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Air and friction in the celestial region? Some difficulties in the Aristotelian theory of the production of celestial heat and their solution in the Middle Ages

Abstract
This paper explores the medieval debates raised by problems with the Aristotelian theory of the production and transmission of solar heat presented in *De Caelo* II, 7 and *Meteorologica* I, 3. In these passages, Aristotle states that celestial heat is generated by the friction set up in the air by the motion of celestial bodies. This statement is difficult to reconcile with the Aristotelian cosmology, which presupposes that the heavenly bodies are not surrounded by air, but by ether, and also that the celestial spheres are perfectly smooth, and therefore cannot cause any friction. In their commentaries on *De caelo* and on *Meteorologica*, the Latin commentators elaborated a model that solves these difficulties. In this attempt, they invoke a non-mechanic principle, namely celestial influence.

[Key Words: Aristotle, Late-medieval Philosophy, Physics, cosmology, production of solar heat, De celo, Meteorologica]

Introduction

The[1] Aristotelian theory of the production and transmission of solar heat, presented in *De Caelo* II, 7 and *Meteorologica* I, 3, raised debates among the commentators from Antiquity. In these passages Aristotle explains that motion generates heat. This is proved by the fact that the air surrounding bodies that are thrown rapidly and with force, such as projectiles, heats up, such that lead bullets aget melted (*DC* II, 7, 289a21-28; *Meteor*., I, 3, 341a17-19; 26-27). Starting from these examples of the sublunar region, Aristotle applies this principle to the supralunar region and comes to the conclusion that the air "underneath the sphere of the revolving body" will necessarily heat up due to the movement of this sphere (*DC*, 289a29-30). Subsequently Aristotle explains that in order for the stars to produce enough heat to reach the Earth, they need to move rapidly and be relatively close to our planet. Only the Sun fits both conditions. The stars, that would move fast enough, are too far from the Earth, while the Moon, which is the celestial body closest to the Earth, moves too slowly. This is the reason why Aristotle considers the Sun as the principal source of heat (*DC* 289a31-33; *Meteor*., 341a19-23). In the *Meteorologica*, Aristotle adds another way that heat can be transmitted to the earthly region: fire in the sphere surrounding the sphere of air is often scattered by the motion of the sphere of the Moon and driven downwards (*Meteor*., 341a14-31).[2]

In both texts, Aristotle states that the motion of the celestial bodies generates heat due to friction with the air. Should one therefore assume the presence of air between the celestial spheres? This would imply that the celestial region is not exclusively made of ether. Or should one assume that Aristotle refers to the air that is underneath the supralunar region? This option seems unlikely, as the celestial sphere is separated from the sphere of air by the sphere of fire. Instead of adopting any explanation that would further complicate the matter, it seems more reasonable to suppose that in these passages Aristotle did not mean to elaborate a precise model of the production of celestial heat. In this case, the mention of air could be explained as making an analogy to the production of heat in the terrestrial region, in which the air surrounding fast moving bodies heats up. Yet it seems difficult that Aristotle would adopt such an imprecise theory which moreover contradicts his own cosmology. In addition, Aristotle not only presents his theory in the *De caelo*, but also in the *Meteorologica* (I, 3, 341a17-31).

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[1] This paper is part of my doctoral research at the University of Fribourg (Switzerland), which is supported by the Swiss National Foundation.

[2] For a detailed explanation of the Aristotelian theory of the production of celestial heat, see V. Cordonier, “La transmission de la chaleur solaire comme mouvement médiatisé chez Alexandre d'Aphrodise. Naissance d’un problème et ambiguïté d'un modèle à l’origine de la tradition médiévale”, in *Lieu, espace, mouvement: Physique, Métaphysique et Cosmologie (xiie-xvie siècles)*. Actes du colloque international. Université de Fribourg (Suisse), 12-14 mars 2015, 1-15, here 5-7.

Whatever be the case, the Latin commentators took him literally when he states that heat is generated by friction caused in the air from the motion of the spheres. They tried to clarify the Aristotelian theory of the production of solar heat and to reconcile it with Aristotelian cosmology and physics by focusing on the following issues:

1) How does motion produce heat?
2) How could perfectly smooth spheres revolving against one another cause any friction?
3) How could this friction heat up the air, which is separated from the celestial sphere by the ether and the sphere of fire?
4) How could celestial motion transfer to the Earth through inalterable celestial spheres?

While the first and more general problem could be solved within Aristotelian physics, the other three entail aporias of the Aristotelian theory of the production of celestial heat. In the following, I will focus on the second and third problem, with a short mention of the first. I will leave the last problem for another occasion.

I shall consider medieval commentaries on Aristotle's *Meteorology* from the 13th to the 15th century by masters who taught at the Parisian Arts Faculty and by continental masters who were strongly influenced by them. For the 13th century, I have consulted the *Questions on Meteorology* attributed to Siger of Brabant contained in ms. Munich, BSB, Clm 9559, ff. 51v-71v[3] and the anonymous set of questions on *Meteorology* transmitted in ms. Paris, BnF, latin 14698, ff. 62v-82v.[4] For the following century, I have used the two redactions of Oresme's *Questions on Meteorology*,[5] as well as the question commentaries on this Aristotelian text by John Buridan,[6] Albert of Saxony[7], Themo

[3] For the list of questions of this commentary and a summary of their content see : F. VAN STEENBERGHEN, *Siger de Brabant d'après ses œuvres inédites*, vol. 1, *Les œuvres inédites*, Louvain 1931 (Les philosophes belges. Textes et études 12). For the arguments in favour of the attribution of this text to Siger of Brabant, see M. Grabmann, *Neu aufgefundene Werke des Siger von Brabant und Boetius von Dacien* (Sitzungsberichte der Bayerischen Akademie der Wissenschaften. Philosophisch-philologische und historische Klasse), Munich 1924, 8-10; F. Van Steenberghen, *Siger dans l'histoire de l'Aristotélisme*, Louvain 1942, 515-527; J. J. Duin, *La doctrine de la Providence dans les écrits de Siger de Brabant*, Louvain 1954, 205-207.

[4] Gauthier proposed to attribute this text to James of Douai, a Parisian master active in the second half of the thirteenth century: R. A. Gauthier, "Trois commentaires 'averroïstes' sur l'Éthique à Nicomaque" in *Archives d'Histoire Doctrinale et Littéraire du Moyen Âge* 16 (1947), 187-336, here 227-229; Id., *Magnanimité: l'idéal de la grandeur dans la philosophie païenne et dans la théologie chrétienne*, Paris 1951, 468-469, footnote. This attribution was contested by Costa: I. Costa, *Anonymi Artium Magistri Questiones super Librum* Ethicorum *Aristotelis* (Paris, BnF, lat. 14698), Turnhout 2009, 60-79.

[5] For information about the two redactions of Oresme's *Questions on Meteorology*, see A. Panzica, "Une nouvelle rédaction des *Questions sur les Météorologiques* de Nicole Oresme", in *Bulletin de philosophie médiévale* 57 (2015), 257-64; Ead., "Nicole Oresme à la Faculté des Arts de Paris: les *Questions sur les Météorologiques*", in *Archives d'Histoire Doctrinale et Littéraire du Moyen Âge* 84 (2017), 7-89.

[6] For the list of manuscripts transmitting Buridan's *Questions on Meteorology*, see E. FARAL, "Jean Buridan: notes sur les manuscrits, les éditions et le contenu de ses ouvrages", in *Archives d'histoire doctrinale et littéraire du Moyen Âge* 21 (1946), 1-53, here 22-24 and CH. LOHR, *Latin Aristotle Commentaries*, I.1, *Medieval Authors*, Firenze 2010, vol. 1, 257.

Iudaeus,[8] John Versor[9] and Blasius of Parma.[10] For the 15th century, I have consulted two Polish question commentaries on *Meteorology*: Peter of Sienno's[11] and Paul of Worczyn's.[12] These texts, which were written in the years 1420-1425, are deeply influenced by the Parisian tradition, as they follow Oresme and Buridan quite faithftully and often quote them. Among all these commentaries,

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[7] Only two complete manuscripts of Albert of Saxony's *Questions on Meteorology* are known: Erfurt, Dep. Erf., CA 4° 299, ff. 53r-103v and Berlin, Staatsbibliothek zu Berlin — Preußischer Kulturbesitz, lat. 2° 387, ff. 63-102v. Two Krakow manuscripts contain a compilation consisting of questions I.18-I.31 from the first redaction of Oresme commentary on *Meteorology* and questions I.1-I.14, II.7-17, as well as books III and IV, from Albert's commentary: Kraków, Biblioteka Jagiellońska, 635, p. 177-236 and 686, ff. 101ra-134va. A Parisian manuscript contains also a compilation from Albert (II.10–III.9) and Oresme (but in this case the second redaction of Oresme's commentary: I.1–II.9): Paris, BnF, lat. 15156, ff. 226r-288v. Two other manuscripts contain fragments from the first question of Albert's commentary: Wien, Österreichische Nationalbibliothek, Cod. Vind. lat. 5453, f. 48vb and Kraków, Uniwersytet Jagielloński, Biblioteka Jagiellońska, 751, f. 2r-v. On these manuscripts see A. PANZICA, "Albert of Saxony's *Questions on Meteorology*: Introduction, Study of the Manuscript Tradition and Edition of book I-II.2", forthcoming in *AHDLMA* 86 (2019).

