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In Search of the True Nature of the Rainbow: Renewal of the Aristotelian Tradition in the Renaissance and the *De Iride*.[1]

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From the point of view of the history of science the discussion about how the rainbow is formed is one of the most interesting sections of Aristotle's philosophy of nature (*Meteorologica*, Book 3, Chapter 4). This chapter clearly shows that for Aristotle the explanation of a natural phenomenon cannot be reduced to its mathematical formulation but must consider the whole of the changes that take place during its production. In this case, Aristotle acknowledged the need to resort to mathematics in order to single out the cause of the rainbow. Therefore, he did not hesitate to make use of the results obtained by the contemporaneous science of optics, but he also had to go beyond them since one of the essential aspects of the phenomenon, colour, seemed to have been almost ignored in the exact mathematical studies made by the scientists of that time.

With regard to this point, it is relevant to refer to questions extensively dealt with in other Aristotelian works. In the first place, we must refer to the discussion about the so-called "sciences subordinated to mathematics" which takes place in the *Analytica Posteriora* (I.9, 76a9–25 and I.13, 78b36–79a10). These "subordinated sciences", which included optics and harmonics, were devoted to some natural phenomena by assuming principles taken from geometry and arithmetic. These principles explained the cause of a phenomenon by specifying the *reason why* (διότι) it took place, whereas the fact *that* (ὅτι) it took place, i.e. *what* it was, was the object of the subordinated natural science. So the science of harmony studied sounds by expressing them as simple numerical ratios and optics did the same thing for vision by using lines, angles, and triangles.

From this point of view, the case of the rainbow was still more interesting, since it was an example of "double subordination". On the one hand, its causes had to be explained by means

[1] For a classic account on this topic see Carl B. Boyer, *The Rainbow: From Myth to Mathematics* (New York: Tamar Yoseloff, 1959).

of optics (*An. Post.*, I.13, 79a10–16);[2] on the other hand, this "science subordinated to geometry" was then based on the theory that the visual rays were expelled from the eye, and this theory was openly in contrast with what Aristotle maintained in the *De anima* (II.7, 418a29–418b14) and in the *De sensu et sensibilibus* (2, 438b2–8): namely, that vision takes place through a change of a *diaphane* (διαφανὲς), i.e. of a transparent substance (such as air, water, etc.), of which light is the activity. By *diaphane* Aristotle meant that which is visible by means of an alien colour. Colour was considered the "proper sensible" of vision and it was also one of the properties or characteristic qualities of the rainbow. Therefore, the theory of colours developed in Chapter 3 of the *De sensu et sensibilibus* had to play an important role in the explanation of the natural phenomenon of the rainbow.

It is easy to understand why the discussion on the rainbow raised a series of philosophical problems within the Aristotelian tradition. Through the Middle Ages the study of this section of the *Meteorologica* was a source of difficulties for commentators who had to deal with an optical science which was much more advanced than the knowledge of optical phenomena available at the time of Aristotle. Thanks to the progress made by *Perspectiva* it was possible for medieval philosophers to study the optical 'causes' of the rainbow on different foundations, in particular because of the greater importance given to the phenomenon of refraction. We just have to mention Theodoric of Freiberg's (ca 1250–ca 1310) *De iride et de radialibus impressionibus* to give an idea of the impressive progress made in this field.[3]

On the other hand, the important results obtained by Theodoric remained unknown to later generations of philosophers, who largely continued to follow the way in which Aristotle dealt with the problem of the rainbow. This long tradition of comments on the *Meteorologica*, which from the 13th century was part of the *curriculum studiorum* of the main universities in Europe, was disturbed by the reappearance of the *Commentaries* on the *Meteorologica* written by Alexander of Aphrodisias (2nd–3rd century CE)[4] and by Olympiodorus (6th century CE).[5] During the first half of the 16th century, scholars who dealt with still unsolved problems on new

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[2] Jacques Brunschwig, "Aristote et le statut épistémologique de la théorie de l'arc-en-ciel," in *Graceful Reason: Essays in Ancient and Medieval Philosophy Presented to Joseph Owens*, ed. Lloyd P. Gerson, 115–134 (Toronto: Pontifical Institute for Medieval Studies, 1983).

[3] Theodoric of Freiberg, *De Iride et radialibus impressionibus: Über den Regenbogen und die durch Strahlen erzeugten Eindrücke*, ed. Joseph Würschmidt (Münster: Aschendorff, 1914).

[4] Alexander of Aphrodisias, *In Aristotelis meteorologicorum libros commentaria*, ed. Michael Hayduck, in *Commentaria in Aristotelem Graeca [CAG]*, vol. 3,2 (Berlin: Georg Reimer, 1899). Alexander of Aphrodisias: *In quatuor libros meteorologicorum Aristotelis commentatio lucidissima*, trans. Alessandro Piccolomini (Venice: Apud Hieronymum Scottum, 1561).

[5] Olympiodorus, *In Aristotelis meteora commentaria*, ed. Wilhelm Stuve, in C*AG*, vol. 12,2 (Berlin: Georg Reimer, 1900). Olympiodorus, *In meteora Aristotelis commentarii*, trans. Giovanni Battista Camozzi (Venice: Apud Aldi Filios, 1551).

foundations, often in contrast with the medieval tradition, mainly referred to these works. Nevertheless, the results of these new studies did not cause the science to progress any further.

In this essay I shall select the works by Alessandro Piccolomini (1508–1578)[6] and Francesco Vimercati (1512–1571)[7] to illustrate the distinction between mathematics and natural philosophy, which was peculiar to the Aristotelian way of dealing with the rainbow. The discussion of these works will provide a background against which I shall analyse the work of Bernardino Telesio more precisely (1509–1588).[8]

1. Aristotle's Treatment of the Rainbow in the Meteorologica

Before going further, I think it will be useful to summarize Chapters 4 and 5 of Book 3 of the *Meteorologica*. In Chapter 2, Aristotle had already dealt with haloes, rainbows, mock suns or parhelia and rods.

> The complete circle of a halo was often visible round the sun and moon and round bright stars, and as frequently by night as by day […]. The rainbow never formed a complete circle, nor a segmental circle larger than a semicircle. […] After the autumn equinox it occurred at all hours of the day; but in summer it did not occur round about midday. No more than two rainbows occurred at the same time; of two such simultaneous rainbows each is three coloured, the colours being the same in each and equal in number, but dimmer in the outer bow and placed in the reverse order. For in the inner bow it is the first and largest band that is red, in the outer it is the smallest and closest to the red band of the inner. […] The cause of all the phenomena was the same, for they were all phenomena of reflection [ἀνάκλασις]. They differed in the manner of reflection and in the reflecting surface, and according as the reflection was to the sun or some other bright object (*Meteor.* III.2, 371b22–25, 371b26–27, 371b30–372a5, 372a17–21).[9]

From the last part of this quotation it seems that Aristotle followed the theory of those writers on optics who explained vision by means of visual rays coming out of the eye. According to

[6] Alessandro Piccolomini, "Tractatus de Iride," in Alexander of Aphrodisias, *In quatour libros meteorologicorum Aristotelis commentatio lucidissima*, trans. Alessandro Piccolomini, 117–129 (Venice: Apud Hieronymum Scottum, 1561). On Piccolomini's scientific works see Rufus Suter, "The Scientific Work of Alessandro Piccolomini," *Isis* 60/2 (1969): 210–222. For his participation in scientific disputes see Giulio Cesare Giacobbe, "Il Commentarium de certitude mathematicarum disciplinarum di Alessandro Piccolomini," *Physis: Revista Internazionale di Storia della Scienza* 14/2 (1972): 162–193; Giovanni Ferraro, "Dimostrazioni matematiche e conoscenza scientifica in Alessandro Piccolomini," in *Saggi di letteratura architettonica: Da Vitruvio a Winckelmann III*, ed. Howard Burns, Francesco Paolo Di Teodoro and Giorgio Bacci, 215–234 (Florence: Olschki, 2010); Joël Biard, "La certitude des mathématiques et ses fondements selon Piccolomini," in *Alessandro Piccolomini (1508–1579): Un Siennois à la croisée des genres et des savoirs*, ed. Marie-Françoise Piéjus, Michel Plaisance and Matteo Residori, 247–257 (Paris: Université Sorbonne nouvelle Paris 3, 2012).

