraction and repulsion in analogy to sexuality. The male entity (magnet) assumes the active role, while the female entity (iron) assumes the passive role.[62] In his pairs of recombination Cardano only denies the existence of two causal relationships: Iron does not attract iron, and iron does not repel the magnet. The case of the iron attracting the magnet, he again explains in such a way that if the man cannot attract the woman, he approaches her by his movement towards her (*cum enim masculus non potest trahere foeminam ad se, ut etiam in animalibus, accedit ad illam*). It is probably this particular understanding of attraction that Cardano had adopted as prototypical in 1550.

Cardano's idea from *De subtilitate*, that the magnet is moved towards iron like an animal to its food, reversed Averroes's and Alexander's analogy.[63] Although his theory of magnetic food had some alchemical followers, most of them made no comments on the assumed causal representation of this idea. Authors such as Robert Norman (1581) and Tommaso Campanella (1590) explicitly promoted the active movement of the magnet towards

[62] Cf. also Sander (2020) chap. 8.1.3.2.4.4.

[63] Averroes had explained that the food was moved *ex se* to the body part. Although Alexander had compared the movement of the animal to its food with the magnetic phenomenon, in his analogy he attributed the role of the animal to iron.

iron, together with its vitalistic implications.[64] However, Norman limits this movement to occur only if the magnet is good and the iron is heavier than the magnet, stating that "the Weight of the Stone exceed not his Attractive Strength."[65]

The idea of an actively (self-)moving magnet was also met with bitter criticism. The primary criticism levied against this theory was its vitalist implications, but the implied causal representation was rejected as well.[66] The most significant critique was provided by Julius Caesar Scaliger (1557).[67] He elucidated that the iron moves to the magnet for its own perfection, like being conveyed to its maternal source or descending towards the center of the Earth (*Sed movebitur ferrum potius ad Magnetem, tanquam ad matricem suam, cuius abditis principiis perficiatur: quemadmodum ad centrum terrae.*) Scaliger's reply is thus characterized by an Aristotelian notion of teleology, which has guided philosophical thought since the accounts of Alexander and Averroes.[68] This movement, however, is generated by an internal force, as there is no direct contact between the magnet and the iron, which is analogous to the way in which an infant attempts to reach the nipple of the breastfeeding mother (*ab interna virtute potius, quam ab externa, a qua non tangitur, moveatur: veluti movetur catulus ad mamillam*).[69]

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[64] See Campanella (1992) p. 546: "sicut fingit Marta [i.e. Giacomo Antonio Marta], et alii Peripatetici et dicunt de ferro tracto a magnete; non enim trahitur, sed sponte vadit ad ferrum, ut alibi narravimus." This theory is also in line with Campanella's vitalist idea. See Sander (2020) chap. 8.1.3.2.4.3. However, see also Campanella (1992) pp. 373, 547: "Concitatur vero motus ex appetitu acquirendi quod est bonum, sicut currit ad magnetem ferrum et animal ad casam vel citum concitat cursum; quandoque concitatur motus, ut cito fugiatur quod molestum est. [...] Sed nec magnes attrahit ferrum, ut putant illi, sed forma ferri vires intendit et crassitiem devincit, ut ad superpositum tendat magnetem, cuius contactum sui conservativum esse persentit." See also White (1642) p. 277.

[65] Vgl. Norman (1585) p. 3. Similarly in Cyrano de Bergerac (1932) p. 229, (2004) p. 295: "le morceau d'aimant est plus gros, il attire le fer; ou si la pièce de fer excède en quantité, c'est elle qui attire l'aimant, comme il arrivoit jadis dans le miraculeux effet des pommes de Pylade et d'Oreste, de l'une desquelles quiconque avoit mangé davantage étoit le plus aimé par celui qui avoit mangé de l'autre."

[66] See also Sander (2020) chap. 8.1.3.2.4.

[67] Cf. Scaliger (1557) fols. 156*v*-157*r*.

[68] Cf. Sander (2020) chap. 8.1.3.2.5.