[8] Native of Münster in Westphalia, Themo Iudaues studied at the Parisian Arts Faculty and incepted in 1349, under the master Dominicus of Clavasio. He subsequently taught in Paris and Erfurt (1350). On Themo's career and works, see H. Hugonnard-Roche, *L'œuvre astronomique de Thémon Juif* (Hautes Études Médiévales et modernes 16), Genève-Paris 1973, esp. 11-23. Themo's *Question on Meteorology* are transmitted in a considerable number of manuscritps, the major part of which have an Italian origin: Città del Vaticano, BAV, Vat. lat. 2177, ff. 1r-92v; Padova, Seminario vescovile, cod. 24, ff. 1r-50v; Ferrara, Biblioteca comunale Ariostea, Ms. Classe II, n. 380, ff. 1r-60v; München, BSB, Clm 6962, ff. 93r-146r; Venezia, Biblioteca Nazionale Marciana, lat. XIV, 129, ff. 77r-122v (olim: Venezia, Biblioteca del Monastero di S. Michele, 136); Paris, BnF, lat. 6547, ff. 1r-33r (incomplete copy). Themos' *Questions* were printed many times in the Renaissance: the first edition was printed in Pavia in around 1480; other editions were printed in Venice by Ottavianus Scous in 1496, 1507, 1515, 1522 (with Gaetanus of Thiene's commentary on Meteorology). Georges Lockert printed Themos's *Questions* in Paris in 1516 and 1518 (with other commentaries on Aristotle by Parisian masters of the 14th century: Albert of Saxony's *Questions on Physics* and on *De caelo*; John Buridan's *Questions on De anima* and on the *Parva naturalia*).

[9] John Versor († after 1482) obtained the degree of Master of Arts in 1435 and taught in the Parisian Arts Faculty. His *Questions on Meteorology* are transmitted in a great number of manuscripts and Renaissance editions: see O. WEIJERS, *Le travail intellectuel à la Faculté des arts de Paris: textes et maîtres (ca. 1200-1500)*, Turnhout 2003, vol. 5, 174; CH. LOHR, *Latin Aristotle Commentaries*, I *Medieval Authors*, Firenze 2010 (Corpus Philosophorum Medii Aevi. Subsidia 17), vol. 1, 346]. To the manuscripts mentioned in these inventories we have to add the manuscript Salamanca, Biblioteca Universitaria, 2463, ff. 202r-219v, and the following copies, which have a Polish origin: Krakow, Jagiellonian Library, 2007, ff. 163r-192r; BJ 2024, ff. 340r-398v; BJ 2072, ff. 114r-139v; Poznań, Archiwum Archidiecesjalne 36, ff. 61r-106r); Munich, Bavarian State Library, Clm 520, ff. 222r-255r. On the Polish copies see A. Panzica, "Commenter les *Météorologiques* à l'Université de Cracovie au XVe siècle: de l'assimilation des modèles parisiens à la naissance d'une tradition polonaise", forthcoming in *Recherches de Philosophie et Théologie Médiévales* 2020.

[10] Blasius of Parma (1347-1412) taught in Pavia, Padua and Bologna. His *Questions on Meteorology* are transmitted in five manuscripts: Città del Vaticano, BAV, Chigi, O IV 41, f. 59r-105r; Città del Vaticano, BAV, Vat. lat. 2160, f. 62r-138v; Firenze, Biblioteca Medicea Laurenziana, Ashburnham 185, f. 1r-59v; Chicago, University Library, 10, ff. lra-37va (incomplete copy); Città del Vaticano, BAV, Vat. lat. 4082, ff. 82vb-85va (only qq. I.8-9). For the recent identification of the las witness, see A. Panzica, "Les *Questions sur les Météorologiques* du manuscrit Vat. Lat. 4082 : Blaise de Parme, Nicole Oresme et l'*Inter omnes impressiones"* forthcoming in *Bulletin de philosophie médiévale* 61 (2019).

[11] Peter of Sienno († before 1460) obtained the degree of Master of Arts at Krakow University in 1408. His *Questions on Meteorology* are transmitted in manuscript Wrocław, Biblioteka Uniwerstyteka, IV Q 54, ff. 13r-165r.

[12] Paul of Worczyn (ca. 1380 – † after1426) studied in Prague (bachelor in 1403), Leipzig (maser of Arts in 1409) and Krakow (doctor in Theology in 1423) and taught in Leipzig and Krakow. The only known complete copy of his *Questions on Meteorology* is contained in ms. Kraków, Biblioteka Jagiellońska, 2073, ff. 112r-224r. The prologue of this work is transmitted also in ms. 2007 (ff. 163r-v) of the Jagiellonian Library and ms. Clm 520 (ff. 222r-v) of the Bavarian State Library in Munich. The fourth book is also transmitted separately in ms. 2024 (ff. 375r-398v) of the Jagiellonian Library.

only the first book of Buridan's *Questions* is edited.[13] I have quoted Oresme's and Albert's from the editions I am preparing,[14] and the other texts from the manuscripts.

As a preliminary step for the discussion of the production of celestial heat, I will shortly present the medieval debate about the connection between motion and heat (§ 2). I will subsequently treat in more detail the problems posed by the Aristotelian theory of motion and heating of the sphere of fire in more detail (§ 3) before coming to the solution commonly adopted by medieval commentators of Aristotle's *Meteorology* starting from the thirteenth century (§ 4-5).

2. Motion and heat: a not self-evident connection

The Aristotelian assertion that movement generates heat raised many questions among Latin commentators of the *Meteorologica*, who tried to determine the causes and the modalities of this process. These developments, absent in the Late-antique and Arabic commentators of the Aristotelian text, are a peculiarity of its Latin reception and take the form of digressions.[15]

As showed by Galle, from the thirteenth century onwards, Latin commentators try to explain why local motion generates heat.[16] Some authors, like Thomas Aquinas[17] and the author of the *Questions on Meteorologica* of ms. Paris, BnF, latin 14698,[18] hold that motion is the *per se* cause of heat and refer to metaphysical arguments to support this position. [19] Other authors, such as Albert the Great,[20]

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[13] It is however difficult to access this edition, as it is part of an unpublished doctoral dissertation: S. Bages, *Les Questiones super tres libros Metheororum Aristotelis de Jean Buridan: étude suivie de l'édition du livre I* (Thèse de Doctorat de l'École des Chartes, 1986).

[14] The first book and the first two questions of the second book of Albert of Saxony *Questions on Meteorology* (which corresponds to the first book of Aristotle's *Meteorology*) are in press and will be published in the *Archives d'Histoire Doctrinale et Littéraire du Moyen Âge* 86 (2019): A. Panzica, "Albert of Saxony's *Questions on Meteorology*: Introduction, Study of the Manuscript Tradition and Edition of Book I-II.2".

[15] In his commentary of the *Meteorologica*, Albert the Great explicitly qualifies the analyses of the production of heat through motion and light as digressions. Albert the Great, *Meteora*, lib. 1, tract. 1, cap. 11, ed. P. Hossfeld (Köln, 2003), 14-16: *Et est digressio declarans, qualiter ex motu generatur calor*; cap. 12, 17-18: *Et est digressio declarans, utrum lumen sit causa caloris in inferiori spatio aeris*.

[16] On this problem see G. Galle, "Scholastic Explanations of Why Local Motion Generates Heat", *Early Science and Medicine* 8 (2003), 336-370.

[17]Thomas Aquinas, *In Aristotelis libros De caelo*, II, 7, lect. 10, Opera omnia iussu impensaque Leonis XIII P. M. edita, vol. 3 (Roma, 1886), 158, n. 10. On Aquinas' theory of the production of heat through motion, see G. Galle, "Scholastic Explanations", 353-355.

[18] Anonymous, *Questiones in Meteorologica*, I.12, ms. Paris, BnF, latin 14698**,** f. 67ra: "Propter hoc dicendum, secundum intentionem Philosophi, quod motus generat calorem per se, et hoc videtur sentire Philosophus in VII *Metaphysice*. Hic enim loquit de hiis [67rb] que per se generantur ab agente, et ibi dicit quod motus generat calorem; ergo motus generat calorem per se. Item, secundo *Celi et mundi* dicit Philosophus quod de aptitudine motus est ut generetur calorem. Omne autem generativus per se oportet quod aliquo modo sit univocum et simile ipsi generante".

[19] Medieval commentators always refer to Averroes as being in favour of the idea according to which motion is an essential cause of heat. This position was indeed defended by the Commentator in his *Great Commentary* on Aristotle's *De caelo*: Averroes, *Commentarium magnum in libro De celo et mundo*, II, 7, comm. 42, ed. F. J. Carmody (Leuven, 2003), vol. 2, 355: 197-205. On Averroes' theory of the production of heat through motion see G. Galle, "Scholastic Explanations", 346-349.

Peter of Auvergne[21] and the author of the *Questions on Meteorologica* attributed to Siger of Brabant,[22] argue that motion is the accidental cause of heat and use a physical explanation. Galle insisted on the fact that in the thirteenth century these explanations were considered as mutually exclusive.[23] On the contrary, I found that these explanations seemed complementary after the second half of the fourteenth century.

The thesis according to which motion generates heat by accident and only under certain conditions was predominant among Latin commentators. The main argument in favour was that if motion were an essential cause of heat, all movements should produce heat in the same way. On the contrary, Parisian commentators as Oresme, Albert of Saxony and Themo Iudaeus, stressed the fact that, when two bodies move against one another, the parts that are in contact heat up more than the ones that are not. For example, as shown by Aristotle in *De caelo*, the parts of a moving body in contact with the air wear out faster than the ones that are not. Other examples introduced by the commentators concern drilling and sharpening iron: we observe in fact that the exterior parts of the drill and the iron heat up more than the interior ones.[24]

While almost all commentators concur that the movement causing friction in the parts of the moving bodies generates heat, they do not agree on the cause of this phenomenon. According to Albert the Great and Nicole Oresme, heat is generated as friction induces a rarefaction of the moving bodies' surfaces. As it is, in the Aristotelian system of qualities rarefaction is related to heat,

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[20] Albert the Great, *Meteora*, lib. I, tract. 1, cap. 11, ed. Colon., 15: 19-41. On Albert the Great's theory of the production of heat through motion, see G. Galle, "Scholastic Explanations", 349-351.

[21] Peter of Auvergne, *Questiones in De caelo*, II.24, in G. Galle (ed.), *Peter of Auvergne, Questions on Aristotle's De caelo: a critical edition with an interpretative essay* (Leuven, 2003), 219: 110-125.

