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The Mathematics of Natural Action in Seventeenth-Century Jesuit Scholasticism (Hurtado, Arriaga, Oviedo, Compton)

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This paper discusses the notion of the "sphere of action" (*sphaera activitatis*) as developed by a group of seventeenth-century Jesuit intellectuals: Hurtado, Arriaga, Oviedo, and Compton. The problem inherited from fourteenth-century natural philosophers was to describe natural action which is spatially limited and decreases with distance at a regular rate. To capture natural patterns, scholastic philosophers introduced various forms of regularity or "uniformity," the relevant type for the present context being "uniform difformity." While the scholastic tradition also defined more sophisticated forms of regularity, these were not part of the discussion in the analyzed corpus.

Keywords: Jesuit scholasticism – Oxford Calculators – natural philosophy – natural action – sphere of action – Pedro Hurtado de Mendoza – Rodrigo de Arriaga – Francisco de Oviedo – Thomas Compton Carleton

Introduction

This study focuses on seventeenth-century Jesuit debates on *sphaera activitatis* in the sense of an action's reach and decrease with distance (see Krafft 1970 and Heilborn 1981).[1] The notion motivated by thirteenth-century Aristotelian natural philosophy was restated in terms of fourteenth-century Oxford mathematical language. In the "second" scholasticism, Jesuit intellectuals adopted the Aristotelian programme and *some* of the widely available

[1] For its scholastic use, see Lewis (1975); Hanke (2024) and (forth.).

calculatory techniques.[2] Unlike in the medieval era, late-scholastic physics was being both challenged by competing paradigms and extended by new Latin translations of Ancient texts.[3] While some late-medieval achievements were marginalized, debates on "sphaera activitatis" perpetuated the medieval framework.

A coherent group of four seventeenth-century Jesuits constitutes the primary corpus of this study: Pedro Hurtado de Mendoza (1578 – 1641), Rodrigo de Arriaga (1592 – 1667), Francisco de Oviedo (1602 – 1651), and Thomas Compton Carleton (1591 – 1666),[4] who pertain to the third generation of Jesuit intellectuals (Sousedík 1997, 64; Heider 2016, 1 – 3). Hurtado, Arriaga, and Oviedo are commonly labeled as a conceptualist trio (Heider 2014, 184), Arriaga was Hurtado's pupil and studied theology with Compton in Valladolid, and Arriaga and Oviedo disputed each other's theories, an exchange pondered by later authors. The primary sources originated between 1608 (the Pamplonian manuscript of Hurtado's *Physicae disputationes*) and 1669 (the revised edition of Arriaga's *cursus*), i.e., after the codification of Jesuit education in *Ratio studiorum*. The group is held to have had significant relations with outsiders: Descartes' account of rarefaction was argued to have been influenced by Arriaga (Sousedík 1997, 103 – 121),[5] Boyle references Suárez, Hurtado, and Arriaga (Boyle 1666, 35),[6] Arriaga was appreciative of modern experimental philosophy (Grant 1996, 349ff.; Sousedík 1997, 103), and Compton discussed Descartes' views on hylomorphisms.[7] The study of these authors will thus contribute to the current knowledge of seventeenth-century scholasticism, interpreted here as a continuation of fourteenth-century calculatory tradition.

I. Problems, Sources, Contexts

The debate on *sphaera activitatis* covers a wide range of (pseudo-)empirical phenomena, including magnetism, electricity (torpedo fish), light and sound,

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[2] See Schmitt (1975); Wallace (1981a, 2018), Feingold (2003); Grant (2003); Hellyer (2005); Blum (2012); Di Liscia – Sylla (2022); Gellera (2022). Wallace (1981b, 90) pointed out that the level of mathematization was decreasing in seventeenth-century scholasticism.

[3] See Rubio (1609, 342 – 352), referencing multiple Ancient and scholastic sources.