[69] However, Scaliger noticed later that it had also been observed that a large piece of iron could attract a small magnet. This, too, he directed, somewhat inconsistently, against Cardanos self-moving magnet, but did not explain whether an internal fortune in the magnet

Although the Jesuit author of a groundbreaking study on magnetism, Leonardo Garzoni (c. 1580), developed an original and independent theory of magnetic attraction and repulsion, he remained committed to Aristotle's natural philosophy at the same time. He assumed the internal cause of the movements of a magnet or iron in its substantial form.[70] While he considered the rotation to the poles as a completely independent, intrinsic movement, the attraction and repulsion of the magnet he believed to be caused by an alteration of the form of the iron from without. As a consequence of this change, the iron moves towards the magnet by its form or quality.[71] Garzoni, however, renames attraction and repulsion to *sequela* and *fuga* because of this internal or intrinsic motion, which was taken up by Niccolò Cabeo (1629).[72]

Another Aristotelian, Fortunio Liceti**,** devoted considerable attention to Scaliger's criticism of Cardano. In 1618, he articulated his perspective in *De spontaneo vivantium ortu*: "It seems far more probable to me that the iron is attracted by the magnet only in the metaphorical sense, but hurries to the

must then be assumed here. Cf. Scaliger (1557) fol. 176*r*. See also *ibid.*, fol. 185*v*: "Nanque etiam Magnes a ferro trahitur." See also Libavius (1601) p. 98, who cited this as his primary counterargument against Cardano.

[70] See also Garzoni (2005) p. 126: "il moto di questa pietra nasca da interno principio, il quale sia forma sostantiale, media, nel grado di essere, tra le forme de gl'elementi et l'anima, che muovendo il suo mobile verso dui termini opposti, non si conveniva a corpo semplice."

[71] See also Ugaglia (2006) p. 65, on this theory.

[72] Cf. Cabeo (1629) p. 168. Cabeo seems to follow Gilbert's expression and the associated notion of reciprocal attraction, see *ibid.*, p. 198. See Sander (2020) p. 620 n. 168. Ugaglia in Garzoni (2005) p. 236 n. 209, refers to Sarpi's expressions *subitio* and *discessio* in Sarpi (1996) p. 147. Sarpi also states: "onde il moto del ferro alla calamita, senza esser toccato, sarà più tosto approssimazion che attrazione." However, Garzoni probably did not know Scaliger's work, and he rejected Cardano's theses, but not because of his causality-theoretical assumption of a magnet moved to iron. In the Aristotelian oriented *Disputationes metaphysicae* (1597) the Jesuit Francisco Suárez essentially adopts Averroes' position, but understands explicitly that the attraction is actually caused by the magnet. Suárez (1866) p. 664: "Breviter tamen, quantum ad rem praesentem spectat, admittimus attractionem illam fieri effective a magnete. [...] Addendum subinde est magnetem imprimere ferro aliquam qualitatem motivam qua illud ad se trahat." Moreover, he sharply differentiates this position from Alexander's opinion, which had already been refuted by Thomas Aquinas, Albertus Magnus and Galen. *Ibid.*: "Alexand. enim, lib. II Quaestionum naturalium, c. 3, existimavit ferrum non trahi a magnete nisi ut a fine, ipsumque interna et innata virtute quasi naturali pondere se movere ad magnetem. Hoc tamen reiiciunt Albertus, II Metaph., tract. III, c. 6; D. Thomas, VII Phys., lect. 3, text. 10; et Galenus, lib. III de Facultatibus naturalibus, c. ultimo." On Galen's criticism of Alexander, see also Pines (1961).

magnet in the physical sense."[73] However, since the magnet is inanimate, it is not moved internally but externally. This is not analogous to an infant seeking the comfort of its mother's breast, but rather to a heavy body seeking the center of the earth.[74] It seems that Liceti was aware of the scholastic distinction between animate and inanimate self-movement, being equivalent to the distinction between external and internal movement.[75]

In his 1640 treatise, *Litheosphorus*, Liceti revisited this concept and once more asserted that the iron did not reach the magnet as a girl hurried to the flower.[76] Liceti also makes reference to Aristotelian teleology as a means of justifying his argument and provides an explanation as to why the iron is more inclined to move towards a magnet that has been reinforced (as an 'armed' or iron capped magnet) than towards one that is pure. In his later works and letters, Liceti reverted to his original causal, eventually quite classical conception, which he distinguished from Scaliger's.[77]