[7] Francesco Vimercati, *In quatuor libros Aristotelis Meteorologicorum commentarii* (Paris: Apud Vascosanum, 1556). On Vimercati see Neal W. Gilbert, "Francesco Vimercato of Milan: A Bio-Bibliography, " *Studies in the Renaissance* 12 (1965): 188–217.

[8] Bernardino Telesio, *Liber De iride* (Venice: Apud Felicem Valgrisium, 1590). See also Bernardino Telesio, *De rerum natura* (Naples: Apud Horatium Salvianum, 1586), 4, chaps. 10–15.

[9] Aristotle, *Meteorologica*, trans. Henry D. P. Lee (Cambridge, MA: Harvard University Press, 1952), 241–245.

this theory, the rainbow was produced by a reflection of visual rays towards the sun. Our vision is reflected from substances which have a smooth surface, just like it is from water. In some mirrors, shapes are reflected, and in others only colours. "Colours are only reflected in mirrors that are small and incapable of subdivision by our sense of sight" (*Meteor.* III.2, 372b1–3). For the rainbow, the small mirrors were the little drops of water hanging in some clouds. But how to explain the genesis of colours?

In Chapter 3 of *De sensu et sensibilibus*, Aristotle reviews several hypotheses (1–2) and presents his own solution (3).

> (1) Firstly, white and black may be juxtaposed in such a way that by the minuteness of the division of its parts each is invisible while their product is visible; and thus colour may be produced. This product can appear neither white nor black, but, since it must have some colour and can have neither of the above two, it must be a sort of compound and a fresh kind of tint. In this way, then, we may conceive that numbers of colours over and above black and white may be produced, and that their multiplicity is due to differences in the proportion of their composition; […] and colours may, indeed, be analogous to harmonies. […]
> (2) This is one of the ways in which colours may be produced; a second is effected by the shining of one colour through another. This we may illustrate by the practice sometimes adopted by painters when they give a wash of colour over another more vivid tint […].
> According to the theory of juxtaposition, just as we must assume that there are invisible spatial quanta, so must we postulate an imperceptible time to account for the imperceptibility of the diverse stimuli transmitted to the sense organ, which seem to be one because they appear to be simultaneous. But on the other theory there is no such necessity; the surface colour causes different motions in the medium when acted on and when not acted on by an underlying tint.
> (3) But let us premise that substances are mixed not merely in the way some people think – by a juxtaposition of their ultimate minute parts, which, however, are imperceptible to sense – but that they entirely interpenetrate each other in every part throughout; […]. On the other hand, things which cannot be resolved into least parts, cannot be mingled in this way; they must entirely interpenetrate each other; and these are the things which most naturally mix. […] Now, all this being so, it is clear that when substances are mixed their colours too must be commingled, and that this is the supreme reason why there is a plurality of colours; neither superposition nor juxtaposition is the cause. In such mixtures the colour does not appear single when you are at a distance and diverse when you come near; it is a single tint from all points of view (*De Sensu et Sens*. 3, 439b21–29, 439b32–33, 440a7–10, 440a22–28, 440a34–440b3, 440b10–13, 440b14–19). [10]

From the idea of *mixtio* (μίξις), one could have asked whether the black and white present in any colour were related by numerical ratios, or whether one was predominant over the other; then ask to what extent such predominance could be determined more precisely through mathematics. From what Aristotle writes in Chapter 6 of *De sensu et sensibilibus*, it is clear that the infinite divisibility of the *mixtio* implies insurmountable limitations to visual perception, i.e. that which is extremely small could not be perceived unless it is placed within something

[10] Aristotle, *De Sensu and De Memoria*, trans. George R. T. Ross (Cambridge: Cambridge University Press, 1906), 57, 59–61.

sufficiently large; only in this case, from being potentially visible it will become actually visible (*De Sensu et Sens*. 6, 446a4–15).

Given these insurmountable limitations, we can formulate our question in a new way: how far can a natural philosopher go in his attempt at mathematicizing reality, when he needs to resort to mathematics in order to explain the causes of some phenomena? If, in the case of the rainbow, Aristotle did not go as far as that, this is probably a consequence of the nature of optical science in his time: it seems that those who dealt with optical problems only discussed colours in connection with other questions, such as the formation of reflected images in small mirrors or the ratio between the increased distance from the seen object and the augmented darkness. Increased distance naturally caused the exact perception of colour to become lost.

For Aristotle the "proper sensible" of sight could never become the object of a purely mathematical investigation. This was true even in the case of the rainbow, although essential aspects of it were related to quantitative considerations.

The colours of the rainbow were formed by the reflection of the visual rays coming out of the eye in the little drops hanging in some clouds; these little drops were like small mirrors, and when the cloud, the sun, and the observer were arranged on the same line (with the observer in the middle) the little drops reflected the visual rays towards the sun, so as to present an altered image of the colour of this bright body. This alteration was caused by the visual ray meeting the substance of the cloud—water—which is dark by nature. According to the formation of colour, which I have previously described, the sunlight operated as the white and the cloud as the black.

However, how to explain the formation of the three colours of the rainbow and their order? In addition, why, in the double rainbow, was the external one less bright and why were the colours arranged differently? All these questions must be dealt with in the theory of *mixtio*, which must follow the rules of optical science, according to which the theory of vision was treated in a geometrical manner. Aristotle answered the first of these questions in Book 3, Chapter 4 of *Meteorologica*:

> Bright light shining through a dark medium or reflected in a dark surface (it makes no difference which) looks red. Thus one can see how the flames of a fire made of green wood are red, because the fire-light which is bright and clear is mixed with a great deal of smoke; and the sun looks red when seen through mist or smoke. The reflection which is the rainbow therefore has its outermost circumference of this colour, since the reflection is from minute water-drops. […] We must, as has been said, bear in mind and assume the following principles. (1) White light reflected on a dark surface or passing through a dark coloured medium produces red; (2) our vision becomes weaker and less effective with distance; (3) dark colour is a kind of negation of vision, the appearance of darkness being due to the failure of our sight; hence objects seen at a distance appear darker because our sight

> fails to reach them. […] At any rate, they give the reason why distant objects appear darker and smaller and less irregular, as do also objects seen in mirrors, and why too the clouds appear darker when one looks at their reflection in water than directly at them. This last example is a particularly clear one: for we view them with a vision diminished by the reflection. […] The reason is clearly that, just as our vision when reflected through an angle and so weakened makes a dark colour appear still darker, so also it makes white appear less white and approach nearer to black. When the sight is fairly strong the colour changes to red, when it is less strong to green, and when it is weaker still to blue (*Meteor*. III.4, 374a3–10, 374b9–15, 374b17–22, 374b28–33).[11]

As we have seen, the increased darkness of the bright colour of the sun, and the formation of the colours of the rainbow which follows from it, is mainly caused by the reflection taking place in the little drops, which act as small mirrors.

Which mathematical aspects of reflection are relevant here? The increased distance of the reflected visual ray compared to direct vision certainly is. However, one must be careful not to regard the phenomenon as solely caused by the different distance and not to strictly apply this explanation to the other examples reported by Aristotle.