[4] For up-to-date overviews, see the relevant entries in Jacob Schmutz' *Scholasticon* (which is under maintenance for now) and in Sgarbi (2022). For Hurtado and Arriaga see Sousedík (1997, 100 – 138); Saxlová – Sousedík (1998); and Novák – Novotný (forth.), for Compton, see Embry (2015, 25).

[5] Cf. Glombíček (1999, 224 – 230).

[6] Boyle is analyzed in Guerrini (1999, 207 – 219).

[7] See Compton Carleton (1649), *ad indicem*.

but also female attractiveness and a basilisk's ability to kill a human with mere sight (!) (Hurtado de Mendoza 1624, 258). On the theoretical level, the debate revolves around three issues: first, the spatial limits of natural action; second, the decrease of natural action with distance; third, the propagation of light (which is a paradigm of natural regularity). These typical contexts include the *Physics* or *De generatione et corruptione* commentaries (or their equivalents), and, given the relevance of optics, *De Anima* commentaries (or their equivalents) and optical texts; the analyses of action and reaction; theological contexts (Thomas de Vio Cajetan 1889, 27 – 28). The first context allows us to trace the Ancient and medieval background to the debate, whose beginning appears to be the authority *agens et patiens non agunt, nisi approximata*, related to *De generatione et corruptione* (I.6, 322b23 – 24) (Hamesse 1974, 168), that is, "action and passion ought properly to be possible only for such things as can touch one another."[8] In the 1503 *Auctoritates Aristotelis et aliorum Philosophorum*, another relevant principle, namely "omne agens naturaliter in agendo repatitur et omne patiens in patiendo reagitur, *primo De generatione*," is extended with a note that this further requires the appropriate distance (Anonymous 1503, h2v).

Viewing proximity as a condition for natural action became an element of late-medieval handbooks. While the thirteenth-century *Summa pauperum* and its late fourteenth or early fifteenth-century adaptation *Parvulus philosophie naturalis* appear to subscribe to the literal reading of the requirement of contact (see Albert of Orlamünde 1890, 477), the fifteenth-century commentary on the *Parvulus philosophie naturalis* by Bartolomaeus Arnoldi of Usingen applies the principle to metaphorical forms of contact as well (Bartholomaeus 1499, fols. 78r – v). In the British *Termini naturales*, the relevant passage introduces conditions for action, which in one of the manuscripts include the requirement that *sufficiens* approximacio *sit inter agens et passum*.[9]

Some of the late-medieval *De generatione et corruptione* commentaries cite Averroes' and Grosseteste's accounts of the propagation of sound and light. While the motivating problem is whether action and reaction require contact, the discussion often revolves around the mathematics of the

[8] See Aristotle (1955, 222 – 223) and *Conimbricenses* (1600, 303, text. 43) for the relevant Latin and Greek texts.

[9] See *Termini naturales*, Worcester, Cathedral Library, F.118, fol. 33va. The note appears to be relatively rare in the group of manuscripts surveyed in Hanke (2023). See also the amplifications of *Termini naturales* (possibly) by Thomas Netter of Walden (15th century) MS Cambridge, Corpus Christi College, ms. 378, fol. 72r and *Libellvs sophistarvm ad vsvm Oxoniensium* (1525), p3r (surveyed in Ashworth 1979).

propagation of light, captured in terms of *sphaera activitatis*,[10] the linear decrease in the intensity of light with distance being held to be a common view (see Lička 2022).

II. Scholastic Mathematics of Regularity

The decline of interest in medieval calculatory works occurred after the mid-sixteenth century, ironically at a time when mathematics had become indispensable to science (Clagett 1959; Wallace 1981a; Wallace 2018; Di Liscia – Sylla 2022). One significant outlier was Francisco de Toledo (1534 – 1596), a pupil of Domingo de Soto, whose access to the medieval scientific tradition rendered him a significant source for later authors (Lewis 1975, 128, 144 and ff.).[11] Toledo did not go beyond the fourteenth-century state-of-the-art regarding *sphaera activitatis*: he claimed that natural action takes a spherical form and its intensity decreases with distance linearly or "uniformly difformly," which he holds to be a common view (Toledo 1585, fol. 297rb).[12] Saying that natural action decreases uniformly difformly means, to use Murdoch's term, employing the language of the latitudes of forms.[13] The three currently best-researched analyses of complex regularities are Jacobus de Sancto Martino's *Tractatus de latitudinibus formarum*, Jacques Legrand, and Francisco de Toledo.