In contrast, Daniel Sennert (1633) disregarded Scaliger's critique, reasoning that the phenomenon would be indistinguishable whether the magnet attracts the iron or vice versa.[78] He postulated that the underlying cause

[73] See Liceti (1618) p. 115: "mihi tamen longe probabilius est a magnete ferrum [...] attrahi metaphorice, [...] physice vero ferrum sponte sua currere ad magnetem."
[74] See *ibid.*, p. 116: "Quum ergo ferrum inanime sit, iam id accurrit ad magnetem, non ab interno, sed ab externo motum principio; non quidem ut catulus ad mammam, aut anima ad beatitudinem, sed ut grave ad centrum, ac leve sursum." See also *ibid.*, pp. 270-1.
[75] Burley, on the other hand, insisted on an internal cause of the movement, since the moving quality resides in the iron. Cf. Weill-Parot (2012) p. 103. See also Graiff and Pomponazzi (1979) p. 116: "Averrois enim, ut vidistis, dicit quod motus ferri ad magnetem non est ab extrinseco, sed ab intrinseco et non est vera attractio."
[76] Cf. Liceti (1640) pp. 184-7: "ferrum, quod movetur ad magnetem esse corpus; negamus primo, ferrum vere ac proprie seu physice a magnete trahi; sed ferrum potius ad magnetem accurrit, ut ab eo perficitur [...] Ut ergo puella sponte movetur accurrens ad florem, a flore non attracta et non mota nisi metaphorice [...], tamquam a fine [...] sic ferrum sponte movetur ad magnetem, non attrahitur a magnete, nisi metaphorice, velut a fine quo perficitur. Nec obstat, quod magnes videatur ferro perfici, nam armatus habet maiorem vim attrahendi ferrum [...] Ferrum igitur accurrit magis ad magnetem armatum ferro, quam ad inermem; quia simul et ad magnetem perficientem, et ad ferrum sibi simile fertur. [...] ferrum sponte sua ab interna seu virtute, seu propensione moveri potest, ad magnetem a quo perficitur."
[77] See Liceti (1645) p. 29, (1646a) p. 299, (1646b) p. 223.
[78] Cf. Sennert (1633) p. 433: "Nam hic iam non disputo id, quod Scaliger, Exercit 102. s. 6. habet, An magnes trahat ferrum, an ferrum magnetem. Sive enim hoc, sive illud verum sit, una tamen caussa est."

must be identical in both scenarios. Others, such as Petrus Magirus (1639), openly criticized Scaliger's arguments. Magirus, in fact, advanced the claim that iron is the more perfect metal, reversing the teleological logic while simultaneously invoking the alchemical concept of attraction by some *spritus.* Consequently, he asserted that the magnet is deficient, and "therefore the iron draws the magnet and not the magnet the iron" (*Quapropter ferrum trahit magnetem, et non magnes ferrum*).[79] The notion that iron attracts the magnet (Mode II) had already been put forth by Scaliger himself, albeit without any substantial theoretical backing, as an empirical observation. However, Magirus, despite being a vocal critic of Scaliger, offers a natural philosophical (*ad hoc*) justification for this proposition.

The aforementioned schemes all assume a unidirectional, causally asymmetrical representation, whereby a distinction can be made between an *agens* and a *patiens* or a *motum* and a *finis*. In 1652, when Alexander Ross engaged in combat with his adversary Thomas Browne, a reciprocal concept of magnetic causality had already gained significant traction among numerous authors, including Browne:

> [...] when [Browne] saith, "There is coition, syndrome, and concourse of the Load-stone and Iron to each other"; For I doe not think that the stone is moved at all to the Iron, for every naturall motion hath its reason and end; the end of attraction in animals and vegitables is for aliment; the motion of stones and other heavy bodies downward, is to enjoy their Matrix, or Center: but no end can be assigned why the Loadstone should draw or move towards the Iron: the motion therefore is in the Iron, and other metals, which are moved to the Loadstone, as to their Matrix, saith Scaliger; therefore it is no more wonder for Iron to move to the Loadstone, then to move downwards, the end and efficient cause being the same in both motions, to wit, the enjoyment of their proper place or matrix.[80]

Ross, to some extent, is reactionary in his rebuke of the opinions expressed by not only Browne but also René Descartes, Johann Baptist van Helmont, Mark Ridley, Fortunio Liceti, and William Gilbert. He aligns himself with Scaliger and his teleological idea in this critique.[81] Browne, the more