[22] Anonymous (Siger of Brabant?), *Questiones in Meteorologica*, I.16, ms. München, BSB, Clm 9559, f. 54vb: "Et ideo dicendum quod motus est generativum caliditatis non per se, sed sicut est movens prohibens, et preter ipsum motum sequitur alia causa caliditatis […]. Cum enim aliqua corpora tangunt se invicem per motum, disgregantur partes corporis quod movetur vel movet per motum, et tunc una pars incipit calefieri et postea alia disponitur ad caliditatem". G. Galle, "Scholastic Explanations", 351-352.

[23] G. Galle, "Scholastic Explanations", 336-370.

[24] Nicole Oresme, *Questiones in Meteorologica*, *redactio nova*, I.8, § 15: "cum aliquid movetur, sicut terebellum, partes extremales calefiunt citius quam partes centrales, et tamen ita bene partes centrales moventur localiter sicut partes extremales; centrales enim non calefiunt nisi a partibus extremalibus primo calefactis»; § 20: «si aliquis sit motus localis sine confricatione et partium distractione, ille non est causa caloris. Patet, quia partes centrales terebelli circa quas non fit confricatio, non calefiunt nisi a partibus extremalibus calefactis propter confricationem. Similiter, si illud ferrum in molendino circa quod volvitur lapis molaris moveretur una cum illo lapide versus eandem differentiam positionis sic quod non fieret confricatio, non calefieret"; Albert of Saxony, *Questiones in Meteorologica*, I.8, § 11: "si illud infra quod movetur ferrum molendini moveretur cum eo et non fieret aliqua confricatio, istud ferrum non calefieret. Iterum quando aliquid taliter calefit, tunc partes interiores non calefiunt, posito quod ita velociter moverentur, quia non confricantur et non calefiunt ex motu, nisi forte ex consequente, quia, exteriores calefacte, calefaciunt interiores. Iterum quando sagitta fortiter proicitur, si plumbum esset involutum cum ligno et non confricaretur cum aere, numquam calefieret aut liquefieret, ymmo semper talia calefiunt in superficie. Iterum etiam, quando lapis colligitur vel percutitur cum ferro et generantur sintille, ignis non fit nisi ubi est talis confricatio". Themo Iudaeus, *Questiones in Meteorologica*, I.7, ed. 1522, Venetiis apud Iunctas, f. 92vb: "Item videmus quod quando aliquid calefit propter motum, adhuc partes centrales vel interiores [*ed*.: inferiores] non calefiunt aliquo modo, posito tamen quod ita velociter [93ra] moveantur sicut quedam alia que calefiunt. Et hoc est quia non confricantur cum aliquo. Et si contingeret quod calefierent, hoc magis esset propter alterationem ab aliis partibus calefactis, et hoc esset propter motum localem istarum partium. Item si telum vel sagitta de ligno ubi esset plumbum infixum in medio ligni fortissime moveretur, non calefieret neque liquefieret plumbum, sed calefactio fieret in superficie ligni ubi fit confricatio".

but neither Albert the Great nor Oresme produced a convincing explanation of how heat is generated through rarefaction.

In his *Questions on Meteorology*, Buridan states that any movement implying friction of the surfaces of the moving bodies generates heat by itself. In doing so, he refers to Averroes' *Great commentary* on *De caelo* and to the opinion of the physicians. According to Averroes' essentialistic explanation, motion is a natural property of fire by which fire is reinforced (*vigoratur*) and without which gets extinguished. The physicians, on their side, maintain that some natural properties are shared by all members of a certain species without any explainable cause, as these properties are essential to that species. In this sense, heat is essential to any motion implying rarefaction in the same way as laughing is essential to the human species. [25]

With this assertion, Buridan manages to combine the physical explanation, which saw heat as an accidental product of the friction between moving bodies, and the metaphysical one, according to which every movement generates heat by itself.[26] This solution is justified on a philosophical level: as the relationship between rarefaction and heat is postulated, and not demonstrated, the physical explanation of the generation of heat through friction relies ultimately on a metaphysical basis. In fact, the supporters of the theory that every movement generates heat believed in an essential relationship between motion and heat. Albert the Great, on his side, goes one step further stating that not all movements generate heat, but only those which imply friction. However his explanation stops here. To explain why rarefaction generates heat, he has to resort to a metaphysical theory: rarefaction and heat are intrinsically related and the first causes the second by itself. Buridan's

[25] John Buridan, *Questiones in Meteorologica*, I.4, § 7, Bages, 55-56: "Sed bene dubitant doctores et expositores unde est et quare quod talis motus confricatus et distractus calefacit, et multi super hoc assignant rationes non multum valentes, et alii probabiliores"; § 11-12, Bages, 58-59: "Et Averrois, commentator Aristotelis, in 2° *Celi* posuit quod multe sunt proprietates ignis naturales, ut caliditas, siccitas, raritas, levitas et motus localis. Idcirco si ignis movetur, vigoratur, et si quiescit, extinguitur; et cum ignis vel mixtum fuerit de aliquibus harum proprietatum in actu, secundo consquuntur naturaliter alie. Propter hoc ergo in igne vel aere vel mixtis sequitur caliditas ex rarefactione vel motu locali veloci. Et alii dixerunt corporibus naturalibus multas virtutes convenire a tota specie, et non deberet de talibus querere aliam causam. Et sic a tota specie contingit motui distractivo calefactio, sicut a tota specie hominis contingit ridere et ignis calefacere. Sed qualicumque modo vel virtute dicamus sic motus calefacere, oportet quod hoc sit per corporum que sic calefaciunt confricationem et partium se tangentium velocem et violentam distractionem". In this passage Buridan does not specify who are the supporters of the second theory, but only refers to them as "alii". However, in another passage of his *Questions on Meteorology* he attribute this theory to the physicians: "sed etiam et formas substantiales istorum inferiorum quibus ab arte divina mediante celo date sunt secundum totas suas species virtutes proprie potentes in effectus proprios sibi convenientes, quorum rationes reddi non possunt per qualitates elementorum et mixtiones et proportiones eorum, quas virtutes vocant medici "a tota specie" non ex ignorantia cause, sicut fatui eis imponunt, sed ex vera scientia: sciunt enim hec provenire ex substantialibus naturis ipsorum corporum naturalium per virtutes proprias quas secundum suas totas species habent ab arte divina, etc.", I.17, § 17-18, Bages, 235-236.

[26] Galle, who studied Buridan's position on the production of heat trough motion basing on Buridan's *Questions on De celo*, has classified this author among the supporters of the essentialistic explanation (Galle, "Scholastic Explanations", 364). However, in his *Questions on Meteorology*, Buridan states that not every kind of motion generates heat, which seems to exclude that, according to him, motion is *per se* a cause of heat: "Apparet mihi de ista questione prima conclusio quod in multis casibus, motus localis [...] calefacit [...]. Sed etiam in multis casibus motus frigefacit", Buridan, *Questiones in Meteorologica*, I.4, § 3, Bages, 53. For a detailed analysis of Buridan's discussion of the production of heat trough motion, see A. Panzica, *De la Terre à la Lune. Les débats sur les Météorologiques d'Aristote au Moyen Âge latin (XIIe-XVe siècle)*, forthcoming.

analysis therefore reveals the compatibility of the physical and metaphysical theories about the production of heat through motion, hitherto considered as alternative to one another.

Buridan's approach to the question of the production of heat through motion will serve as a model for the commentators of the *Meteorologica* of the fifteenth century. The Parisian master John Versor, who took up the work of Buridan, holds that Albert's and Aquinas' theories agree, with the first describing how motion generates heat (*quomodo*) and the latter explaining the causes of this phenomenon (*quare*).[27]

Latin commentators commonly agree on the fact that light is another important source of heat. In accordance with *Meteor*. I, 3 340a29-32, in which Aristotle states that the reflection of celestial rays is the cause of heat in the lowest region of air, and following the optical theories about burning mirrors,[28] medieval authors admitted that the light of the stars, particularly of the Sun, could produce heat in the terrestrial region.[29] Nevertheless this explanation could not be applied to the

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[27] John Versor, *Questiones in Meteorologica*, I.4, Köln, 1488, f. 2vb: "Sciendum primo quod, ut dicit Sanctus Thomas, motus localis de per se et non solum per accidens, sicut quidam dixerunt, habet calefacere. Et fundat se in maxima metaphysicali, scilicet quod primum in unoquoque genere est causa omnium illorum que sunt posterius. Cum ergo motus localis sit primus omnium <motuum>, sequitur quod est per se causa omnis motus et alterationis. Et quia inter qualitates secundum quas est per se alteratio caliditas est prima et magis activa, sequitur quod motus localis primus est causa calefactionis quam cuiuscumque alterationis. Cum hoc tamen stat quod sit causa aliarum alterationum secundum quod corpus mobile est magis vel minus dispositum ad alias qualitates que sunt principia alterationum. Si tamen corpus mobile aut corpus iuxta quod fit motus localis sit calefactibile, magis habet quod sit calefactivum talis corporis quam alterativum secundum aliam alterationem. Non tamen sequitur quod celum calefiat, licet velocissime moveatur. Sed corpus iuxta quod movetur, secundum quod est susceptibile caloris, motu suo calefit [...]. Sciendum secundo quod, ut dicit dominus Albertus, quando aliquid mobile localiter est passivum et susceptivum peregrinarum impressionum, talis motus localis distrahit quodammodo partes eius, et distrahendo rarefacit, et rarefaciendo calefacit. Et quia est calefactivus et distractivus partium mobilis, etiam calefactivus. Et sic ex hoc satis patet quod sit calefactivus, dum tamen mobile sit passibile. Et iste modus loquendi non differt a priori, nisi quia melius explicat modum per quem motus localis calefacit quam assignare videtur causam quare sit calefactivus. Sed Sanctus Thomas causam assignat et non loquitur de modo calefaciendi. Et ita, si queratur causa quare motus localis est calefactivus, potest assignari ratio Sancti Thome; si ergo queratur de modo, assignabitur ratio Alberti. Sit igitur conclusio responsiva ad quesitum: motus localis est per se calefactivus. Conclusio satis patet per explicationem duarum opinionum predictorum doctorum".