Tractatus de latitudinibus formarum employs the geometric method introduced by Nicolas Oresme to represent uniform, uniformly difform, and uniformly difformly difform latitudes, latitude being a measurable value of a certain parameter (Smith 1954).[14] A latitude is uniform if its degrees are equal through all spatial or temporal parts; it is uniformly difform if its degrees increase or decrease uniformly; it is uniformly difformly difform if the increase or the decrease of the degrees is uniformly difform (Smith 1954, 1 – 5). To use a modern example, the constant velocity is uniform, the constant change of velocity or acceleration amounts to uniformly difform velocity, and the constant change of acceleration (i.e., jerk) amounts to uniformly difformly

[10] See Oresme (1996, 146); Albert of Saxony (1505, fol. 140vb); Marsilius of Inghen (1500, fol. k2va).

[11] While it cannot measure up to his logic handbook recommended in the Jesuit *Ratio studiorum* (see Lukács 1986, 397 – 398), the influence of Toledo on Hurtado, Arriaga, Oviedo, and Compton can be easily documented.

[12] Cf. Lewis (1975, 157 – 162).

[13] See Clagett (1959, 199 – 253); Murdoch (1975, 271 – 348); and Murdoch – Sylla (1978, 231 – 241); for post-medieval debates, see Lewis (1975).

[14] Daniel Di Liscia is preparing a new critical edition of the text. See also Di Liscia's edition of *Latitudines breves* in Di Liscia (2016) and Sylla (1973) for a more general take.

difform velocity or uniformly difform acceleration.[15] For some reason, uniformly difform difformity is later redefined in terms of the increments (or decrements) following a certain ratio. Uniformly difform latitudes are represented by right-angled triangles and uniformly difformly difform latitudes are represented by right-angled triangles with curved hypotenuses (Smith 1954, 37 – 38). To illustrate this, consider the visual aids preserved in the manuscript (Wien, Österreichische Nationalbibliothek, Cod. 4953, fol. 15r), representing uniformly difform difformity and uniform difformity, respectively, with the degrees and the increments in the sense of differences of subsequent degrees inscribed:[16]

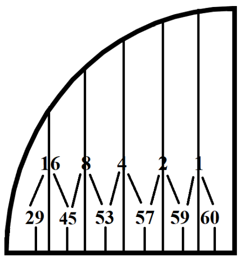

Fig. 1

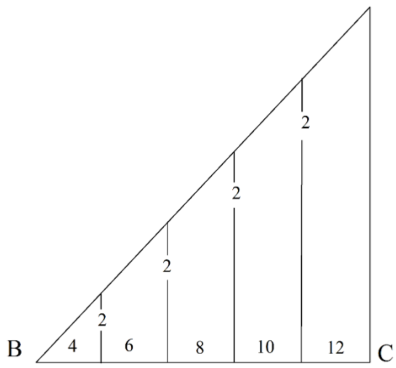

Fig. 2

[15] For the modern terminology, see, e.g., Young – Freedman – Ford (2013, 35 – 44); for the corresponding scholastic terminology, see Clagett (1959, 210 – 212).
[16] See also Smith (1954), *figures*. Note that the written text and the visual aid seem to be mathematically flawed.

The increments are *not* identical in fig. 1 (as opposed to fig. 2) and the ratio between the subsequent increments is held to be 1.5:1 in the text and 2:1 in fig. 1; the ratio neither occurs nor is held to occur between the subsequent degrees.