Alessandro Piccolomini, in his "Tractatus de iride" published as an appendix to his Latin translation of Alexander of Aphrodisias's *Commentaries* on the *Meteorologica*, thinks that such negligence would be wrong, for if the reflected vision of a cloud in a mirror or on the surface of water is represented by a geometrical figure, one gets two sides of a triangle, whereas the third side corresponds to the direct vision. Now it is true that two sides of a triangle are always bigger than the other side (Euclid's *Elements*, Book 1, prop. 20), but in this case the side corresponding to the visual ray, which goes from the eye to the reflecting surface, is negligibly small compared to that which goes from this surface to the cloud. Hence, one can regard it as minimally affecting the formation of colour. According to Vitelo's measurements reported in his *Perspectiva*, clouds can reach a height of between three and five German miles (ca. 5900–7400 metres), whereas the observer's distance is at most four feet (Roman feet ca 30 cm).[12]

In the Aristotelian framework, it was more difficult to establish the cause of the subsequent formation of three colours: red, green, and blue (violet). The slightly weakened view of the original colour changed into a view that was increasingly weak. Was the increased distance a sufficient cause for this weakening of the view? And even if this were true, would it have been possible to exactly determine this variation? Aristotle tackled these problems thus:

> In the primary rainbow the outermost band is red. For the vision is reflected most strongly on to the sun from the largest circumference, and the outermost band is the largest: and corresponding remarks apply to the second and the third bands. […] This, then, is why the rainbow is three-coloured and

[11] Aristotle, *Meteorologica*, 255–257, 259, 261.
[12] Piccolomini, "Tractatus de Iride," 121.

> why the rainbow is made up of these three colours only. The same cause accounts for the double rainbow and for the colours in the outer bow being dimmer and in the reverse order. For the effects here are the same as those produced by an increase in the distance of vision on our perception of distant objects. The reflection from the outer rainbow is weaker because it has farther to travel; its impulse is therefore feebler, which makes the colours seem dimmer. The colours are in the reverse order because the impulse reaching the sun is greater from the smaller and inner band; for the reflected that is closer to our sight is the one reflected from the band that is closest to the primary rainbow, that is, the smallest band in the outer rainbow, which will consequently be coloured red. And the second and third bands are to be explained analogously (*Meteor*. III.4, 375a2–4, 375a28–375b9).[13]

In the primary rainbow, Aristotle regards the extension of the bands of colours as the main cause of the weakened vision without considering the variation of distance. However, in the external rainbow he regards the increased distance as the main cause, and seems to put this in relation to the augmented width of the angle of incidence, which according to the optical theories would explain the weakened view through increased departure from the perpendicular.

It seems that these two different explanations could only be reconciled in the case that there was not always a direct relationship between increased distance and weakened view. One could imagine a visual power which kept the same strength up to a certain distance and then quickly weakened. Before that happened, the intensity of the vision would be caused by the small mirror, whereas later the increased distance, or more probably the increased width of the angle of incidence, would be the main cause.

2. Ancient Commentaries on Aristotle's Theory

Aristotle's passage on the rainbow raises a real problem. It seems that he was satisfied with the result that he had obtained, but later commentators did not seem to be equally satisfied. Alexander of Aphrodisias relates that some authors regarded the second rainbow not as a reflection of the visual rays towards the sun but as an image of the internal rainbow reflected in a cloud placed outside the first one.[14] It is likely that this argument was meant to explain the space without colour between the two rainbows. Aristotle never pointed out this discontinuity

[13] Aristotle, *Meteorologica*, 261, 265.

[14] Alexander of Aphrodisias, *In quatuor libros meteorologicorum*, 81: "Aliqui quidem igitur dicunt, quod secunda iris, non per refractionem ad Solem fieri accidit, sed ad ipsam praeinexistentem iridem. Ita quod usus ipse ad exteriori nube, quae simili quidem modo disposita ad refractionem sit, sicut et prima, in qua prima iris est, ad praeinexistentem iridem refrangatur, et ex tali refractione secunda iris appareat; quapropter et languidiores sunt secundae iridis colores, tanquam ex secunda rursus refractione producti." *CAG*, vol. 3,2, 159, 9–15: τινὲς μὲν οὖν φασι τὴν δευτέραν ἶριν οὐ κατὰ τὴν πρὸς τὸν ἥλιον ἀνάκλασιν ἔτι γίνεσθαι, ἀλλὰ κατὰ τὴν προϋπάρχουσαν ἶριν, ὡς τῆς ὄψεως ἀπὸ τοῦ ἐξωτέρου νέφους ὁμοίως ἔχοντος, ὡς εἶχε καὶ τὸ πρῶτον, ἐφ' οἷς ἡ ἶρις, ἀνακλωμένης ἐπὶ τὴν προϋπάρχουσαν ἶριν, καὶ διὰ τῆς ἀνακλάσεως ἐκείνην ὁρώσης· διὸ καὶ ἀμαυρότερα τὰ χρώματα τὰ τῆς δευτέρας, ἅτε ἀπὸ ἀνακλάσεως γινόμενα δευτέρας.

between the two bands of red, but later, as reported by Alexander in his *Commentaries*, some other authors wondered why the empty space between the rainbows was not red, though it was nearer the larger band of the internal rainbow than the first band of the external rainbow.[15] Would not the reflection of the visual rays also show the same colour in this part of the clouds? The little information given by Alexander may suggest that once more the difficulty should be dealt with on the basis of optical science. This science taught that reflection should not occur from just any position: view, reflecting surface, and bright body ought to have specific positions and distances.[16]

Alexander of Aphrodisias's work was very influential in the Renaissance, as can be deduced from the frequent reprinting of Piccolomini's Latin translation. However, no solution could be found in it for the difficulties raised by Aristotle's text.

Olympiodorus's *Commentaries* on the *Meteorologica* are a different case, as they introduced a new element in the explanation of the formation of the rainbow's colours: they placed the clouds reached by the visual rays at different distances. The appearance of the three colours of the rainbow would depend both on the distance travelled by the visual rays and on the length of the distance covered inside the cloud. According to this point of view, when our vision meets the nearest clouds, it would have travelled a shorter distance and therefore would be stronger, whereas at the same time it would absorb a small quantity of the darkness of the water, thus causing the appearance of red.[17]

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[15] Alexander of Aphrodisias, *In quatuor libros meteorologicorum*, 81: "Quaeret autem aliquis, nam si minor peripheria exterioris iridis phoeniceum colorem habet, quae prope ampliorem primae iridis peripheriam est, quae et ipsa per simile colorem retinet; propterea quia ab ambabus his peripheriis, fortior fit refractio visus ad Solem; quid nam, non et quod intermedium istarum peripheriarum est omne phoeniceum etiam habet colorem?" *CAG*, vol. 3,2, 160, 21–26: ἐπιζητήσαι τις ἄν, εἰ ἡ ἐλάττων περιφέρεια τῆς ἐξωτέρας ἴριδος φοινικοῦν ἔχει τὸ χρῶμα, οὖσα πλησίον τῆς μείζονος περιφερείας τῆς πρώτης ἴριδος, ἣ καὶ αὐτὴ τοιοῦτον ἔχει τὸ χρῶμα τῷ πλείους ὄψεις ἀπὸ τούτων ἀνακλᾶσθαι πρὸς τὸν ἥλιον, τί δήποτε οὐχὶ καὶ τὸ μεταξὺ τῶν περιφερειῶν τῶν εἰρημένων πᾶν φοινικοῦν ἔχει τὸ χρῶμα.

