SYLVAIN ROUDAUT

# HEAT, COLDNESS, AND CONTRARIETY IN LATE SCHOLASTIC PHILOSOPHY

**Abstract**

While it is well known that heat played a dominant role in the development of modern science, the fact that its status had already begun to evolve drastically in earlier periods is much less recognized. Although not pertaining exclusively to the Aristotelian framework, by the late Middle Ages, heat was deeply embedded in the Aristotelian worldview, which dominated much of Western natural philosophy. In this framework, heat was classified as a fundamental quality, interacting with other elemental qualities in natural processes. In Aristotle's system, heat, along with cold, wet, and dry, was part of a theory of contrariety that explained change and transformation in the natural world: this is the aspect of Aristotle's theory of heat that is privileged in this paper. In the early modern period, unlike concepts such as 'substantial form', which were discredited by modern science, heat persisted but underwent a profound ontological shift. No longer a positive entity, it came to be understood as a process, specifically a form of motion, marking a decisive departure from medieval interpretations. This study traces the pre-history of this transition by analyzing how the notion of positive contrariety between heat and cold was progressively dismantled in the late Middle Ages and Renaissance. First, it examines the shift from a binary model of contrariety to a relative scale of thermal properties. Second, it discusses Cardano's critique of the Aristotelian view of cold as a positive contrary, which stimulated significant debate. Finally, it explores how redefinitions of resistance in the 16th century further undermined the traditional model, paving the way for mechanistic and empirical approaches that culminated in modern thermodynamics.

**Keywords**

Aristotelian Tradition, Heat (Historical Concepts), Aristotelian Theory of Contrariety (Heat and Cold), Girolamo Cardano, Prehistory of Thermodynamics

**Author**

Sylvain Roudaut
CNRS - SPHERE (Université Paris Cité)
sylvain.roudaut@u-paris.fr
ORCID: 0000-0002-0626-0714, SCOPUS: 57192997253

## *1. Introduction*

While it is well known that heat played a dominant role in the development of modern science at the dawn of the 17th century, the fact that its status had already begun to evolve drastically in earlier periods is much less recognized. Although not pertaining exclusively to the Aristotelian framework, by the late Middle Ages, heat was deeply embedded in the Aristotelian worldview, which dominated much of Western natural philosophy. In this framework, heat was classified as a fundamental quality, interacting with other elemental qualities in natural processes. In the Aristotelian system, heat, along with cold, wet, and dry, was part of a theory of contrariety that explained change and transformation in the natural world.[1]

In the *Categories*, Aristotle had characterized contrariety as the second typical feature of qualities.[2] Not all qualities admit of contraries, as entities like shapes or figures, representing according to Aristotle the fourth species of qualities, do not have proper contraries. More precisely, a key aspect of Aristotle's theory is the distinction between two types of contrariety. The first is positive contrariety (*contrarium positivum* following the scholastic term of art). For Aristotle, contraries like heat and coldness were not simply opposites in the sense that one was the absence of the other. Rather, they were positive contraries, meaning that both heat and coldness were real beings that acted upon matter in opposed ways. This stands in contrast to privative contraries (*contrarium privativum*), where one member of the pair is

[1] See Anton (2001), Bogen (1992). Aristotle explicitly presents heat and cold as contraries in this passage: "as principles we have firstly that which is potentially perceptible body, secondly the contrarieties (I mean, e.g., heat and cold), and thirdly Fire, Water, and the like. For these bodies change into one another (they are not immutable as Empedocles and other thinkers assert, since alteration would then have been impossible), whereas the contrarieties do not change" (*Gen. corr*. II 1.329a32-b3; Aristotle 1984, p. 539). This aspect of Aristotle's theory of heat is privileged in this paper (it is not claimed to be the only relevant aspect: for example, see Freudenthal 1995 for 'vital heat' in Aristotle).

[2] Firstly, "things called paronymously because of these or called in some other way from them are Qualified"; secondly "There is contrariety in regard to qualification. For example, justice is contrary to injustice and whiteness to blackness, and so on; also things said to be qualified in virtue of them – the unjust to the just and the white to the black. But this is not so in all cases; for there is no contrary to red or yellow or such colours though they are qualifications" (Arist. *Cat.* 8.10b12-17; Aristotle 1984, p. 16).

defined by the absence of the other, such as darkness with respect to light. For Aristotle, who opposed alternative views defended by ancient philosophers on heat and cold,[3] these properties are positive powers that actively interact and oppose each other.

Aristotle's arguments for this position rested on several key points: a privation cannot act, but coldness does; a privation does not admit of degrees, but coldness can vary in intensity. These arguments supported Aristotle's broader metaphysical structure, in which positive contrariety explained the oppositions and affinities between the elements and the continuity of processes in nature. This notion was crucial to explaining the structural relations between the four classical elements (earth, water, air, and fire) and their corresponding qualities. It also justified the continuity of natural processes, such as heating and cooling, through the gradual replacement of one quality by its opposite within the same subject.

This distinction between two types of contraries was not without its challenges. Aristotle's use of contrariety to explain change was based on the idea that contraries naturally repel one another. Consequently, Aristotle's concept of contrariety implies that contraries, by definition, cannot be present in the same subject at the same time.[4] However, since change in the category of quality is, according to him, a continuous process, Aristotle seems compelled to admit that a certain continuity exists in the transition from one contrary to its opposite, as in every natural motion in the proper sense of the term. Although a quality is, in itself, something indivisible, its gradual reception during an alteration entails a divisibility according to the subject, which presupposes intermediate states between, for example, hot and cold.[5] To the eyes of a reader of Aristotle seeking to understand how such gradual change is possible, these intermediate states could suggest the

[3] See, e.g., Lloyd (1964).

[4] Arist. *Metaph.* Δ 10.1018a25-32: "We call contraries (1) those attributes that differ in genus, which cannot belong at the same time to the same subject, (2) the most different of the things in the same genus, (3) the most different of the attributes in the same receptive material, (4) the most different of the things that fall under the same capacity, (5) the things whose difference is greatest either absolutely or in genus or in species" (Aristotle 1984, p. 1608).

[5] Arist. *Ph.* VI 5.236a35-b18.

simultaneous presence of contraries in the same subject, at least for the duration of the change.

Under the dominance of Aristotelian concepts in natural philosophy, medieval thinkers inherited these paradoxes. However, during the early modern period, the concept of heat experienced a profound redefinition. Unlike other Aristotelian concepts, such as substantial form, heat was not erased from the new philosophical and scientific discourses but underwent a shift in its ontological status. Whereas in the Aristotelian framework it was considered a thing (a positive entity existing in nature), heat was reconceptualized as a process – specifically, a type of motion.[6] This marked a radical departure from the medieval understanding, influenced by the rise of mechanistic philosophy and the growing emphasis on empirical observation and mathematical modeling in natural philosophy.

This evolution was, however, the final phase of several stages of conceptual development depending on various factors. One such factor was the redefinition of coldness as the mere privation of heat. This historical departure from the medieval Aristotelian conception involved a complex interplay of metaphysical, empirical, and mathematical ideas that is still understudied.[7] Yet, the redefinition of heat not only reflected broader shifts in the ontology of natural properties but also laid the groundwork for the development of thermodynamics and the scientific study of heat in the centuries to come.

This study is devoted to trace the pre-history of the modern reconceptualization of heat, focusing on how heat and the notion of positive contrariety were disentangled in the late Middle Ages and Renaissance. To this end, this paper will proceed in three main sections. First, I will explain how the conception of heat prevailing in the late Middle Ages had already shifted away from the idea of pure contrariety between heat and coldness by implying the use of a relative scale rather than a binary opposition of these properties. Second, I will explore how one of the main arguments – the argument from action – supporting the Aristotelian definition of cold as a positive contrary was contested by Girolamo Cardano in the early 16$^{th}$ century, and

[6] On this, see Pasnau (2011) pp. 473-81.