[79] Cf. Magirus (1639) p. 157. See also Sander (2020) chap. 2.1.2.4.
[80] Ross (1652) p. 191.
[81] Browne (1646) p. 66, (1650) p. 51: "And first not only a simple Heterodox, but a very hard Paradox, it will seem, and of great absurdity unto obstinate ears, if we say, attraction is unjustly appropriated unto the Loadstone, and that perhaps we speak not properly, when

progressive of the two, correctly identified an important linguistic insight: "perhaps we speak not properly, when we say vulgarly and appropriately the Loadstone draweth Iron." The underlying concept of "coition of the Loadstone and Iron to each other," which may be considered groundbreaking, rejects the traditional search for an active and passive component and abandons the concept of 'attraction' to some degree. This perspective was prominently articulated by William Gilbert in his 1600 treatise, *De magnete*. In this context, he elucidated that the conjunction of two magnetic bodies manifests a *coitio*, which precludes the possibility of 'attraction' in the manner observed with amber and light bodies.[82] In the taxonomic classification of 'magnetic bodies' established by Gilbert, no qualitative distinction is made between minerals such as magnet and iron. This lack of differentiation also raised questions about the logical coherence of ascribing different causal roles to these minerals.[83] In Gilbert's model, magnetic bodies, regardless of composition (e.g., iron, steel, or magnet), move towards each other from their own magnetic form (Mode IV). According to Gilbert, causality here is not reciprocal. Instead, the two bodies are drawn together by a kind of self-movement, rather than by a mutual attraction.[84]

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we say vulgarly and appropriately the Loadstone draweth Iron; and yet herein we should not want experiment and great Authority. The words of *Renatus des Cartes* in his Principles of Philosophy are very plain: *Praeterea magnes trahet ferrum, sive potius magnes et ferrum ad invicem accedunt, neque enim ulla ibi tractio est*. The same is solemnly determined by Cabeus [1650: *Cabius*]. *Nec magnes trahit proprie ferrum, nec ferrum ad se magnetum provocat, sed ambo pari conatu ad invicem confluunt*. Concordant hereto is the assertion of Doctor Ridley, Physitian unto the Emperour of Russia, in his Tract of Magnetical Bodies, defining Magnetical attraction to be a natural incitation and disposition conforming unto contiguity, an union of one Magnetical Body with another, and no violent haling of the weak unto the stronger. And this is also the Doctrine of Gilbertus, by whom this motion is termed Coition, and that not made by any faculty attractive of one, but a Syndrome and concourse of each; a Coition alway of their vigours, and also of their bodies, if bulk or impediment prevent not. And therefore those contrary actions which flow from opposite Poles or Faces, are not so properly expulsion and attraction, as Sequela and Fuga, a mutual flight and following. [1650: *Consonant whereto are also the determinations of Helmontius, Kircherus, and Licetus.*]"

[82] See Gilbert (1600) pp. 46-60, 130-1; Sander (2020) chap. 2.3.2.1. On this, see also Georgescu (2017); King (1959); Roller (1959) pp. 141-4; Wang (2016) p. 712.

[83] Cf. Sander (2020) chap. 8.1.3.2.5.1.

[84] For more details, see *ibid*., chap. 8.1.3.2.4.1 and 8.1.3.2.7.2. See also Gilbert (1600) p. 68.

Upon evaluation of the positions of Ross's name dropping, it can be stated that Mark Ridley and Gilbert followed this idea closely.[85] Liceti, however, had not opted for this idea. In contrast, Van Helmont does not discuss a mutual approach or *coitio* but rather a mutual pull.[86] In this instance, the causality is therefore reciprocal, given that both attract each other respectively (Mode III). This concept was subsequently embraced by alchemical theories, as evidenced by the works of Robert Fludd (1636) and Pierre Jean Fabre (1646). These theorists postulated that both the magnet and iron exhibit a mutual attraction through an exchange of a *spiritus*.[87] In this case, a mutual, active attraction is postulated.

[85] See Ridley (1613) p. 80.

[86] See Helmont (1652) p. 856: "An videlicet Magnes ferrum trahat, an vero ferrum trahat ipsum Magnetem? Nescientes utrimque esse reciprocum tractum."