[16] Alexander of Aphrodisias, *In quatuor libros meteorologicorum*, 81: "An neque ex qualibet quidem parte refrangi habet visus, secundum opinionem eorum qui sic visionem fieri existimant; neque ab omni parte refrangi habet lumen ad visum, secundum aliorum opinionem, qui sic fieri visionem arbitrantur? Verum determinata ac definita sunt loca refractionum, ac praefinitam distantiam esse oportet luminosi ipsius corporis a speculis ipsis, quae suspicere eius lumen habeant. Quapropter ab his quidem refractio accidit fieri, quae huiusmodi determinatum habeant situm." *CAG*, vol. 3,2, 160, 28–33: ἢ οὔτε ἀπὸ παντὸς μορίου ἡ ὄψις ἀνακλᾶται καθ' οὓς οὕτως τὰ τοιαῦτα ὁρᾶται, οὔτε ἐπὶ τὴν ὄψιν ἀνακλᾶται τὸ φῶς ἀπὸ παντὸς μορίου καθ' οὓς οὕτω τὸ ὁρᾶν, ἀλλ' ὡρισμένοι οἱ τόποι τῶν ἀνακλάσεων καὶ δεδομένην χρὴ τὴν ἀπόστασιν εἶναι τοῦ τὸ φῶς ποιοῦντος σώματος ἀπὸ τῶν δεχομένων αὐτὸ κατόπτρων· ἀπὸ τούτων οὖν γίνεται, ἃ ταύτην τὴν θέσιν ἔχει.

[17] Olympiodorus, *In meteora Aristotelis*, 65*r*: "Nubes enim, in quibus iris faciem ostendit suam, quia in exilia corpuscula minutaque stillicidia divisae discerptaeque sunt; et quaedam ipsarum longe ab oculis abductae iacent, quaedam vero propius consistunt; radii oculorum qui plurimi sunt, foras emissi ad regionem nubis quidam incursu suo propioribus nubibus obvii ad id quod apparet, reflectuntur hoc est ad Solem; quidam autem radii quibusdam a conspectu procul summotis nubibus incidunt; alii autem in alias ab oculis multo quoque adhuc remotiores nubes incurrunt. Sed radii quidem qui ad propiores nubes perveniunt, et quasi per exiguum nigrum, idest per nubilium aera ipsum aspiciunt Solem, non multum falluntur, quippe qui neque multum via defessi languent, et per brevia aeris nubilia ipsum cernunt. Ideoque phaeniceam Solis faciem in nubibus iis intuentur…" *CAG*, vol. 12,2, 236,

Though interesting, this new explanation would introduce an idea of *mixtio*, which in this case depends on the portion of the cloud traversed by the visual rays. Would it not be possible to solve the problem by explaining the phenomenon with a changing angle of incidence? According to Olympiodorus, vision became ever more weak the more the rays of the visual cone departed from its axis, i.e. from the ray that met the reflecting surface along a perpendicular line. Now in the case of the double rainbow the perpendicular rays and those nearest to it fell precisely between the two bands of red, that is in the space where no colour was perceived. The strength of these rays could make it possible to perceive sunlight without any alteration. By moving away from this space, the visual rays were making the angle of incidence wider and wider, so that the perception of the different colours of the rainbow placed at the right, and the left of the space taken up by the rays near the perpendicular, became weaker. In this way, both the contrary order of the arrangement of the colours in the two rainbows and the space without colour could be explained.[18]

However, would it have been possible to combine the two theories on the formation of colour, one that refers to the portion of the cloud crossed by the visual rays and the other that uses the variation of the angle of incidence of the same rays? It would seem a simple affair, but Olympiodorus did not explore the problem further.

24–33: ἐπειδὴ γὰρ τὰ νέφη, ἐν οἷς ἡ ἶρις ἐκφαίνεται, κατακεκερματισμένα ἐστὶν εἰς μικρὰς ῥανίδας καὶ τὰ μὲν αὐτῶν πόρρω κεῖνται τῆς ὄψεως, τὰ δ’ἐγγυτέρω, αἱ ἐκ τοῦ ὄμματος ἐπ’ αὐτὸ ἐκπεμπόμεναι ἀκτῖνες πλεῖσται οὖσαι αἱ μὲν εἰς τὰ πλησίον νέφη προσπίπτουσαι ἀνακλῶνται πρὸς τὸ ὁρατόν, τουτέστι τὸν ἥλιον, αἱ δὲ εἰς τὰ πορρωτέρω, αἱ δὲ ἔτι εἰς τὰ πορρωτέρω. ἀλλ’αἱ ἀλλ’ αἱ μὲν εἰς τὰ πλησίον νέφη προσπίπτουσαι ἀκτῖνες ὡς ἂν δι’ὀλίγου μέλανος ὁρῶσαι αὐτόν, τουτέστι ἀχλυώδους ἀέρος, οὐ πάσχουσι πολλὴν τὴν ἀπάτην ἅτε δὴ μὴ πάνυ ἀσθενήσασαι καὶ δι’ὀλίγης ἀχλύος αὐτὸν ὁρῶσαι. ὅθεν φοινικοῦν χρῶμα ὁρῶσιν αὐτὸ τοῦ ἡλίου ἐν τοῖς νέφεσιν ἐκείνοις.

[18] Olympiodorus, *In meteora Aristotelis*, 65*v*: “Quum enim a visu nostro radii multi defluant, qui in rectam lineam ad rem spectabilem immittitur radius, qui itidem axis est cuiuslibet coni geniti, valentiorem et perspicaciorem videndi vim habet quam reliqui radii, qui non in rectam sed in obliquam partem perferantur. Et ex his rursum radiis qui recto et perpendiculari radio propiores sunt, videndo magis pollent quam qui a perpendiculari longius decidunt; ex quo fit, ut radius ad libramentum immissus quum validissimus omnium existat, nullum in videndo mendatium patiatur. […] Caeteros vero radios perpendiculari confines mendatium et fraudem pati certe contigit, sed exiguam. Hos vero qui longius ab eo radio qui axis cuislibet coni est, absistunt, in magnum mendacium et errorem incurrere. Iis rebus ita constitutis in iride nubes multi ab oculis emissi radii circumquaque oberrare videntur; quorum quidem radiorum unus in rectum emissus perpendicularis existit, aliqui autem huic proximi adiacent, alii procul a recto decidunt. Sed radius ad libramentum iniectus medio inter utrunque arcum spatio incidit in eum scilicet locum, qui inter utrasque phaeniceas lineas media regione interiacet, quo quidem in loco nullius mendax omnino coloris similitudo apparet.” *CAG*, vol. 12,2, 238, 20–30: ἐπειδὴ γὰρ ἐκ τοῦ ὄμματος πιπτουσῶν ἀκτίνων ἡ κατὰ κάθετον φερομένη πρὸς τὸ ὁρατόν, ἥτις καὶ ἄξων ἐστὶ τῶν γινομένων κώ-νων, ἰσχυροτέρα ἐστὶ τῶν μὴ κατὰ κάθετον, ἀλλὰ πλαγίων φερομένων (καὶ τούτων αἱ πρὸς τῇ καθέτῳ ἰσχυρότεραί εἰσι τῶν πόρρω τῆς καθέτου), συμβαίνει τὴν μὲν κάθετον ὡς ἰσχυροτάτην οὖσαν μὴ πάσχειν ἀπάτην ἢ σπανίως ἔχειν, τὰς δὲ πρὸς τῇ καθέτῳ πάσχειν μὲν ἀπάτην, ὀλίγην δέ, τὰς δὲ πόρρω πολλὴν πάσχειν ἀπάτην. τούτων οὕτως ἐχόντων ἐπὶ τῆς ἴριδος φαίνονται ὄψεις πολλαὶ παρὰ τὰ νέφη, ὧν ἡ μέν ἐστι κάθετος, αἱ δὲ παρὰ τὴν κάθετον πίπτουσιν, αἱ δὲ πόρρω τῆς καθέτου. ἀλλ’ ἡ μὲν κάθετος ἐμπίπτει ἐπὶ τὸ μεταξὺ τῶν δύο ἰρίδων, ἐπὶ τὸ τῶν μεταξὺ δύο φοινικῶν περιφερειῶν, ἔνθα οὐδὲν ὅλως ἀπατηλὸν φαίνεται χρῶμα·

3. Piccolomini's and Vimercati's Assessments of Aristotle's Rainbow Doctrine

The commentaries by Alexander of Aphrodisias and Olympiodorus became the main reference point during the Renaissance, though they did not completely replace the contributions by medieval commentators on the *Meteorology*. An extreme position was adopted by Alessandro Piccolomini: in his "Tractatus de Iride", he declared all studies made by the *Latini* to be utterly useless. Structured as a mathematical treatise, Piccolomini's work tackled, among other questions, the one concerning colours changing towards black in relation to increasing distance and weakening vision.