[7] The modern transformations of heat have benefited from much more scholarly attention. A classic work on this topic is Fox (1971).

how this view sparked various reactions and debates among contemporary thinkers. Finally, I will show how the concept of resistance, when redefined in a specific way that gained prominence during the 16th century, helped move away from viewing heat and cold as positive contraries.

### *2. Late Medieval Views on Heat and their Ontological Implications*

Anticipating developments in early modern science, the problem of intensive variations – how to account for varying degrees of heat and cold – emerged as a central issue in late medieval natural philosophy.[8] This question was key to an important re-evaluation of contrariety, since the fact that qualities admit of degrees raised the problem of whether they are truly opposed to their contraries.

Medieval thinkers proposed different solutions to explain how properties like heat and coldness admit of degrees, with some emphasizing metaphysical interpretations and others proposing solutions that leaned more on empirical observation. The dominant theory that emerged during this period was the 'addition theory' of intensity, which interpreted qualitative properties like heat and cold through a quantitative model. According to this theory, the intensity of heat or cold could be conceived as an additive process, where increasing or decreasing degrees are understood as the addition or loss of intensive degrees (*gradus intensivus*) within one quality.

One of the competing theories against which the addition theory was developed can be labelled the 'admixture theory.' According to this view, varying degrees of intensity of a quality, like degrees of heat, are to be explained by different ratios of heat and coldness within the same subject. According to this view, the hotter a subject, the less its heat is mixed with coldness.

One of the few defenders of this view was Albert the Great (ca. 1206-1280), who allowed for the possibility of mixed contraries within the same subject to explain intermediate degrees like tepidity.[9] However, most medieval philosophers, following Aristotle's lead, agreed that contraries cannot coexist within the same subject, meaning that heat and cold should not be

[8] See Sylla (1973), and (1971-1972), Roudaut (2021) and the bibliography therein.
[9] Albert the Great (2013) tr. 5, c. 12, p. 128a.

able to exist simultaneously in the same body. But while the 'admixture theory' in its raw form was generally rejected in the Middle Ages, many medieval thinkers found some plausibility in the idea of mixture between opposing states to explain intensive variations.

For this reason, the axioms relating to heat and coldness as positive contraries came to change in the late 13th century. Although earlier thinkers like Henry of Ghent (1217-1293) might be considered as equally innovative on this point, one of the most influential contributions to this debate came from John Duns Scotus (ca. 1265-1308). Scotus accepted the 'addition theory' of intensive variations but he challenged the usual understanding of contrariety:

> From the instant of change, the motion of the attenuation of heat and the motion of the intensification of cold occur therefore simultaneously – neither of which involves anything that happens first or at some instant in which, by a sudden change, a degree of cold is introduced that is entirely incompossible with heat. At this first <instant>, heat no longer exists, and up until then, heat was present – so that heat has no last moment of its being, but had a last instant of being at rest; and cold has no first instant of its beginning to exist [*simpliciter sui esse*], though it has a first instant of being at rest (that is, what it receives through change, though this is not rest).[10]

Let us point out at the immediate consequence of this argument. Scotus proposed that when a hot object becomes less hot, there is no clear reason to prioritize either of the following propositions:

(a) The body becomes less hot.
(b) The body becomes colder.

According to Scotus, it is correct to describe the object as both losing a degree of heat and gaining a degree of coldness. This means that a body can simultaneously possess degrees of both heat and coldness. Scotus does not

[10] John Duns Scotus (1973) II, d. 2, p. 2, q. 5, p. 330, n. 396 [unless otherwise indicated, translations are mine]: "Currunt igitur simul, ab instanti mutationis, motus remissionis caloris et motus intensionis frigoris, – quorum neutrius est aliquid primo et in aliquo instanti in quo per mutationem subitam inducitur aliquis gradus frigoris omnino incompossibilis calori: in illo primo, calor non est, et usque ad illum calor fuit, – ita quod calor nullum ultimum sui esse habet, sed habuit ultimum in esse quieto; et frigus nullum primum habet simpliciter sui esse, licet habeat in esse quieto (scilicet quod accipit per mutationem, licet illud non sit quies)."

claim that gaining coldness and losing heat are the same process, but rather that they are necessarily correlated. While he maintains that heat and coldness are formal contraries that cannot be in the same subject, he accepts that, *at least during the time of qualitative change*, degrees of heat and cold are mixed in the same subject. Even though Scotus' position is not fully explicit on this point, we can conjecture that, according to him, heat and cold are incompossible in the same subject when perfectly actualized but that they are mixed during qualitative change.

Scotus' influential treatment of the problem of intensive variations opened the door to new discussions on the nature of contrariety and shaped subsequent debates on the nature of contraries in the early 14th century. In the wake of Scotus' ideas, several attempts to revise the concept of contrariety emerged, particularly concerning how to explain variations in intensive properties like heat and coldness. One of the most original contributions came from Walter Burley (ca. 1275-1344). Burley took the bold step of arguing that heat and coldness not only belong to the same genus (as acknowledged by Aristotle) but also to the same species. In his *Tractatus primus*,[11] composed in the late 1310s, Burley posited:

> Contrary forms, for instance hot and cold, black and white, belong to the same most specific species [*speciei specialissime*]. The first argument is the following: When two things are equally distant by a formal distance from the most perfect being in some species, then if one of them belongs to this species, so does the other.[12]

Burley's view was provocative. It implied that heat and cold, despite being contraries, belonged to a common continuous scale, and not to two distinct scales that would correspond to two different species. Interestingly, however, Burley did not abandon the term 'contraries' to designate heat and cold. Rather, his point was to reinterpret the conceptual framework of genera and species inherited from Aristotle. He sought to demonstrate that contrariety should be located *within* the level of species, and not only between two

[11] On this treatise, see De Rijk (1996).

[12] Walter Burley, *Tractatus primus*, f. 209vb: "Formae contrariae, videlicet calor et frigus, albedo et nigredo, sunt eiusdem speciei specialissimae. [...] Prima ratio talis est quandocumque aliqua duo aequaliter distant distantia formalia perfectissimo in aliqua speicie, si unum illorum diversorum sit in illa species reliquum etiam in illa specie."

species within a given genus. Based on considerations different from those of Scotus, his position led to dissociating the notion of contrariety from that of opposing species, viewing contrariety instead as a continuum of states belonging to the same scale.

By the early 14th century, a less radical but much more influential approach came from John Buridan (ca. 1300-1358), one of the main leading figures in the Parisian intellectual milieu. Buridan claimed that attenuated degrees of heat and coldness are not contraries in the same way that maximal degrees are. According to Buridan, only the extremes – such as maximal heat and maximal cold – are true contraries, while intermediate degrees represent a gradation rather than opposition.

As Buridan puts it, contrary forms are impossible in the same subject, but *contrary degrees* are not:

> I therefore state a third conclusion, that it is possible for some degrees of heat to exist simultaneously with some degrees of cold in the same subject. [...] The fourth conclusion is that it is impossible for any degrees of contrary forms to exist simultaneously in the same subject.[13]

This distinction between contrary forms and contrary degrees allowed Buridan and the proponents of this view to account for phenomena like tepidity, where neither pure heat nor pure coldness is present, without violating the principle that contraries cannot coexist in the same subject. This theory helped explain empirical phenomena observed in nature and became widely accepted within the academic circles of 14th-century Paris. One consequence of it was that it made contrariety a matter of quantity of degrees, and not a formal incompatibility between two opposite essences, as Buridan himself acknowledges:

[13] John Buridan (2016) III, q. 3, pp. 30-1: "Pono ergo tertiam conclusionem quod possibile est esse simul aliquos gradus caliditatis cum aliquibus gradibus frigiditatis in eodem subiecto. [...] Quarta conclusio est quod impossibile est aliquos gradus formarum contrariarum esse simul in eodem subiecto."