[87] Cf. about Fludd (1638) fol. 126*v*: "Sed, quoniam ferreum corpus non tam cito relinquet Spiritum suum internum, ideo sequitur, simul cum suo Spiritu attrahi ad Magnetem: (experientia enim docemur, quod magnes a ferri Spiritibus nutriatur et in suo vigore augeatur) atque iterum, ipsum ferrum Spiritus sibi similes in Magnete reperiens, appetit pariter aequali coitione, ut ipsorum fieret particeps atque in coniunctio sive unio haud aliter inter eos facta, quam inter marem et foeminam." Cf. also Fabre (1646) vol. II, p. 242: "hinc magnes trahit ferrum, et ferrum magnetem, quod habeant invicem eandem et similem substantiam primordialem et seminalem, ex qua fiunt et componuntur in visceribus terrae, quae substantia similis, et eadem similis et eosdem de se mittit et eiicit spiritus subtiles et tenues, qui ab attrahente substantia, in se ipsam convertuntur, tanquam in alimentum sui ipsius, hinc fit ut attractis hisce spiritibus, attrahatur et ipsa substantia, ex qua oriuntur hi spiritus, ut fonte potiatur ipsorum spirituum." Cf. also Sander (2020) chap. 2.1.2.3.1 for these theories. See also Cyrano de Bergerac (1932) p. 229, (2004) p. 295: "Or le fer se nourrit d'aimant, et l'aimant se nourrit de fer si visiblement, que celui-là s'enrouille et celui-ci perd sa force, à moins qu'on les produise l'un à l'autre pour réparer ce qui se perd de leur substance." Fludd, however, is not consistent in his causal description and in other parts of his work formulates a transitive, unidirectional theory of attraction. See also Fludd (1638) fol. 111*r*: "Accidit ob hanc causa[m], spiritum internum Martialem in Magnete attrahere ferrum ad se, et occulto quodammodo videri nutrimentum ex eo ad se fugere et allicere." Thus Fludd, *ibid*., fol. 116*r* refers to a "mutual love", based on a sexual analogy of attraction, but then claims that the female stone attracts the male iron, and thus positions himself explicitly against Averroes, Scaliger and Nicholas of Cusa, who assume that the iron approaches the magnet as its mother. Cusanus actually calls the magnet the "mother" of iron, according to the language of the alchemists. See Sander (2020) p. 58 n. 78. Scaliger had also used a similar analogy (*mammilla).* See *ibid*., p. 618 n. 155. On Fludd's theory, see also *ibid*., chap. 5.1.3.4.2 and 8.1.3.2.4.4.

René Descartes's magnetism account of his *Principia philosophiae* (1644) is presented in yet a different manner.[88] He emphasizes that iron and magnet do not really attract each other, but approach each other. Neither the alchemical concept of mutual attraction nor the notion of an intrinsic movement of both *relata* make such a claim.[89] For Descartes, the air between the magnet and the iron is displaced by outflowing particles, resulting in the successive closing of the gap as the magnet and the iron are 'budging up'. This corpuscularian explanation has a long history, dating back to antiquity, promoted by Plato, Plutarch, and Lucretius.[90] Alexander of Aphrodisias had critiqued the theory of the pre-Socratic Empedocles, arguing that it had the allegedly counterfactual consequence of positing that magnet and iron move towards each other.[91] For Alexander and the majority of his successors, the immovable role of the magnet was an indisputable fact that every theory had to take into account. Even atomistic theories, such as those proposed by Democritus (according to Alexander's testimony) or Epicurus (according to Galen's report), implied a mechanical attraction of iron to a stationary magnet caused by atoms rather than a mutual approximation.[92]

Robert Fludd (1638) characterized Lucretius's ancient stance as a form of *coitio* and identified Giovanni Costeo (1589), among other proponents, as an adherent of this view.[93] Indeed, Costeo referenced this concept in his

[88] See Descartes (1964-1974) vol. VIII, p. 302: "Praeterea magnes trahit ferrum, sive potius magnes et ferrum ad invicem accedunt; neque enim ulla ibi tractio est, sed statim atque ferrum est intra sphaeram activitatis magnetis". See also Sander (2020) chap. 8.1.3.2.8.3.2.2, (2022), (2024).