[28] According to the tradition, Archimedes used concave mirrors to concentrate the Sun rays and burn the Roman invaders' ships that were beseiging his home city Syracuse in 212 BC. The example of burning mirrors was commonly used by medieval commenators of Aristotle's *Meteorology* in order to prove that the Sun's rays generate heat. See for instance: Albert the Great, *Meteora*, lib. 1, tract. 1, cap. 12, ed. Colon. VI/1, 16:37 - 17: 12; John Buridan, *Questiones in Meteorologica*, I.5, § 7, Bages, 72-73 ("Tertia conclusio est quod lumen solis est calefactivum: patet per experientiam quod per multos radios simul agregatos vel per cristallum rotundum vel per speculum concavum fit ignis et comburitur innatum comburi"); Nicole Oresme, *Questiones in Meteorologica, redactio antiqua* I.11, § 26, ed. Panzica, in preparation ("Ideo dico ulterius quod posset experiri si lumen Lune calefacit, et hoc per magnum speculum concavum vel per vas vitreum plenum aqua, quia si ita sit, tunc posset fieri unum speculum per quod tot radii congregarentur, quod si sunt calefactivi comburerent, nisi sit impedimentum"; *redactio nova* I.9, § 18, ed. Panzica, in preparation (Item hoc [namely, the heating power of the stars] potest experiri per magna specula comburentia, congregando radios Lune vel radios aliarum stellarum); Albert of Saxony, *Questiones in Meteorologica*, I.9, § 17, ed. Panzica, forthcoming in *AHDLMA* 2019 ("Tunc de Sole non est dubium quod calefacit per lumen, ut patet ad sensum et per experientias de speculis comburentibus").

[29] The fact that sunlight generates heat was obvious and did not require any demonstration. As far as the other planets are concerned, commentators often refer to the Aristotelian assertion according to which nights of full Moon are hotter than the others (*De partibus animalium*, IV, 680a31-34). This fact was considered a proof that the light of the Moon has heating power. For some commentaries on *Meteorology* holding this view, see: John Buridan, *Questiones in Meteorologica*, I.5, § 7, Bages, 73 ("Quarta conclusio est quod lumina astrorum sive ab astris ad nos multiplicata sunt calefactiva. Hoc enim arguitur de luna per Aristotelem in 4° *De partibus Animalium*, dicentem quod noctes sunt calidiores in pleniluio propter lumen lune"); Nicole Oresme, *Questiones in Meteorologica, redactio antiqua* I.11, § 26,

spheres of fire and air, as the production of light trough heat required a process of reflection. Such a process could only occur in a dense body, such as the terrestrial surface, and not in the spheres of air and fire. Alhough medieval commentators conceded that the difference in density between these two spheres did produce some reflection,[30] they considered that this reflection was not strong enough to cause heat. In order to explain the heating of the spheres of air and fire, medieval commentators had to recurr to a different explanation.

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ed. Panzica, in preparation ("Dico tertio quod lumen Lune et stellarum calefacit; et probo istud primo auctoritate Aristotelis in quarto *De partibus animalium*, ubi probat hoc per hoc quod ceteris paribus noctes sunt calidiores in plenilunio"); *redactio nova* I.9, § 18, ed. Panzica, in preparation ("Item specialiter de Luna patet, quia lumen Lune est calefactivum, auctoritate, in De animalibus, ubi dicit quod noctes in plenilunio sunt calidiores"); Albert of Saxony, *Questiones in Meteorologica*, I.9, § 17, ed. Panzica, forthcoming in *AHDLMA* 2019 ("Iterum de Luna patet per Aristotelem in quarto *De partibus animalium*, et per hoc concludit quod noctes sunt calidiores in plenilunio"). More generaly, most medieval commentators maintain that the stars and the planets reflect the light of the Sun. As a result, their light must be considered of the same nature as the light of the Sun and needs to cause the same effects, first of all heating up the bodies it reaches. See for instance John Buridan, *Questiones in Meteorologica*, I.5, § 7, Bages, 73 ("Et hoc est rationabile [namely, the fact that all celestial bodies generates heat] quia, sicut habetur in *De Proprietatibus Elementorum*, omnia astra recipient lumen a sole sicut et luna; modo recipiens ab aliquo virtutem aliquam, debet cum illo participare in simili effectu illius virtutis"); Nicole Oresme, *Questiones in Meteorologica*, *redactio nova* I.9, § 18, ed. Panzica, in preparation ("Et breviter sit ista prima conclusio: lumen Lune et etiam lumen aliarum stellarum calefacit. Patet: lumen Solis calefacit; ergo et lumen aliarum stellarum. Antecedens patet experientiam [...]. Consequentia principalis patet: nam lumen aliarum stellarum non est nisi lumen Solis reflexum; si ergo lumen Solis est calefactivum, et lumen aliarum stellarum erit calefactivum. Et confirmatur, nam calefacere est de ratione ipsius luminis; ergo, si est aliquod lumen quod est calefactivum, sicut lumen Solis, sequitur quod omne lumen erit calefactivum"; Albert of Saxony, *Questiones in Meteorologica*, I.9, § 17, ed. Panzica, forthcoming in *AHDLMA* 2019 ("Tunc dico de Luna et stellis quod lumen eorum calefacit, quod patet quia non est nisi lumen Solis reflexum vel refractum. Et iterum quia si aliquod lumen calefacit, ergo et omne, ex quo est per se et ratione luminis"). In favour of the thesis according to which celestial bodies receive their light from the Sun, scholastic authors often referred to the *De causis proprietatum elementorum*, an Arabic treatise which they attributed to Aristotle. This text, which was commented by Albert the Great, is published in the Cologne edition of Albert's *Opera Omnia*: *De causis proprietatum elementorum*, ed. P. Hossfeld, Aschendorff 1980 (ed. Colon. VI/1), lib. 2, tract. 1, cap. 1, 90: 24-59. For the discussion about the heating power of the Sun and the other celestial bodies in medieval commentaries on Aristotle's *De caelo*, see. Grant, *Planets, Stars, and Orbs: the Medieval Cosmos, 1200—1687*, Cambridge-New York 1996, 603.

[30] A detailed explanation of this phenomenon can be found in the first redaction of Oresme's *Questions on Meterology*: "Primum est quod omnis radius in medio duorum dyaphanorum diversorum in perspicuitate frangitur. Hoc patet in *Perspectiva* et a Lyncolniense [Alhacen, *De aspectibus*, VII, II, 8.1-8.5, ed. P. Pietquin, *Le septième livre du traité De aspectibus d'Alhazen, traduction latine médiévale de l'Optique d'Ibn al-Haytham*, Bruxelles 2010, 100-109; Robertus Grossatesta, *De iride seu de iride et speculo*, ed. L. Baur, *Die philosophischen Werke des Robertus Grosseteste, bischofs von Lincoln*, Münster 1912, 74: 9-10]. Et patet etiam experientia. Et ideo, si denarius sit in fundo vasis, est aliquis locus a quo posset videri si vas sit plenum aqua, et non videretur si esset plenum aere; et causa est quia radius visualis frangitur in medio inter aerem et aquam, que sunt diversa in perspicuitate. Et similiter Sol prius luceret in fundo si esset plenum aqua quam aere, propter eandem causam. Secundo suppono quod aer est densior vel magis opacus quam ignis in spera, et ignis quam celum, tanto vel plus quanto aqua est densior aere. Et hoc est rationabile, quia elementa proportionaliter se habent in raritate et densitate sicut se habent in gravitate et levitate".

3. The motion and the heating of the sphere of fire: the problems posed by the Aristotelian theory

If one accepts the principle that only the motion implying friction generates heat, it is difficult to explain how the motion of the planets and the spheres, which does not cause any friction, could possibly generate heat in the sublunar region.[31]

This difficulty was aggravated by another problem. We have seen that in the third chapter of the *Meteorologica*, Aristotle states that the fire and the air that are located in the upper atmosphere move in a circular motion because they are carried by the rotation of the celestial sphere. This circular motion scatters the fire and drives it downwards, causing heat (*Meteor*. I, 3, 340b29-341a31).

The commentators of the *Meteorologica* noticed that attributing a circular motion to the sphere of fire caused some difficulties. In fact, according to the Aristotelian theory of natural places, every element should be accorded only one type of motion: the celestial bodies have a circular motion, while the bodies of the sublunar region have a rectilinear one (*DC* I, 2, 268b30-269a2). Hence it seems difficult that fire, which moves upwards in a rectilinear way, could also rotate in the upper atmosphere.[32] Moreover this motion seems in contradiction with the principle according to which every element should keep still once it reaches its natural place (*DC*, I, 9, 279b1-2).[33]

Yet the rotation of the sphere of fire and the upper part of the sphere of air is proven by the movement of comets. Medieval commentators believed like Aristotle that comets are atmospheric phenomena, and not celestial bodies. Like all other sublunar bodies, comets must have a rectilinear motion, and not a circular one, which is against all observation. The only way to explain their

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[31] For instance, Blasius of Parma expresses this difficulty in the following terms: "Licet iste conclusiones sint bene dicte, non tamen conferunt proposito, quia questio principalis querebat utrum celum suo motu calefaciat ista inferiora [...]. Modo, cum spere supercelestes non sint dure, et etiam cum tali motu corporum supercelestium non sit fricatio aliqua, cum sint corpora valde bene polita, hinc est quod ex dicta difficultate non posset videri quomodo celum per motum eius calefaciat hic inferiora"; *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 70va. Cf. Albert of Saxony, *Questiones in De celo*, II.19, ed. B. Patar (Louvain-Paris, 2008), vol. 2, 370: 34-44; 372: 79-83.