From what has been said follows the sixth conclusion, namely that the contrariety of forms is not based on the simple natures [*rationibus*] of the forms <themselves>, but on the quantity of their degrees.[14]

This view led to what I have labelled the 'new admixture theory,' which further refined the idea (already suggested by Scotus) that degrees of contrary qualities can exist simultaneously in the same subject.[15] According to the historian of science Pierre Duhem, this theory comes very close to considering coldness and heat as the same property but with opposite signs.[16]

This approach gained wide acceptance in the 14th century. Written at a slightly earlier period, from the late 1320s to the 1340s, the works of the so-called 'Oxford Calculators' implicitly relied on the same conception of qualities like heat and coldness, although this implicit assumption was not as thoroughly theorized as in the Parisian tradition.[17] Following Buridan's guiding ideas, other thinkers like Marsilius of Inghen (ca. 1340-1396) drew the same consequences regarding the nature of the opposition between coldness and heat. Marsilius observes that, although heat (*caliditas*) and coldness (*frigiditas*) as abstract terms referring to individual qualities are contraries and, as such, belong to distinct species, the concrete adjectives 'hot' and 'cold' can refer to things belonging to the same species because there is a continuous scale of degrees between the opposite maximal degrees of heat and coldness. Given that heat and coldness can be reduced, ontologically speaking, to hot and cold things, it follows that heat and coldness can be of the same species:

[14] *Ibid*., p. 31: "Ex istis dictis sequitur sexta conclusio, scilicet quod contrarietas formarum non attenditur ex simplicibus rationibus formarum, sed ex quantitate graduum."
[15] See Roudaut (2021) ch. 7, for further details and references; Caroti (2004); Clagett (1941) pp. 37-8.
[16] As interesting as it is, this thesis appears to be too strong and does not hold up well under detailed analysis since, as we will see below, authors such as John Buridan and Marsilius of Inghen posit a distinction within qualities like heat between active power and resistive power (each of these two powers having its own degree distinct from the other), making the idea of a simple 'opposite sign' problematic. Duhem (1913) p. 402, followed by Clagett, (1941) pp. 37-8, fn. 8, saw Buridan as the initiator of this theory. As evidenced by the existence of similar ideas in the late 13th century, this claim cannot be maintained any longer.
[17] See, here again, Sylla (1973).

The contrariety of things is not sufficiently determined by their species. This is clear because, if that were the case, any coldness would be contrary to any heat, because any coldness and any cold <thing> and any heat and any hot <thing> belong to the same most specific species.[18]

We can see here that this new understanding of contrariety resulted in a transformation of the conceptual framework proper to Aristotelian physics, in which qualitative causal interactions are structured by oppositions between contrary species, such as heat and coldness, comprised under a common genus.

Not all thinkers accepted this new approach, however. Albert of Saxony (ca. 1320-1390) was a notable dissenter. In his *Questions on Aristotle's Physics*, Albert follows the position described below, which he considers less problematic with respect to the notion of contrariety:

According to the other position, every degree of heat is contrary to every degree of coldness, and no degree of heat is compatible with any of coldness. This position excludes that intensification and attenuation obtain through the mixture of contrary forms. For instance, the attenuation of heat does not follow from the presence of some degree of coldness [...]. Thus, this opinion conceives that, just like what is in the middle between up and down is not actually in contrary places, thus tepidity, a quality that is in between hot and cold, is not constituted by a mixture of degrees of heat and coldness [...].[19]

Albert's position shows that, even in the late 14th century, there remained some suspicion that conceptualizing heat and its intensive variations in quantitative terms led to problematic metaphysical consequences.

Despite oppositions like Albert of Saxony's to the 'new admixture theory' of primary qualities, this conception of heat and coldness became

[18] Marsilius of Inghen (1521) III, f. 10ra: "Contrarietas rerum non attenditur sufficienter penes speciem. Patet, quia tunc omnis frigiditas omni caliditati essent contraria, quia omnis caliditas cum omni caliditate et omnis frigiditas cum omni frigiditate est eiusdem speciei specialissime [...]."

[19] Albert of Saxony (1999) V, q. 9, p. 838: "Alia opinio ponit quemlibet gradum qualitatis cuilibet gradui frigiditatis esse contrarium nec aliquem gradum caliditatis posse stare cum aliquo gradu frigiditatis. Et ista opinio point intensionem et remissionem non fieri per admixtionem alterius formae. Verbi gratia, non ponit remissionem caliditatis fieri per admixtionem alicuius gradus frigiditatis [...]. Unde ista opinio imaginatur quod, sicut illud quod est in loco medio inter sursum et deorsum non oportet quod sit in locis contrariis, ita nec tepiditas, quae est qualitas inter caliditatem et frigiditate, habet aliquos gradus caliditatis et frigiditatis [...]."

dominant from the 14th century onward. In Italy, which witnessed some of the most significant advances in natural philosophy during the Renaissance, the treatise written by James of Forlì (d. 1414) on the intensification of forms – the most influential treatise on this topic until the end of the 16th century – endorsed the same theory.[20] Blasius of Parma (ca. 1350-1416) and Paul of Venice (ca. 1369-1429), two important masters active at the turn of the 15th century in North Italy, accepted the same view.[21] As Marshall Clagett has shown, what may be regarded as the most innovative works on heat produced during the 15th century, namely those of Giovanni Marliani, relied on the same conception.[22]

This view was still commonly defended in the late 16th century. This is true of 'scholastic' thinkers, who were the leading representatives of the Aristotelian-oriented theories of nature, in contrast to the novel conceptions of nature proposed by the so-called *novatores*. Francisco de Toledo (1532-1596) and the Coimbran commentators explicitly express their allegiance to it.[23] Francisco Suárez (1548-1617) likewise leans toward this view.[24]

---

[20] James of Forlì (1496) pars 2, f. 20vb: "Secunda conclusio, licet impossibile sit qualitates contrarias esse simul etc, tamen possible est qualitates que sunt eiusdem specie cum suis contrariis esse in eodem subiecto primo. Cf. 22rb: Tertia conclusio principalis est non est necesse omnes qualitates similes secundum speciem habentes contrarium eidem qualitati contrariari, patet de caliditate summa et caliditate remissa que licet sint eiusdem specie, caliditas tamen summa cuilibet frigiditati est imcompossibilis, et contraria et caliditas remissa non."

[21] On Paul of Venice, see Roudaut (2022). On Blasius of Parma, see Biard (2022b) and the bibliography therein for additional bibliography.

[22] Clagett (1941) pp. 37-8, notes that Marliani's influential *De reductio aquae calidae* assumes this conception.

[23] Francisco de Toledo (1588) II, c. 3, q. 4, p. 240: "Scias enim quod non quicunque gradus formae est incompossibilis cum quocunque gradu, nam calor ut septem potest esse cum frigiditate, ut uno, unde cum illa siccitate ignis, vel cum saltem quinque gradibus illius possunt esse duo vel tres humiditatis [...]"; College of Coimbra (1616) II, c. 3, q. 8, a. 2, col. 602E-603B: "Duae qualitates primae contrariae in gradibus remissis possunt eidem rei inesse. [...] Probatur vero haec sententia hisce argumentis. Aqua tepida habet simul aliquid caloris, et frigoris, igitur frigus, et calor remissa possunt in eodem simul reperiri. Antecedens ostenditur, primum quia tepor nihil est aliud, quam frigoris, et caloris permistio, neque facile est tertiam aliquam simplicem qualitatem excogitare."

[24] Francisco Suárez, *Disputationes metaphysicae*, disp. 46, sect. 2, n. 6; sect. 3, n. 17; cf. disp. 5, sect. 8, n. 23, although Suárez left undetermined in this discussion how contrary degrees relate to one another.