Piccolomini indicated the changing distance, weakening visual power, and reflection as the main causes of the changing colours and of their formation by different reflections of the visual rays towards the sun. This was the conclusion Alexander of Aphrodisias had already reached, but it was possible to go further and relate the formation of the colours of the rainbow to the angle of incidence of the visual rays in the cloud, as Olympiodorus had pointed out. In the external band of the first rainbow the angle of incidence was greater, and therefore the penetration and the *mixtio* of the visual ray with the darkness of water was less. However, while reflection alone could be sufficient to cause the altered perception of the colour of the sun, it seemed that this could not happen with much greater angles of incidence, where the *mixtio* could not take place. By reducing the angle of incidence, the penetration of the visual rays increased and as a consequence the *mixtio* of the visual rays with the colour of the small drops of water also increased. Thus red, green, and blue (violet) were formed. Blue (violet) was the last perceivable colour because the visual rays nearest to the perpendicular, though they could most deeply penetrate and mix with the cloud, did not have a sufficient angle of incidence to cause the altered perception of the colour of the sun. To cause the appearance of colours, the angles of incidence had to be between a maximum and a minimum inclination.[19]

It is obvious that if the change of the angle of incidence were the only cause of the appearance of colours, it would not be possible to explain the contrary order of their arrangement in the

[19] Piccolomini, "Tractatus de iride", 124: "Radius enim visualis, si nimis forti extiterit, tunc aut nubem penitus pertransit, sicut radius perpendicularis, aut valde penetrans, quamvis maxima fiat dicta permixtio, debiliter tamen valde refrangetur, cum propinquior sit ipsi perpendiculari, ac naturam ipsius nimis sapiat, et ex hoc coloris phantasiam non causabit. Atqui e contra si radius magis quam necesse sit distabit a perpendiculari, tunc quamvis ad maximum angulum refrangantur , tamen modica fiet talis permixtio quam diximus luminis cum nigro nubis, et propter hoc etiam coloris emphasim non produxerit. Necesse est igitur quod radius ipse, nec nimis accedat ad perpendicularem, nec etiam nimis elongetur ab ea. Nam ad coloris productionem, non solum requiritur sufficiens ac debita permixtio luminis cum nigro nubis quae ex sufficienti penetratione causatur, quod non nimis longe a perpendiculari contingit fieri, sed etiam requiritur quod sufficiens refractio fiat, ad sufficientem, scilicet angulum; adeo quod non in tantum penetret, quod ad nimis parvum angulum reflectatur."

second rainbow. Another element ought to be considered, which by its change would counteract the effect of the increasing angle of incidence: this element is distance. In other words, red would continue to appear up to the maximum value of the angle of incidence, but the increased distance would weaken the strength of the vision of this red, making it appear first green and then blue (violet).[20]

But how to explain the colourless space between the two red bands? For Piccolomini this was due to the juxtaposition of two red colours with very different intensity: the red of the first rainbow would be much stronger then the red of the second, which would cause a change of the colour towards white in the space between the two colours. To explain this phenomenon in the formation of the colour red, Piccolomini referred to a presumed diverse structure or constitution of the external part of the cloud in which the rainbow is formed: that part would be less dense and its little drops would be 'badly' placed.[21]

Frequent references to ancient commentators were also made by Francesco Vimercati in his *Commentaries on the Meteorologica*, which was the most important edition with commentary on Aristotle's work published in the 16th century. Telesio certainly knew it, as he used Vimercati's translation, with few changes, in the first chapters of his *De iride*.

In his comment on the Aristotelian passage concerning the double rainbow, Vimercati pointed out the difficulty of explaining the contrary order of the arrangement of the colours; it seemed evident to him that, if one strictly followed the laws of optical science, the arrangement of the colours in the internal rainbow should also be inverted since the visual rays nearer the perpendicular are always stronger than those departing from it.[22] Olympiodorus's solution

[20] Piccolomini, "Tractatus de iride", 125: "Distantiam enim pro colore puniceo generando sufficiens est, quare inferior peripheria secundae iridis punicea est […]. Secunda vero peripheria, cum iam determinata ac proportionalis illa distantia defecerit, ex qua talis refractio fieri habet, ut color punicens generetur; tunc quidem cum refractio ex nimia distantia debilis iam fiat, (ex nimis longa enim et nimis brevi distantia, debilitatur refractio, ut diximus) fulgidum ipsum tendit magis ad nigrum, ac viridem colorem producet; et consequenter alurgum in extima peripheria secundum eadem rationem, extra quam peripheriam nullus amplius color apparet, propter elongationem partium nubis a debita distantia pro refractione sufficienti ad colorum generationem."

[21] Piccolomini, "Tractatus de Iride", 124: "Cum igitur e regione Solis rorida nubes constiterit, atque id iridis phantasiam secundum stillas disposita fuerit, tunc quaedam determinata distantia est inter nubes et Solem, ac inter nubem et visum, secundum quam non solum luminis cum nigro nubis permixtio ac penetratio, sed etiam refractio sufficiens est, ad hoc quod fulgidum ipsum non multum ab albedine deficere videatur, adeo ut puniceus, color producatur. Et haec determinata distantia incipit in exteriori iridis peripheria, ac perdurat extra ipsam, usque ad aliquam nubis partem, quod totum intervallum ex sui natura puniceum apparere debet. Sed quoniam, ut superius explanavimus, quilibet color iuxta nigrum positum, albior videtur, iccirco cum puniceus hic color, qui in dicto intervallo est, iuxta partem illam nubis valde remotam, situs est, a qua propter hoc quod nimium distantia superexcedit, refractio nobilissima est […] propter hanc, inquam, iuxtappositionem albus apparet, et etiam in coloribus iridis quae ab ipsa Luna fit, est videre. Cum igitur nubes ipsa, in illa quidem parte ad quam intervallum dictum terminatur, non multum densa sit, et bene secundum stillas disposita, tunc quidem secunda fit iris."