[32] This difficulty was raised by almost all the commentators. See for instance, for the thirteenth century: ANONYMOUS (Siger of Brabant?), *Questiones in Meteorologica*, I.9, ms. München, BSB, Clm 9559, f. 53ra: "Intelligendum quod motus circularis ignis non est naturalis igni secundum propriam naturam ignis, quoniam unius corporis simplicis est unus motus simplex secundum naturam, et ignis est corpus simplex; ergo eius tantum erit unus motus naturalis. Ignis autem motum naturalis est motus rectus sursum; ideo etc. »; Anonymous, *Questiones in Meteorologica*, I.14, ms. Paris, BnF, latin 14698, f. 68ra: "Motus naturalis qui debetur ignis secundum suam naturam est motus a deorsum in sursum. Iste enim est motus levium. Motus enim qui est violentus et contra naturam est a sursum in deorsum. Uni autem corpori est tantum unus motus naturalis, quia unum corpus naturalem tantum habet unam naturam, et motus naturalis est secundum naturam illius corporis. Et ex hoc apparet quod motus circularis ipsius ignis non est motus qui debetur ei secundum suam naturam, sed alius motus". For the fourteenth century see for example: Nicole Oresme, *Questiones in Meteorologica, redactio antiqua*, I.4, § 4: "unius corporis simplicis est unus motus simplex, ut dicitur primo *Celi*; cum ergo ignis naturaliter habeat motum sursum, non habet alium motum nisi sit violentus; ergo non movetur circulariter a celo ».

[33] Nicole Oresme, *Questiones in Meteorologica, redactio antiqua*, I.4, § 5: "Quinto: omne corpus naturale, quando est extra locum naturale, movetur illic, et dum pervenit, quiescit naturaliter; ergo, cum locum sursum sit naturalis igni, ignis naturaliter habet quiescere".

circular motion while maintaining the Aristotelian thesis of their terrestrial nature is therefore to attribute this motion to the air surrounding them.[34]

But there is more: as we have seen above, Aristotle states that the celestial sphere heats up the sublunar region not just through the motion of the celestial bodies, but also through the motion of the sphere of the Moon, which drags the sphere of fire and throws the fire downwards. Nevertheless, according to Aristotle, the surface of the celestial sphere is perfectly smooth and should thus not be susceptible of dragging other bodies.[35] In such case, one has to explain how the sphere of the Moon can transmit its motion to the sphere of fire and to the sphere of air, generating heat in the latter.

4. The motion of the sphere of fire: the solution of the medieval commentators

In the first redaction of his *Questions*, Oresme introduces a series of distinctions in order to clarify how two contiguous bodies can move with respect to one another. He claims that an uneven surface cannot be contiguous to a smooth one without some void intervening, unless this space was filled by some unevenness of the contiguous bodies.[36] He subsequently explains that a body A contiguous to another body B can move in three violent ways:

1) It can move towards B and pull it (*expulsio*).
2) It can move away from B and pull B to itself (*attractio*).
3) It can move sideways, dragging B along (*detractio*).[37]

[34] Nicole Oresme, *Questiones in Meteorologica*, *redactio antiqua*, I.4, § 24: "Hoc non obstante est tertia conclusio quod [spera ignis] movetur secundum Aristotelem. Cuius signum est quia comete moventur circulariter, que sunt in aere; et per consequens aer et ignis ita moventur". John Buridan, *Questiones in Meteorologica*, I.4, § 15, Bages, p. 61: "Scitur autem quod sic moveatur ignis per stellam comatam que aliter non posset moveri motu diurno, cum non sit in celo sed in igne vel aere, et non posset sic velociter moveri dividendo medium quiescens, ideo sic movetur delata in motu. Et ex eodem motu stelle comate, creditur communiter quod sic moveatur superior regio aeris quia ibi putatur esse stella comata et non in spera ignis, eo quod valde cito consumpta esset materia eius propter excessivam ignis caliditatem"; John Versor, *Questiones in Meteorologica*, I.4, ed. 1488, f. 4ra: "Et quod sic moveantur docet experientia de motu comete, qui est de natura elementari et secundum rei veritatem generatur in suprema regione aeris […] et circulariter movetur, ut ad sensum patet". Albert of Saxony, *Questiones in De celo*, II.19, Patar, vol. 2, 371: 69 – 372: 75.

[35] John Buridan, *Questiones in Meteorologica*, I.4, § 13, Bages, 60: « Sed tunc est dubitatio quomodo ex motibus corporum celestium generetur caliditas in spera ignis et in superiori regione aeris, quia celum non est distrahibile et ignis etiam ibi non videtur distrahi sed potius volvi cum ipso celo motu diurno, sicut contentum movetur ad modum continentis, ut homo in navi. Et cum hoc etiam celum ponitur esse perfectissime leve et politum, et tale non habet distrahere corpus quod tangit"; Nicole Oresme, *Questiones in Meteorologica*, *redactio nova*, I.8, § 6: "Deinde specialiter probatur quod motus celi non calefacit speram ignis. Patet: nam hoc esset quia celum movet speram ignis secum; sed hoc non, quia ipsum celum est corpus politissimum, et ergo in nulla sui parte ignis potest sibi adherere ut circumducatur vel rapiatur una cum cello"; Albert of Saxony, *Questiones in Meteorologica*, I.8, § 3: "Deinde arguitur in speciali quod celum non calefaciat speram ignis per suum motum quia non movet ipsam, cum sit corpus politum, et etiam iste motus esset violentus, et nullum violentum est eternum; et tamen, si sol moveret, semper moveret".

[36] Nicole Oresme, *Questiones in Meteorologica*, *redactio antiqua*, I.4, § 18: "Tunc dico correlarie quod nullum asperum et politum possunt esse contigua per totum: patet statim, quia tunc esset vacuum inter illas asperitates, si non repleretur locus per asperitatem corporis coniuncti".

[37] Nicole Oresme, *Questiones in Meteorologica*, *redactio antiqua*, I.4, § 19: "Tertia distinctio: quod corpus contiguum alteri tripliciter potest moveri. Uno modo versus sibi contiguum, illud pellendo, sicut homo expellit aerem ante se; se-

In order for one body to drag another (3), their surfaces must be both uneven and in contact. Hence it follows that a body with a smooth surface cannot possibly drag another one. For instance, a perfectly smooth wheel cannot move the air surrounding it. In the same way, the celestial orbs, whose surfaces are perfectly smooth, cannot drag each other and the sphere of the Moon cannot drag the sphere of fire. The surfaces of the celestial spheres, as the commentators argue, do not have any unevenness or "teeth" (*dentes*) who could grab on each other, as happens for example with the sickle and the straw. [38] Indeed, if the sphere of the Moon was to carry the sphere of fire, this motion would not be natural but violent, and would not last indefinitely, since, as Aristotle explains, no violent motion can be perpetual (*DC* II, 3, 286a17-18).[39]

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cundo recedendo et per accidens attrahendo sibi contiguum, sicut homo dum movetur attrahit aerem qui est retro se; tertio lateraliter distrahendo, sicut homo movet aerem collateralem. Et secundum hoc triplex est motus violentus a corpore contiguo, scilicet expulsio, attractio, detractio, et hoc sive moveatur circulariter sive recte".

[38] Nicole Oresme, *Questiones in Meteorologica, redactio antiqua*, I.4, § 20-22: "Tunc pono conclusionem quod nullum corpus perfecte planum detrahit corpus sibi contiguum, licet possit expellere vel attrahere. Patet, quia omnis talis detractio fit per interpositionem partium asperarum invicem, sic quod unum intrat aliud secundum tales partes. Et ideo puto quod si esset una rota perfectissime plana, que solum moveretur circulariter, ipsa non moveret aerem circumstantem. Ex hoc sequitur correlarie quod in celo una spera non detrahit aliam, nec violentat, quamvis moveatur diversimode. Et hoc innuit Commentator, secundo *Celi*, ubi dicit quod ibi non est motus raptus nisi methaphorice et similitudinarie, quia rapere et detrahere est cum violentia, ut ipse dicit [Averroes, *In De celo*, II, comm. 3]. Secundum est quod nec etiam celum motu suo rapit aut detrahit ista inferiora, sicut est spera ignis. Patet, quia superficies concava orbis lune est perfectissime polita – patet secundo *Celi*, igitur superficies convexa ignis sibi contigua est perfecte plana, per primum correlarium; ergo non se invicem detrahunt, immo tunc ignis impediret motum celi"; Nicole Oresme, *Questiones in Meteorologica, redactio nova*, I.8, § 22: "Quantum ad secundum sit ista conclusio quod ignis non ex hoc movetur circulariter cum celo quod celum trahat ignem secum. Patet, quia celum est ita politum quod in nulla parte ignis potest sibi adherere, sic quod ignis una cum ipso circumducatur et ab ipso celo rapiatur. Secundo, a simili: unus orbis celestis motu suo non vehit secum alium; ergo nec in perpetuo celum rapit et trahit secum ignem. Consequentia tenet de se; sed antecedens patet Commentatorem in secundo *Celi*, ubi dicit quod ibi non est raptus nec violentia, nisi fictitie"; John Buridan, *Questiones in Meteorologica*, I.4, § 17, p. 62: "Alia conclusio ponitur quod ignis in spera sua non movetur circulariter motu tractus corporis a corpore, primo quia ille motus esset violentus, quod non videtur rationabile; secundo quia trahens debet habere continuationem vel colligationem cum tracto, vel saltem deberet habere difformes superficies ut partes unius intrent in partes alterius ut rastrum in stipulam, et hoc non invenitur in celo; tertio quia trahens tangit tractum et movet ipsum cum eo". Albert of Saxony, *Questiones in Meteorologica*, I.8, § 17: "Tunc de secundo, qualiter ignis movetur cum celo, est conclusio quod hoc non est quia celum trahat ignem propter contiguitatem. Probatur, quia corpus politissimum non est natum trahere secum aliud, quia talis tractio fit per hoc quod partes unius corporis intrant partes alterius corporis propter asperitatem. Secundo, quia per idem diceretur quod una spera celi trahit secum aliam, quod est falsum, ut dicit Commentator, secundo *Celi*; unde ibi non est raptus neque violentia nisi fictitie". Blasius of Parma, *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 71rb: "concavum orbis lune, quod est locus ignis, est valde tersum et politum, et *non habet dentes*, ut rastrum, quibus dentibus capiatur ignis et moveatur sic et taliter, scilicet motu tracto". Cf. Nicole Oresme, *Le livre du ciel et du monde*, II, 15, Menut and Denomy, p. 440, l. 212 – p. 442, l. 225: "[...] mouvement n'est pas cause de chaleur fors la ou est violence et confrication, si comme il est dit devant, et ou ciel n'est quelcunque violence [...]. D'autre partie, les cielz sont tres perfectement speriques et polis [...], et donque il ne freent en rien un a l'autre ne a autre chose par leurs mouvemens, et par consequent, il ne se entre-eschauffent en rien par ce. Apres le ciel en descendant est l'espere de l'element du feu [...]. Et samble que le mouvement du ciel ne face en ce feu quelcunque chaleur premierement, car [...] la superfice concave du ciel en laquelle est contenu l'element du feu est souverainnement polie et si est aussi la superfice convexe de l'element du feu, et donques par ce mouvement n'est faite confrication ne distraction ne violence ne eschauffement par consequent".