Toledo's definitions fit the tradition of *latitudines*, as documented by Lewis (Lewis 1975, 191 – 196).[17] His example of uniformly difform difformity is a geometric progression (1; 2; 4; 8), where the values are unequal and the increments are proportional, as opposed to uniform difformity with unequal values and equal increments (Toledo 1585, fol. 134va). As opposed to *latitudines*, Toledo's analysis has no geometric component.

Legrand introduced a different approach and suggested that the classification of uniformity and difformity can be extended *ad infinitum* (Thorndike 1934, 575 and Di Liscia 2022, 299 – 300). He defined uniformity as the equality of degrees (Legrand ca. 1400, fol. 43v). Uniformly difform phenomena display either the constant increment (or decrement) between values (*secundum excessum*), or the constant ratios of values (*secundum proportionem*), e.g., the sequences (1; 2; 3) and (1; 2; 4; 8) respectively (Legrand (ca. 1400, fols. 43v – 44r). These would count as uniformly difform and uniformly difformly difform for the aforementioned authors. The last notion introduced explicitly is that of uniformly difform difformity; the example being the sequence (1; 2; 4; 5; 7), where odd increments are equal to one and even increments are equal to two (Legrand ca. 1400, fol. 44r – 45r). Further forms of uniformity can be reached by taking a random sequence and adding a similarly random sequence to it (Legrand ca. 1400, fol. 45v). Hypothetically, (1; 2; 4; 9; 10; 12; 17) would be uniformly difformly difformly difform based on a repeating pattern of increments 1 – 2 – 5. On this interpretation, the fundamental idea behind Legrand's theory of uniformity is that of periodic repetitions.

III. Theory of Natural Action: the Mathematics of *sphaera activitatis*

Having summarized some of the relevant sources, the seventeenth-century debates on natural action can now be introduced and properly evaluated.

Hurtado's disputations on the *Physics* are preserved in three versions: a 1608 manuscript and the 1615 and 1624 printed editions, the relevant differences being negligible.[18] The core of his theory is that the spatial limitation of natural action is intrinsic to the acting force (*[a]gentia naturalia propter limitationem suae virtutis non posse actionem protendere vltra diffinitos*

[17] The source also discusses Galileo's *Juvenilia*.

[18] See Hurtado de Mendoza (1608, fols. 80r – 81r); Hurtado de Mendoza (1615, 346 – 347); and Hurtado de Mendoza (1624, 260 – 261).

limites). The paradigm of the theory is the propagation of light. The example is significant from the scholastic perspective, since light has no counteracting resistance, as opposed to local motion through the plenum, and is instantaneous (Hurtado de Mendoza 1624, 260).[19] While one might wonder why an exceptional phenomenon would be a good paradigm, the point is that if even light displays weakening of effect, any natural action must as well, and if the intensity of light decreases with distance, distance alone must be the reason for this decrease, for no other factors are present (Hurtado de Mendoza 1624, 261). As the opening "experimental" confirmation of the concept, if the intensity of light did not decrease with distance, a single lantern would illuminate the entire city of Pamplona, which is held to be absurd (Hurtado de Mendoza 1624, 260). Furthermore, Hurtado eliminates two alternative explanations. The first attributes the decrease to the properties of the medium and is dismissed by insisting that light is not counteracted by any resistance and the medium is held to be uniform in this particular setting of the situation (Hurtado de Mendoza 1624, 260). As it seems impossible to have provided any genuine empirical evidence in Hurtado's era, the argument is heavily theory-laden and both sides are probably presupposed to share a common ground. The second alternative theory assumes that light propagates through the reproduction of light sources of equal intensity but decreasing ability to produce light, a distinction Hurtado views as baseless (Hurtado de Mendoza 1624, 260).