The variety of names associated with this theory should not create the false impression of an absolute consensus regarding the relationship between heat and coldness. First, not everyone accepted this view, as some preferred a more rigid interpretation of the incompossibility of contraries in the same subject. Second, there was ongoing debate about the precise process by which degrees of heat expel degrees of cold, with differing opinions on whether the increase of the former precedes the expulsion of the latter in some way, or if the two were strictly simultaneous.

The scientific importance of what has been termed here the 'new admixture theory' should not be underestimated. Elaborated in technical discussions over intensive variations, this theory implied a clear departure from the opposition of heat and coldness as positive contraries. Since heat and coldness are contraries, according to it, only at their extremes, and since in nature we encounter only mixed bodies that do not possess their elements at their most intense degree, it follows that ordinary heat and coldness are not true contraries. Aware of the potentially devastating character of this view for the coherence of an Aristotelian theory of nature, scholastic thinkers openly tried to maintain a sense in which Aristotle's statements about the incompossibility of contraries in a subject were still true. On a theoretical or, more precisely, *terminological* level, they continued to define heat and coldness as positive contraries. However, *in practice*, their views effectively denied this conception of heat, along with the conceptual framework – based on the theory of genera and species – on which it depended. To this extent, late medieval views on heat were far less opposed to the innovative theories put forward by 16th-century *novatores*, such as Girolamo Cardano, than is typically assumed.

### *3. Positive Contrariety vs. Pure Privation*

The debate over whether coldness should be understood as a positive contrary to heat or as a mere privation of it had deep roots in ancient philosophy. Arguments for the view that cold is simply the absence of heat were available to medieval and Renaissance thinkers through works like Plutarch's *De primo frigido* (Περὶ τοῦ πρώτως ψυχροῦ).[25]

[25] Plutarch (1959).

But some arguments also stemmed from considerations *internal* to the Aristotelian conception of nature. One of them, having to do with cosmology, came from the necessity to reconcile two claims, namely that:

1) Elemental virtues (including coldness) come from the heavens.
2) The light by which the heavens transmit virtues to terrestrial bodies only conveys heat.

One obvious way to reconcile these seemingly contradictory claims was to postulate that coldness arises in terrestrial bodies from a lack of exposure to celestial heat, depending on the duration of exposure or the fluctuating distance from planets reflecting solar light.[26] In the late Middle Ages, as Edward Grant as shown, the problem was lively debated, as experience seemed to show that moonless nights are colder than those with moonlight.[27]

Despite the difficulty of accommodating the cosmological principles of Aristotelianism with such empirical arguments, the view that cold is a mere privation of heat had very few defenders before the 16th century. One of the rare exceptions in the late 14th and early 15th centuries, prior to the rise of openly anti-Aristotelian theories of nature, was Blasius of Parma. Blasius subscribed to the conception of heat and coldness as two extremes on a relative scale described above but, unlike his contemporaries, he argued that this conception implied that coldness is merely a privation of heat:

> In this determination, I will persuasively show that heat does not differ from coldness. And this is the first conclusion. I argue as follows: All heat is a simple form through the privation of degrees of contrary qualities. This clearly appears inductively, for otherwise, any given part of heat would not be heat, and the same applies for all other parts. But heat and coldness together produce one form, which is tepidity. Therefore, it follows that coldness is not specifically distinct from heat. [...] From this, it follows that there is no such thing as coldness, or if there is, it is nothing else than attenuated heat.[28]

[26] This idea seems to have circulated via the transmission of Macrobius. See Macrobius (1847) p. 464: "In coelo easdem inesse zonas quae insunt terrae; atque causam hujus diversitatis esse solem: qui, ut accessu sua causa caloris est, ita recessu frigus inducit." Note, however, that this quote is absent from the new critical edition of the text by Willis.
[27] Grant (1994) pp. 603-5.
[28] Blasius of Parma, *Quaestiones super libros Physicorum*, V, q. 10, f. 156vb: "In quo processu solaciose persuadebo caliditatem a frigiditate non differre. Et hoc pro prima conclusione.

Blasius does not spell out here all the assumptions of his argument but his reasoning may be reconstructed as follows. Heat is a quality that is 'simple' in the sense that it is a quality unmixed with any contrary and not composed of more basic qualities. It is, however, composed of degrees. Since heat and coldness can combine to compose a middle quality – namely tepidity – it follows that the degrees of heat and coldness belong to the same species. Thus, heat and coldness are not different in nature, but only differs in degree.

Blasius offers additional arguments for this view, which he seems to consider plausible. However, in the vast majority of his writings on natural philosophy, he adheres to conventional terminology, describing heat and coldness as contrary species of qualities.[29]

The resurgence of a firmer defense of the privation theory of coldness can be traced to the work of Girolamo Cardano (1501-1576), one of the first thinkers in the 16th century to argue that cold is nothing more than the absence of heat. In his *De subtilitate*, composed in 1550, Cardano presents a new interpretation of the elements, rejecting the Aristotelian quadripartition of fire, water, air, and earth as primary elements of nature.[30] Instead, he argues that fire should not be considered an element in the same way that water or earth are, and by extension, that coldness is not a real, positive quality but simply the privation of heat. Cardano applied the same reasoning to dryness, which he argued was merely the privation of wetness.

Although Cardano rejects the notion of coldness as a positive contrary, he does not challenge the ontological status of heat as a quality. For him, heat remains a real and positive property of matter, and he does not attempt to reduce heat to motion – the central idea of modern thermodynamics.[31] In

---

Arguam sic: omnis caliditas est forma simplex per privationem graduum contrariorum qualitatum. Patet inductive, et quia alioquin non quaelibet pars caliditatis esset caliditas, et sic de aliis. Sed caliditas et frigiditas faciunt unam formam quae est tepiditas. Ergo sequitur quod frigiditas non distinguitur a caliditate specifice. [...] Ex hiis sequitur quod nulla est frigiditas, aut si aliqua sit, illa non est nisi remissa caliditas."

[29] This way of presenting radical ideas while labeling them as merely 'probable' and not fully committing to them is characteristic of Blasius' philosophical method; see Biard (2022a) pp. 15-6, 181.

[30] On Cardano's natural philosophy, see Ingegno (1980) pp. 209-71 and (1988); Kessler (1994).

[31] The relationship between heat and motion was discussed by medieval and Renaissance scholars, but the main issue at the time was to explain their correlation through a causal link

fact, as recent research has shown, although Cardano's position can be labeled as 'anti-Aristotelian,' it was deeply influenced by the Paduan Aristotelian tradition.[32] Paduan Masters such as Alessandro Achillini, Pietro Pomponazzi, Agostino Nifo, and Francesco Vimercato, were influenced by Aristotle's *Meteorology*, particularly book IV, where Aristotle assigns primary importance to water and earth and seems to leave aside the usual quadripartition of elements. What Cardano did was to "[develop] the two-element theory of *Meteorology* IV into a veritable cosmology."[33]

The main challenge for Cardano's position is what can be labelled the 'argument from action.' A privation, indeed, cannot act. According to Aristotelian reasoning, coldness must be considered a real quality because it produces observable effects in nature, such as cooling, solidifying, condensing, and separating things:

> However, you reply: 'If cold is nothing in act, but merely the privation of heat, how can cold <bodies> cool, like hot <bodies> heat?' Cold is always to be found with a great amount of matter. It is indeed impossible to find something very thin to be cold. A great amount of matter prevents heat from penetrating and prevents from moving, which is why <coldness> cools. [...] Certainly, coldness is, like I said, nothing else than the privation of heat [...].[34]

As can be seen, Cardano's strategy consists in reinterpreting the terminology of action associated with coldness. Coldness, strictly speaking, does not do anything. It merely *prevents* heat from operating, where the term 'prevents' must be understood as a privation of action caused by a large or dense quantity of matter. All operations attributed to coldness can be reduced to the incapacity of heat to penetrate and move dense bodies. Now, an incapacity,

---

(motion causing heat) rather than to identify them with each other or to reduce one to the other. For an overview of the problem, see Galle (2003).