[22] Vimercati, *In quatuor libros*, 332: "Nunc ea dubitatio diluatur, qua obiici contra Aristotelem solitum est, si ex aspectu validiori color puniceus, minus valido viridis et purpureus appareant, rationi consonum, imo vero necessarium esse, ut intimus ambitus puniceus, extimus purpureus vedeatur. Aspectus enim radios ab intimo ad

should be rejected since he placed the perpendicular visual ray in the space between the two red bands of the rainbows, whereas according to the last part of Aristotle's treatment of the question that ray fell in the centre of the cloud.[23]

What then was the cause of the appearance of the colour, which was the farthest away from the bright sun, in the place of the strongest reflection? According to Vimercati, some authors thought that this inversion was only accidental, and essentially due to two obstructing factors: the narrow internal space and the greater density of the cloud in its central part than in the external one.[24] Other authors denied that these factors could solve the difficulty, since the greater density of the central part of the cloud would have suggested placing the colour red in the internal band.[25] The observed order of the arrangement of the colours could be explained by the fact that the visual rays near the perpendicular would penetrate more deeply into the cloud and for that reason would absorb more darkness of the water,[26] whereas the mixture would gradually lessen along with the increasing distance from the perpendicular. Reflection would thus take place at different levels of depth, and the greater strength from the optical point of view would become greater weakness of preservation of colour.

How to solve the difficulties raised by the commentators, and especially how to explain the colourless space between the two rainbows? To answer these questions, Vimercati also turned to Alexander of Aphrodisias, but unlike Piccolomini, he did not consider the geometrical aspects of the problem. Rather, he thought that one should not understand Alexander's argument as based on the distances of points from a reflecting surface**,** so that the statement "a

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Solem, quam ab extimo validiores referri; quandoquidem perpendiculari radio, qui ad centrum arcus fertur, sunt propiores, monstratumque sit a perspectivis radium perpendicularem validissimum esse, nec unquam reflecti aut frangi; eos autem,qui ab illo recedunt, quo minus abducuntur, validiores esse, quo magis, imbecilliores."

[23] Vimercati, *In quatuor libros*, 333: "An huic dubitationi occorrendum est, illud tradendo, quod Olympiodorus, utriusque arcus colorum diversitatem assignans, ex Ammonio commemoravit, nempe radium perpendicularem ad illud spatium ferri, quod inter utrunque arcum positum est. Illud itaque spatium, quod radio valentiori conspicitur, absque errore ullo a nobis apprehendi, tum id, quod sequitur, puniceum, qui color a Solis colore minus quam caeteri recedit, utpote minori errore conspectus. An prorsus falsum est, radium perpendicularem ad spatium id ferri, quandoquidem (ut post docebitur) ad nubis centrum fertur."

[24] Vimercati, *In quatuor libros*, 333: "Hanc igitur dibitationem aliqui aliter sustulerunt, concedentes, per se quidem colorem, qui ad candidum magis accedit, in intimo ambitu apparere debuisse, ob eamque causam puniceum, nigriorem autem veluti purpureum in extimo, ex accidenti tamen ob duo impedimenta, candidiorem, qui est puniceus in extimo, et purpureum in intimo apparuisse; ac impedimenta quidem esse ambitus illius interioris parvitatem, atque nubis, in qua apparet, crassitiem et densitatem, quae longe maior est, quam in exteriori. His ergo duabus de causis Solis colorem in interiori ambitu minus perfecte repraesentari."

[25] Vimercati, *In quatuor libros*, 333: "Sed si ex radiis validioribus, quales sunt, qui iuxta perpendicularem habentur, color Solis in nube perfectius apparere per se debeat, illis profecto impedimentis non tolletur, quo minus appareat; nam et a nube densiori magis reflectentur, utpote eam minus penetrantes…"

[26] Vimercati, *In quatuor libros*, 333: "An vero potius dicendum est, radios perpendiculari proximos, quoniam caeteris validiores sunt, debiliter admodum, et ad angulos parvos reflecti, imo vero ipsam nubem magis penetrare, illique magis admisceri, ob eamque causam Solis colorem debiliter valde repraesentare, ac quo magis a perpendiculari recedunt, eo debiliores esse, validiusque et ad angulos maiores referri, ideo colores ad candidum propius accedentes, et a nubis nigredine remotiores ostendere."

reflection does not take place from just any point in a mirror” became “a reflection does not take place from just any part of the cloud in which the rainbow appears”. As a consequence, between the two bands of red colour there would be a discontinuity only because that part of the cloud was too far away.[27] This solution supported the explanation that the second rainbow was nothing else than an image of the first. This explanation, however, raised the essential difficulty of the mirror image’s turning over from concave to convex.

Vimercati’s work offered an overview of past opinions but the challenge to find the true cause of this complex natural phenomenon was still open. This challenge was taken up by Bernardino Telesio.

4. Telesio’s De iride

If we now move to analyse Telesio’s *De iride* we must first point out that it removes an ambiguity which was always present in the Aristotelian tradition. In the *Meteorologica*, Aristotle had accepted the theory of the visual rays issuing from the eye, giving up his own theory of vision. Alexander of Aphrodisias had tried to justify this way of proceeding, pointing out that from the point of view of the geometrical explanation of optical phenomena it was a matter of indifference whether vision took place through a visual ray issuing from the eye travelling towards the object that was seen or whether the eye passively received it from outside.[28] Medieval optical science had rejected this ancient theory, and Telesio accepted the general opinion on this point.

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[27] Vimercati, *In quatuor libros*, 333, 338: “An vero, inquit ille [Alexander], non ab omni nubis parte aspectus ad Solem, aut lumen Solis ad aspectum reflectitur, sed reflexionem loca definita sunt et certa, definitamque et certam splendidi lumen mittentis corporis a speculo distantiam esse oportet? Ab his igitur speculis ita distantibus, situmque certum habentibus, arcum et colores repraesentari. Quibus in verbis videtur Alexander docere, ideo colorem nullum inter utrunque arcum apparere, quia nulla ibi reflexio ad Solem seu ad aspectum efficiatur […] Neque enim haec (ut mihi videtur) est Alexandri (quemadmodum nonnulli crediderunt) sententia, sed quod in spatio illo nubes nimis distet; siquidem ait, certam luminosi corporis et speculi distantiam esse oportere, et ab his speculis, quae ita distant, reflexionem fieri; quasi dicere vellet, ab hac nube media non fieri, quoniam longius distet, quam ut possit reflectere. Nec vero ait Alexander, ab omni puncto speculi cuiusvis reflexionem non fieri, ut quidam putarunt, sed ab omni nubis, in qua arcus apparet, parte.”

[28] Alexander of Aphrodisias, *In quatuor libros meteorologicorum*, 72–72: “Quoniam vero, quantum ad praesentem rationem attinet, nihil refert sive dicatur, quod visus ipse ad speculum ad aequales angulos refractus, in rem visibilem incidens, cum sub huiusmodi refractione res ipsa contigerit, illam videat; an dicatur potius quod res ipsa quae videri habet, propter aliqualem habitudinem, vel situm ad speculum per intermedium diaphanum patiens quidem atque affectum, emphasim faciat in speculo, quod quidem taliter diaphanum existat, ut non solum a colori pati possit, adeo ut alteri diaphano acceptam qualitatem elargiri valeat, verumetiam et conservare, propter politiem ac splendorem, emphasim possit; ita quod ab ipso dehinc tanquam ab aliquo colorato patiatur rursus atque efficiatur diaphanum ipsum quod intermedium est. Quoniam, inquam, nihil refert in praesenti negotio, sive hoc dicatur sive illud, opinionem sequitur modo, quae emissionem radiorum ponit, quam quidem mathematici approbant.” *CAG*, 3,2, 151, 20–30: ἐπεὶ δὲ οὐδὲν ὅσον ἐπὶ τῷ λόγῳ διαφέρει ἢ τὴν ὄψιν λέγειν ἀπὸ τοῦ κατόπτρου ἀνακλωμένην πρὸς ἴσας γωνίας, ὅταν ὑπὸ τὴν τοιαύτην ἀνάκλασιν τύχῃ τὸ ὁρατὸν ὄν, προσπίπτουσαν αὐτῷ ὁρᾶν αὐτό, ἢ αὐτὸ