Arriaga's disputations on generation and corruption are preserved in two distinctly different versions, but the core of the theory of natural action is not affected by these revisions; in both cases, this passage is relatively short. His theory is formulated in similar terms to Hurtado's, including the example of a lantern that would illuminate the entire world, if not for the fact that every created agent is naturally associated with a limited sphere of action (*differentia prouenit ex diuersis agentium naturis*). Interestingly, Arriaga introduced another paradigmatic example of the theory, the propagation of sound, which would play a major role in his exchange with Oviedo (Arriaga 1632, 567; Arriaga 1669, 670). The majority of the passage discusses the difference between the activity of substantial forms as opposed to accidental forms, motivated by the objection that as substantial forms produce equal substantial forms, so should the effect of accidental forms be equal to their source; this is Arriaga's way of

[19] For the instantaneous motion (e.g., the propagation of light), see Hurtado de Mendoza (1624, 296 – 297).

discussing the decreasing effect of natural agents with distance. Arriaga argues that while the reproduction of substantial forms does not include weakening (otherwise it would have stopped and substantial form would have ceased to exist), accidental forms are incapable of such perfect reproduction and their effect is always weakening (*accidentia…possunt assimilare passum in specie, licet non possint in intensione*) (Arriaga 1632, 567 – 568; Arriaga 1669, 670 – 671).[20]

Compton's theory is doctrinally close to those of Hurtado and Arriaga, with some interesting terminological shifts that neatly assemble various pieces of scholastic intellectual production. He opens with the metaphysical principle that action follows being (*operari sequitur esse*), whence the perfection of an agent implies the perfection of its effects, among others in the sense of spatial reach (Compton Carleton 1649, 438). Consequently, created agents are associated with *finite* spheres of activity, whose sizes are determined by the potency of the agent. Compton's line of thought begins with the idea that all created beings are associated with natural limits of operation (*certi à naturâ praescripti fines in operando*); tacitly, supernatural agency is excluded from this consideration, as divine power is, presumably, not bound by any spatial limits. Furthermore, note that the sphere of activity is defined exclusively in terms of natural limits of operation, and the fact that the effect of an operation decreases with distance is introduced independently later. The primary examples are the propagation of light (which is no surprise) and heat, but another example is that whiteness is "more active" that blackness, whence is associated with greater sphere of action (Compton Carleton 1649, 438), which should remind us that quantitative tools are applied to complement a specific background theory. Lastly, Compton (re-)introduces the principle that natural action decreases *linearly* with distance; he explicitly uses the term "uniformly difformly" to capture this regularity and the theory is held to be backed by "everyday experience" (*experientia enim quotidiana ostendit pro maiore subiecti distantiâ effectum decrescere, et res naturales agere vniformiter difformiter*) (Compton Carleton 1649, 438). The principle is motivated by the question of whether accidental agents, such as heat, can "assimilate the close object of their action (*passum*) perfectly" (Compton Carleton 1649, 438), in other words, whether the effect of such agency can be constant regardless of the distance. Unlike Hurtado, who argued by elimination, Compton states without proof that the sole reason for the decrease is the distance (*[h]uius autem ratio assignari alia non*

[20] Reproduced in Compton (1649, 438).

potest, nisi quòd maior propinquitas conducat, distantia verò obsit intensioni effectûs). Interestingly, he draws the analogy to the propagation of a quality being slowed down in proportion to the intensity of the counteracting opposite (as a sidenote, that this is why divine action is instantaneous); terminologically speaking, this means that distance is a source of resistance. Incidentally, this is where Compton echoes the *locus* with the impossibility of the entire world being illuminated by a small candle: the underlying reason is, however, not the notion of the sphere of activity, but rather the notion of natural action being uniformly difform (Compton Carleton 1649, 438).

An interesting debate was concerned with further interpretation of the phrase "uniformly difform," used to capture the mathematical properties of the sphere of action. The question was whether the decrease in effect is continuous *per partes proportionales*, or comes in steps, *per partes aliquotas*, i.e., whether the geometrical model of natural action is a pyramid or steps. In the seventeenth century this controversy had already been reconstructed as a polemic between Hurtado and Arriaga on one side and Oviedo on the other (Soares 1703, 37 – 38; De Benedictis 1723, 563). The debate deserves future attention, but its presentation is limited to the basics of the exchange between Arriaga and Oviedo.

