Ancient Commentators on Aristotle

GENERAL EDITOR: RICHARD SORABJI

PHILOPONUS:
On Aristotle Meteorology 1.4–9, 12

Translated by
Inna Kupreeva

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Conventions

[…] Square brackets enclose words or phrases that have been added to the translation or the lemmata for purposes of clarity, as well as those portions of the lemmata which are not quoted by Philoponus.

<…> Angle brackets enclose conjectures relating to the Greek text, i.e. additions to the transmitted text deriving from parallel sources and editorial conjecture, and transposition of words or phrases. Accompanying notes provide further details.

(…) Round brackets, besides being used for ordinary parentheses, contain transliterated Greek words and Bekker pages references to the Aristotelian text.

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Introduction

This volume completes the Ancient Commentators publication of the translation of John Philoponus' extant commentary on Aristotle's *Meteorology* I. Philoponus' extant commentary is incomplete. All we have is just the commentary on book 1, and even that is not complete: all the Greek manuscripts that reached us contain the same lacuna running from the end of chapter 9 and into chapter 12. It is not clear whether Philoponus ever published a complete commentary of the whole of *Meteorology*. There is little doubt that he intended to do so.[1]

The title of the work in the two Greek MSS used by Michael Hayduck, the *CAG* editor, to establish the text, is: 'Part one of the commentary on the first book of Aristotle's *Meteorology* [being part of] three by John of Alexandria, the Grammarian.'[2] This title is confirmed by two rubric subtitles in one of the manuscripts (V = Coislinianus 166) between chapters 3 and 4, and 8 and 9. In both cases, it is indicated that the completed section belongs to the commentary on book 1 of Philoponus' commentary.[3] The manuscript rubrics in both cases are well attested by the text of the commentary.[4] The division probably serves the purposes of teaching.[5] It is not clear whether Philoponus ever wrote a commentary on book 4, but he certainly knew it and considered it to be the last book of *Meteorology* and preparatory background reading for the biological corpus.[6]

The extant material covers Aristotle's discussions of the 'sky' phenomena formed from the matter of the two exhalations, the dry and the humid ones, in the upper layers of the sublunary cosmos, in the region common to air and fire. Chapters 4-8, treating of related subjects, form a unit, as indicated by Philoponus himself and by the manuscript rubrication.[7] In chapter 4, Aristotle discusses the so called 'shooting stars', the range of phenomena largely coinciding with the meteors of modern astronomy. Chapter 5 is devoted to the discussion of 'chasms', 'trenches' and phenomena of colouration in the sky: all these match the phenomena of the *aurora borealis*. Comets are the subject in chapters 6 and 7, and here Aristotle's nomenclature does not differ from ours. Chapter 8 is about the Milky Way. In chapter 9, Aristotle begins his discussion of the phenomena whose matter is moist exhalation. The surviving opening fragment of

Philoponus' commentary on this chapter introduces the phenomena that happen in the region common to air and water. The extant fragment of commentary on chapter 12 is devoted to hail.

Philoponus' sources

The commentary tradition

Philoponus' sources to which we can find direct and indirect references throughout the commentary fall into two groups. On the one hand, Philoponus makes use of the earlier commentaries on Aristotle's work produced by philosophers. The most important written commentary of this sort is by Alexander of Aphrodisias. Philoponus quotes it frequently and mainly accurately, not leaving any doubts that he uses the same commentary as the one that has reached us under the name of Alexander.[8]

Another, no less important, philosophical commentary Philoponus draws on is the unpublished lectures of Ammonius. The presence of Ammonius' material can be established on the basis of some parallels in Olympiodorus' commentary.[9] Philoponus' use of Ammonius is more restricted than in the commentaries which he published as notes from Ammonius' seminars. Substantial parts of the argument are not only his own, but also such that Ammonius would possibly not share, e.g. the argument against the Peripatetic (Aristotle's and Alexander's) theory of the sun heating the sublunary cosmos by friction. That this is Philoponus' own argument, is clear both from its general tenor and from Philoponus' references to his other works in which he criticises Aristotle's theory of the fifth element.[10] Indirectly, Ammonius is also responsible for Philoponus' (and Olympiodorus') interest in scientific matters. It is clear from Olympiodorus' commentary that Ammonius attempted to introduce a contemporary scientific point of view into the interpretation of Aristotle's *Meteorology*.[11] Ammonius knows Alexander's commentary well. In some cases, he provides more detailed explanations where Alexander appears to be too terse (e.g. 106,9-10), and sometimes he criticises Alexander's interpretations.[12]

J. Combès, on the basis of references in this commentary, suggested that Philoponus is using Damascius' lost commentary on Aristotle's *Meteorology*.[13] Philoponus refers to Damascius on three occasions. The first one is at the end of the discussion of Alexander's defence of Aristotle's theory of sun's heating by friction (44,21-36). Philoponus says that Damascius attributes to Alexander the view according to which different planets exercise specific physical effects on the sublunary bodies.[14] It is not clear whether the context of this attribution has to do with the discussion of *Meteorology*. The second reference has to do with the motion of comets: Damascius says 'elsewhere' (*heterôthi pou*) that their motion is supernatural: an idea which Philoponus claims to have refuted (97,20-1). The reference of 'elsewhere' is not clear.[15] The third, most extensive and most relevant set of references, is at the end of the commentary on 1.8 (116,36-117,31), in the passage unfortunately preceded by a lacuna, which makes the exact context of discussion elusive. Damascius apparently speaks of a supernatural status for the Milky Way, discussing in this connexion the myth of the Milky Way as an abode of souls.[16] Damascius obviously criticises Aristotle's theory of the Milky Way – so he does comment on *Meteorology* at least to that extent. The selection of topics (physical influence of planets, nature of comets, Milky Way) certainly suggests broad interest in the subject of meteorology, and Combès' argument that Damascius wanted to restore to the myth its place in the interpretation of the cosmos is quite plausible, even though the nature and format of Damascius' exegetical work is not clear from Philoponus' quotations.

The scientific tradition

Philoponus is certainly familiar with astronomical literature, possibly through the instruction of Ammonius. At one point his commentary suggests that Aristotle's *Meteorology* was commented on by someone with astronomical knowledge and interest: in 1.4, where the 'length' and 'width' of a shooting star are taken by an unnamed reader to refer not to its shape in the sky, but to its astronomical coordinates.[17]

One of the most important astronomical doctrines, the one that formed the background of any astronomical curriculum in Philoponus' time, is that of Ptolemy. Philoponus is clearly familiar with Ptolemy's works, most obviously with the *Almagest* which he uses on several occasions.[18] These have to do with the use of some basic concepts and terminology, such as the star magnitudes,[19] epicycles,[20] the precession of equinoxes,[21] and the structure of the Milky Way.[22]

The work *Planetary Hypotheses* was known to both Athenian and Alexandrian Neoplatonists.[23] Philoponus says that according to Ptolemy the number of heavenly spheres is nine. It is possible that this attribution is made on the basis of *Planetary Hypotheses* 2.[24] On the other hand, Philoponus seems unfamiliar with Ptolemy's hypothetical measurement of the size of the universe in *Planetary Hypotheses* 1, so it is not clear to what extent he had access to this work.[25]

Apart from Ptolemy's work, which by his time has firmly gained the status of a 'classical' school text, Philoponus probably made ample use of various commentaries, textbooks and manuals.[26] These could have included the works by Theon of Alexandria, particularly his treatise *On the Astrolabe* (now lost). Philoponus also drew on

Ammonius' instruction in astronomy; apart from the unpublished lectures on Aristotle's *Meteorology*, which might have included astronomical examples and explanations, he probably consulted also his lost treatise *On the Astrolabe*.[27]

Philoponus is also familiar with some optical writings of his time, which are difficult to specify more precisely (they may or may not be Ptolemy's *Optics*).[28]

Aristotle's sublunary cosmos in *Meteorology*

In the treatise *De Caelo*, Aristotle develops a view about the locations of the four 'simple bodies' (earth, water, air, fire) in the sublunary cosmos according to which the lowest, and centremost, position is occupied by earth, the heaviest element, and the top, or outermost, position is occupied by fire, the lightest element. In between there are water (also a 'heavy' element, but lighter than earth) and air (a 'light' element, but heavier than fire). In the *Meteorology*, this picture of a layered cosmos becomes more nuanced. Aristotle explains that the structure of the upper sublunary cosmos is determined by the two kinds of evaporation that rise from the earth continually, the smoky (dry) and the vaporous (moist) exhalations. Thus the two upper sublunary layers are not made up of pure fire and air, but rather of certain types of elemental mixtures, although the fourfold division of layers maintains its significance in defining the prevalent elements within the evaporated mixtures. The uppermost layer is mostly fire, with the fiery ingredient decreasing gradually as it gets lower, and being almost completely replaced by air at the lowest border of the upper region of the sublunary cosmos. So to some extent the 'natural places' of the four elements are preserved in the distribution of prevalence from the top down.

The fiery stuff that makes up the upper boundary of the sublunary cosmos is not the same as the fire here on earth. As Aristotle explains, the word 'fire' in a strict sense is used to refer to flame, while the upper region is constituted by the material which is called 'fire' generically, being hot and dry, and consequently susceptible to kindling. Because of its inflammable nature, Aristotle calls it 'tinder', using the word *hupekkauma,* which in Greek refers to dry combustible stuff, such as firewood and straw. According to Aristotle, this 'tinder' constitutes the matter of the fiery sky phenomena such as meteoroids, aurorae, comets and even the Milky Way. It is their material cause. The efficient cause of these phenomena, which brings them about in this or that part of the tinder sphere, is the revolution of the heavens around the earth. In *Meteorology* 1.3, Aristotle argues that the rotation of the heavens causes, by friction against the sublunary sphere, the heating of the sublunary cosmos, with the special role played by the sun. In chapters 4-8, which are the subject of Philoponus' commentary in this volume, this friction is still the ultimate efficient cause of all the processes of ignition in the atmosphere, although each class of events has specific, more complex and ramified, causal chains.

In chapters 9-12 of book 1, Aristotle discusses the phenomena of clouds, mist, drizzle, dew, hoarfrost, rain, snow and hail; and in chapters 13 and 14 he starts the discussion of rivers and the sea. Philoponus' extant commentary covers only the beginning of chapter 9 (clouds, mist and drizzle), and most of chapter 12 (hail). The discussion of hail elucidates the mechanism of interaction between the hot and the cold as 'mutual replacement' (*antiperistasis*), one of the key concepts of Aristotle's physics of material compounds.

Philoponus' views

Several general features of Philoponus' methodological approach which shape his reading of Aristotle's treatise and set his exegesis apart from other commentaries can be marked in a preliminary way.

(1) *Reality and appearance* is an important issue for all the commentators on *Meteorology* – as well as for its author. It is important to establish as far as possible whether the features of a sky phenomenon are what they seem to be or whether they are merely apparent, resulting from aberrations of our vision and other limitations of our observation processes. Philoponus distinguishes three classes of sky phenomena: those that are fully real, those that are mere appearance, and a 'mixed' class, i.e. those that have both some reality and also some appearance that does not correspond to any reality. Aristotle does not spell out this trichotomy in so many words, but it is certainly suggested by the text as well as found in the earlier tradition, even though a more frequent kind of division is dichotomist.[29] The first, 'real', class includes shooting stars formed by squeezing (1.4), as well as snow, hail and rain (1.9-12); the second class, 'mere impressions', includes 'chasms', 'trenches' and colours seen in the air (all the auroral phenomena discussed in 1.5) as well as visual illusions here on earth; the third class, phenomena which are partly real and party mere impressions, includes the shooting stars formed by burning (1.4).[30]

(2) *Mechanism of appearance*: *sight-streams*. The division between reality and appearance presupposes some method of establishing the status of a particular phenomenon under investigation. Hence a more specific theory of observation and observer is in order – and in fact, mathematical astronomy had been using a number of assumptions about vision in geometrical optics quite early on. One such assumption was that human vision operates by means of sight-streams,

which somehow flow out of the pupils of eyes in the shape of regular cones that reach the object of sight with their bases. This assumption was of great importance, because knowing the geometry of sight-streams in conjunction with the values for some angles and distances that could be obtained by direct measurement allowed the geometers and astronomers to calculate the magnitudes not accessible to such measurement. The sight-streams are treated as physical processes (Ptolemy, in stating the equality of the angles of incidence and reflection, compares reflection to the elastic rebound). But the assumed physical characteristics of sight-streams in all such cases are important only insofar as they are needed to explain their geometrical characteristics. Aristotle himself resorts to this theory of vision in the third book of *Meteorology* discussing rainbow and haloes, but we see nothing of it in the *De Anima*, where physical characteristics become more important. Philoponus in his commentary on *De Anima* 2.7 extensively discusses the respective merits and drawbacks of the two different theories of vision – 'sight-streams' and 'activities' (*energeiai*) – and does not arrive at any explicit conclusion, although his personal preference is probably for the sight-streams theory. In the *Meteorology* commentary, he is committed to a strong physicalist version of the sight-streams theory, and this will account for some of the special features of his interpretation of Aristotle.