[39] Nicole Oresme, *Questiones in Meteorologica, redactio antiqua*, I.4, § 5: "Quarto: talis motus non potest esse naturalis, quia habet alium; nec violentus, quia movetur a celo motu perpetuo, et nullum violentum est perpetuum, ut dicitur primo *Celi*"; *redactio nova*, I.8, § 7: "Secundo, certum est quod ille motus circularis ignis non esset igni naturalis, cum ex primo *Celi*: 'uni corpori simplici non insunt plures motus naturales' [*DC* I, 268b30-269a2]. Sed quia igni naturaliter inest moveri sursum, sequitur quod sibi non inest naturaliter moveri circulariter, et per consequens inest sibi violenter; et cum violenta non diu durant, cum nullum violentum sit perpetuum, non est verisimile quod tam diu

Buridan offers some more reasons for the difficulties posed by the movement of the sphere of air. First of all, he excludes that the sphere of fire is moved by the sphere of the Moon as the latter, just as every other planetary sphere, moves from East to West. If the sphere of the Moon carried the sphere of fire, as the commentators argue, one would notice that the comets, situated in this sphere, would always move from East to West, which goes against all observation. In fact the comets do not just move in the opposite direction, but also upwards and downwards. Moreover, if the sphere of the Moon carried the sphere of fire, the comets would be delayed by the same amount of time as the sphere of the Moon with respect to diurnal motion, which is false.[40] Neither can one accept that the sphere of fire is moved by the Intelligences that move the orbs, or by the Intelligence that moves the outermost sphere, given that the Intelligences have no special relationship (*appropriatio*) with any sublunar element, differently from what it happens with their spheres. Buridan, supported by Blasius of Parma explains that there is no compelling reason for the first mover to move the sphere of fire and not the other spheres. The relationship between the first mover and the universe is analogous to that of the intellect and the parts of the body: like the intellect, the first mover, which is not locally determined, acts upon the universe as a whole, and not on one part more than another.[41]

After having excluded these possibilities, the commentators conclude that the celestial sphere communicates its circular motion to the sphere of fire by transmitting its virtue (*virtus*). While thirteenth century commentators as the anonymous authors of the sets of questions transmitted in ms. Paris, BnF, latin 14698 and ms. Munich, BSB, Clm 9559, refer to a relationship of obedience (*obedientia*)[42] that binds the sublunar bodies to the heavenly ones, later commentators describe this

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durasset motus circularis ipsius ignis una cum celo". This conclusion was also shared by other commentators of this milieu. See for instance Albert of Saxony, *Questiones in Meteorologica*, I.8, § 3: "Deinde arguitur in speciali quod celum non calefaciat speram ignis per suum motum quia non movet ipsam, cum sit corpus politum et etiam iste motus esset violentus, et nullum violentum est eternum; et tamen, si Sol moveret, semper moveret»; Blasius of Parma, *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 71rb: «Tertia conclusio est hec: ignis in regione eius non movetur circulariter motu tracto a celo. Ista conclusio patet, quia motus tractus non est sine violentia, et nullum violentum est perpetuum, primo *Celi*".

[40] John Buridan, *Questiones in Meteorologica*, I.4, § 17, Bages, 62: "Et illa [spera lune] non movet secum speram ignis trahendo quia tunc cometa moveretur secundum obliquum circulum sicut et luna, et tantumdem vel plus retardaretur a motu diurno sicut et luna, que tamen apparent falsa".

[41]John Buridan, *Questiones in Meteorologica*, I.4, § 18, Bages, 63: "Et quod non sit ibi tractus vel pulsus vel violentia aliqua, probatur quia non videtur quod motores celestes separati a magnitudine et immutabiles debeant habere appropriationem in movendo ad ignem vel ad aliud corruptibile, et quia si primus motor, loquendo modo naturali haberet appropriationem ad ignem cum celo in movendo ipsum motu diurno, non videtur ratio quare non haberet potestatem in sic movendo super totum aerem, aquam et terram cum ille primus motor sit toti mundo et cuilibet parti eius principaliter assistens sine distantia et situ". Blasius of Parma, *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 71rb: "Secunda conclusio est hec: ignis in regione sua non movetur circulariter a primo motore. Patet hec conclusio quia, si moveretur sic a primo motore, non posset reddi ratio quare etiam non sic moveretur aer et aqua et terra, cum nichil sit quod sibi resistat, et cum ita sit quod primus motus non sit <magis> applicatus speris supercelestis quam inferioribus. Est enim assistens toti mundo et indistanter se habens, sicut intellectus humanus indistanter se habet respectu cuiuslibet partis corporis humani".

[42] Anonymous, *Questiones in Meteorologica*, I.14, ms. Paris, BnF, latin 14698, f. 68ra: "Omnia enim illa que fiunt sub corpore celesti gubernantur a corpore celesti et nata sunt ei obbedire. Et quia ignis propinquius est illi corpori celesti, ex

relationship in terms of an influence (*influentia*) exerted by the celestial sphere on the terrestrial one.[43] Regardless of the choice of terminology, all medieval commentators maintain that the heavens induce some virtues that incline the elements to follow their movement. As the sphere of fire is the closest to the celestial sphere, it is the most suitable to receive its properties. That is why its motion resembles diurnal motion. Starting with the fourteenth century, commentators compare the celestial influence to the attraction exerted by a magnet on iron. Like magnetic force, celestial influence decreases with distance. Although it reaches the upper part of the sphere of air, it is not strong enough to transmit any circular motion to water and earth.[44]

This model explains the different movements of the comets. Like the sphere of fire and the upper part of the sphere of air, comets receive the motive influence of the celestial bodies, particularly of

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hoc contingit quod ignis continue movetur circulariter sicut celum, ita quod hoc non est ex natura sua, nec etiam contra naturam, sed hoc est ex corpore celesti, cuius natus est obbedire"; Anonymous (Siger of Brabant?), *Questiones in Meteorologica*, ms. München, BSB, Clm 9559, I.9, f. 53ra: "Quamvis tamen non sit secundum naturam eius [*scilicet*: ignis], tamen per aliam naturam communem qua corpora inferiores nata sunt obediri corporibus superioribus potest dici naturalis".

[43] The question of the influence (*influentia*) exerted by the supralunar sphere on the terrestrial region was commonly discussed by medieval commentators of Aristotle's *Meteorology*. Based on *Meteor*. I, 2, 339a21-24, a passage in which Aristotle states that all virtue in the sublunar region derives from the supralunar sphere as from its first cause (G. VUILLEMIN-DIEM (ed.), *Meteorologica, Translatio Guillelmi de Morbeka*, Leiden 2008 (Aristoteles Latinus X.2 2), 10: 34-36: "Est autem ex necessitate continuus iste superioribus lationibus, ut omnis ipsius uirtus gubernetur inde. Vnde enim motus principium omnibus, illam causam putandum primam"), medieval commentators explored the modalities and the limits of the celestial action. Starting with the thirteenth century, the commentators mentioned three modalities of the celestial causation: motion, light and influence. E. Grant discussed these three modalities of action based mainly on commentaries on Aristotle's *De caelo*: *Planets*, 586-615. For a discussion about commentaries on Aristotle's *Meteorology* from the 12th to the 15th century, see A. Panzica, *De la Terre à la Lune. Les débats sur les Météorologiques d'Aristote au Moyen Âge latin (XIIe-XVe siècle)*, forthcoming.