[32] On the Paduan tradition preceding Cardano's activity, see Martin (2022). As pointed out by Del Soldato (2020) p. 124, Cardano's attitude toward Aristotle's authority is more nuanced than it seems, as the Italian philosopher criticizes the Aristotelians of his time far more than Aristotle himself.

[33] Lüthy and Nicoli (2022) p. 19.

[34] Girolamo Cardano (1664) l. II, 61: "Verum rursus dices: si frigus nihil est actu, sed sola caloris privatio, quomodo frigida refrigerant, ut calida calefaciunt? Frigus semper est cum multa materia, impossibile vero tenuissimum aliquid esse frigidum, multa enim materia impedit, ne calor penetrare possit neque moveri, quare hoc modo refrigerat. [...] Equidem (ut dixi) nihil aliud est frigidum, quam caloris privatio [...]."

ontologically speaking, is nothing more than a privation, although it may be described using active verbs.

While Cardano's view represented a sharp rejection of the Aristotelian doctrine, another famous and influential anti-Aristotelian theory of contrariety in the 16th century was that of Bernardino Telesio (1509-1588). Like Cardano, Telesio radically departs from Aristotelian cosmology by rejecting the doctrine of the four elements. He argues that heat and coldness operating in matter suffice to account for the full range of natural phenomena, dispensing with the need for any further physical principles, including substantial forms. In contrast to Cardano, however, Telesio maintains that heat and coldness are *positive* contraries, i.e., opposing real qualities that are the fundamental driving forces of change in the natural world.

Despite Telesio's criticisms of Aristotle, his terminology preserves some aspects of the conceptual background of the Aristotelian theory of contrariety.[35] In Telesio's view, heat and coldness indeed behave like form and privation at the metaphysical level, while retaining their status as positive contraries at the empirical level.[36] Telesio argues that, when properly understood, Aristotle's theory of natural change – as a relation between two contraries successively determining a common substrate – ultimately leads to his own theory of heat (representing the form) and coldness (representing the privation) as the sole two principles acting upon matter.[37] In fact, Telesio relies on passages where the Stagirite himself compared the relation between heat and coldness to that between form and privation.[38]

One important reason for Telesio's theory is that, according to him, not all actions could be reduced to incapacity or privation of heat's operations. In particular, the active character of coldness is necessary for explaining the whole variety of bodies – whose structure can be either homogeneous or heterogeneous – that we observe in nature:

---

[35] On Telesio's anti-Aristotelian stance and the evolution of his reputation as an opponent of Aristotle, see Garber (2016).
[36] Hattab (2017) p. 442.
[37] Bernardino Telesio (1587) l. III, p. 83: "Ipse id Aristoteles utrum eadem omnium principia sint inquirens apertissime pronunciat. Omnium, inquit, principia eadem sunt, et non eadem, veluti corporum forsan sensibilium, calidum quidem, ut forma, frigidum alio modo privatio est; et materies id, quod haec est, potentia primum per se."
[38] Arist. *Metaph.* Λ 4.1070b11-13.

The hot, indeed, gathers those things that are of the same kind [*generis*]; for they say that fire separates, as it gathers things that are of the same kind; for it happens to also separate things that are different. Cold, however, joins and gathers similarly both things that are of the same kind and those that are not of the same kind.[39]

Telesio was not isolated. Other *novatores* willing to follow Telesio, like Tommaso Campanella (1568-1639), also posited a relation of real contrariety between heat and coldness.[40] In response to these new doctrines, many 16th-century Scholastics sought to develop consistent rebuttals in defense of the traditional Aristotelian view of heat and coldness. They argued that, while heat and coldness had indeed to be conceived as positive qualities, they alone could not account for all natural changes. Instead, they maintained that these qualities had to be understood in conjunction with the substantial forms of the elements, which explained the deeper ontological structure of earth, air, fire, and water. Regarding the conception of heat and coldness, the essential difference between the Scholastics and *novatores* like Telesio and Campanella lied in the fact that, for the former, the role of heat and coldness in natural change was mediated by substantial forms.

In the 16th century, the reception of the works of Alexander of Aphrodisias (ca. 150-215), renowned as an eminent commentator of Aristotle, further complicated this problem, as Alexander was held to have defended that elemental qualities are the 'forms' (i.e., the substantial forms, in scholastic terminology) of the four elements. Defenders of the traditional scholastic doctrine according to which the substantial forms of the elements are different from elemental qualities pointed out that, while substantial forms do not have positive contraries, qualities like heat and coldness do, thereby

[39] Bernardino Telesio (1587) l. III, p. 87: "Calidum enim, quod congregat ea, quae generis eiusdem sunt; segregare enim quod inquiunt facere ignem, congregare est ea, quae sunt eiusdem generis; contingit nanque, excipere aliena. Frigidum autem, quod coniungit, et congregat similter et ea, quae eiusdem et que non eiusdem sunt generis."

[40] Tommaso Campanella (1939) p. 194: "*Delli principij attivi*. In questa mole corporea materiale di tanta statua disse Dio che nascessero due fabri incorporei, ma non potenti senza corpo stare; et però son nati il calore e'l freddo, principij attivi, et però di potenza diffusive: Subito nemici furo, volendo ciascun di loro occupar tutta la stanza materiale: onde a combattere cominciaro, havendo ordinato Dio che di tal discordia gran bene riuscisse." On Campanella's view on qualities, see Granada (2007).

suggesting that elementary qualities could not be entirely identical to the elements' substantial forms.

The most orthodox scholastic Aristotelians of the 16th century thus maintained a nuanced position:

(1) Heat and coldness are real qualities.
(2) They are real contraries.
(3) However, they are not the substantial forms of the elements themselves.

It is often assumed that the eventual decline of the conception of coldness as a positive contrary to heat was driven primarily by the rise of atomist and corpuscularist theories of matter, which became dominant in the 17th century.[41] This is partly true, as atomism played a decisive role in the reduction of heat to motion. However, the role of atomism in the decline of the contrariety between heat and coldness has been overstated. For instance, key figures in the revival of corpuscularianism, such as Julius Caesar Scaliger (1484-1558) and Daniel Sennert (1572-1637), continued to hold that heat and cold were positive contraries. Even Pierre Gassendi (1592-1655), one of the most radical defenders of atomism, maintained that heat and cold were real opposites. By contrast, one of first modern thinkers who explicitly endorsed the view that coldness is a privation of heat, namely Cardano, continued to think within a quality-based ontology, distinct from mechanicist perspectives that would later reduce heat to motion.[42]

Other traditions undeniably played a role in the transformations of heat in the 16th century. When Galileo (1564-1642), in his early notebooks, enumerates the different conceptions of the relation between heat and coldness, he notes, in addition to the Aristotelian view (which he still deemed correct at that time) and the reductionist stance of Plutarch, that "physicians" hold a hybrid view in which there exist two types of cold – one positive and the

[41] For instance, Rozemond (2009) p. 80, writes: "[...] Insofar as I am aware, thinkers who regarded cold as a privation of heat had a mechanistic account of heat. I know of no representative of the view that cold is a privation of heat where heat as it appears to us is a quality existing in the physical world."
[42] As Lüthy (2012) pp. 86-8, has shown, an atomist reinterpretation of Cardano's natural philosophy can be found in David Gorlaeus.

other privative. Galileo is repeating here doxographical teachings common at that time, and typical of the Jesuit tradition in which he was trained, as evidenced by William Wallace.[43] In fact, this idea that some coldness was privative could be traced back, in the medical tradition, to Galen (129-216), who viewed the coldness proper to aging, to some diseases and death as a decrease of natural heat (*per extinctionem caloris naturalis*).[44] The increasing importance of medical theories for natural philosophy in the 16th century led to the dissemination of the idea that the Aristotelian perspective was ill-equipped to address cases where coldness was more accurately defined as a privative phenomenon in relation to heat. These observations concerning the role of non-Aristotelian traditions in the transformations of the concept of heat raise the question of the precise role that scholastic Aristotelians played in the ultimate rejection of Aristotle's conception of heat and coldness as positive contraries. As the next section of this study will argue, the late scholastic tradition still contributed in its own way to this process.