(3) *Awareness of the limits of our knowledge in this field.* Aristotle is well aware that in the study of sky phenomena, which is the most traditional part of his physical corpus, questions of the reality vs appearance of the discussed phenomena can rarely (if at all) be settled by mere observation. Therefore he says we should be satisfied if we manage to derive an explanation that lies within the realm of possibility, since full verification in these matters cannot be carried out. Philoponus is in agreement with this methodological maxim. Generally, in the part of the commentary printed in this volume he shows less disagreement with Aristotle's theories than in the previous one, and even his disagreements seem to be dictated by methodological caution rather than by strong views on the subject matter. Thus he has no strong objections to Aristotle's theories of shooting stars, aurorae, and comets. He is clearly dissatisfied with the theory of the Milky Way (in this he follows Ammonius' lead), but he is not at all forthcoming on an alternative. In fact, when an alternative theory is offered by Damascius, Philoponus condemns it as ill-argued and methodologically faulty, suggesting that the question requires many more observations to establish whether the facts are really the way Aristotle presents them or not, and whether the phenomena discussed belong to reality or are to some extent or wholly the result of mere appearance, such as optical illusion (98,5-8).

The argument

Chapter 4. Shooting stars

In modern astronomy, the term ‘shooting stars’ is used to refer to meteors. Aristotle’s discussion in this chapter seems to be based on observations of meteoric phenomena. Notably, Aristotle introduces his own explanation of these phenomena without any preceding discussion of the views of his predecessors. The reason for this omission is not entirely clear. Perhaps it is that in most early sources ‘shooting stars’ are often not treated as a class on their own, but as a kind of fiery phenomenon akin to comets (with comets providing a paradigmatic case). This is how they are presented in ‘Aët.’ 3.2. The only earlier thinker who has a distinct theory of ‘shooting stars’, not reducing them to comets, seems to be Anaxagoras, on whose view the ‘so called shooting stars fall down in the manner of sparks, for which reason they are immediately extinguished’.[31] The doxographical sources give no further details about the nature of the ‘sparks’, so it is not clear what the actual theory was. In any case, Aristotle’s *Meteorology* appears to be one of the very few ancient sources where ‘shooting stars’ are treated as a distinct class of phenomena, different from comets and other lights in the sky.

In accordance with Aristotle’s general theory, shooting stars are formed high up in the sky from the ‘smoky exhalation’, dry inflammable stuffs constantly evaporated from earth and forming the upper layer of the sublunary cosmos. So meteors, on the view defended by Aristotle, are of sublunary provenance.

In the commentary, Philoponus first of all elucidates the common causal mechanism by which all the ‘sky’ phenomena discussed in chapters 4-8 are produced. The most relevant types of cause are efficient (the rotation of heaven and its effects in the atmosphere) and material (the two kinds of exhalation and their interactions in the upper layers of the sublunary cosmos). Philoponus explains that the ‘global’ efficient cause is the same for all phenomena, and their differences, which are captured by current study and observation, are due to the differences of material substrate involved in each case.

Following Alexander, Philoponus points out a difficulty raised by this explanatory scheme: why do the same efficient cause (regular rotation of the heavens) and the same material cause jointly produce effects that lack regularity?[32] He seconds Alexander’s solution: the irregularity is due to the material cause whose generic sameness does not involve physical regularity, but rather its contrary. Philoponus illustrates this with a medical example: different parts of the body can be differently equipped to resist the morbid effects of heating. Similarly in the cosmos at large, the same heating will produce different effects depending on the particular material condition of the affected parts. It will be noticed that at this point Philoponus does not pause to challenge the Aristotelian theory of heating by friction, presumably because the theory of heating by quality (which Philoponus endorses) does not have any tangible advantages in the explanation of night phenomena.

Aristotle distinguishes between two types of meteors: those formed by 'burning' and those formed by 'condensation' or 'squeezing out'. The distinction seems to be based on observation: the first class covers phenomena where no meteorite is formed, the meteoroid being burned in the atmosphere; in the second case, the meteor's motion is such as to suggest that there is some sort of a body being thrown, and in some cases, Aristotle says, the body does actually fall to the ground or into the sea. Aristotle also suggests that these two classes differ in their original location, the 'burning' meteors being formed higher up, the 'squeezed' lower down.

In his discussion of meteors, Philoponus applies his tripartite classification of the sky phenomena in terms of reality and appearance, mentioned above (p. 5). The meteors formed 'by burning' belong to the 'mixed' class. What we see as a fiery moving object is in fact a relay of minuscule ignitions running along the suitable bit of exhalation as in Bengal fires. When the supply of tinder runs out the ignitions cease and the 'shooting star' disappears.[33]

The meteors formed by 'squeezing' are real things: they are chunks of inflammable smoky exhalation compressed and pushed out by cold air, which catch fire as a result of this rapid motion (presumably also by friction against the other parts of atmosphere).[34] Aristotle says that we can sometimes see these shooting stars run aground or sink into the sea.[35]

Philoponus draws attention to the fact that both Aristotle's theories of 'shooting stars' have to explain the direction of a meteor's motion. There are two possible difficulties with this. First, on the standard theory of natural motion, which might apply in the case of 'burning' meteors, fire should be moving upwards while in fact these meteors are seen moving in various crosswise directions.[36] Secondly, in the case of forced motion, which takes place with 'squeezed' meteors, the direction should be random, but it tends to be downwards.[37]

Philoponus' explanation of the first difficulty just spells out the mechanism of 'burning': he points out that what seems to be a star is in fact a short-lived process of ignition; the direction of the chain of ignitions exactly follows the shape of the part of exhalation that serves as fuel; it is ultimately this shape that defines the apparent 'motion' of a meteor.[38]

In the case of forced motion, Philoponus explains, the upward movement of the 'squeezed' meteors is prevented by the density of the cold air that collects up in the sky in the gaps between the sun rays reflected from earth. Because these gaps fall in between the hot rays, they are cold, and the higher up the larger the gaps are. So this cold front gains density and blocks the upward routes of the 'squeezed' meteors, which thus have to go down, through a more rarefied medium.[39]

Aristotle adds the explanation of why the 'squeezed' meteors move sideways: the sideways motion results from a mixture of forced downward and natural upward motion (342a21-7). Philoponus spells this out with the help of an example in which two ants moving on the inner surface of the adjacent sides of a square at the same speed, starting simultaneously at two opposite vertices, illustrate two different motions, natural (upwards) and forced (downwards), assuming they are equal.[40] What happens when these two motions act upon the same object causing it to move with one mixed motion is similar to what happens when the two ants run into each other, and since each continues to move with its own motion, they start moving together, with the same motion, along the diagonal of the square.[41] In [Aristotle]'s *Mechanics* 1, we find a more rigorous proof of the principle, according to which the motion that is a result of two different but proportionate motions is along the diagonal of the parallelogram formed by these two different motions.[42] Philoponus here gives an ingenious illustration of this principle.

Chapter 5. 'Chasms', 'trenches' and blood-red colours

Phenomena described as 'chasms', 'trenches', and blood-red colours, together best correspond to what we know as the *aurora borealis*.[43] Identifying them as such was made difficult early on by doubts that any auroral effects, typically northern phenomena, could be at all observed as far south as in the region of the Mediterranean, but it has been argued since that the descriptions of aurorae in ancient writers are based on observation.[44] So we should not perhaps be surprised that Aristotle's ancient commentators never question the phenomenon itself and concentrate on the mechanism of its appearance.

Notably, it is in the course of his discussion of aurorae that Philoponus introduces the tripartite distinction of the meteorological phenomena mentioned above. 'Chasms', 'trenches' and 'colourations' all belong to the class of mere appearances. This categorisation is somewhat more radical than what we find in other commentators, all of whom admit a certain amount of reality involved in the formation of these phenomena (e.g. Alexander, Olympiodorus). Philoponus' explanation of the mechanism by which auroral phenomena are produced to some extent explains his disagreement with other commentators.

Aristotle describes the formation of auroral colours as based on two processes: some colour effects are produced by light when it passes through a not fully transparent medium, such as thicker clouds; other effects are produced when this light is reflected from the exhalation; deep dark 'chasms' are formed when a light stream is for some reason broken or obstructed. Alexander in his commentary speaks of the two factors involved in these processes: (i) the superposition of colours (black and white) which occurs due to the light passing through the thick medium of cloud or mist and produces the appearance of colouration, in accordance with a hypothesis set out by Aristotle in *De Sensu* 3;[45] and (ii) the reflection of light from the surfaces in the atmosphere which enhances this variety. Both processes act upon the observer but do not, strictly, depend on the presence of the observer for their coming to be, as the light will be refracted in case (i) and reflected in case (ii) whether or not the observer is present. Not so for Philoponus, who understands the 'superposition' as the effect of the observer being stationed under the semi-transparent surface: the sight-streams of the observer reflected from this surface get mixed with the light that passes through the cloud, and this mixture produces the impression of colour. The observer's sight-streams are a physical component of this mixture; without this component, and thus the individual observer, the colours in question would not be produced at all: therefore Philoponus says that no effect takes place in the air, but the auroral phenomena are present only in our apprehension and perception.[46] Philoponus says that the air is affected in the same way in which it is affected by the colour of the light passing through the coloured glass: on a certain reading this might suggest that there is still some kind of objective colouration underlying our perception; but Philoponus clearly assumes that the role of coloured glass in this case is played by the sight-streams of the observer rather than by the coloured cloud.

The 'chasms' and 'trenches' are those black parts of the sky which produce an impression of depth, looking like huge folds on the 'curtain' of the aurora sky. According to Philoponus, they occur when light in the middle is occulted by a thick black cloud which slows down the eye rays (72,34), a similar explanation at this point as the one given by Alexander (25,8-15). Philoponus criticises some unknown commentators who interpreted the difference between the 'chasms' and 'trenches' in terms of breadth (68,5) and gives his own explanation in terms of depth. According to it, when this cloud is less condensed, there is a trench (less depth); and when it is more condensed, there is a chasm (more depth). Alexander explains the terms 'trench' and 'chasm' in a reverse way: trench is deeper and chasm shallower (25,19-22).[47] Philoponus insists that his interpretation is in better agreement with the wording of Aristotle's text.[48]

Chapter 6. Comets: earlier views

Aristotle discusses three earlier theories of comets. According to the first one, attributed to Anaxagoras and Democritus, what appears as a comet is a conjunction of several planets.[49] The second, Pythagorean, explanation says that the comet is one of the planets which appears less often than the others. The third theory, the most technical of the three, and of which most details are known, belongs to Hippocrates of Chios. On this third view the comet's body is a planet (i.e. wandering star), and its tail is the reflection of our sight-streams from the mist formed in the atmosphere under its location.[50] According to Hippocrates, the comet's tail is seen as fiery because of the reflection of our sight-streams towards the sun.

The formation of a comet, according to Hippocrates, requires some vapour in the region under the comet-planet, in order to provide a reflecting surface for our sight-streams. Our sight-streams first travel to this vapour, which, like a mirror, reflects them towards the sun. As a result, we get the appearance of a tail, which seems to be attached to the comet.[51] Another requirement is that of a close distance between the sun and the comet-planet: otherwise our sight-streams will be exhausted before reaching the mist, and we shall not see a reflection, i.e. the comet's tail. Therefore the comet sighting in the northern hemisphere is restricted to very few times and locations that satisfy these two conditions (supply of vapour in the atmosphere and manageable distance). The comet cannot be formed (a) when the sun and the star are between the tropics, since there is not enough moisture to form the vapour; (b) when the sun is distant from the star, e.g. the sun being in the winter solstice and the star in the summer solstice or vice versa; (c) when both the sun and the comet-star are in the winter solstice, i.e. with the sun in the southern hemisphere, because the distance between the sun and the comet-planet is too great for the sight-streams to traverse. The only possible position for sighting a comet is, on this view, (d) when both the sun and the planet are in the summer solstice.[52]

Philoponus is clearly interested in a precise presentation of Hippocrates' argument. Aristotle reports that according to Hippocrates, the comet-planet is seen less frequently than other planets 'because of being the slowest in time to fall behind' (343a4-5). Alexander takes 'to fall behind (*hupoleipesthai*)' as meaning 'to go around its own circle' (27,12-21). As we learn from Olympiodorus, Ammonius argues against this interpretation, proposing instead that 'to fall behind' means 'to lag behind the sun'.[53] Philoponus does not name Ammonius, but seconds the objection (79,30-6) and gives an extensive criticism of Alexander's reading of Hippocrates' theory, arguing that had it been true, we would have seen more, not less, of the comet because it would have to be distinct from the sun. Philoponus also points out that

Alexander's interpretation is in conflict with the assumption that the comet-planet is concurrent with the sun (although in fact Philoponus' own interpretation cannot be made consistent with it either).[54]

Philoponus adds his own criticisms of Hippocrates' argument as analysed above. He points out that in case (c), i.e. when both the comet and the sun are in the winter solstice, the distance between the sun and the comet is not always unmanageable for the sight-streams. For at the time of the night when the comet-planet lies in the earth's shadow, but the sun has not yet traversed a great part of its day circle and has not reached the point of midnight, our sight-streams travelling to the comet-star can reach the sun and be reflected from it, so that we must see a comet at that point as well. Furthermore, in case (d), with the sun and the comet both in the northern (i.e. summer) tropic, when according to the version of Hippocrates' theory stated above we should see the comet, that will not always be the case, e.g. we will not see the comet at or around midnight, because at that time the distance between the comet and the star will be the greatest, but it is more likely to be seen before dawn or right after the sunset.