[44] John Buridan, *Questiones in Meteorologica*, I.4, § 19, Bages, 64: "Ideo consequenter dicitur probabiliter quod ignis a celo moveatur modo consimili sicut ferrum ad magnetem, videlicet quod celum influit per suum motum qualitatem in elementa secundum quam innata sunt sequi ipsum sicut ferrum sequitur magnetem"; Nicole Oresme, *Questiones in Meteorologica, redactio nova*, I.8, § 23: "Secunda conclusio: ignis sic movetur, videlicet circulariter una cum celo, per virtutem sibi impressam a celo, eo modo quo ferrum movetur insequendo magnetem. Patet, quia ex quo non movetur motu raptus, sicut dicebat prima conclusio, non videtur esse alius modus dicendi nisi dicatur quod sic movetur per virtutem sibi impressam a celo"; Albert of Saxony, *Questiones in Meteorologica*, I.8, § 18: "Secunda conclusio est quod ignis sic movetur per virtutem quandam impressam in ipso a celo, eodem modo quod ferrum moveretur insequendo magnetem. Probatur, quia non videtur aliter motus, ex quo non est ibi tractus sive raptus, nec intelligentia est applicata ad movendum ignem sive corpus corruptibile, et eodem modo movetur superior regio aeris"; Themo Iudaeus, *Questiones in Meteorologica*, I.7, ed. 1522, f. 93ra: "Secunda conclusio: quod ignis movetur circulariter propter quandam impressionem vel influentiam in ipsum ignem a celo factam. Item sicut ferrum movetur ad magnetem et ad modum magnetis, sic similiter est de igne suo modo. Ista probatur, quia non videtur aliquis motus alius quod non sit violentus nec raptus, nec est aliqua intelligentia approximata igni, et ideo oportet quod hoc sit per unam influentiam influxam a celo igni. Et conformiter potest dici de aere in superiori regione, licet tamen ibi possit moveri per tractum ab igne, quia non est planus in convexitate, ut patet in littera". Blasius of Parma, *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 71rb: "Quarta conclusio: ignis movetur a celo quadam [*ms.*: quidam] influentia et modo consimili quo magnes attrahit ferrum. Hec conclusio patet, quia non videtur aliter modus ponendi. Unde ymaginandum est celum habere quandam virtutem actractivam a qua ignis consequitur et conservatur in esse". This theory appears also in the *Questions on Meteorology* that can be found in the margin of Matteus Mei de Eugubio's *Questions* transmitted in ms. Firenze, Biblioteca Laurenziana, Fesul. 161, f. 73r-84v. See f. 74ra, *marg. sup.*: "Sed quare <et> qualiter ignis movetur cum celo? Respondetur quod ignis movetur per quandam virtutem sibi impressam in ipso a celo, eo modo quod ferrum movetur insequendo magnetem, ita quod non movetur quia celum trahat ipsum ignem propter contiguitatem. Patet, quia cum sit politissimus, non est aptus trahere secum aliud, quia tractio fit per hoc quod partes unius corporis intrant partes alterius corporis propter asperitatem". See also Nicole Oresme, *Le livre du ciel et du monde*, II, 15, Menut, Denomy, 442: 236-238: "Et peust l'en dire raisonnablement que une de elles est l'influence du ciel ou la vertu de l'intelligence qui le meust qui encline cel aer a ensuir le mouvement du ciel".

the planets, which move is from West to East in opposition to diurnal motion.[45] The West-to-East motion of the comets could be explained by the fact that these bodies, which are not as light as fire or air, follow the diurnal motion with a certain delay, thus giving the impression that they move in the opposite direction.[46] Another possible explanation for the West-to-East motion was to suppose that the comets start following a planet situated in the West and end up following another one situated more to the East as the first one loses its dominance.[47] As for the rectilinear motion upwards and downwards, this can be explained by the fact that the comets follow the motion of a certain planet on its epicycle or by the fact that the exhalation that constitutes the comet is lighter at the beginning, when there is a lot of rarefied and inflammable matter, and heavier at the end, when this matter is exhausted and a denser matter remains.[48]

Once we admit the circular motion of the sphere of fire, it is necessary to clarify if it happens naturally or violently. Both cases seem impossible in the context of Aristotelian physics, since Aristotle attributes rectilinear motion to the elements and states that no violent motion can last indefinitely (*DC*, II, 3, 286a17-18). This would seem to exclude the eternal circular motion of the sphere of fire.

While the commentators acknowledge that the circular motion of the sphere of fire cannot be considered natural, they also affirm that it cannot be considered violent either. A violent motion carries one element away from its natural place; in the case of fire, this motion would be downwards, towards the Earth. Moreover, a violent motion comes from an external agent and not from a principle intrinsic to the moving body. But as circular motion does not remove fire from its natural place and does not come from an extrinsic principle, it should be rather considered beyond

[45] Nicole Oresme, *Questiones in Meteorologica*, *redactio nova*, I.17, § 10: "Causa primi, quod movetur motu diurno, est propter motum ipsius aeris continentis cometam. Sicut enim vinum movetur ad motum dolii continentis ipsum, ita cometa movetur ad motum aeris continentis ipsum; sed quia aer movetur motu diurno ad motum celi, sequitur, etc".

[46] Anonymous (Siger of Brabant?), *Questiones in Meteorologica*, I.32, ms. München, BSB, Clm 9559, f. 58ra: "Motus autem e contrario, scilicet ab occidente ad orientem, est quoniam stella comata non est corpus aliquod ita leve sicut ignis vel aer. Est enim aliquam grossitiem habens; et ideo non potest a velocitate corporum superiorum ita velociter circumferri sicut alie stelle". Anonymous, *Questiones in Meteorologica*, I.30, ms. Paris, BnF, latin 14698, f. 73va: "Secundo videtur moveri cometa ab occidente versus orientem, sicut planeta, videlicet subtardantes. Et iste motus adhuc est a natura celesti: quia enim pars suprema mundi sensibilis revolvitur [*ms*.: resolvitur] et circumducitur cum corpore celeste, tardius revolvitur et circumducitur quam corpus celeste, et ideo comete qui cum illo aere circumducuntur tardius moventur quam natura celestis. Et ex hoc videtur quod huiusmodi comete moventur contra incessum celi primi, scilicet ab oriente versus occidentem".

[47] John Buridan, *Questiones in Meteorologica*, I.13, § 19: "Quarto dicitur quod quasi motu latitudinis alique illarum stellarum inveniuntur declinare versus austrum et alique versus septentrionem, et dicitur quod hoc est insequendo aliquam stellam vel constellationem tunc vigentem et fortiter influentem in illam stellam et sic attrahendo eam versus se sicut magnes ferrum".

[48] Nicole Oresme, *Questiones in Meteorologica*, I.17, § 12: "Aliquando etiam cometa movetur ascendendo et descendendo, et huius causa est quia taliter movetur planeta in suo epiciclo, cuius planete motum cometa insequitur. Vel aliter posset dici quod in principio inflammationis, cum est ibi multum de materia subtili et inflammabili, cometa ascendit, et postea, materia subtiliori consumpta et grossiori remanente, e converso descendit".

nature (*preter naturam*).[49] A common solution to this problem was based on the distinction between particular and universal natures.[50] This distinction implies that, in addition to a simple motion that is derived from its particular nature and from a particular agent, every simple body can also have another motion by its universal nature and by a universal agent. In this sense, the circular motion is not in contradiction with the terrestrial nature of fire. Although beyond the particular nature of fire (by which it moves upwards), this circumstance is in accordance with its universal nature and is caused by a universal agent (the heavenly spheres).[51]

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[49] Anonymous, *Questiones in Meteorologica*, I.14, ms. Paris, BnF, latin 14698, f. 68ra: "Iterum evidenter apparet quod iste motus circularis, non est contra naturam ipsius ignis, sed [qui] motus qui est a sursum in deorsum est contra naturam eius. Unde iste motus circularis non removet ignem a suo loco naturali, et propter hoc dicendum quod iste motus circularis ipsius ignis, si <non> est motus naturalis ipsi gravi, nec est etiam violentus et contra naturam eius, sed est preter naturam eius. Unde differt 'secundum naturam', 'preter naturam' et 'contra naturam' eius". Anonymous (Siger of Brabant?), *Questiones in Meteorologica*, I.9, ms. München, BSB, Clm 9559, f. 53ra: "Nec etiam est contra propriam naturam vel naturalem inclinationem eius, quoniam contrarii motus sunt qui a contrariis incipiunt et ad contraria terminantur; et ideo, cum motus ignis sit a deorsum in sursum, motus contrarius huic motui debet esse a sursum in deorsum. Sed talis non est motus circularis. Per motum enim circularem salvat ignis suum locum naturalem et eandem distantiam ad locum deorsum. Et ideo ille motus non est nec secundum naturam ignis nec contra naturam ignis ». Nicole Oresme, *Questiones in Meteorologica*, *redactio nova*, I.8, § 24: "Sed diceres: quomodo ergo ille motus inest igni? Respondetur quod inest sibi preter naturam, sicut etiam dicit Aristoteles in primo *Celi*. Et potest dici ei impertinens; impertinens enim in arte obligatoria dicitur quod nec sequitur ad positum nec repugnat posito: ita motus circularis ignis, quia nec inest ei naturaliter nec inest ei violenter; ergo potest dici impertinens sibi". Albert of Saxony, *Questiones in Meteorologica*, I.8, § 21: "Tertia conclusio: quod totum celum cathegorematice influit istam virtutem motivam ignis et aeris; et ideo attribuendum est magis parti nobiliori […]. Patet ergo qualiter ista moventur a celo et qualiter iste motus non est contra naturam sed preter naturam, quia non est deorsum et quia est a virtute impressa, sicut de ferro ad magnetem". Paulus of Worczyn, *Questiones in Meteorologica*, I.18, ms. Kraków, BJ 2073, f. 144r: "Respondetur, secundum Orem et Albertum, quod nec sit naturalis nec violentus, sed est motus preter naturam. Primum patet secundum Orem, quia non sequitur formam ignis talis motus, cum ignis secundum suam formam et naturam <movetur> sursum, eo quod omne leve movetur sursum, ex secundo *Celi* [...]. Secundum aliquos autem talis motus dicitur impertinens, quia impertinens dicitur quod nec sequitur nec repugnat, ut dicitur in arte obligista. Sed motus in spera ignis nec omnino sequitur nec repugnat, igitur dicitur impertinens".

[50] For the difference between particular and universal nature, see N. Weill-Parot, *Points aveugles de la nature. La rationalité scientifique médiévale face à l'occulte, l'attraction magnétique et l'horreur du vide (XIIIe-milieu du XVe siècle)*, Paris, 2013, 271-367. N. Weill-Parot shows that the concept of universal nature was used also for the localisation of the sphere of fire (285-287). However, he does not mention cases where this distinction is used to explain the Aristotelian thesis of the *Meteorologica* according to which the circular motion of the celestial sphere carries the sphere of fire and the upper part of the sphere of air.