### *4. The Status of Resistance*

One of the issues that contributed to disentangle the concepts of heat and positive contrariety in the late medieval and early modern period was the problem of resistance and its nature. Understanding this requires an explanation of how resistance emerged as a lively topic of debate regarding the interactions between heat and coldness. This debate was intimately linked to the problem of reaction, where the challenge was to explain how opposing forces could act and react upon each other. The challenge was particularly complex because the Aristotelian understanding of action posits two asymmetric entities, the agent and the patient, with the agent required to exert a force greater than that of the patient (a principle that will be called below the 'principle of the agent's superiority'). How can a cold body react on a hot body that acts upon it, particularly when the hot body is larger and more intense?

[43] See Wallace (1984) pp. 79-80, who demonstrates that Galileo's presentation of the debate closely matches that of the Jesuit Paolo Valla's.
[44] Galen (1643) II, p. 23a.

An influential solution to this problem, developed by Parisian masters of the 14th century such as John Buridan, Albert of Saxony, Nicole Oresme, and Marsilius of Inghen, posited that qualities like heat and coldness could engage in mutual action and reaction because they possess two distinct properties, i.e., an active power (*potentia activa*) and a resistive power (*potentia resistiva*), having different degrees.[45]

For instance, heat was conceived as highly active but with a very low degree of resistance. A cold body could then react on a hot body despite being affected by it, because its degree of activity, while inferior to the hot body's active power, was still superior to the hot body's resistance. This explanation allowed these philosophers to account for how heat and coldness can act and react on each other while saving the principle of the agent's superiority.

This explanation of reaction was widely – though not universally – accepted in the 15th and 16th centuries, yet it raised a serious difficulty: What is the exact relationship between activity and resistance? Are they really distinct powers, or are they aspects of the same quality only distinguished by the mind (corresponding to what scholastic philosophers called a *distinctio rationis*)?

Opposed to the medieval Parisian tradition that defined activity and resistance as two distinct powers, many thinkers – most notably the so-called 'Oxford Calculators' – rejected any real distinction between them, arguing that to resist is simply to act. This debate persisted in the scholastic tradition during the Renaissance.[46] A defender of the conceptual distinction between activity and resistance often discussed in the 16th century was Paul Soncinas (d. 1494). He argues that these properties were *relative*, not absolute, and therefore not mind-independent.[47] For Soncinas, the same coldness can be described as active in terms of its physical effects on bodies (e.g., cooling) but it can also be described as resistive in terms of its impeding effect on heat.[48] This

[45] See Caroti (1989).
[46] See Caroti (1995).
[47] On this topic, see the pioneer work of Des Chene (1996) pp. 49-50, on which this section heavily relies concerning Soncinas, Zabarella, and Suárez.
[48] Paul Soncinas (1579) IX, q. 6, 209b: "[...] Esse activum et esse resistivum est esse relativum, cum dicatur ad aliud, nihil enim est activum aut resistivum in seipsum. Et ideo, sicut eadem res est albedo et similitude, ita eadem res est activitas et resistentia."

mind-dependent character of action-related properties implies that activity and resistance are not ontologically distinct powers (*potentiae*) but simply different ways of describing one quality with respect to other qualities.

By contrast, Jacopo Zabarella (1533-1589) and Francisco Suárez (1548-1617) – representing the Paduan and scholastic branches of Aristotelianism, respectively – both defended the idea that resisting is really distinct from acting. For Zabarella, resistance is not an action but something fundamentally different: resistance is neither an active power nor a passive one. According to him, resistance has no contrary, as it refers to the diminution or privation of another thing's action. By differentiating resistance from any type of action or power, Zabarella makes room for a *sui generis* phenomenon that exists alongside reaction, and which lies outside the class of items organized into pairs of contraries (agent vs. patient; active vs. passive powers). His strategy for legitimizing this particular conception of resistance involves integrating it into the more familiar terminology of reaction by making a distinction between two types of reaction. In contrast with *positive* reaction, which falls into the category of action and occurs when heat positively acts on coldness to diminish it, Zabarella calls "privative reaction" the resistance offered by coldness against its destruction by heat. For a reader familiar with Aristotle's understanding of reaction, where 'reaction' typically signifies 'contrary action' or 'action in return,' the concept of privative reaction might appear as a pure contradiction.

Through this conceptual reworking, resistance is thus presented as a non-active phenomenon – the tendency of a thing to maintain its own state in opposition to external forces, which is defined independently of any contrariety.[49] Zabarella attributes resistance to the effort (*nisus*) of a form to persevere in its own being: When coldness resists heat, it does so not through an active power, but through its natural tendency to conserve its own state.[50] Thus, while the active power of coldness is defined in opposition to heat, its resistance arises from an intrinsic inclination to persist that is not a relational property.

[49] Jacopo Zabarella (2016) vol. 1, l. XII, p. 538, l. 9.
[50] *Ibid*., ll. 8-27.

While pertaining to a different intellectual trend, Francisco Suárez similarly elaborates on the concept of resistance, arguing that it is ontologically identical to a thing's tendency to conserve its own being. Rejecting Soncinas' view, Suárez also notes that resistance essentially entails a type of privation – specifically, the privation of an external agent's action. In his *Disputationes metaphysicae*, he writes:

> Regarding this sense of resistance, therefore, it must be said that it does not consist in any positive act coming from that power which is said to be the force of resistance, but it rather consists in the privation of an act. [...] Hence such a power of resistance is rather some impotency, or some kind of incapacity, than some kind of power. [...] This actual and formal resistance only consists in the fact that the subject, in virtue of a quality or disposition existing in it, prevents another form or action from being introduced in it [...]. And from this, it can be understood that what is commonly said about this latter mode of resistance is true, that one quality can be more active than resistive, and vice versa; because this resistance does not derive from activity, but precisely from information or disposition.[51]

We can see that Suárez is indebted to the medieval Parisian tradition described above, positing a distinction between activity and resistance. However, unlike for Buridan and his ilk, who defined resistance as a *power*, Suárez makes it clear that resistance does not fall into the category of power or action, strictly speaking. The resistance of a quality is, rather, its *incapacity* to undergo change, stemming from its disposition to maintain its own state. As such, resistance is not defined as a positive contrary to anything else.

The same view was common in the late 16th century scholastic tradition. Before Suárez, Francisco de Toledo had distinguished three meanings of the term 'resistance,' defining the resistance proper to a quality as its self-conserving tendency, by which it "defends" itself against external action,

[51] Francisco Suárez, *Disputationes metaphysicae*, disp. 43, sect. 1, nn. 9-11: "De hoc ergo resistendi modo dicendum est non consistere in aliquo actu positivo, proveniente a virtute illa quae vis resistendi esse dicitur, sed consistere potius in privatione actus. Unde talis resistendi vis potius est impotentia, vel incapacitas quaedam, quam propria potentia, ideoque non debuit tertium illud membrum in divisione potentiae adiungi. [...] Unde talis resistendi vis potius est impotentia, vel incapacitas quaedam, quam propria potentia [...]. Nam haec actualis et formalis resistentia solum in hoc consistit, quod subiectum per qualitatem aut dispositionem in ipso existentem, impedit ne alia forma vel actio in ipsum introducatur [...]. Atque hinc intelligitur de hoc posteriori resistendi modo verum esse quod communiter dicitur, unam qualitatem posse esse magis activam quam resistivam, et e converso; quia haec resistentia non consequitur activitatem, sed praecise informationem aut dispositionem."