After his detailed analysis of this hypothesis, Philoponus turns to Aristotle's refutations of Hippocrates. Here his argument may also to some extent follow the logic of Ammonius' exposition.[55] Some of Aristotle's refutations target all the mentioned hypotheses in common.[56] In his exposition, Philoponus occasionally refers to the observations made by himself, or in his school.

Aristotle argues that a comet cannot be a planet or a conjunction of planets, because planets never go beyond the zodiac belt, whereas comets can be seen both north and south of it (Philoponus 81,25-31).[57]

Further, several comets have been seen simultaneously, which contradicts both 'conjunction' and 'single planet' theories.[58]

Moreover, a comet is not a planet because some fixed stars have also been seen having tails.[59] Aristotle cites his own observation of such a star, 'in the thigh of the Dog' (Canis Maior), and notes that the tail was 'feeble', particularly so for those who looked at it directly, and a little brighter for those who took a side look at it. It has been argued that Aristotle here is the first to describe the technique of 'averted vision' used by astronomers in observations.[60] If that is indeed the case, then Philoponus' commentary shows that later astronomers and opticians tried to develop an explanation of this phenomenon consistent with their chosen theory of vision. Philoponus suggests that the axis of the visual cone, because of its strength, i.e. the high intensity of the visual stream (a physical characteristic), cannot perceive visual objects that lack intensity (such as the feeble light of the comet tail), but the sight-streams at the sides of the cone, being themselves weaker than the axial ones, are better at forming visual impressions of feebler objects of vision.

Philoponus is here drawing on some contemporary optical source, possibly Ptolemy's *Optics*.[61]

Aristotle's final common objection to both the 'comet-conjunction' and 'comet-planet' theorists is that all the observed comets disappeared without a last setting.[62] He attacks Democritus who apparently claimed to have seen some stars appearing after the dissolution of a comet. Philoponus gives a very detailed analysis of Aristotle's comet rising, and seconds his argument, saying that he also knows of no cases where stars would be left behind the comets (although he gives no examples of such obvious absence observed).[63] He suggests that Democritus was misled with regard to the phenomenon. Aristotle also reports that he observed the conjunction of Jupiter with a star in Gemini from which no comet resulted and notes that the size of the stars allows us to treat them as indivisibles, i.e. having no size in a physical sense, so the addition of such entities would not result in increased light (343b28-344a2). Philoponus accepts the evidence and agrees with the argument.

Aristotle also refutes some of the more specific positions of the earlier theories. Against Hippocrates' view that a comet's tail is reflection he objects that in that case we should sometimes be able to see this planet without a tail, but this never happens (343a26-41). Philoponus develops an additional objection against those who believe the tail is real, not just an appearance. Assume the comet is a conjunction of planets: still, where does the tail come from? It might be an effect of emitting sparks, such as is seen with some of the large stars (Sirius and Venus): but in that case we are talking of a visual illusion of the kind that happens with those whose sight is weak in the humid air.[64]

A further special objection made by Aristotle against Hippocrates' theory refutes its consequence (d), according to which comets are seen only in the northern part of the sky. Aristotle cites as a counter-example the great comet of 373/2 BC which rose in the west and says that apart from that many comets were seen in the south. Philoponus supplies a further example of a comet seen in the south 'in our own time'.[65] Aristotle (343b4-7) also mentions a comet seen around 427/26 BC in the north in winter, with the sun in the winter solstice, i.e. in the south, which refutes consequence (b) of Hippocrates theory.[66]

Chapter 7. Comets: Aristotle's own theory

According to Aristotle, the matter of comets is smoky exhalation, which occupies the area from tinder sphere (inclusive) to the tops of the highest mountains (i.e. including air and fire which are moving along with the heavenly sphere).

Philoponus explains Aristotle's view according to which the nature of comets is the same as that of meteors (discussed in 1.4), the difference being the amount of matter and strength of the incipient fire which ignites the part of exhalation that is the core of the comet (92,5-22). The term 'comet' can be used generically, according to Philoponus (92,25-9), also covering the Milky Way. Comets in a more specific sense differ in shape: the oblong ones are called 'beams', the triangular 'bearded'; there are also 'jar-shaped' ones and some others.[67]

Aristotle distinguishes between the two types of comets: those formed 'by themselves', i.e. not visibly associated with any star or planet, and those that are seen as 'following a star'. The first type is formed in the lower parts of air and tinder stratum, the second in the upper region, closer to the stars. Aristotle devotes a special discussion to the second type of comets, formed under the stars. Aristotle at this point gives no example of a 'comet-star',[68] and none of the three later Greek commentators is forthcoming with any new data (whereas there are some new examples of ordinary, stand-alone, comets). In fact, they seem to have a difficulty pinning down this effect and its correct explanation, and Philoponus ends up on a mildly sceptical note, questioning the phenomenon and pointing out that more observations are needed to establish what it is and then explain it.

Aristotle makes it clear that the stars in question are involved in the production of this type of comet, although he does not make the details of this production entirely clear saying only that in this case, the comet that arises under the star is formed from the smoky exhalation condensed by the motion of this star. Alexander understands the role of the fixed stars in line with Aristotle's theory of the sun's heating the atmosphere by friction. Notably, he does not attribute the cause of a comet-star to any particular star, e.g. the one that appears to acquire a tail. One might suppose that the mechanism of comet-formation is similar to that of the sun's heating in that, just as in the case of the sun, the main job of friction is done by the lowest sphere of the moon, with the sun exerting special influence due to the specifics of its size and location close to the earth, so in the case of stars and planets, specific influence of even remote luminaries can be triggered by the suitable mixture of smoky exhalation which becomes the matter of a comet.[69] But Alexander, as usual, is reluctant to speculate in the commentary.

Philoponus' interpretation of Aristotle's theory seems to assume a stronger role for the individual stars in comet formation. Rather surprisingly, Philoponus says that just like Hippocrates of Chios, Aristotle believes that stars and other luminaries can attract the sublunary materials, such as exhalation.[70] Presenting his reading of Aristotle, he explains the mechanism of comet formation as follows: 'When the stars too by their motion draw into themselves an exhalation of this kind (*eis heautous helkousi toiautên*), when this exhalation happens to catch light due to the aforementioned causes, the star seems to become a comet' (94,35-95,1).

The motion of the first type displays the irregularity characteristic of the sublunary region as a whole. The motion of the second type is so regular that it produces an impression that a fixed star or a planet has obtained a 'tail' and become a comet. This difference is going to present a problem for Aristotle's theory, Philoponus argues.

Philoponus follows Aristotle and Alexander in his explanation of the nature of the comet's tail. He points out its affinity with the halo in that, just as in the case of the halo, so in the case of the comet produced by the star, its appearance does not represent correctly its nature: it appears to lie in the same plane with the star, but is in fact much lower. He also points out the difference: the halo is reflected light, whereas the comet's tail is a real fiery formation.

Chapter 8. The Milky Way.

The 'Milk' (*gala*), or 'Milky Way' (*galaxias*), the visible part of the spiral of our galaxy, attracted the attention of early natural philosophers. Aristotle begins his discussion of the phenomenon with the analysis of three different views of his predecessors: (1) a theory attributed to Pythagoreans according to which the 'Milk' is the sun's old orbit, its light being formed by the residual heat of the sun; (2) a view he attributes to both Anaxagoras and Democritus, according to which the Milky Way is the light of the stars which becomes visible due to the sun being screened off by the earth's shadow; (3) the view of some thinkers according to which the shining of the Milky Way is formed by a reflection of our sight-streams from the stars onto the sun (screened off by the earth). This last theory looks similar to Hippocrates of Chios' theory of comets, and although Aristotle gives no names at this point, Philoponus identifies the author of this view with Hippocrates.[71]

Aristotle refutes all the three mentioned views. Against the Pythagoreans, he says that if the sun's movement produced such an effect in its old tracks, this effect should be even more visible in its present orbit along the ecliptic circle; but that is not the case.

With regard to the view of Anaxagoras and Democritus, Aristotle's objection is that had this theory been true, the picture of the Milky Way would have been changing with the sun's movement along the ecliptic, because the earth's shadow would have been following this motion and screening off different stars at different times. Aristotle adds a further objection based on the 'astronomical theorems', according to which the earth's shadow does not reach as far as the sphere of fixed stars. Aristotle gives no precise data concerning the size of the earth's shadow, but in Philoponus' commentary (104,30-105,15) we find calculations close to those given by Ptolemy in *Almagest* 5.15. It is not clear whether Philoponus consulted Ptolemy's work directly or whether he used an intermediary source. Ptolemy's more complex argument is adapted by Philoponus for the needs of the exposition of Aristotle's objection; but he demonstrates full understanding of the geometrical reasoning underlying the calculations.

Aristotle's refutation of the third hypothesis, the 'reflection' theory of the Milky Way, once again involves an appeal to the absolute stability of the phenomenon which is inconsistent with the idea that it is produced by reflection of our sight-streams from a moving object, namely the sun, whose movement is not at the same distance from nor at the same speed as that of the sphere of fixed stars. Philoponus' comment on Aristotle's refutation is particularly interesting inasmuch as it seems to contain a reference to the precession of the equinoxes, which he is trying to use in explicating the objection to the 'reflection' theory. The attempt is neither very clear nor very convincing. Aristotle says that if the mirror and the object seen in the mirror are in motion being at the same distance from the observer but not at the same distance from, nor moving at the same speed as, each other, it is impossible for the reflection (as seen by the observer) to stay the same (345b15-19). In this example, the observer is stationed on earth, the object seen in the mirror is the sun, and the mirror is the mist under the stars of the Milky Way in which the reflection of our sight-streams from the sun creates the appearance of milky-coloured sheen. Philoponus takes Aristotle's remark about moving not at the same speed (*ouk isotakhôs*) in a technical sense and says that the sun clearly moves faster than 'the rest', i.e., presumably, the fixed stars.[72] Aristotle's example used to illustrate the unevenness of motion and distance does not go beyond the variations of location which occur because of the sun's movement along the ecliptic circle. It has nothing to do with the difference between the stars and the sun in the speed of rotation. Yet Philoponus' attempt to use post-Aristotelian astronomy in the commentary is in itself remarkable.

Aristotle's own view of the Milky Way is an extension of his theory of smoky exhalation as the material cause of all sky phenomena. The Milky Way is predictably a sublunary formation whose mechanism is very similar to that involved in the formation of comets that build up under the stars. In fact, the whole Milky Way is such a huge common 'tail' formed under certain stars located on a great circle which intersects the ecliptic at two points.

Philoponus' discussion of Aristotle's theory contains several parallels with Olympiodorus' commentary which reveal their common source in Ammonius' lectures. We owe this to the reference in Olympiodorus' commentary. Olympiodorus distinguishes four arguments in favour of Aristotle's view and four objections. The four objections answering each of the points of the argument, as stated above, come, as Olympiodorus tells us, from 'the great Ammonius' (Olympiodorus, *in Meteor.* 75,24-5). It is a safe guess that the presentation of Aristotle's arguments that includes these four points is also the work of Ammonius.

Some traces of both the presentation and the counterargument are found in Philoponus' commentary: there are elements of common structure and on some occasions even the same quotations from Aratus' poem used in the two presentations of the argument, and this despite all the very tangible stylistic differences between the two commentaries.

Aristotle's four arguments in favour of his theory of the Milky Way are these. (1) *From analogy with comets*: just as a comet is a condition of exhalation caused by individual random factors, so the Milky Way is a permanent condition of the upper layers of the atmosphere caused by the same factors (supply of suitably mixed fuel and heating by friction) being more regular. (Ol. 74,26-75,2, cf. Philop. 110,24-32). (2) *From size*: the Milky Way is formed around the great circle (i.e. the circle which is concentric with, and has the same radius as, the cosmos), which explains its size: the great circles of the cosmos move with the highest speed (Ol. 75,2-14, cf. Philop. 111,31-112,32). (3) *From location*: the Milky Way does not coincide with the zodiac and avoids the tropics, for the same reason that comets do not often come about in the region between the tropics, namely because these areas are dry and have not enough suitable matter for the Milky Way (Ol. 75,14-19, cf. Philop. 111,11-23). (4) *From the fixed stars*: the Milky Way runs over the areas where fixed stars are most numerous and densely located, being almost continuous with each other (Ol. 75,19-23, cf. Philop. 110,34-111,5 and 112,32-113,9).