[51] Nicole Oresme, *Questiones in Meteorologica*, *redactio antiqua*, I.4, § 29-30: "Ad secundam dico quod aliqui motus tales sunt naturales, nec fiunt solum ab inclinatione mobilis, sed cum hoc ab agente universali; et aliquando sunt violenti respectu nature particularis, et non universalis; ideo simpliciter nichil est contra naturam. Ad tertiam, de igne, concedo quod unius corporis simplicis est unus motus simplex per suam formam propriam, sicut per levitatem, sed potest habere alium ab agente universali per virtutem impressam". John Versor, *Questiones in Meteorologica*, I.4, ed. 1488, f. 4ra: "Dubitatur iuxta textum utrum ignis et suprema regio aeris naturaliter moveantur motu circulari. Respondetur quod, secundum naturam propriam, non moventur circulariter, sed recte moventur. Nec etiam moventur illo motu contra naturam, quia nichil quod est a superioribus ad inferiora est contra naturam inferiorum, sed moventur secundum naturam communem, sive supra naturam propriam, quia inferiora nata sunt obedire superioribus". Petrus of Sienno, *Questiones in Meteorologica*, I.14, ms. Wrocław, BU, IV Q 54, f. 33r: "Primo *Celi* dicitur quod unius corporis simplicis est tantum unus motus simplex. Intelligitur per formam propriam, et sic etiam ignis est unus motus simplex sursum per formam propriam, sicut per levitatem. Sed potest bene alium habere ab agente universali per virtutem in eo impressam. De tertio argumento [33v], motus ignis in spera nec violentus est nec contra naturam particularem, sed est preter eam, sed non preter naturam universalem".

5. The production of heat in the sphere of fire: the solution of the medieval commentators

In the light of all these considerations, it is possible to explain how the motion of the celestial bodies generates heat in the sphere of fire and in the upper part of the sphere of air. The Latin commentators maintain that the sphere of fire does not generate heat through its friction with the celestial sphere, as both are completely smooth. One has therefore to suppose that heat in the sphere of fire is produced indirectly. By conveying its circular motion to the sphere of fire, the heaven causes the parts that make up the atmosphere to rarefy and to separate in a process that generates heat through friction. Celestial motion is transferred more intensely to the upper region of the sphere of fire, which therefore moves quicker than the lower one. Speed decreases as we move away from the celestial sphere. It is this difference in speed between the parts of the spheres of fire and air that causes the particles of these spheres to rarefy and generate heat.[52] This solution, which can be found

[52] John Buridan, *Questiones in Meteorologica*, , I.4, § 19, Bages, 64: "Sed celum talem virtutem influit magis in illud quod est sibi propinquius, ideo quod est propinquius celo de ipso igne consequitur perfecte vel quasi motu diurnum, et quod est minus prope minus perfecte consequitur et retardescit a motu diurno quia minus intense recipit de illa virtute sicut ferrum magis distans a magnete tardius movetur ad ipsum; et tandem sic deficit virtus illa propter longe esse a celo quod non habet amplius potestatem movendi ignem vel aerem". Nicole Oresme, *Questiones in Meteorologica, redactio antiqua*, I.8, § 14-15: "Tunc de tertio pono conclusionem quod ignis et aer in sua spera immediate calefiunt motu suo ex rarefactione. Patet, quia ibi fit quedam distractio, quia movetur circulariter, et cum hoc motu mixto, qui etiam est mixtus ex motu locali et ex rarefactione. Secunda conclusio: quod hoc fit mediate a motu celi. Patet, quia eo quod celum movetur, imprimitur in istis quedam virtus motiva localiter ex qua sequitur calefactio, ut dictum est. Et principaliter ex motu solis, qui est satis prope et satis velox »; *redactio nova*, I.8, § 25: "Quantum ad tertium, dico quod ignis non calefit a celo per confricationem eius ad celum. Patet, quia ibi nulla est confricatio, propter hoc quod ipsum celum est corpus politissimum. Sed tamen, quia virtus celi supra est fortior quam infra, partes superiores ipsius ignis moventur velocius quam partes inferiores; et similiter, partes superiores aeris moverentur velocius quam partes inferiores. Et ergo, quia partes inferiores non ita velociter insequuntur partes superiores, ibi fit quedam distractio partium et rarefactio quam consequitur caliditas, et sic ibi causatur calor". Albert of Saxony, *Questiones in Meteorologica*, I.8, § 20: "Secunda conclusio est quod hoc fit quia virtus impressa celo in ipso orbe ignis est fortior prope celum quam longe descendendo et quam in aere, et continue venit debilitando. Et ergo partes ignis superiores moventur velocius, et quia alie non insequuntur ita velociter, ideo in hoc fit quedam distractio et rarefactio, sicut in confricatione, et ex hoc potest causari calefactio; et ita in aere, qui movetur sic usque ad superficies altissimorum montium". Themo Iudaeus, I.7, *Questiones in Meteorologica*, ed. 1522, f. 93ra: "De tertio, scilicet qualiter celum ignem calefacit, sit prima conclusio quod hoc non fit per confricationem celi cum igne. Probatur, quia celum et ignis non confricantur, quia sunt politissima corpora in superficiebus se tangentibus; sed ille non fricant, ut patet per predicta. Secunda conclusio, quod hoc fit a virtute causata a celo in ipso igne, que fortior est prope [*ed*.: propter] agens vel celum quam longe, descendendo versus inferiora. Est fortior etiam in igne quam in aere, et sic procedit continue debilitando. Et ideo partes ignis superiores calefiunt fortius et moventur velocius, et sic consequenter de aliis". Blasius of Parma, *Questiones in Meteorologica*, I.4, ms. Città del Vaticano, BAV, Vat. Lat. 2160, f. 71rb "Quinta conclusio: ignis movetur circulariter velocius aeri. Ista conclusio patet, quia ignis non [71va] movetur circulariter nisi per quandam influentiam a celo defulsam, que influentia intensius recipitur in parte propinqua quam remota. Et ex hac conclusione sequitur hoc correlarium, scilicet quod oportet aerem contriri et dissolvi. Hoc patet, quia pars aeris que est magis propinqua velocius circuit quam pars remota et, cum totus aer sit ut unum continuum, oportet partes aeris notabiliter remotas ab igne separari et dissolvi a partibus superioribus aeris cum contritione quadam. Et ex isto correlario pono unam conclusionem, et est: celum suo motu calefit speras generabilium et corruptibilium – intensius propinquas, remissius remotas". Anonymous, *Questiones in Meteorologica*, ms. Firenze, Biblioteca Laurenziana, Fesul. 161, f. 74ra, *marg. sup*.: "Sed qualiter ignis calefit a motu celi? Respondetur quod non propter confricationem, ut tactum est, sed quia virtus impressa celo in ipsi orbe ignis est fortior prope celum quam longe descendendo inferius et quam in aere, et continue venit debilitando, scilicet descendendo. Et ita partes ignis superiores moventur velocius, et quia alie non insequuntur ita velociter, ita in hoc fit quedam distractio et rarefactio in confricatione, et ex tali potest causari calefactio, et ita in aere qui movetur usque ad superficies altissimorum montium". Paulus of Worczyn, *Questiones in Meteorologica*, I.18, ms. Krakow, BJ 2073, f. 143v: "Sed dubium est per quem modum celum calefacit etc. Dicitur, secundum Orem, quod ratio quia virtus celi est fortior <in partes superiores> quam partes inferiores, et sic partes inferiores non ita velociter insequuntur partes superiores, et sic tunc fit quedam distractio et rarefactio, sicut in confricatione ad quem sequitur calefactio".

in the Parisian commentaries on the *Meteorologica* starting with the mid-fourteenth century, will be adopted by all the other commentators on this Aristotelian text.

Conclusion

Aristotle stated that celestial heat is generated by violent friction of the air caused by the circular motion of the celestial bodies (*DC*, II, 7, 289a21-23). In addition to that, the fire surrounding the air is carried by the circular motion of the celestial sphere and driven downwards (*Meteor*., I, 3, 341a28-31). The adherence to the Aristotelian cosmology involving smooth spheres required commentators to dismiss the possibility of friction both between both the different orbs and the lower border of the celestial sphere and the upper one of the sublunar region, namely the sphere of fire. To solve these problems, Latin commentators explain that the friction causing celestial heat occurs in the sublunar region and is due to the difference of speed between the particles of the spheres of fire and air. It is only in this sense that it can be affirmed that the motion of the celestial bodies generates heat through friction with the air surrounding them. Despite their terrestrial nature, the spheres of fire and air have a circular motion, which derives from the impulse of the celestial sphere. Yet this impulse is not a mechanical one, but is caused by celestial influence, a principle that forces the elements to be assimilated to the celestial bodies.

It is worth noticing that the medieval analyses about the production of heat in the sphere of fire through the motion of the celestial bodies have an exegetical character. The primary goal of the commentators was to solve difficulties and (apparent) contradictions in the Aristotelian theory of the production of heat exposed in *De caelo* II, 7 and *Meteor*. I, 3. Observation and experience playe a modest role in these discussions. This is due both to the particular nature of this problem, which concerns the upper part of the atmosphere, a region that escaped direct observation, and to the general character of scholastic natural philosophy, which is based rather on textual interpretation than on empirical observation.[53] Whatever the case may be, the solution medieval commentators gave to this exegetical problem marks an important departure from Aristotelian physics, which is based on a contiguity. In order to save the coherence of the Aristotelian explanation of the production of celestial heat, the Latin commentators have to recur to a non-contiguous principle, namely the celestial influence. It is not the only case. They will adopt a similar solution for another major problem relat-

[53] A significative example of this way of proceeding in relation to meteorological phenomena is represented by the medieval analyses concerning the curious luminous phenomena described by Aristotle in the fourth and the fifth chapters of *Meteorology*. Before explaining the causes of these phenomena, Buridan states that it is not necessary to prove their real existence: "Quod ergo appareant tales impressiones, non oportet probare sed supponere tamquam ea que visa sunt et experta sicut nobis narrantur", *Questiones in Meteorologica*, I.10, § 3, Bages, 140.

ed to the passages we have considered, namely the transmission of celestial heat to the Earth. I will address this issue on another occasion.