without being identified to reaction as such.[52] The Coimbran commentators present a similar threefold typology of resistances (negative, privative, and contrary), where a quality's resistance is a special property distinct from action and reaction.[53]

A close conception of resistance also attracted the attention of early modern natural philosophers such as Galileo. In his early works usually called the *Juvenilia*, Galileo discussed the nature of resistance in opposition to contrary actions:

> The first doubt is: What is resistance? [...] I say first that resistance is not formally an action. [...] I say, secondly, that resistance is not a passion. [...] I say, third, that resistance is the permanence in its own state against a contrary action. I said 'against a contrary action.' Resistance indeed, although it is not an action, connotes however a contrary action, which it impedes. I said 'permanence in its own state' because I do not distinguish resistance from the very existence of the thing, as it persists; on the contrary, resistance formally means this permanence in its <own> state, and it connotes the impediment of a contrary action.[54]

Here, Galileo echoes the Jesuit perspective exemplified by Suárez, emphasizing that resistance is neither an action nor a passion but rather the persistence of a thing in its own state against opposing forces. Remarkably, this property is primarily used to define the relations between heat and coldness rather than, as it would later be, the behavior of bodies moving through space. Let us note that for Zabarella, Galileo, or Suárez, resistance is not supposed to *replace* reaction as the correct description of how heat and coldness interact. It is rather presented as a *complementary model* for describing how a quality like heat behaves and relates to external actions, this behavior being defined independently of contrariety.

The recognition of resistance as a distinct concept within Aristotelian natural philosophy has profound implications for the understanding of

---

[52] Francisco de Toledo (1588) I, c. 7, q. 15, 144-5.

[53] College of Coimbra (1616) I, c. 9, q. 3, a., 3, col. 490E-491B; a. 4, col. 492D-493B.

[54] Galileo Galilei (1890) pp. 170-1: "Prima dubitatio sit, quid sit resistentia. Dico, primo: resistentia non est formaliter actio [...]. Dico, secundo, resistentiam non esse passionem. [...] Dico, tertio, resistentiam esse permanentiam in proprio statu contra actionem contrariam. Dixi 'contra actionem contrariam': nam resistentia, quamvis non sit actio, connotat tamen actionem contrarii, quam impedit. Dixi 'esse permanentiam in proprio statu': quia non distinguo resistentiam ab ipsa existentiae rei, ut permanet; immo resistentia formaliter dicit hanc permanentiam rei in suo statu, et connotat impedimentum actionis contrariae."

heat-related phenomena. It appears as a complementary conceptual tool alongside contrariety and reaction for explaining the interactions between heat and coldness. However, since this concept may be extended to all sorts of phenomena, unlike reactions based on contrariety, it is easy to see how this complementary model could also appear as a *competing* model for theorizing thermic phenomena.

While scholastic Aristotelians did not eliminate the concept of contrariety or the associated idea of reaction, they increasingly acknowledged that resistance provided an equally compelling explanation for the behavior of heat. Moreover, resistance could be generalized to other natural processes, thus becoming a broader principle for understanding physical change. This shift towards the concept of resistance fits well with the late 16th-century move toward grounding physical explanation in conservation laws and early notions of inertia. The idea that things tend to conserve their own state and resist change would later become central to the development of mechanical philosophy, laying the groundwork for later scientific advancements in understanding the nature of motion and resistance.

## *5. Conclusion*

The evolution of the notions of heat and coldness in the late medieval and early modern periods demonstrates a gradual shift in how these concepts were understood within Aristotelianism. With respect to its final development in the 17th century, this shift was, however, incomplete. The persisting understanding of coldness as a positive contrary to heat in these periods reveals the deep-rooted importance of contrariety for maintaining the coherence of Aristotelian natural philosophy, but also highlights the emergence of significant transformations in the conceptual framework that would eventually lead to a new paradigm of heat.

In the late Middle Ages, confronted with the problem of explaining how one and the same quality can have different degrees of intensity, Scholastics already began to analyze heat and coldness as inverse values on a same scale. While remaining committed to the Aristotelian framework of contrariety, they sought to circumvent the principle of incompossibility of

contraries in the same subject. This shift did not erase the distinction between positive and privative contrariety but it was nonetheless crucial, as it introduced the idea that heat and coldness were not opposite essences, but rather extremes of a single continuum.

In the Renaissance, major transformations occurred, coming from anti-Aristotelian trends exemplified by Cardano or Telesio. The most systematic attempt to destroy the Aristotelian view on heat came from Cardano, who undertook to show that the 'argument from action' in favor of it could be denied. Importantly, these trends, which might be labeled as 'anti-Aristotelian,' were often indebted to doctrines on heat developed within different branches of Aristotelianism itself.[55] These theses and the reactions they generated marked a period of intellectual flexibility around the Aristotelian framework, where traditional concepts such as contrariety, power, and privation could be reconciled with new observations and theories. The resulting landscape was one of doctrinal plurality, where heat was still defined as a real quality, whereas the status of coldness generated much more disagreement.

However, even the most orthodox branches of scholastic Aristotelianism, such as the Jesuit school, began to incorporate a new explanatory framework that moved away from the traditional notion of positive contrariety between heat and coldness. Defining resistance independently from the notions of power and action, which traditionally come in opposite pairs, late scholastic Aristotelians saw this concept as a compelling explanation for thermic phenomena and, simultaneously, as a more universal feature of natural processes. The increasing acceptance of resistance within scholastic thought – even among those who continued to adhere to a quality-based framework – indicates a growing openness to new ways of thinking about thermic phenomena, taking into account self-conserving properties of matter akin to the laws of inertia and conservation principles.

The late scholastic tradition never fully disentangled heat from contrariety, for its understanding was still based on the distinction between an agent and a patient, which implied a duality of (active and passive) powers that

[55] On the relative nature of the term 'anti-Aristotelianism' during the Renaissance and its primarily institutional significance, see Del Soldato (2020) pp. 120-6.

prevented it from viewing heat exchanges as a process aimed at thermic equilibrium through purely quantitative laws. Still, the conceptual shifts that took place between the 14th to the 16th centuries undeniably set the stage for a revised conception of heat, which will eventually acquire a new ontological status in the 17th century. These developments reflect the complex nature of intellectual change in this era, illustrating how terminological continuity and conceptual innovation coexisted in the transitional period separating the premodern world from what is still often called the 'Scientific Revolution.'

**Acknowledgments:** Many thanks to Simone Guidi, Enrico Pasini, and two reviewers for helpful comments on a previous version of this article.

## Bibliography

**Primary Sources**

Albert of Saxony (1999) *Expositio et quaestiones in Aristotelis Physicam. Quaestiones (l. IV-l. VIII)*. Vol. 3. Ed. B. Patar, Louvain-la-Neuve & Louvain & Paris: Éditions de l'Institut supérieur de philosophie & Peeters.

Albert the Great (2013) *Liber de praedicamentis*. Ed. M.S. Noya, C.G. Steel, S. Donati, *Opera omnia*, vol. 1/1b. Münster: Aschendorff.

Aristotle (1984) *The Complete Works of Aristotle. The Revised Oxford Translation*. Ed. J. Barnes. Princeton: Princeton University Press.

Bernardino Telesio (1587) *De rerum natura iuxta propria principia. Libri IX*. Napoli: Orazio Salviani.

Blasius of Parma, *Quaestiones super VIII libros Physicorum* (secunda redactio). Ms. Vatican Library. Vat. lat. 2159.

College of Coimbra (1616) *Commentarii in duos libros de generatione et corruptione Aristotelis Stagiritae*. Venezia: Andrea Baba.

Francisco de Toledo (1588) *Commentaria, una cum quaestionibus, in librum de generatione et corruptione Aristotelis*. Lyon: Sibille de La Porte.

Galen of Pergamon (1643) *De temperamentis*. *Epitome galeni opera*. Lyon: Jean Caffin & François Plaignard.