Ammonius' objections, which Olympiodorus calls 'demonstrations' (*apodeixeis*), are as follows. (1) *From the unchanged*: had it been the condition of the air, it would have been subject to alteration, as is not the case (75,26-9). (2) *From the universal* (*katholou*): in general, none of the air conditions is seen from different parts of the earth as one and the same; but the Milky Way looks the same from all parts (75,29-31). (3) *From the moon*: as Ptolemy has shown in the *Almagest*, the objects that display a greater parallax (*parallattônta*) are below those whose parallax is smaller; thus the Milky Way should be above the moon which does have parallax (75,31-4).[73] (4) *From the rest of the planets*: the Milky Way is above the planets; argument: it is in the sphere of fixed stars, for had it been below it, it would blunt the colour of the stars in the constellations of Sagittarius and Gemini with which it overlaps; but it does not; in fact, these stars are still seen as brighter when passing through the Milky Way (75,34-76,2). Particularly interesting are (3) and (4), because they show that Ammonius himself treated the Milky Way as not a sublunary but a heavenly phenomenon, a view of which Philoponus approves but which he ultimately seems hesitant to endorse fully. Both Olympiodorus and Philoponus mention some objections not contained in this list. Olympiodorus adds that the Milky Way would occult the stars of these constellations, as it does not. Philoponus adds the objection to the argument from the multitude of stars (114,17-30).

The end of Philoponus' discussion of the Milky Way contains a very interesting debate with Damascius. Rather frustratingly, this part opens with a lacuna which possibly hides some crucial details of Damascius' involvement with Aristotle's text and with its interpretations in the two major Platonic schools of the time. But even what we have is both historically valuable and instructive. Damascius seems to be claiming, against Aristotle, that the Milky Way is not a sublunary, but a heavenly phenomenon. He develops some strong arguments (some in fact *ad hominem*) against the 'sublunary' interpretation of the Milky Way. But the main thrust of his solution seems to go well beyond the dry criticism. As Combès plausibly suggests in his survey of the fragments in Philoponus, Damascius is probably trying to rehabilitate the mythological interpretation of the heavens, bringing it in agreement with both the evidence and the scientific demonstrations. Damascius approvingly quotes the dialogue by Heraclides of Pontus about the soul's journey, where the Milky Way is said to be the abode of the soul after leaving the body,[74] but makes several amendments to the main theory: there is no reason to make the Milky Way some sort of an ontological intermediary identifying it only with the souls. It should be regarded as a divine entity, on a par with other heavenly gods.

Philoponus does not like this interpretation at all. In his criticism, he emphasises that the subject matter is within the remit of the science of nature, so there is no need to adduce supernatural or mythological accounts to explain the phenomena. Moreover, when it comes to the science of nature itself, one should proceed with due caution, carefully examining the evidence, trying to get the most accurate idea of the phenomena, and develop the explanations accordingly, on the basis of natural causes. In this debate Philoponus poses as a defender of methodological integrity of the study of nature, which makes it difficult to see it merely as a debate between a Christian and a pagan, even though some such tensions may arguably be in the background of the two positions.[75] Admittedly, Philoponus most probably believes that his Christian outlook is in good agreement with his naturalist methodology, but it is still true that this methodology could be and has been formulated independently from any religious outlook, and it seems that it does have its own appeal for Philoponus. In any case, we have another interesting document of a debate on 'How to do physics' between two major representatives of late antique Platonism.

Chapter 9. Vaporous exhalation

Only two fragments of Philoponus' discussion of vaporous exhalation are extant: the opening of chapter 9 (346b10-33) and a part of chapter

12 with a missing opening (348a23-b34). Chapter 9 is the general introduction of this second type of exhalation. Philoponus follows Aristotle's explanation of the mechanism of evaporation and his enumeration of the phenomena produced by vaporous exhalation. He dwells a little bit on Aristotle's claim that the 'moving, ruling and first of the principles is the circle' of the ecliptic (346b20-3). Philoponus explains that the sun is said to be the 'first' cause of the processes in the air in the sense of 'ultimate', whereas their proximate and secondary cause is the heating and cooling produced by the sun's motions.[76] He offers another explanation of the 'first': the motion of the sun along the ecliptic circle is called the first principle because it is the efficient cause of the sublunary sky phenomena, as opposed to the matter of these phenomena (dry and moist exhalations) which is the secondary cause and co-cause (*sunaition*) (120,15-26). Philoponus probably uses the term 'co-cause' (*sunaition*) following Aristotle's usage in *De Anima* 2.4, where it does refer to material cause in the way Philoponus intends it here, rather than the Stoic notion of co-operant cause which presupposes several causal agents of this status.[77] Philoponus concludes the discussion of causes with a remark hardly provoked by Aristotle's text, to the effect that 'the first' has to be taken as such only with reference to the world of natural things, which, for Philoponus, includes the motion in a circle, 'for if somebody ascends to the cause of the motion in a circle, he looks for a cause which is transcendent, not natural. But the task of the student of nature is to give natural causes'.[78] By 'transcendent' causes (*exêirêmena*) Philoponus probably does not mean the explanations of heavenly motions provided by mathematical astronomy. The limits of natural philosophy could be at least discussed that way with an Aristotelian who took the boundary between the world of nature (coming to be and perishing) and the heavens as a demarcation between the natural and the transcendent. Philoponus, however, has already shown his commitment to the whole cosmos made of the four elements,[79] so he does not need to demarcate the sublunary region as nature against the heavens as a totally different nomological realm. It is much more likely that, as in his debate with Damascius, he is here targeting the attempts to combine natural and supernatural causes in one picture. In this methodological position, Philoponus is much closer to Aristotle than to Plato who does not mind myths as vehicles of scientific truth in his dialogues.

Philoponus explains in detail the mechanism by which the sun causes coming to be and perishing. Discussing the evaporation of moist, he uses an ambiguity in Aristotle's text to advance once again his own theory of the sun's heating by the quality of heat rather than friction. Aristotle says that 'the moist evaporates under [the action of] sun rays *and the other heat coming from above*' (346b23-4), and Philoponus argues that the only kind of heat Aristotle could have in mind is the qualitative heat of the sun, so the upper cosmos is made of fire and Plato is right.[80]

The commentary ends abruptly in a lacuna after Philoponus elucidates Aristotle's claim that the exhalation from water is vapour and the formation of water from air is cloud (346b32-3), explaining that the intermediary stage in the processes of evaporation and condensation is the same (122,31-123,17).[81] In his explanation, he invokes the mechanism of *antiperistasis*, mutual interaction of the principles of heat and cold, which is discussed in more detail in the last extant chapter.

Chapter 12. Hail

In chapter 10, Aristotle discusses the formation of dew and rime; chapter 11 introduces rain, snow and hail. Indicating a parallel between dew and rime on the one hand and rain and snow on the other (the former are produced by cooling of small quantities of moist on the ground, the latter by cooling of larger quantities of moist in the air), he points out that in the case of hail, there is no similar parallel precipitation formed on the ground. The reason for this lack of parallel is explained in the following chapter 12. The text of Philoponus' commentary again has a lacuna at the beginning, which corresponds to the coverage of about one Bekker page of Aristotle, from the beginning of the chapter to 348a20. Thus we do not have Philoponus' discussion of Aristotle's preliminary difficulties about hail: why it is formed during warm seasons and in mild climes rather than in cold weather (347b36-348a5) and why water freezes in the upper region at all (348a5-14). The extant commentary, after the lacuna, begins with the refutation of Anaxagoras' theory of hail. Aristotle presents Anaxagoras' theory as an attempt to solve the two problems he outlined. The solution says that hail is formed when warm air raises the clouds high into the upper air where they manage to freeze because of the excessive cold.[82] The cold is explained by the distance from earth, which has as its consequence larger gaps between the reflected sunrays and as a result also their diminished heating effect. This is supposed to explain both why hailstorms happen in warm weather (it takes a lot of heat to raise the clouds high enough to freeze) and why hail gets frozen (temperatures are very low). Aristotle criticises the solution, pointing out that if Anaxagoras is right, there should be many hailstorms in the higher places, but this is not the case. Moreover, there are a number of signs that hail comes from lower clouds. Thus, many hailstorms come from clouds which on their movement towards earth make a loud noise that ceases when they come close to earth and a lot of hail falls, with hailstones of large size and the shape which is not round: an indication that they have not travelled a long distance, but were formed close to earth (348a23-30).

The central concept used by Aristotle in the explanation of hail formation is the 'mutual replacement' (*antiperistasis*) of the hot and the cold: according to the view presented by Aristotle in this chapter, the hot and the cold can act upon each other so as to enhance each other's respective dominant properties. The cold can cause heating (that is why it is good for winter crops to be covered with snow) and the heat can cause cooling (summer heat can diminish our innate heat and thus cause indigestion). Both Aristotle and Theophrastus often use explanations of this sort.[83] They are potentially problematic, because they seem to override the laws of elemental transformation established by Aristotle in his discussion of the four simple bodies in *GC* 2.2-4 and may look like a flexible 'master' principle by which to solve any particular problem concerning specific physical processes involving heat and cold. Philoponus realises this well, and therefore explains the way the principle works in some detail. He says that we should not think of this principle as merely subjective, based on our sensations of heat and cold during the hot and cold seasons, i.e. that it only seems to us that underground enclosures are warmer in winter, because it is cold outside, and the same spaces seem to us cooler in the summer because it is hot outside (125,21-126,15). In fact, there are many signs that show the objective background of our seasonal sensations of hot and cold: vapour rising from wells in winter (evaporation), and the already mentioned indigestion of animals in summer.

Moreover, one should not think of *antiperistasis* in a simplified way, as though the heat and the cold themselves, as it were, migrate to take each other's place.[84] In order to have a competent grasp of the principle, we need to consider all the processes involved in its realisation. In winter, the cold air outside and the earth become dense because the moisture freezes and the air gets condensed and also freezes. This dense shell blocks the passages by which the hot air inside the earth could get out, and thus prevents the transformations of the hot and the cold into each other on the basis of elemental chemistry (as described in *GC* 2.2-4). Instead, the hot stuffs collect inside and the cold outside produces insulation, so that the hot stuffs exercising a heating effect on the subterranean environment can gradually get hotter. The same process takes place in our bodies: as the skin pores get smaller in winter because of cold, the enclosed innate heat becomes more active and heats the inner parts more and more. In the summer, the skin insulation is removed, so the heat gets dispersed, and the inner parts undergo cooling effects (therefore we cannot digest well enough, become sleepy and lazy, etc).[85]

The same principle works in the case of hail. What accounts for the condensation and freezing of water within the clouds is the heat outside the cloud, which makes the cold retreat deep inside.[86] With Philoponus and Aristotle, we have to presuppose that there is in the cloud some amount of inner heat that gets dispersed in warm weather leaving behind a much colder entity. But this allows Aristotle to say that hail is formed not very high up, as the main cause of its formation is not the cold, but the *antiperistasis* of hot and cold. This account, even if not more correct, is certainly more nuanced than that of Anaxagoras and takes much better care of a host of technical problems indicated by Aristotle himself; we can certainly derive satisfaction from Aristotle's methodological dexterity at the level of 'puzzle-solving'.[87] Thus it is more consistent with Aristotle's assumption that the hailstones could not possibly travel a long distance. Also in accordance with this account, the high season for hailstorms is not the summer (because there is not enough moisture), but the spring and early autumn: given the *antiperistasis*, there is no need to involve excessive heat in order to raise clouds very high up. Philoponus agrees with all this. He raises a problem of how exactly the hail freezes: is it in or outside the cloud? It can't be outside, since in accordance with the theory, outside is warm air. But if it froze when inside the cloud, it is not clear why the water stayed there for long enough to freeze rather than falling down as rain, and why the hail when frozen is not melted by the warm air outside. The answer Philoponus helpfully gives is that the cloud possesses considerable depth, so that the condensed and frozen water does not get to contact with the warm air immediately, and in fact can stay solid for a long time (128,24-129,12). He also explains that the cold inside the cloud, although great, is still not great enough for the vapour to freeze directly into the snow, but the intermediate water stage is involved (129,12-21). Philoponus helps explain why the coagulation of the hailstones is stronger the nearer earth it takes place: because the hailstones formed close to earth arrive in good order, not having been thinned down or dispersed during their brief journey (129,26-130,10). The commentary ends in a lacuna, therefore we do not know whether Philoponus raised any really interesting difficulties concerning the *antiperistasis* principle. Where the text leaves off, he seems satisfied that it not only is consistent with Aristotle's main doctrine of elements, but also works in all the minuscule details. Maybe Philoponus also derived methodological satisfaction from this puzzle-solving.

There are clearly many problems raised by Philoponus' commentary which could not be discussed in any detail in an introductory survey. My task in this introduction was to show that it is a very rich and interesting text, not always easy, but certainly rewarding, from which the students of ancient philosophy and science can learn a good deal.

Note on translation of some terms

The text contains plenty of technical terms. Most of them are explained in the notes. I list here some familiar terms which may have a slightly less familiar technical meaning in the text of which the reader should be aware.

'Things, processes in the sky' (*meteôra*). The Greek adjective *meteôros* means 'high up', 'high above'. In this text, *meteôra* refers to those phenomena that are a part of Aristotle's sublunary cosmos; so although they are high above, they are always below the sphere of the moon, and are made of the four sublunary elements (earth, air, fire, water). For this region I reserve the word 'sky', while the word 'heaven' translates the term *ouranos* used by Aristotle, among other things, to refer to the upper region of stars and planets made of the eternal imperishable element aether.

'Sight-streams' (*opsis,* pl. *opseis*). The word *opsis* means 'sight', 'vision', sometimes 'the organ of sight'. In this text, Philoponus uses it mainly to refer to the physical streams which are emitted from our eyes, behave in accordance with the known principles of geometrical optics, and serve us as the instrument of vision. With very few exceptions, even when context requires translating *opsis* as 'sight', the theory of sight-streams is presupposed.