[89] Descartes admits, however, that the iron moves more easily than the magnet.

[90] Cf. Radl (1988) p. 189. See also Sander (2020) chap. 8.1.3.2.8.1.

[91] Cf. Radl (1988) p. 79.

[92] Alexander emphasizes, for example, that Democritus's doctrine states that he had provided an explanation as to why the magnet was not conveyed to iron, but remained unmoved.

[93] Cf. Fludd (1638) fol. 97*v*: "Lucretius Carus, quidam sectae Epicureicae Poeta, videtur somniare, ferri attractionem procedere ab atomorum ex subiecto effluxione: Nam, quemadmodum (inquit ille) iuxta Epicureorum opinionem, atomi subtiles ex re qualibet emanant, ita pariter atomi, quasi semina Magnetica a ferro per quandam coitionem ipsius cum Magnete in locum sive spatium interpositum, quod est inter eos, emittuntur, et per unionem aut complicationem corporis utriusque, ferrum attrahitur etc." In what follows, however, he criticizes the idea of an eccentric, spherical propagation of particles or atoms. Although Fludd relies on Gilbert (1600) p. 3, who also mentions Costeo, he avoids the word *coitio* and does not criticize it here either.

corpuscular theory, which he expanded upon in his Avicenna commentary. He stated that the attraction was "common work and fruit of both magnet and iron" (*mutua ergo utrique est opera et mutuus fructus*), a notable shift from his earlier work (1578), where he still advocated for Averroes's model.[94] Pierre Gassendi also offered a critique of the unidirectional causal representation, advocating instead for a reciprocal model that would align with his corpuscular natural philosophy.[95] In a critical letter dated 1642, Pierre de Cazré lectured Gassendi, relating to the latter's corpuscularian theory, that magnet and iron spontaneously move towards each other (*utrimque sponte naturae incitata in mutuos amplexus accurrunt*).[96] Cazré's argument aligns with Gilbert's, abandoning the concept of attraction. Gassendi however raises the objection that it is then impossible to explain why the magnet is only able to exert its attraction within a relatively limited sphere of influence.[97]

Other opponents of the corpuscular idea argued that these theories simply and unjustly denied a fundamental mode of action – that of attraction. They asserted that the entire removal of this principle renders the theory inconsistent with reality, as it implies that everything is merely a matter of pushing and shoving. Such allegations were leveled by Martin Schoock against Descartes and by Jacques Primerose against Henricus Regius, a disciple and later colleague of Descartes.[98] Schoock explicitly refers to the Aristotelian theory of motion and subsumes magnetic attraction

[94] Cf. Costeo (1578) p. 268; Costeo and Avicenna (1589) p. 515. See also Sander (2020) chap. 8.1.3.2.8.2.

[95] See Gassendi (1658) vol. II, pp. 5, 123, 126, 133; see also Hobbes (1839) vol. I, pp. 427-8: "Supposito ergo corpuscula minima, ex quibus in ipsis terrae visceribus concrevit magnes, motum sive conatum a natura sua, per lineam prae brevitate invisibilem, habere, ut modo dictum est de gagate, reciprocum, una erit in utroque lapide attractionis causa. [...] Siquidem enim in magnete motus reciprocus sive itus reditusque partium supponatur."

[96] See Gassendi (1658) vol. VI, p. 450. On this controversy, see Sander (2020) chap. 8.2.2.

[97] Cf. Gassendi (1658) vol. III, p. 633. Cf. also Sander (2020) chap. 8.1.2.2.3.1.

[98] Cf. Schoock (1643) pp. 229-31: "Sin vero nex de illis studiosus credere debeat agere per attractionem, quod nihil per attractionem agere soleat, liquido ostendatur attractionem entium classe movendam esse [...] Democriti atomi magneticis profluviis seminibusque turgeant [...] definire placuerit quid aut corpus magneticum sit, aut quid magnetici in quoque corpore inveniatur, et ad qualium entium classem hoc referri debeat." See also Schoock (1660) pp. 228, 246, 249. See the *Antidotum adversus Henri Regii* in Maire (1647) pp. 9-10. See also Sander (2020) chap. 8.1.3.2.8.3.2.1.2.