Arriaga holds that natural action is uniformly difform in the sense that for each action, there are certain zones where the effect is identical both as regards the velocity of propagation and the degree of the effect (Arriaga 1632, 526). The examples include the propagation of sound: observers can allegedly hear the sound equally, even if they are not equally distant from its source if they are relatively close to each other. The argument focuses on velocity but, presumably, should apply to intensity as well, based on the context (Arriaga 1632, 526). Oviedo criticized this position and reproduced Arriaga's argument based on the propagation of sound, but countered his view by claiming that the decrease of natural action is continuous (Oviedo 1640, 551, 555). In the later edition of his textbook, Arriaga replies by relating the debate to the principle that spatial proximity is a condition of action, which he views as confirmed by experience. However, he states that the question cannot be solved empirically. Even though he ultimately retains his position as the more probable, this is certainly an interesting point (Arriaga 1669, 628).

To summarize, the mathematical analysis of natural action upheld by the four authors breaks down to three statements: first, the intensity of action in general decreases with distance; second, this decrease is regular (either continuous or step-wise); third, at a certain distance the intensity of action reaches zero. These were labeled as "observations," which in scholastic sources covered everyday observations with the naked eye, although often it could hide borrowings from other authors (Unguru 1991, 168);[21] also, recall that Arriaga was skeptical as to whether certain aspects of the theory were open to experimental testing. From the modern perspective, the third point is inconsistent with the mathematics of inverse square laws, which includes the formula for the relation between the intensity of light and distance: such actions become unobservable and negligible but never disappear.[22] To a scholastic author, that was both empirically absurd and conceptually unacceptable, for a finite agent can only have a finite reach. The three requirements are relatively loose and there are multiple of ways of satisfying them; while uniform difformity is one of them, there are alternative descriptions depending on the degree of precision of one's mathematical apparatus: recall the multiple forms and definitions of regularity discussed in the previous section, where, at the very least, uniformly difform difformity as introduced in the *latitudines* tradition is a serious candidate. The mathematical theories of natural action are appealing from the modern perspective but the combination of mathematical rigor with everyday intuitions shows the limits of scholastic physics. While everyday experience appears to confirm that action decreases with distance, the mathematical details remain underdefined without precise measurements, which are impossible without proper scientific instruments as were then unavailable. In such a situation, it seems tempting to let everyday experience "confirm" a theory that is either a scholastic commonplace or one's favorite flavor of scholastic thought.

IV. Conclusions

Scholastic authors introduced three different views of uniformity, namely *increment-based* (uniformity as equality of increment or of increment of increments etc.), *ratio-based* (uniformity as a constant ratio between either values or increments of values etc.), and *period-based* (uniformity as periodic repetition), and thus had at their disposal several ways to capture a regular decrease ultimately reaching zero. The common view for the four seventeenth-century Jesuits was that natural action propagates spherically, it

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[21] Unguru quotes Lejeune and Lindberg, who discusses the example of Witelo, whose alleged experimental data were "copied in its entirety from Ptolemy's *Optics* and additionally garnished with absurd data…which could *not* have been obtained by actual measurements."
[22] For the history of inverse-square law in various branches of science, see Gal – Chen-Morris (2005).

is spatially limited, and its effect decreases with distance linearly. While the debate can be traced back to fourteenth-century sources, no part of it requires going beyond Toledo and Suárez, whose sources were Nipho and Pomponazzi (see, for instance, Lewis 1975, 308). Toledo claimed that the intensity of light and, by extension, of every natural action, is decreasing in a linear way, and the seventeenth-century Jesuits followed the same path. The scholastic solution to the mathematical problem of natural action thus settled on the simplest model satisfying the requirements. However, "Y in/decreases with X in a regular way; therefore, the phenomenon is uniformly difform" is, even from the scholastic perspective, a *non sequitur* (regardless of the interpretation of "uniformly difform"). The fact that it was held as legitimate shows how much of the languages of latitudes of forms can be lost within a single generation.

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