'Tinder' (*hupekkauma*). The Greek word literally means 'inflammable material', something that burns well such as dry branches or straw. Here it refers to the upper layer of the sublunary cosmos made up of the hottest and driest part of the smoky exhalation, which catches fire very easily. This layer has a spherical form and is sometimes called 'the tinder sphere'. This is where meteors, comets, aurorae and the Milky Way are formed.

Planet (*planêtês astêr*). This literally means 'wandering star'. The translation is mainly normalised in line with the modern usage. It is important to remember that when Philoponus speaks of 'stars' without further qualification, he most often means both planets and 'fixed' stars, and sometimes he can refer to what we call a planet as a 'star' (because 'planet', 'wandering', is for him merely an adjective).

Comet (*komêtês astêr*). This literally means 'hairy star', and therefore can sometimes be referred to simply as a star. Otherwise the translation is normalised in line with modern usage.

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As ever, I am grateful to my family in Russia for their support. I dedicate the book to the memory of my cousin Maxim Luchinin (1975-2009), who did modern science but also had time for ancient ideas. He is sorely missed by all those who knew him.

Notes

1. Cf. 70,37-71,4 (to book 3); 100,25 (to book 2) below.

2. 1,1-3. *Ioannou Grammatikou Alexandreôs tôn eis to proton tôn Meteôrologikôn Aristotelous exêgêtikôn tôn eis ta tria to proton.* (I am grateful to Damian Caluori for drawing my attention to this title.)

3. Between chapters 3 and 4: 'the second part [of the commentary] on the first [book] of Aristotle's *Meteorology* [being part] of the three'; between chapters 8 and 9: 'part three of the commentary on the first book of Aristotle's *Meteorology* [being part] of the three' (118,27). The second manuscript used by Hayduck, M (Paris. 1892), in both places has insertions by a later hand saying, respectively, 'second division' (*logos deuteros*) and 'third division' (*logos tritos*).

4. At the end of his commentary on chapter 3, Philoponus says: 'Since these arguments are sufficient, we stop the lecture (*akoê*) and give here a limit to the first division (*entautha tôi prôtôi tmêmati didomen peras*)' (53,26-7, see vol. 1, p. 84 and n. 239). At the end of the commentary on chapter 8 in this volume he says: 'Let us therefore also give here a limit to this division and move on to the next [topics] from a new start' (118,25-6).

5. Cf. Philoponus *in An. Pr.* 1,1-4.

6. See 3,14-16 (vol. 1, p. 31).

7. See above, nn. 3, 4.

8. On the authorship problem with Alexander's *Meteorology* commentary, see Sharples 1987, 1184.

9. See 64,33-5 and n. 64 ad loc., and discussion at pp. 17-18 and n. 55 below.

10. Olympiodorus in his commentary on 1.3 also defends Aristotelian and Alexander's version of the theory of sun's heating by friction, developing some new arguments against possible objections.

11. e.g. the multiple reflections, 108,10-11 and n. 309 below.

12. See, e.g., n. 157 at 79,30-6 below.

13. Combès 1986, XXXIX-XLI.

14. See 44,25-6, vol. 1, p. 75 n. 201.

15. See 97,20-1 and n. 244 below. On a charitable view it could be interpreted as implying that Philoponus has in mind some particular work by Damascius, relevant to *Meteorology*, while 'elsewhere' Damascius says this. But this is of course highly speculative.

16. See pp. 8 and 102-4 and nn. 359-71 below.

17. See Philoponus *in Meteor*. 59,11-13 and n. 33 ad loc.

18. See the Index of Passages Cited.

19. Cf. 66,23-5 and n. 70 ad loc.

20. See 109,31-2 and n. 316 ad loc.

21. See 110,14 and n. 320 ad loc.

22. See 103,37 and n. 284.

23. Proclus *in Tim*. 3.62,22-63,20, cf. Neugebauer 1975, V B 7, 6 (918-19 and n. 9).

24. See 110,14 and n. 320 below. R. Sorabji suggests this with respect to the attribution of nine spheres to Ptolemy by Philoponus in *De opif. mundi* 3.3 and 1.7. It is perhaps important to note that speaking of eight spheres, Ptolemy refers to the spheres of 'fixed' stars, the sun, and the outermost of the set of nested spheres that contribute to the motion of the moon and each of the five planets (cf. *Planetary Hypotheses* 2.10). The ninth sphere is the one we cannot see; it accounts for the precessional rotation of the sphere of 'fixed' stars (ibid., 2.11). The total number of spheres needed to explain the motions of planets is greater (using different methods, Ptolemy gets the figures of 41, 29, and, assuming that each heavenly body moves by itself, i.e. without a separate sphere, 22) (ibid., 2.17).

25. See 116,18 and n. 355 ad loc.

26. Cf. an anonymous reference to the 'astronomical theorems' at 104,3-4 and n. 285; and the parallel in Theon of Smyrna on shapes of shadows (104,24 and n. 289).

27. On the sources of Philoponus' *On the astrolabe*, see introduction in Segonds 1981.

28. Cf. 69,22 and n. 92; 85,24 and n. 193; 85,41-86,5 and n. 195 ad loc.

29. 'Aët.' 3.5.1; [Aristotle] *Mund*. 4.395a28 (dichotomy, without the 'mixed' class); *Schol. Arat*. 811 (trichotomy), cf. Alexander *in Meteor*. 23,21-6. See Mansfeld 2002, 27, 31 n. 30.

30. See Philoponus *in Meteor*. 69,3-19; cf. 75,11-13.

31. 'Aët.' 3.2.9.

32. 58,3; cf. Alexander 33,2-24.

33. 61,7-62,2.

34. 62,9-31.

35. 342a10. Gilbert 1907, 642 is wrong to say that Aristotle 'definitely and expressly speaks only about the seeming (scheinbaren) fall of meteorites in the sea or on the ground', emphasising *phainesthai* in *hôste kai eis thalassan kai eis gên phainesthai piptonta*: *phainesthai* with participle, as here, means precisely: 'be clearly seen to fall into the sea etc' ('seeming' would require infinitive *piptein*).

36. 62,2.

37. 62,31.

38. 62,2-9.

39. 62,31-63,9.

40. See Fig. 1 on p. 48 below.

41. 66,3-17.

42. [Aristotle] *Mechanics* 1 (848b9-23); this principle is then used to demonstrate that the motion along the circle with a greater radius is faster than the simultaneous motion along the circle of a smaller radius.

43. In a recent, otherwise very useful, survey of Aristotle's theory of comets and other fiery sky phenomena, T. Heidarzadeh apparently overlooks a distinction between the 'shooting stars' and the aurorae including 'chasms' among the 'different forms of burning exhalation' (Heidarzadeh 2008, 8 at n. 22). For Aristotle, auroral phenomena belong to a different class, as Philoponus and other commentators correctly see.

44. See Stothers 1979, Lee and Thillet ad loc.

45. Aristotle, *De Sensu* 3, 440a7-15, cf. Alexander *in Sens.* 55,10-56,6. It is worth pointing out that although in both his commentaries on *De Sensu* and on *Meteorology*, Alexander speaks of superposition as a cause of the *appearance* of colour effects, to be distinguished from real colouration, for him, unlike Philoponus, this does not involve the dependence of appearance on an individual observer. Olympiodorus essentially agrees with Alexander's explanation.

46. 71,33-4.

47. Olympiodorus agrees with Alexander (Ol. 44,37-45,1) and gives his own explanation of 'breaking out' (*aporrhêgnumenou*) (Ol. 48,25-31).

48. See 73,23 and n. 117 below.

49. 342b27-29 (DK 59A 81, 68A92).

50. As Alexander points out, Pythagoreans treat the tail as a part of the comet, whereas for Hippocrates, it acquires the tail only when passing through humid areas of the sky (and this produces the impression of a tail) (27,1-11). Olympiodorus' interpretation anachronistically emphasises the fact that the comet itself is made of the fifth body, while its tail is sublunary (45,28-30).

51. See Fig. 2 on p. 61 below and a detailed discussion of Hippocrates' theory in Wilson 2008.

52. See Figs 2 and 3 on pp. 61, 97 below.

53. Ol. 51,12-15.

54. See 79,9-12 and n. 155 ad loc. Olympiodorus spells out this assumption (45,24-7). Ammonius may be the common source of this argument.

55. Cf. previous note. Here again, Philoponus argument exhibits a number of parallels with Olympiodorus' fourfold classification of common objections: (1) from place; (2) from the multitude (*ek tou plêthous*); (3) from fixed stars; (4) from destruction. Ol. 52,21-2

56. They are marked in the text of Philoponus commentary under the lemmata 343a22-6, 343b8-14, 343b14-17 and 17-25.

57. This corresponds to Olympiodorus (1), n. 55 above. Ol. 52,30-53,3 gives an example of a comet that arose in 565 and moved during two months (August and September) from the head of the Dragon (a polar constellation) to the Capricorn.

58. = Olympiodorus (2), n. 55 above. Philoponus also refers here to 'our own' observations of different comet shapes (82,16-17 at n. 178).

59. 85,8-86, 11 (= Olympiodorus (3), n. 55 above).

60. Barrett 1977, see 85,5-7 and n. 191 ad loc. below.

61. 85,22-36; see n. 193 ad 85,24 below.

62. 343b14-17, see n. 196 ad 86,11-12 below (= Olympiodorus (4), n. 55 above).

63. Notably, Seneca criticises the testimony of the fourth-century historian Ephorus, perhaps another supporter of 'conjunction' theory, who claimed that the great comet of 373/2 BC 'separated into two stars; but apart from him no one has reported this' (*QN* 7.16.1-3, tr. Hine).

64. 82,34-83,6 and n. 181 at 83,1- 6 below.

65. See n. 187 at 84,19-21 below.

66. See p. 11 above.

67. See 92,35 and n. 200 ad loc.

68. Although one might, perhaps, think of his earlier example of a comet-star in the constellation Canis Maior at 343b8-14 (see n. 60 above and n. 191 ad 85,7 below).

69. Alexander *in Meteor*. 34,35-35,5. For his interpretation of the theory of sun's heating by friction, see vol. 1, Introduction.

70. Philoponus *in Meteor*. 77,17-19. Aristotle does argue, in *Phys.* 7.2, that heat can exercise the power of attraction (I discuss this in Kupreeva 2004); but in his discussion of the sun's heating he never invokes this feature of heat, as a possible cause, of natural upward motion, perhaps understandably, as on his view heat itself in these cases is derivative from friction.

71. Diels prints Aristotle's passage (345b9-12) among the evidence for Hippocrates' views (DK 42.6), adding Alexander's comment: 'He says that the third opinion about the Milky Way is the one that states that the Milk is the reflection of our sight from some exhalation, which seems to be the Milk, onto the sun, thus providing our sight with a reflecting surface for the sunlight that it sees, as Hippocrates and his circle said the comet is also formed (*hôs elegon hoi peri Hippokratên kai ton komêtên ginesthai*)' (38,28-31 = DK 397,10-14). It is not entirely clear whether Alexander indeed attributes this doctrine to Hippocrates rather than just pointing out the obvious parallel between the two (cf. Thillet 2008, 490 n. 104). In any case, Philoponus seems to take it for granted that this theory belongs to Hippocrates.

72. The only other possible interpretation of 'the rest' (*allôn*), that does not involve precession, would be the outer planets, but they have nothing to do with this particular discussion, where the terms of comparison are the fixed stars and the sun. There is further, more specific, evidence that the Alexandrians (at least Philoponus and Olympiodorus) knew and accepted the precession of equinoxes (see p. 92 and nn. 305, 307 below).

73. Ptolemy, *Almagest* 5.11-19. Parallax is the difference between the true distance of a heavenly body, i.e. its distance from the centre of the earth, and its distance from the observer in the cases where the location of the observer cannot be taken as coinciding with the earth's centre (this is most clearly the case of the moon and the sun, whereas the fixed stars do not display parallax, their distance being too great to be sensitive to different locations on the earth).

74. Heraclides is a philosopher of Plato's circle, certainly a congenial spirit in the cause of joining science and myth in one project, whose work about souls was well known to the late Platonists (see Kupreeva 2009 on the way it was used by different thinkers).

75. For the Christian backdrop of Philoponus' argument, see Évrard 1953, 355, followed by Combès 1982, 39 n. 4.

76. 120,11- 15. Cf. Philoponus *in GC* 2.10, 295,22-3 and Kupreeva 2005, 12. Interestingly, Olympiodorus has it in the reverse order: cooling (and heating) are the proximate and first cause, the sun's motion the remote and secondary (79,30-2; 83,4-11, n. 389 at 120,17 below). Alexander does not raise the issue of ordering.

77. See n. 389 at 120,17 below. Cf. 55,31, where 'co-operant' is in order. For the Stoic concept of *sunaition*, see Hankinson 1998, 243.

78. 120,25-9.