However, this seems to be the only time that Telesio followed the tradition of geometrical optics. In fact, in his critical discussion of the Aristotelian conception he rejects the fundamental assumption which explained the cause of the rainbow by means of optics, i.e. the assumption that the observer must be placed in the middle of the straight line joining the sun and the centre of the mirror consisting of a great amount of small drops forming a cloud. To reject this assumption Telesio resorted to the same examples mentioned by Aristotle himself. In the case of the rainbow which can be seen in the water drops raised by oars when rowing or in the drops splashed by hand, the former assumption is not verified. The same must be said for the rainbow which, in some particular conditions, is formed around the flame of an oil lamp. If then we add the experiences made with a transparent prism of glass to the examples mentioned by Aristotle a different explanation will obviously be needed.[29]

In Telesio's view, the rainbow should be explained on the basis of the assumption that light travels from the sun to the clouds and subsequently shines towards the eye. Light spreads from its source in all directions. In thin bodies such as air, it permeates them and can be perceived even when its source is not directly visible; in dense bodies, smooth and shining, light becomes more intense and while it doesn't penetrate them it is very bright and its colour is not altered.[30] However, that does not happen when the light goes through something coloured, or when, by illuminating a body with a certain density and depth, the light permeates it in a variable manner, making it shine with different colours. This was the case with water and with the clouds, which changed colour from their natural whiteness to an increasingly greater darkness according to

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τὸ ὁρατὸν διὰ τὴν ποιὰν σχέσιν πρὸς τὸ κάτοπτρον διὰ τοῦ μεταξὺ διαφανοῦς πάσχοντος ἐμφαινόμενον ἐν ἐκείνῳ, ὄντι τοιούτῳ [διαφανεῖ], ὡς μὴ μόνον πάσχειν ὑπὸ τοῦ χρώματος δύνασθαι οὕτως, ὡς διαδιδόναι τὴν ἀπ' αὐτοῦ ποιότητα ἄλλῳ διαφανεῖ, ἀλλὰ καὶ φυλάσσειν δυναμένῳ τὴν ἔμφασιν διὰ λειότητά τε καὶ στιλπνότητα, ὡς ἀπ' αὐτοῦ πάλιν τὸ μεταξὺ αὐτοῦ τε καὶ τῆς ὄψεως διαφανὲς πάσχειν ὡς ἀπὸ κεχρωσμένου, τῇ δόξῃ τῇ τῶν ἀκτίνων καθωμιλημένῃ τε οὔσῃ καὶ τοῖς μαθηματικοῖς ἀρεσκούσῃ προσχρῆται.

[29] Telesio, *De iride*, chap. 8, 5v-6r: "Quod igitur dictum est, vel eo una reflexione iridem fieri statuens Aristoteles, quod ibi modo fiat, ubi solum speculum sit nubes, et aspectum nostrum reflectere potest, probandus omnino videdur, minime vero e Solis illam regione tantum constitui decernes, oportere itaque aspectum nostrum medium inter Solem, nubemque fieri, et in eadem omnino linea Solem, aspectumque nostrum et iridis centrum polumque esse; passim enim irides intueri licet, quas inter, Solemque medii nos minime sumus […] et quae ex aqua Soli exposita, vel e guttis a remis sublatis, aut manu sparsis fiunt, nequaquam nobis inter eas, Solemque mediis fiunt, nec quae e serratili spectantur vitro, multoque etiam minus, quae circa lucernam fiunt."

[30] At the beginning of chap. 16 of *De iride*, Telesio refers to his *De rerum natura*. Here in book 4, chap. 10, 145 we read: "Itaque et ubi nullus conspicitur Sol, quo scilicet recta, qua sola progredi lux videtur, deferri non potest, a crasso quopiam retardata, reiectaque, et Sole non dum exorto, et penitus iam abdito, aliquantis per tamen universo in aere, et imis etiam in terris si non fulgida, at bene certe visilis, beneque spectatur clara. Non quidem id accidat nisi ab aere etiam, a se ipsa nimirum, vel summe exili in eo facta, reluceat. Nam quae a densis, aequabilibusque, et nitidis refulget rebus, a quibus, quod nihil eas subeat, integra relucet, et continua amplius, unitaque, nihil ab earum tumoribus, nec a maculis etiam […] intercepta, intercisaque ullis, nihilo, quam a Sole ipso minus fulgida, minusque relucet ingens. […] Nihil imminuitur ab ullo, quin in singulis bene in se ipsam colligitur, proindeque veluti alter Sol facta, a singulis, veluti a Sole ipso effulget, seseque effundit." For a general account of Telesio's light theory, see Martin Mulsow, *Frühneuzeitliche Selbsterhaltung*: *Telesio und die Naturphilosophie der Renaissance* (Tübingen: Max Niemeyer, 1998), 104–139.

their greater depth or density. The cause of this alteration was the black colour of matter, which became more notable when depth and density were more considerable.[31]

One also had to take into account the direction of the light, which could be either perpendicular or inclined. In the former case, light, reflecting on itself and acquiring strength, would have managed to overcome the black structure of matter, whereas in the latter case it would have mixed with matter more and more deeply, becoming altered into different colours.[32]

Hence, the question of the rainbow shifted from a discussion concerning the problem of the formation of images in small mirrors to an analysis of the variation of light in more or less dense bodies.

When the sunlight reached the cloud suitable to show the rainbow by the shortest line, its strength would have prevented it from undergoing any alteration; thereby it was seen without any particular colour. With increased inclination, the light would have been increasingly affected by the darkness of the cloud and would subsequently have formed the red, green, and blue (violet) bands. After the formation of this last colour the inclination of the light would have increased too much and its variation would have been too faint to be perceived.[33]

Once more the inclination would reach a maximum value and a minimum value, but this time it did not depend on the theory of reflection but rather on a somewhat original idea of the emanation of light from the body of the sun.

Although Telesio acknowledged it was a fact that each part of the things that were lit up received light from every point of the surface of the sun, he thought it possible to establish a special relationship between some parts of the cloud and some parts of its surface. The single parts of the cloud would have only shown that alteration of light which was predominant over the other, and that predominance would have depended on the way in which illumination was taking place according to the greater or lesser inclination. Thus Telesio could spot those parts on the surface of the sun which were, in his opinion, mostly responsible for such variation.

[31] Telesio, *De iride*, chap. 16, 14*v*–15*r*: "Et aquas, nubesque permeans, et relucens etiam ab iis, si paulo profundiores, densioresve sint, non albo amplius, qualis, et lucis, et illarum utriusque est color, sed longe pluribus, et omnibus propemodum, qui album, nigrumque intermedii sunt, et ipso etiam nigro colorata relucet, quod nimirum penitus eas subiens, earum materiae nigredinem attingit, et prout maiori, minorive eius portioni immiscetur, eo magis, minusve ab ea exuperatur, ad nigrumque agitur. Itaque ubi humile est mare, album, ubi paulo viride, et ceraleum ubi amplius, et nigrum ubi profundissimum, eo scilicet magis obscurata, ad nigumque acta, quae ab eo relucet lux, quo ampliori ipsius materiae nigredine immista est."
[32] Telesio, *De iride*, chap. 16, 15*r*: "Itaque aquam in vitro contentam matutina, vespertinaque lux, quae scilicet, quod bene obliqua advenit, nihil reflexa inseipsam colligitur. Itaque ab inexistente aquae nigredine esuperata irinis coloribus intingitur omnibus, minime vero et meridiana, quae nimirum bene directa inseipsam reflectitur, proinde copiosa, robustaque facta, materiae nigredinem penitus esuperat."
[33] Telesio, *De iride*, chap. 17, 15*v*: "In nube omnino bene in se ipsam conspissatam, et a luce iridem fieri existimare licet, nec maxime directa, meximeque robusta, nec maxime obliqua, languidaque, sed ab ea quae harum quasi media sit […]."