Galileo Galilei (1890) 'De primis qualitatibus'. *Juvenilia*. *Opera omnia*. Vol. 1. Firenze: G. Barbèra.

Girolamo Cardano (1664) *De subtilitate libri XXI*. Basel: Heinrich Petri.

Jacopo Zabarella (2016) *De rebus naturalibus*. Ed. J.M.G. Valverde, Leiden & Boston: Brill.

James of Forlì (1496) *Tractatus de intensione et remissione formarum*. Venezia: Octavianus Scotus.

John Buridan (2016) *Quaestiones super octo libros Physicorum Aristotelis (secundum ultimam lecturam), Libri III-IV*. Ed. M. Streijger, P.J.J.M. Bakker, Leiden & Boston: Brill.

John Duns Scotus (1973) *Ordinatio*. II, dd. 1-3. *Opera Omnia* VII. Ed. C. Balić *et al.*, Città del Vaticano: Typis Vaticanis.
Macrobius (1847) *Commentarii in Somnium Scipionis*. *Oeuvres de Macrobe*. Vol. 3. Ed. H. Descamps *et al*., Paris: Panckoucke.
Marsilius of Inghen (1521) *Abbrevationes super libros physicorum Aristotelis*. Venezia: Octavianus Scotus.
Paul Soncinas (1579) *Quaestiones metaphysicales acutissimae*. Lyon: Charles Pesnot.
Plutarch of Chaeronea (1959) *On the Principle of Cold*. *Moralia*. Vol. 12. Trans. P.H. De Lacy, B. Heinarson, Cambridge MA: Harvard University Press.
Tommaso Campanella (1939) *Epilogo magno (Fisiologia italiana)*. Ed. C. Ottaviano, Roma: Reale Accademia d'Italia.
Walter Burley. *Tractatus primus*. Ms. Vatican Library. Vat. Lat. 817, ff. 203r-223r.

### Secondary Sources

Anton, J.P. (2001) *Aristotle's Theory of Contrariety*. London: Routledge.
Biard, J. (2022a) *Hypothèse matérialiste et pensée radicale. La philosophie de la nature de Blaise de Parme*. Paris: Vrin.
Biard, J. (2022b) 'Blasius of Parma on the Calculation of the Variation of Qualities and Aristotelian Physics' in Di Liscia, D.A., Sylla, E.D. (eds.) *Quantifying Aristotle. The Impact, Spread and Decline of the Calculatores Tradition*. Leiden & Boston: Brill, pp. 232-54.
Bogen, J. (1992) 'Change and Contrariety in Aristotle', *Phronesis*, 37 (1), pp. 1-21.
Caroti, S. (1989) 'Da Buridano a Marsilio di Inghen: la tradizione parigina della discussione *De reactione*', *Medioevo*, 15, pp. 173-233.
Caroti, S. (1995) 'Da Walter Burley al *Tractatus de sex inconvenientibus*. La tradizione inglese della discussione medievale *De reactione*', *Medioevo*, 21, pp. 257-374.
Caroti, S. (2004) 'Some Remarks on Buridan's Discussion on Intension and Remission', *Vivarium*, 42 (1), pp. 58-85.
Clagett, M. (1941) *Giovanni Marliani and Late Medieval Physics*. New York: Columbia University Press.
De Rijk, L.M. (1996) 'Burley's So-called *Tractatus Primus*, with an Edition of the Additional Quaestio "Utrum contradictio sit maxima oppositio"', *Vivarium*, 34 (2), pp. 161-91.
Del Soldato, E. (2020) *Early Modern Aristotle: On the Making and Unmaking of Authority*. Philadelphia: University of Pennsylvania Press.
Des Chene, D. (1996) *Physiologia: Natural Philosophy in Late Aristotelian and Cartesian Thought*. Ithaca & London: Cornell University Press.
Duhem, P. (1913) *Études sur Léonard de Vinci*. Vol. 3. Paris: Hermann.
Fox, R. (1971) *Caloric Theory of Gases from Lavoisier to Regnault*. Oxford: Oxford University Press.
Freudenthal, G. (1995) *Aristotle's Theory of Material Substance: Heat and Pneuma, Form and Soul*. Oxford: Clarendon Press.
Galle, G. (2003) 'Scholastic Explanations of Why Local Motion Generates Heat', *Early Science and Medicine*, 8 (4), pp. 336-70.

Garber, D. (2016) 'Telesio among the Novatores: Telesio's Reception in the Seventeenth Century' in Muratori, C., Paganini, G. (eds.), *Early Modern Philosophers and the Renaissance Legacy*. Dordrecht: Springer, pp. 119-33.

Granada, M.A. (2007) 'New Visions of the Cosmos' in Hankins, J. (ed.) *The Cambridge Companion to Renaissance Philosophy*. Cambridge: Cambridge University Press, pp. 270-286.

Grant, E. (1994) *Planets, Stars, and Orbs. The Medieval Cosmos, 1200-1687*. Cambridge: Cambridge University Press.

Hattab, H. (2017) 'The Metaphysics of Substantial Forms' in Lagerlund, H., Hill, B. (eds.) *The Routledge Companion to Sixteenth-Century Philosophy*. New York & London: Routledge, pp. 436-57.

Ingegno, A. (1980) *Saggio sulla filosofia di Cardano*. Firenze: La Nuova Italia.

Ingegno, A. (1988) 'The New Philosophy of Nature' in Smith, C.B., Skinner, Q., Kessler, E. (eds.) *The Cambridge History of Renaissance Philosophy*. Cambridge: Cambridge University Press, pp. 236-63.

Kessler, E. (1994) 'Alles ist Eines wie der Mensch und das Pferd. Zu Cardanos Naturbegriff' in Kessler, E. (ed.) *Girolamo Cardano: Philosoph, Naturforscher, Artz*. Wiesbaden: Harrassowitz Verlag, pp. 91-114.

Lloyd, G.E.R. (1964) 'The Hot and the Cold, the Dry and the Wet in Greek Philosophy', *The Journal of Hellenic Studies*, 84, pp. 92-106.

Lüthy, C. (2012) *David Gorlaeus (1591-1612): An Enigmatic Figure in the History of Philosophy and Science*. Amsterdam: Amsterdam University Press.

Lüthy, C. and Nicoli, E. (2022) 'Atoms, Corpuscles, and Minima in the Renaissance: An Overview' in Lüthy, C., Nicoli, E. (eds.), *Atoms, Corpuscles and Minima in the Renaissance*. Leiden & Boston: Brill, pp. 1-32.

Martin, C. (2022) 'Pores, Parts, and Powers in Sixteenth-Century Commentaries on *Meteorologica* IV' in Lüthy, C., Nicoli, E. (eds.), *Atoms, Corpuscles and Minima in the Renaissance*. Leiden & Boston: Brill, pp. 87-112.

Pasnau, R. (2011) *Metaphysical Themes. 1274-1671*. Oxford: Oxford University Press.

Rosemond, M. (2009) *Descartes's Dualism*. Cambridge MA: Harvard University Press.

Roudaut, S. (2021) *La mesure de l'être. Le problème de la quantification des formes au Moyen Âge (ca. 1250-1370)*. Leiden & Boston: Brill.

Roudaut, S. (2022) 'Paul of Venice's Theory of Quantification and Measurement of Properties', *Noctua*, 9 (2), pp. 104-58.

Sylla, E.D. (1971-1972) 'Medieval Quantifications of Qualities: The "Merton School"', *Archive for History of Exact Sciences*, 8, pp. 9-39.

Sylla, E.D. (1973) 'Medieval Concepts of the Latitude of Forms: The Oxford Calculators', *Archives d'histoire doctrinale et littéraire du Moyen Âge*, 40, pp. 223-83.

Wallace, W.A. (1984) *Galileo and His Sources: Heritage of the Collegio Romano in Galileo's Science*. Princeton: Princeton University Press.