79. In *in Meteor*. 1.3 and passim.

80. 122,4-11. Alexander does not comment on this phrase (44,19-21), but Olympiodorus (84,1-5) thinks that Aristotle refers to smoky exhalation-certainly a sound exegetical option, particularly since Aristotle is explaining specifically the evaporation of moist, as Philoponus himself argues immediately before the discussion of heat. (See nn. 398-401 ad 121,35-122,4; 122,11; 122,11-14.)

81. This discussion has a parallel in Olympiodorus (84,17-26); see n. 405 ad 122,31-123,17 below.

82. DK 59 A 85 (which includes apart from Aristotle's citations 'Aët'. 3.4.2).

83. For discussions see Lee 1952, 82, note (b); Solmsen 1961, 412-18, Furley 1989, 145-8; most recently, Federspiel 2003.

84. 126,15-25. Note almost verbal coincidence with Solmsen 1961, 414.

85. 126,26-127,8. This is a traditional topic in Peripatetic physics, cf. the discussion of the question of sleep in Alexander, *Quaest.* 1.20; cf. Steinmetz 1964, Federspiel 2003.

86. 127, 8-16.

87. Thomas Kuhn's description of this stage in the growth of knowledge could be justly, and not ironically, applied to the problem solution in the school of Aristotle.

Textual Questions

1. Notes on the text of Philoponus' commentary printed by Hayduck

60,13. Replace question mark after *ouketi* with a comma (Hayduck notes the problem: with *oude* – exspectas *ê*), taking *oudepote* at 60,15 as emphatic (thanks to Catherine Osborne for suggestion and discussion).

68,20-3. Move the question mark from after *ho aêr* to the end of the sentence (placing it after *ta toiauta*).

69,5. Read: *phloges phêmi kai aiges kai daloi peri hôn êdê proeirêke khiones te kai khalazai kai huetoi*, 'about which he has already spoken before, as well as snow, hail, and rains'. The Greek has: *phloges phêmi kai aiges kai daloi khiones te kai khalazai kai huetoi peri hôn êdê proeirêke*, 'as well as snow, hail, and rains about which he has already spoken before', which is impossible since none of these have been discussed by Aristotle. Hayduck suggested deleting 'snow, hail, and rains', but a transposition would do as well (it does look like an insertion above the line which was copied to a wrong place).

70,32. Delete *tôn asterôn nuktôr*. This must be a gloss on the *kôpêlatountôn nuktôr* which got incorporated in the text of the commentary.

75,36. Perhaps read *eipoien* instead of *eipein* (technically it could also be *eipein* construed with supplied *oimai* as at 75,30, as Jan Opsomer points out to me).

80,12-13. Reading *tou de eis to auto sêmeion phainesthai … to perielthein holon ton heautou kuklon*, following Hayduck's suggestion in the apparatus.

81,1-2. 'Southern tropics', reading *en tois kheimerinois kuklois* as suggested by Hayduck in the apparatus (instead of the *therinois* of the MSS).

81,5. 'In the northern tropics', reading *en tois therinois* as suggested by Hayduck in the apparatus (instead of the MSS *kheimerinois*).

81,9. Either delete the *oukh* following Hayduck, or retain it but understand as emphatic (in each case, the purely negative particle is impossible).

84,6. 'So great a size': keep the MSS reading *tosouton megas*, instead of *tosouton megethos* printed by Hayduck.

94,31. Read *kai khôris asterôn kai meta tôn asterôn tines*. Hayduck prints *kai khôris asterôn kai tôn asterôn tines* (as V). M (followed by the Aldine editor) has: *kai meta asterôn kai tôn asterôn tines*. Hayduck's preferred construction might draw on the text of Aristotle for justification (*tote komêtês ginetai autôn tis*), but it is still anacoluthic (*ginontai* being used as absolute with the first subject (*komêtai*) and as a copula with the second subject, where we also need to supply *komêtai* for the second time). We need not expect Philoponus to follow Aristotle's construction to the letter in a summary statement. Moreover, Aristotle's criticism of Democritus' view of comets as stars has already been discussed. Finally, the occurrence of *meta* in the wrong place in M may suggest that it was in the original.

95,34. Read *autôi* instead of *autois*, as Hayduck suggests in the apparatus.

98,23. Reading *mê tis* instead of Hayduck's *mêtis* (possibly a misprint).

100,21. After *meteôristhenta*, read *kai authis katapesonta*, as Hayduck suggests in the apparatus.

108,21. Perhaps read *legômen* ('let us start our explanation') with Ma and Aristotle manuscripts FHN, instead of the printed *legomen* ('we start the explanation'), as seems indicated in Philoponus' text by *didaxai boulomenos*.

115,5. 'Middle', reading *mesa* instead of *men*, following Hayduck's suggestion in the apparatus.

115,16. Lacuna in the text, read: *eulogon kai hekastou tôn apotelountôn ton kuklon touton tauto ti to pathos ginesthai* (cf. 346a11 above).

115,16-17. End of the lacuna indicated in previous note. The text of the initial sentence could have been something like the following: *ton logon touton homoion einai hêgoumetha ton muthon tôi ek tou galaktos tês Hêras phaskonti* etc.

126,11. *epi ouk agathon ktêsamenôn to peras: ta pros eskhatên Gotthou pepoiêke*. *to peras* MSS (Hayduck obelises), *gêras* coni Diels. Diels understands the sentence as saying *epi ouk agathon ktêsamenôn to gêras: ta tou eskhatên gên oikountos Gotthou pepoiêken*, meaning that he did the same as the Goth who inhabits the earth's limit. Perhaps it is possible to keep the MS reading and supply the sentence as follows: *ta pros eskhatên hêmeran* (or: *anapnoên*) *Gotthou pepoiêken*.

2. Notes on Philoponus' text of Aristotle

60,19. 341b32: *ean de ta mêkê tês anathumiaseôs*. Several Aristotle manuscripts (Fobes's E (first hand correction), W and N) which read *merê* (parts) instead of *mêkê* (lengths) are followed by a number of modern editors (Ideler, Lee, Pepe); although both Bekker and Fobes print *mêkê*. Most recently, Thillet prints *mêkê* but translates *merê* ('les parties'), without a note.

63,32. 342a14: *tou puros anô pheromenou kata phusin*. These words are not found in any of Aristotle's manuscripts (Fobes prints them in angle brackets). The same kind of contrast is drawn in Alexander's commentary at this point (22,23-5): *dia touto gar kai ho keraunos pur ôn eis to katô pheretai, dia tên biaion ekthlipsin, epei tôi ge puri kata phusin hê eis to anô phora*; similarly Olympiodorus in his discussion of lexis (43,1-7). Lee does not include this clause (see n. 2 ad loc.); Thillet prints it, but argues against it on p. 483 n. 62 ad loc.

72,21. 342b13-14 cited in the discussion of lexis: *tou de mê polun khronon menein touto hê sustasis aitia takheia ousa* ('The cause of the brief duration of this is that the condensation is short-lived'); Aristotle's text, and the lemma at 69,1, have *tauta* ('of these [processes]'), not *touto*.

76,3. 342b29. 'Some of the Italians and so-called Pythagoreans': *tôn d' Italikôn tines kai tôn kaloumenôn Puthagoreiôn*. Philoponus' copy of Aristotle has *kai* ('and') omitted by most *veteres* MSS of Aristotle, but he treats *kai* as epexegetic and in effect normalises the text with this interpretation. *kai tôn* MV: *kai kai* (sic) a: *tôn* om. Arist. E: *kai tôn* om. Arist. FHN.

80,22-3. 343a14. 'The southern place', *notiôi topôi* in Philoponus MSS MV and the Aldine edition. Aristotle MSS have different readings: *tropikôi topôi* Arist. HN: *tropikôi* Arist. F: *notôi* Arist. E_1 $H_{corr.}$: *tropikôi* (supra: *topôi*) *oute t notôi* $E_{rec.}$: *notiou merous* Alex. paraphr. Most modern editors follow Fobes who prints *tropikôi*.

88,15. 343b25. 'Has worked hard', *prospephiloponêke* Ma sscr. V, cf. *prosphiloponôn* at 88,20. Philoponus' reading *pro domo sua*. Aristotle MSS, Alexander and Olympiodorus all have *prospephiloneikêke* (and so does the inset text in Philoponus V).

88,34. 343b29. 'With planets', read *pros hautous* instead of *pros autous* (perhaps a misprint).

92,28. 342b25. Reading 'or' (*ê*) with Philoponus manuscripts, as seems indicated by the context. Aristotle manuscripts have 'and' (*kai*), and so does Philoponus' lemma at 75,9. Alexander has *kai*; Olympiodorus' reading is unclear, but cf. his description in the *theôria* 45,14-16: *meta de ton komêtên erei kai peri galaxiou, epeidê ho galaxias ouden heteron estin ei mê komêtês kuklikos*.

94,21. 344a35. 'Stars', *asterôn* Philoponus, *astrôn* all MSS of Aristotle (insignificant variation).

101,23. 345a18. 'By its motion', *hupo tês phoras autou*, where the Aristotle text printed in most modern editions has 'by their motion' (*autôn*). Philoponus' lemma reading coincides with that found in several *veteres*: first hand correction in E (s.X), Matr. B. Reg. 41 (s.

XII), Ambros. E. 93 sup. (s. XII), Laur. 87.7 (s. XIV), Vat. 1027 (XIV), Vat. 258 (XIV).

107,8. Philoponus' lemma has *menoi* (V) or *menei* (V), where Fobes correctly chooses *men* for Aristotle text following MS F, giving the meaning: 'and if the mirror and what is seen were in motion, keeping the same distance from what sees'. Hayduck's apparatus, *menei*] *men* Ma, seems to be mistaken; it should say *menoi*] *menei* Ma. Olympiodorus' lemma has *menei*.

118,25-6. Philoponus treats the passage 346b10-15 as the opening of chapter 9, differently from the editions of Aristotle and the other two Greek commentators, Alexander and Olympiodorus, who take it to be the closing paragraph of chapter 8. The reason may be that Philoponus the Grammarian sees *men oun* at 346b10 and *de* at 346b15 as parts of the same syntactic construction, and judges that they should belong to the same thematic section.

125,6. 348b8. 'And sometimes hail' (*hote de khalazan*). These words are missing in all Aristotle manuscripts except one (Fobes' N rec. = Vat. 258, fourteenth century) and in other commentators, but are well attested as present in the text Philoponus discusses (despite the fact that only one MS, M, has it in the lemma), because Philoponus quotes them again directly in the body of the commentary (127,24).

3. Note on Philoponus' citation from Aratus, *Phaenomena*

100,1. Aratus l. 1091 'May no stars above shine ever', *mêd' eien kathuperthen eoikotes asteres aiei*, where Aratus has *hoi d'eien*: '*may* the stars above shine', etc.

PHILOPONUS
On Aristotle Meteorology 1.4-9, 12

Translation

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John of Alexandria, Professor of Grammar

Commentary on the first book of Aristotle's *Meteorology*

Chapter 4

341b1-5 Having defined these, let us now explain the cause why 53,28
the burning flames appear around the heaven, the shooting
stars, and what some people call 'torches' and 'goats'. All these
are the same and have the same cause but differ in degree.

Aristotle by way of introduction has gone through as many things as 32
need a preliminary explanation prior to the study of things in the sky:
he has defined the proposed goal of the work and the place which it
is has been assigned in the order of his writings on nature, both what
would be logical to teach before it as naturally preceding, and what
he is going to teach after it as following from it. After that he has also 54,1
mentioned the elements of the whole universe, that they are five in
number: the four [elements] of all the sublunary things and the fifth
different from these, of which heavenly bodies are made. [He also
said] that the whole [space] from the earth to the last stars is neither
only fire, nor air alone, nor yet do only the two of these fill this whole 5
interval. He described the order of the elements: the earth, together
with water enclosed in its cavities, is in the centre of all, the next
after that is air, and after that the substance of the fire, which is not
fire, but the tinder of fire,[1] and then, last of all, the fifth element,
which is the matter of all bodies that have circular motion. The
elements inside the sphere of the moon are [according to him] the 10
matter of things that come to be and pass away, whereas the princi-
ple of motion, i.e. the productive cause of these [things] is what has
circular motion.[2] Having said how the four [elements] transform into
each other (for this too is relevant to the goal of the present subject
of study), he subsequently inquired why the clouds are formed nei-
ther down around the earth itself nor in the highest region close to 15
the tinder sphere, and having stated the cause of this he asked last
of all if the heavenly bodies are not fiery, from what source the
sublunary air is heated simultaneously with the sun's appearance.

Having finished that he then embarks on the task that was set out,
to explain the causes of the conditions that form in the sky,[3] and prior
to others, what the flames appearing in the heavens are: the 'running 20
stars' which are called 'shooting' because of their motion,[4] the

‘torches’[5] and ‘goats’,[6] and anything else akin to these that comes about there. And he set out to treat of these in common and simultaneously since their material cause is one, the exhalations from the earth,[7] as will be proved, and similarly the productive cause, viz. the rotation of the heavenly bodies. And what characteristic differentiates each of these, he will explain further. He says that such things come to be ‘around the heaven’, meaning ‘heaven’ either in conformity with the opinion of the many who believe that these things happen in the heaven,[8] or, like Homer, calling air ‘heaven’ (‘And Zeus received the broad heaven in aether and clouds’);[9] or rather, he used a precise wording when he said not ‘in the heaven’ but ‘around heaven’, i.e. in the place near it. He says that all of these [mentioned phenomena] are the same because of the material cause and because they have the same productive cause.