under the concept of traction. Despite the existence of a 'sympathy' between the magnet and the iron, the attraction between them is nevertheless 'violent.' Primerose, on the other hand, aligns with the theories put forth by Galen and Averroes. He asserts that Averroes espoused a variety of forms of attraction and that the iron's movement towards the magnet constitutes one form of attraction.[99]

The concept of mutual magnetic movement, or attraction, had already emerged in the sixteenth century, before Gilbert and corpuscular philosophy.[100] Cardano conceded that iron was attracted by a magnet, but he already observed that the attraction was mutual.[101] In 1589, Giambattista della Porta also discussed the "mutual attraction and repulsion between magnet and iron" (*De mutua magnetis et ferri attractione et expulsione*) in his *Magia naturalis*.[102] Although della Porta incorporated significant portions of Garzoni's unpublished manuscripts, he depicted the causal relationship between the magnet and iron in a markedly different manner and did not cite Aristotelian principles of natural philosophy. Instead, he interpreted the phenomenon of "mutual love" (*mutuus amor*) as an exemplification of 'sympathy.'[103]

## *5. Conclusion*

The numerous and highly different premodern magnetic 'attraction' theories imply or are based on different causal representations of the phenomenon to be explained. While causal theories were *prima facie* meant to 'simply' explain the phenomenon, they actually explained a specific causal representation of the phenomenon under scrutiny. The actual event (or, its perception) – magnet and/or iron move – is mapped to some more abstract,

[99] Primerose misunderstood Averroes because he explicitly distinguishes metaphorical attraction (*finis trahit ad sese*) from magnetic attraction, although these were identified with each other in Averroes.
[100] According to Goddu (1985), the idea of a 'mutual attraction' can already be found in Avicenna and Copernicus, but not with reference to magnetic attraction.
[101] Cf. Cardano (1560) p. 504: "Ob id igitur ferrum a magnete trahitur ac rapitur; mutuo tamen, ut dixi, feruntur alterum ad alterum." What Cardano exactly means by this seems rather unclear.
[102] See Porta (1589) p. 137.
[103] Cf. Sander (2020) chap. 7.1.2 and 8.1.3.2.2.

theory-laden description of what is to be explained. To put it in an overly exaggerated way, no philosopher ever engaged in explaining magnetic attraction as a phenomenon but in explaining a causal representation of this phenomenon. Any causal representation's profile can be specified by two overlapping questions: (1) Is there an attraction between magnet and iron or is one moving towards the other? (2) Do magnet and iron have an actively attracting or passively moving role, or are both equally active and passive? These questions give rise to the six modes of recombining reasonable answers to the two questions. They represent the 'same phenomenon' in six different modes. Each of these modes was argued for in premodern accounts as matter of fact. The many-to-many relations between modes and explanations, i.e. that one mode could lead to many explanations and vice versa, underscores the underdetermination of the theory (explanation) not only by data, but also by more fundamental representations of data (i.e. modes). In a sense, underdetermination of the explanation by data actually depends on the underdetermination of the causal modes by their data.

The favorite option during the Middle Ages was to assume that the iron would move towards the magnet. This mode can rightly be called the 'Aristotelian mode', although Aristotle himself never claimed it. Attraction, properly speaking, did not feature in this causal representation. Instead, its basis was a teleological assumption about the causal relationship. Final causes, or, more generally, purposes and aims in nature, were taken as granted in an ordered cosmos. However, especially in medical authors – following Galen –, the view prevailed that the magnet exerts an active attraction on the iron in analogy to bodily organs. This view was also taken up by numerous alchemical authors, albeit supported by completely different explanations. Only very few thinkers claimed that iron actively attracts the magnet, which underscores a so-believed hierarchical order in the mineral world. On the other hand, many authors referred to Cardano claiming that the magnet moves actively towards the iron driven by vitalistic principles, which implicitly imported final causes or at least desires in substances without minds. Authors of the seventeenth century revived a position occasionally implicit in some ancient atomists, namely that magnet and iron attract each other reciprocally or unite. Gilbert in particular promoted this model strongly by

way of a vitalist assumption, which eventually also was implemented and transformed into corpuscular, mechanistic theories. While the vitalist version again relied on teleological thinking to some degree, thinkers such as Descartes openly rejected final causes in (material) nature as Aristotelian chimeras. As for magnetic attraction, they were dispensable through deterministic and mechanistic accounts of causality. Yet, the causal mode is agnostic to whether iron and magnet move to each other for some vitalist desire or for some vortex of particles. This not only enabled the success of Gilbert's causal model independently of his rather crude explanation but also moves the historiographic focus away from the traditional perspective: the controversy about the causal representation was not about whether there are final causes or just chunks of matter but about how to map the empirical to a foundational, pre-explanatory model.