These parts show two extensive bands symmetrically placed in the two hemispheres. According to him, it is not the whole surface of the sun that spreads the light that causes the rainbow. The outermost parts do not, since the inclination of the light's rays coming from them is too great, and even the central part does not since the light from it reaches the cloud by the shortest line.[34] Through this division of the surface of the sun, Telesio could treat the problem of the double rainbow with great surety.[35]

The illumination coming from the central part explained the missing colour between the red bands of the two rainbows, whereas these last two were the result of illumination by those parts of the extensive symmetrical bands nearer the central zone. This was in fact the light which was striking the cloud in a less inclined way. The more it travelled towards the outermost part of the extensive bands, the inclination of the light increased, and thus in the corresponding part of the cloud the green colour appeared first and then the blue (violet) colour.[36]

To summarize, the lower hemisphere—the one turned towards the surface of the earth—was responsible for the appearance of the internal rainbow, whereas the other hemisphere was responsible for the external rainbow.

The problem which had so strained the minds of the Aristotelian commentators seemed finally to have been resolved, although the premise on which the solution was based was far from sound. Telesio's attempt, however, remained outside the scientific tradition, since this

[34] Telesio, *De iride*, chap. 17, 15*v*: "et ab ea forte, quae nequaquam a Solis parte emanet, quae nubi proximior, earumque, quae nubi expositae sunt, media est omnium; eam enim nubi directam imminere existimare licet; neque ab iis, quae maxime ab illa absunt, maximeque obliquam ad nubem emittunt lucem, sed ab iis, quae utrarumque veluti mediae sunt. Sphericus enim cum sit Sol, assidueque eius superficies immutatur, singulae eius partes proprium ad nubium partes quasvis situm obtineant oportet, eoque singulas a reliquis magis diversarum, quo magis ab iis absunt, obtineant oportet."

[35] In *De iride*, chap. 9, 8v-9v, Telesio had exactly noticed the contradiction in the passage where Aristotle had tied to explain the inversion of the arrangement of colors in the double rainbow. He had also carefully considered the solution of the problem offered in Olympiodorus' passage and had shown that it was untenable by briefly referring to the theories *perspectivorum*. Those explanations were similarly to be reject which had been offered by more recent commentators of the *Meteorologica*, who "ab antiquioribus acceperant acquiescere impotentes, dictarumque diversitatum rationem reddere disperantes, si quomodo Aristoteli placet, iris utraque aspectus ad Solem reflexione fiat exteriorem minime eo pacto exoriri contendunt, sed interioris iridis imaginem esse". This last criticism seems to be directed to Vimercati.

[36] Telesio, *De iride*, chap. 18, 16*r*–16*v*: "A luce porro, quam diximus iridem fieri, non ratio tantum, sed eius colorum ordo aperte quidem in simplici, at multo etiam in duplici amplius manifestat. Propterea enim ubi duplex fit iris, non altera alteri contigua fit, proximaque, sed spatium inter utramque album spectatur. […]. Utraque nimirum iris, prout ab albo spatio magis recedit, magis ad nigrum, obscurumque, et aeque utraque, eodem que tendit modo, in eo tantum ab altera differens altera, quod superioris colores paulo, languidiores apparent, quod iris utraque, et quod utriusque medium est spatium ab universo quidem Sole, at non ab universo simul singuli iridis utriusque ambitus, intermediumque spatium, sed et hoc, et singuli illi a certa illustrantur Solis parte, et inter medium quidem spatium a media iridum ambitus, pro ut ab albo spatio magis recedunt, ita a Soli partibus, quae a media magis absunt; et interior quidem iris a Solis parte, quae infra eam, exterior vero ab ea, quae supra mediam est, illustrari videtur."

tradition continued to refer mainly to the laws of geometrical optics until it finally found the essential precondition for any further research in the law of refraction.

5. Concluding remarks

In this essay I have read Telesio's *De iride* in connection with a scholarly tradition that can be traced back to Aristotle's *Meteorologica* (Book 3) and other sources of the Aristotelian corpus dealing with the formation of colours (*De anima* and *De sensu et sensibilibus*). As I have endeavoured to show, Telesio's attempt to provide an adequate explanation of the phenomenon of the rainbow still operates within an essentially Aristotelian framework. Aristotle's treatment of the rainbow is particularly interesting as a case in which mathematical disciplines such as optics can help to comprehend the phenomenon. However, at the same time, mathematics is incapable of adequately accounting for one of the essential features of the phenomenon, namely its colour. In spite of Telesio's disavowal of Aristotle, he cannot be placed outside the Aristotelian tradition of scholars and their explanation of the rainbow and its colours. Within this tradition I paid particular attention to Alexander of Aphrodisias and Olympiodorus. Although Telesio breaks with the extromissive theory of visual rays put forward by ancient writers on optics, this does not radically alter the framework of his explanation: in fact, this break would seem to bring him even closer to a genuinely Aristotelian theory of vision.

The instance of the double rainbow is a crucial example. The Aristotelian solution de facto entails taking two separate mathematical components into consideration: on the one hand, in relation to the internal rainbow, the magnitude of the arches of the various colours; on the other, in relation to the external rainbow, the observer's distance from the reflecting surface formed by suspended droplets. Ancient and Renaissance commentators, including Telesio, tried to reunite these two mathematical components by employing geometrical analysis and a theory of perception. Further, they addressed the related question of why the space between the two rainbows is colourless.

In my view, it is only through such contextualization that we can understand Telesio's *De iride*. Telesio's theory of the formation of colours, which is so closely linked to the idea of matter, does not greatly differ from some of the solutions proposed in previous centuries, for instance by Olympiodorus. The alteration of the colour of natural light depends on the density and depth of the illumined body. The cause of this alteration is the blackness of matter, which only becomes perceivable when this depth and density is substantial. It can hardly be denied that, given these assumptions, the appearance of a rainbow no longer has to do with the problem of the formation of images in tiny mirrors, but rather becomes a problem related to the variation of light in bodies of varying density. Although these ideas point beyond the Aristotelian conception, Telesio does not take the actual step taken by later writers on optics. He does not argue for the refraction of light rays as one of the causes of the formation of colours. While Telesio thought that the variation of the obliqueness of these rays plays a crucial role in the appearance of the colours of the rainbow, this element is never further explored through an in-depth study of optics.

Using this observation we have an improved appreciation of the importance of the work of other Renaissance scholars for Telesio, among whom are Alessandro Piccolomini and Francesco Vimercati. Piccolomini translated Alexander of Aphrodisias' commentary on the *Meteorologica* and was the author of a *Tractatus de iride*, which are fundamental sources for Telesio's treatment of the rainbow. Far more relevant for the study of Telesio's views is Francesco Vimercati's *Commentaries on the Meteorologica,* which was the most important commented edition of Aristotle's work to have been published in the second half of the 16th century. In this text he reopened the discussion on the phenomenon of the double rainbow.

Telesio derived his discussion of the double rainbow from these sources, and not from any mathematical enquiry—less still from any experimental study. Once he was aware of the fact that it is impossible to come up with a convincing interpretation of the phenomenon within a strictly Aristotelian framework, Telesio departs from it and develops a new explanation. Telesio proceeded using a process of 'elimination' of all those elements which inevitably led to unsolvable contradictions. Although this resulted in a very different interpretation of the phenomenon than Aristotle's, it nevertheless directly derived from it. Telesio's *De Iride* is representative of the wider context of the Renaissance debates about the reception, transformation or refutation of Aristotelian themes.

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