> **341b5-12** The origin of these and many others is the following. When the earth is heated by the sun, an exhalation must arise, not simple, as some believe, but double, one more vaporous, another more breath-like, the first being a vapour coming from the moisture within and upon the earth, and the second smoky, coming from the earth itself which is dry. And of these two, the vapour-like is floating on top because of its heat and the one which has more moisture is settled below because of its heaviness.

The items to be mentioned now [viz. the two kinds of exhalation] are
55,1 the origin not only of those that have been enumerated,[10] but also of all the conditions that arise in the sky, comets, thunderbolts, lightning and thunder-claps. He has already explained that the material cause of all things coming to be and perishing is the four elements. Since he now wants to explain the causes of [the processes] that arise in the sky (for although those [causes], as I said, are common to all things that come to be, yet still there is some sort of special matter for each of the things that differ in genus and [for each of the things that differ] in species; for when the form of the composite [substances] changes, their matter changes accordingly),[11] there must also be some more common matter of all things that come to be in the sky which is the matter of all things undergoing coming to be and perishing, and another, more peculiar to the same things, but not to those that differ in species.

So, at this point he explains in the following way what the matter is which is common to all things in the sky and more generic. Since, he says, the elements in the centre of the universe are two, namely water and earth, and since they are heated by the sun in the way that was described,[12] the exhalations that proceed from them must also be twofold: the one from water moist, as is the steam from the cauldrons when the water in them is heated, the one from the earth dry, such as the one that is seen emitted by burnt wood and incenses; but each of these is hot.[13] For when these two elements, earth and water, undergo this kind of change as a result of being heated by the sun, it is clear that each of them changes only in respect of the cold in it; and that which changes from the cold must become hot.[14] So, it is neither because earth changes in respect of the dry in it, nor because water changes in respect of the moist, but it is plausible that each of the exhalations is hot because the cold in them is overcome by the hot, while the dry persists in one and the moist in the other. Consequently, the one from water is moist and hot, and the one from earth dry and hot. And he calls the former vapour and the latter smoky and breath-like, for breath too is dry and hot.[15] These two together, then, are the common material cause of all things formed in the sky, and the rotation of the heavenly bodies is the efficient cause.

Since each of the two exhalations is hot, it is plausible that they are upward-moving; but the smoky one is lighter, because it has the dry as a co-operant cause of speed, whereas in the other its moisture undercuts its speed, as we have proved this in a precise way elsewhere.[16] Consequently, the one from water, being less light, is closer to the earth in its location while the one from earth floats upon it and is more up in the sky, being lighter. And the former generates the effects in the air, such as mist, rain, snow, hail and the like, while the dry going upwards to its like produces the effects in the tinder, to which belong those set out above, flames and 'torches' and 'goats', and as many as have been enumerated, for all of these are by nature fiery. In due course, as we go on, we shall see the differences between them when Aristotle discusses them.

He says 'both within the earth and upon the earth' either because some [of the moisture] is in its cavities, and some on its surface, or maybe treating both kinds as one and the same: for earth also underlies the water that is in its cavities.

> **341b12-18** And therefore the region around the earth is ordered in this way: the first under the circular motion is the hot and the dry, which we call fire, for what is common to the entire smoky section has no name, but nonetheless because this kind is of all bodies most naturally disposed to burn, we have to use the names in this way.

We have already explained what position and order exists among the five elements towards each other. The same is now deduced, again, from what has been proved about the coming to be of the two exhalations. For, as I have already mentioned previously, one should know that the relation that parts of the elements have towards each other in their mutual transformation is the same as the one that the wholes of these elements have towards each other.[17] Now, the first and the outermost of all is the circular body. For since the things inside change due to its motion, and every body that acts upon the other does so by touching this other body,[18] the body that moves in a circle that is to act upon the rest must contain all of them within itself, in order both that it could act upon them, touching them from all directions, and that they should not escape its effect. For even if it does not touch all of them directly it still does act through the more proximate on the next ones.[19]

The next after this is the hot and dry body, like we said the one exhaled from earth is too; for because of its lightness it must always leap over the other three. And this, he says, we call fire, although it is not fire, as he said earlier too;[20] for it is fire in a strict sense whenever it is kindled above measure and becomes flame.[21] But since the dry and the hot are common to all the things of this sort – such as flame, breath, smoky exhalation and its motley varieties differentiated by the quantity and order of parts, from which there come to be various effects of the [processes] arising in the tinder, for all of which there is no common name – therefore we habitually apply to the class the name of [its member that is] more familiar to us, [on its account] calling the whole set [of different phenomena] 'such and such';[22] or because the tinder is also potentially fire, for it kindles right away whenever it chances upon a small cause. But Aristotle deemed it proper to have a stricter appellation for this common, not yet ignited, hot and dry [substance], calling it 'tinder' as suited to kindle easily from a small cause, and taking this appellation from our ordinary usage, for we call 'tinder' things that are fine-structured, e.g. undershrubs and all those that are suited for easy kindling. Since, then, this is smoky and breath-like exhalation, and the whole region towards the moon is such, he plausibly called it tinder.

57,1 > **341b18-24** But we should know that this tinder, which we have now said is fire, is spread around the outermost sphere about the earth, so that when it happens onto a small motion it often kindles like smoke; for flame is the boiling of the dry current of air (*pneumatos*). So if such a structure is opportunely situated, it catches light whenever it is set in motion by the rotation.

This, he says, the more common [kind] which we called 'tinder' because no established name from the ancients is found (for they call only flame 'fire'), one should know is spread around the outermost part of the whole sphere around the earth; and this [sphere] is the whole [region] below the moon, in which there is all coming to be and perishing. For a single close-pressed sphere is formed out of the four elements: the water which has flown together in the cavities of the earth makes one surface that coincides with the limits [of the earth]; after it, the air stagnant between the rising mountains again forms another surface at their tops; and everything beyond this, composed of the rest of the air and the tinder, which align in shape with the inner surface of the lunar sphere, produces a single close-pressed sphere of all the bodies within, and it is clear that its parts touch [each other] and have a single continuity.[23]

This last part of this sphere, which we call 'tinder', spread around all those within and touching immediately the bodies moving in a circle, if it comes across any small cause occasioned by their motion, is immediately kindled and becomes fire. And he cites smoke as persuasive evidence for this,[24] for if it, being also dry and hot, comes across the adjacent fire, it is easily kindled. For if you put a lamp already quenched and still smoking under another one which is burning in such a way that the rising smoke will join the flame of the burning lamp, you will see that the smoke is kindled from above and the flame by virtue of continuity is carried through it downwards until it kindles the wick of the quenched lamp.[25] And if you place a smoking torch a little closer to fire so as to divert the smoke towards the flame, you will see again the same thing happen, the smoke being kindled and kindling the torch along with itself. But even if you move the torch while turning it around it will bring about the same effect even more strongly because of being kindled by the motion of the current of the air.[26] If, then, tinder is composed of smoky exhalation, then how is it not necessary for it too to be kindled whenever it happens to be subject, by virtue of any cause whatsoever, to a motion more forceful than usual?

341b21-2 For flame is the boiling of the dry current of air[27]

For if the current of air is dry and hot, and such is the flame which has those qualities intensified,[28] it is plausible that when due to some cause the current of air boils, it becomes flame. So the current of air is the tinder of the fire, that is to say, the smoky exhalation.

341b22-4 So if such a structure is opportunely situated, it catches light whenever it is set in motion by the rotation.[29] 58,1

The present project is a solution of a difficulty. For somebody might raise a question: if the whole of the tinder is of the same nature (for the smoky exhalation which is the matter of fire is the hot and dry current of air), but also the efficient cause is one and the same, namely the motion of the heavenly bodies, which is one and always regular, why is it that some portion of the tinder is kindled while another is not, and at different times different [parts of it] are affected by this?[30] Therefore he says that the irregularity of these events is not owing to the efficient cause, i.e. the circular motion, but to the material [cause]: for the portion of it which is suitably disposed for burning is kindled by the motion of the surrounding [viz. of the heavenly sphere]. For tinder is neither impassive nor unalterable, but very susceptible to affection due to its fine texture. For different parts of our body are also heated at different times, and the part which is weakened by something oozes and gets inflamed, whereas one that has had its defences boosted repels the [morbid] influx.[31] So what is strange if the portions of the tinder are subject to affection in precisely the same way, and at different times different portions of it are kindled, either because at some point there come to be more exhalations from earth, or because [the parts in question] happen to be more rarefied or condensed, or because a certain part, frequently torn out by motion from the continuity of the whole and as it were hurled forth, bursts forth flame, or through some other causes of this kind? For sometimes rarefaction and sometimes condensation make the underlying [bodies] suitable for kindling. And the tinder is condensed either by the moisture of the underlying air, or being compressed because of the abundant exhalation coming from below, or because of the sun's retreat from its different parts at different times.[32] But sometimes it becomes more rarefied, either again [due to] being further heated by the motion of the body around or because the sun draws near it. And neither do the very dry bodies, such as wood that has rotted, nor those that are very moist, such as wood which is newly cut, catch light. And dense texture often makes kindling difficult, and so does loose one, on the contrary, when it is considerable. For neither is a sponge easily kindled, nor cork nor ebony, nor ivory, the latter owing to its density and the former owing to the great fineness of texture. But those things which are well-disposed for kindling with regard to each of these qualities are subject to this effect. This, then, is the cause of the effects that occur in the tinder, and he explains the differences of these (i.e. flames, torches, 'goats', and 'shooting stars') next.

> **341b24-32** It is differentiated in accordance with the position and quantity of the tinder: if the tinder has both breadth and length, we often see a burning flame like that of stubble burnt on plough land, and if only lengthwise, then the so-called torches and goats and stars. If the tinder is more extended in length than in breadth, when it throws off sparks simultaneously as it burns (this happens because the tinder catches fire at the side, in small bits, but at the source), it is called 'goat', and when this effect is absent, 'torch'.

It is clear from the preceding that the cause of differences between the effects taking place in the tinder is not the efficient cause, i.e. not the revolution of the heavenly bodies, for this motion is one and always unchangeable, but matter and the underlying [body], i.e. the exhalation that is brought up to that region, and its abundance and scarcity and continuity or being scattered, and its position length-, breadth- and depthwise, and the relation of these to each other.

Some took him to mean by ‘length’ the dimension from east to west and by ‘breadth’ the dimension from north to south.[33] For such people it would follow that depth too would be its position in respect of up and down, i.e. the centre and the periphery.[34] But since neither Aristotle obviously uses this dimension, nor Alexander, perhaps it is possible to understand length simply as its greater dimension, no matter in what position, either south- and northwards, or east- and westwards, or up and down, or in whatever way it is inclined towards these dimensions. For we call the greater dimension of stones, wood planks, water, as in the rivers, and generally of all things that are not shaped in either natural or artificial shape,[35] length; that on each side of the surface of the length, to the right and to the left, breadth, and the rest, that which does not completely fall under our sight-stream,[36] unless the body is transparent, depth. For if we understand the westward-eastward dimension to be length, the northward-southward breadth, and this latter can be greater than the former, and the one that is depth greater than two others, and he calls the dimension that is greater in length ‘torch’, he should have given another name to the one that is greater in breadth, and yet another one, again, to the one greater in depth. But now he has said nothing of this sort. Therefore length should be understood as the greater dimension, in whatever position.

What then does he say about them? That when the exhalation, being somehow abundant in both length and breadth, is kindled, that is called ‘flame’; for it is similar to the stubble burned on all sides in the plough land, or to a heap of wood, or a marsh burnt on all sides.[37] If length is great and breadth small, he says, it is called ‘torch’, for it is similar to a torch which has only one piece of wood along its whole length, for this one too has a great length and a small breadth.[38] And if this torch also sends off sparks, when the sparks, i.e. small eruptions of fire, are kindled on each side of it, and as it were suspended from it, while being separated from each other and not continuous, as the shoots on a palm-branch (for this is what he means by ‘this happens because the tinder catches fire at the side, in small bits, but at the source’, i.e. ‘in connexion with the source’), such a shape of burning tinder is called a goat. For the goat’s flocks of wool too are separate from each other and suspended, hanging down from a goat. And this, he says, happens when on each side of an exhalation that is extended in length, close to it, some small ones arise, but such exhalations happen to be scattered elsewhere. For when a torch is burning,[39] and these [small portions of exhalation] are kindled severally because of being close to it, the torch seems to be as it were sending off sparks, and has them as though hanging down because they are not continuous with each other; from which it got its name, ‘goat’.[40]

Is it the case then that the exhalation can be extended west and east but not north and south, nor[41] that the [sparks] from either side can ever be [scattered] to north and south at all, but only to east and west?[42] But this is arbitrary and completely irrational, since that matter is disordered and carried up at different times in a different way. Therefore by length he means only the greater dimension of the exhalation, however oriented, as we have already said.

> **341b32-342a3** And if the lengths[43] of the exhalation are scattered in small portions in many directions, to a similar extent in breadth and in depth, then what are thought to be shooting stars are formed. For sometimes the exhalation ignited by motion generates them, and sometimes the hot is separated and forced out by the air collected by cooling, and therefore their motion seems to be due to throwing rather than burning.