And yet, or specifically for the foundational status of these models, authors rarely based their respective models on empirical observations, and when they did, their evidential character resulted in theory-laden conclusions from the observed. If, for example, the *agens* role of the magnet in the attraction was concluded from the fact that it preserves its force in iron filings, the premise is that this conservation presupposes a force in the magnet, which thus actively included the capacity of attraction. Some also took the physical size of magnet or iron into account for causal relationality, for example when they claimed that only a particularly large piece of iron was able to attract the magnet. But the authors partly explained this themselves by the fact that the greater weight only had the effect that this object was inert to move because of its weight. Another interesting observation is that while the described causal modes were crucial to map the phenomenon of magnetic attraction, these modes were rarely involved in another high key issue: explaining geomagnetism and the North-pointing of a compass needle.[104] While Gilbert or Descartes designed homologue accounts of both the earth's magnetism and magnetic attraction, the very phenomena of geomagnetism were unknown to antiquity, and not much addressed by medieval natural philosophers. Its causal relation to magnetic attraction remained rather vague for many authors before 1600. Whether authors

[104] See Sander (2020) chap. 6.2.2.

regarded it as a mere corollary to their accounts of attraction, or just begged the question, is difficult to say.

It was natural-philosophical or metaphysical assumptions about the nature of 'attraction' that determined the actors' side-taking in this debate. The most important natural philosophical assumption was that every movement had to be caused by something else. This Aristotelian principle was often explicitly mentioned in the debates, or the magnetic phenomena were explicitly discussed as a challenge for that principle – not only by supporters of Aristotelian natural philosophy, but also by Neoplatonists or adherents of corpuscular philosophy.[105] In this lies a strong legacy of Aristotelian natural philosophy: it didn't quite define the vocabulary but the syntax, by asking the virulent question instead of giving the definite answer.

Many philosophers explicitly discussed these tacitly Aristotelian questions controversially. The 'true' causal representation of magnetic 'attraction' was thus an important point of contention for the actors. It might be a modern intuition (or insight) that magnetic phenomena do not obey the logic of a unidirectional and asymmetric causal model presupposed by a concept of attraction in the strict sense. However, this account informed by eighteenth-century electromagnetism must not obscure that precisely these unidirectional models of causality dominated much of Aristotelian physics and remained attractive to premodern scholars for a great part. This hidden Aristotelian factor playing out might have even benefited from Aristotle's silence on the matter itself – his 'only preparing' a conceptual framework enabled and coordinated disagreements. It allowed for one controversy with conflicting but commensurable positions.

Mapping these individual positions (specific magnetism theories) to their underpinnings (causal modes) allows for a different, alternative historiographical view. It breaks the narrative of camps, such as 'Aristotelianism vs corpuscularism' etc., by providing a discursive map of intriguingly

[105] Cf. for example Campanella (1638) vol. I, p. 155; Collegium Conimbricense and Aristotle (1592) pp. 670-3; Digby (1645) p. 232; Ficino (1559) p. 120; Hobbes (1839) vol. I, p. 427; Liceti (1618) p. 115; Marcellus and Aristotle (1508) fol. 51*r*; Nifo and Aristotle (1552) fol. 240*r*; Pandolfi (1658) p. 258; Pico della Mirandola (1520) fol. 199*r*; Schoock (1660) p. 249; Suárez (1866) p. 664; Walter Burley and Aristotle (1589) pp. 865-7; Wolfson and Chasdaj Crescas (1929) pp. 90-2.

different demarcation lines and implicit alliances among those camps, which many actors and many historians took (and take) for granted. This is not an argument to replace or revise these 'traditional camps' – which historiography has greatly challenged on various accounts already – but proposes a different take on the history of natural philosophy: One that highlights the immanent multilayered nature of premodern theory making over the rhetorics of controversy.

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