This is the account of the coming to be of shooting stars. For he has now declared their material cause, that the exhalation from which they come to be must be not continuous but scattered in small particles in length, breadth and depth, i.e. along every dimension of the place in which they come to be. Their way of coming to be, he says, is twofold, one when such matter is burnt, evidently, by the revolution of the heavenly bodies, another when it is forced and squeezed out, as though hurled. In order to make his explanation clear, the occurrence should be considered as follows. The dry exhalation moving upwards from below must either arrive at its own totality,[44] i.e. that of the tinder (for that is the limit of its motion), or remain below if it is prevented from travelling forward by advancing cold, and therefore condensed, air which does not allow it any passage up-
61,1 wards. Now, the exhalation that is brought to the tinder and gets scattered in small pieces, produces the kind of shooting stars that are due to burning, as Aristotle posited, and not the ones that are due to pressure: for compared with the exhalation, the tinder is rarer, so it does not hold it together by force and contrary to nature, so as to squeeze it out by compression. By contrast, the exhalation which stays below in the air due to the aforementioned cause[45] produces the kind of shooting stars that are due to compression and squeezing.

We shall start by giving a systematic treatment of the way the shooting stars caused by burning come to be, and we shall then speak about the other [kind]. For since the smoky exhalation which is in the tinder is scattered, as has been said, in small portions and is not continuous, when the revolution of the universe kindles the part that is in a suitable condition, heated by its motion, the kindled part passes this on to the adjacent one and kindles it, and that one [kindles] the one after it, and so in succession, the kindling part being always quenched, until no part in a suitable condition for burning is left. And so it creates the appearance of the [star] running.[46]

For it is not one flame that is moving but the same effect as the one we have already mentioned before with the lamps:[47] when we place a lamp which has just been quenched and is smoking under the burning one, the thick smoke carried to the flame is kindled in some parts and kindles the bit of smoke continuous with itself, the first being always extinguished and wasted away because of its fine texture, and that next kindles the one after it, and this happens in succession down to the wick; and it is manifest that it is not one flame carried down from above but, as I said, each time another part of the smoke is kindled, the kindling part being quenched right away because of the thin texture of the smoke which cannot sustain the flame for a long time but is completely sinking.

As in this case, so too it happens with a shooting star, as I have said,[48] and therefore, as [the exhalation] is easily kindled and quenched, the first of the two [bits] passes on to the one after it and is quenched as its matter is dissolved, and the second, kindling in a similar way the third one that is next, is itself withered away, and this happens continuously until no further bit of the exhalation is found that is suitable for producing a flame. Since one bit going out and another catching light goes on continuously, it seems that one and the same flame is running through. The same thing happens if you consider the kindling of a long and fine-textured fibre of a papyrus or tow, likewise fine, which is placed [next to it] lengthwise,[49] or something else of this kind. In this case too it is not one flame travelling from the beginning to the end, but because part by part, one bit is catching fire while another goes out, it seems to be one, and because of the passage of kindling from one bit to another, the one flame seems to be running along. But whereas in the examples, because they are close by, what is going on is clearly seen, in the case of shooting stars, by contrast, the great distance of the material from us prevents [our] perception from accurate discernment of what is happening, but reason hunts it down and discovers it. Now, it has been sufficiently explained how what seem to be runnings come about in the case of the shooting stars that are produced by burning.

And the motion from one kind of dimensions to another of the exhalation scattered, as has been said,[50] in all directions happens as follows. If its parts are positioned one above the other as regards depth, and the upper part is kindled first, then the flame seems to be carried down from above; if the lower part was kindled first, on the contrary, upwards from below. If [its parts are oriented] from east to west, and the easterly bit was kindled earlier, then it is carried there towards the west; and so on for north and south, and in whatever way the position of the parts of exhalation is slanted in relation to these [four directions].

Now, it has been explained that the shooting stars that develop due to burning come to be in the tinder and what the manner of their coming to be is. As regards the ones that come to be by extraction and a kind of hurling, firstly they have for matter the smoky exhalation, which (for the reason I gave) is kept back in the air.[51] But secondly, the manner of their coming to be is something like the following. It has been said that the two exhalations, the vaporous one from water and the smoky from the earth, ascend being somehow intertwined with each other. So, when abundant vapour is given off by the moist bodies and the air when cooled is condensed (for although we do indeed say that the vaporous exhalation too is hot, it is nevertheless colder than the air, because it rises from water, particularly since vapour is a passage and as it were a mid-way point of change from water into air, which neither is pure air nor remains unadulterated water, and change from water into air takes place due to heat, therefore the mid-way point between these two must be neither cold as water nor hot as air; and what is less hot being admixed to what is more so restrains the latter's heat); so, when, as I said, the air cooled by abundant vapour given off by water is condensed and in addition to this simultaneously, as a result of the very proximity of the water, receives into itself some of the smoky part given off together with vapour, this [smoky part], collected into one by compression exerted by the air on all sides and unable to rest because of having some warmth and being vaporous, is shot out by the pressure of the surrounding air like the pips shot out from our fingers. After this, being compressed and forced together by the strong and concerted motion, it finally catches fire.[52]

But why does the exhalation give the appearance of being thrown down for the most part, so that shooting stars fall on the ground and into the sea, while [the cases when it moves] in the opposite direction are scarcer? I say that it has been shown that the upper parts of the air around the earth are more cooled because the reflected rays there are very far apart, whereas these rays enclose the air around the earth in the middle, and owing to its density they heat it by their motion and friction.[53] In effect, when compression is developing from above, the fiery substance enclosed within by cooling inevitably gets pushed downwards from above, and gets expelled from there as through the more rarefied [bodily substances], while on the contrary, of course, the pips pressed out from the fingers go upwards where they are farther apart, since fingers are close together from below. So in the case of the compression of the exhalation from above due to the density of the air it is entirely inevitable that this is squeezed out downwards. Therefore, as we said, the shooting stars are seen to fall into the sea and on the ground, but because of the fine texture of their substance they are immediately extinguished. But it is not impossible, when the lower part becomes denser, for the enclosed exhalation to be hurled upwards. But this occurs more rarely for the reasons given. For what reason they mostly have the appearance of being thrown sideways, we shall listen to what the philosopher has to say.

> **342a3-12** Someone might raise a difficulty as to whether the process is like that in which the exhalation placed under the lamps kindles the lower lamp from the flame above (for its speed is amazing, similar to throwing and not like a different fire coming to be each time) or whether the shooting stars are each the instances of throwing of the same body. It seems that they are due to both causes [for there are those that come about in much the same way as from a lamp, but some are also shot out by squeezing, as pips from fingers, so that we see them falling onto the earth and into the sea, both at night and by day, from a clear sky].

He wants to explain the two ways of motion of shooting stars which we have already mentioned before.[54] Through the present difficulty he argues using illustrations that each is possible. He uses the case of lamps as an illustration in the argument that the process in question is that of kindling. For this kindling because of the speed of the smoke of the burning is in some way similar to throwing, but is not throwing.[55] Throwing is the motion of one fire, as when someone throws a torch, it is not the kindling of another fire each time, as what is seen to happen with the lamps.[56] And he gives as a pattern of shooting stars [moving] by throwing the pips pressed out by fingers. And he adjudicates that each limb of the dilemma is true, because some of the shooting stars are produced by burning, others by throwing. The connective 'or' is disjunctive.[57] He asks whether the motion of the shooting stars is of some such kind as the kindling of fire, whereby each time another matter is kindled by continuity, or whether it is not this, but rather, he says, the projection of the fire being thrown downwards from above. So he shows, as I said, that each of the two is true.

> **342a12-14** And it is thrown downwards because the condensation which propels them has a downward inclination. Therefore thunderbolts also fall downwards, even though fire in accordance with nature moves upwards.[58]

He inquires how the shooting stars that are formed due to throwing and thunderbolts are carried downwards. What, then, is the cause? Given that vapour is condensed by cooling and encloses the dry exhalation which is rising along with it, if, on the one hand, its lower part is more condensed, it squeezes out fire upwards from below, i.e. in the natural direction. This is no surprise and needs no enquiry, 64,1 because this is the natural movement of fire. If, on the other hand, the upper part of the vapour is more condensed, then as it presses the heat enclosed by its condensation, it forcibly pushes it downwards, so such fires are seen to be falling into the sea and on the ground. 'Because the condensation which propels them has a downward inclination' means either that it inclines downwards, contrary to nature, the fire that it propels, or that the vapour itself is becoming heavier because of the condensation and therefore being inclined downwards, drags along downwards the enclosed fire, which is fine-textured and easy to move. For he next speaks about this vapour as follows: 'For as it contracts and inclines downwards, it is condensed and creates a downward pressure of the hot'.[59]

> **342a14-16** For the origin of all these is not burning, but the separation due to pressure, since everything hot is naturally disposed to move upwards.

'Of all these', i.e. of the shooting stars thrown downwards to the ground and to the sea, and likewise of thunderbolts, for none of these come to be by burning, he says, but by the hot being compressed by condensation, as has been said. However the exhalation itself is also heated and ignited by the friction of the condensation. Why, then, does he say 'not burning'? In my view, [this is said] by comparison with the other [kind of] shooting stars which have this apparent motion not due to throwing, but produce an appearance of motion by the burning of matter, bit by bit in temporal succession.[60] But the motion of things propelled by pressure is real and not, like the former, the one which creates an impression of motion by burning,[61] but is produced by projection and expulsion by condensation of the cooled air that surrounds it and really moves. Therefore these latter things are carried to the ground and into the sea, which is a proof that their motion is real.

> **342a16-21** As many things as are formed in the highest region come to be because the exhalation is burned; and as many as are formed lower down do so because the moister exhalation is separated due to contraction and cooling, etc. [For this [exhalation] when it condenses and inclines downwards, becomes thickened and pushes the heat back, causing it to be thrown downwards.] [62]

He now determines what kind of shooting stars come to be due to burning and what by throwing. The difference between them is taken in five ways: (i) from the place in which they come to be; (ii) from the efficient cause; (iii) from the manner of coming-to-be; (iv) from the one and many; (v) from the local motion.[63] (i) From place, because

some are formed in the tinder by burning, while others by throwing 65,1
into the air below the tinder. (ii) From the efficient cause, because some get kindled from the motion of heavenly bodies, others from the condensed cooled air rubbed against the dry exhalation. (iii) From the manner of coming to be, because one kind come to be due to the burning of smoky exhalation, the other due to the squeezing out and throwing of the same. (iv) From one and many, because one kind are formed by expulsion of one bit of exhalation that is not scattered, the other by the burning that results from many separate [instances of burning], since different bits of matter are burnt one after another. (v) From the mode of the motion, because those formed by burning rarely move upwards from below, but more frequently with the other motions; while those formed by expulsion move by every mode, as he will show in due course, and because those formed by burning have a [mere] appearance of motion, while the other kind really move.

> **342a21-7** The position of the exhalation, in whatever way it happens to be oriented in respect of breadth and depth, accounts, accordingly, for its motion upwards, downwards, or sideways. Most move sideways, because of moving with two motions, forced downwards and natural upwards, and all such things move along the cross-section; therefore the motion of the shooting stars is for the most part crosswise. [The material cause of all these is then the exhalation, the moving cause in some cases the upward movement, in other cases the condensation of contracted air.]

'The position of the exhalation' Alexander understands as referring not to that of the smoky, but of the cold exhalation.[64] The position, he says, that the cooled condensed exhalation has, and the direction in which it is turned, is also the direction in which the fire is carried which is ejected from it. For if the ejection of the heat goes upwards, then the condensation is from below; if the ejection is downwards, then the upper part is condensed.[65] Again, if it is ejected in the northward direction, the condensation is in the south, but if towards the south, [the condensation is] in the north; and the same with west and east and all other positions. The same can be the case with the exhalation [that produces shooting stars] by burning, as we have said before. If the smoky exhalation is spread east- and westward, and the burning starts from the east, then there arises the appearance of westward motion; if it is kindled from the west, there arises the illusion of eastward motion; and similarly with northward and southward, and the remaining position.[66]

Why the shooting stars formed by expulsion move sideways, he explained most clearly by saying it is because the ejected exhalation simultaneously moves with two motions, one natural, the upwards motion (for this is natural to fire), another forced and contrary to nature, produced by compression, the downwards one. Therefore there arises a motion mixed of both, the sideways one. Suppose you were to imagine two ants [moving] on some solid surface, coming face to face with equal force. As they come together from opposite places, 66,1 and meet, contact and push each other, they are no longer borne along the same straight line as previously, but will be forced by the collision to move with an oblique and crosswise motion.[67]

'For', he says, 'all such things move along the cross-section'. For the cross-section of rectangles is crosswise with respect to the sides by which the rectangle is formed. So, he likens the sideways ejection of the shooting stars to the motion along the cross-section of objects which previously moved along the sides of the rectangle but have been pushed out by each other at the corner by a mutual collision so that they get carried off at a diagonal. Assume a rectangle ABCD, with its cross-section, i.e. diagonal, AD; let two ants of equal strength be moving, one from C to A and another, again, from B to A. When they are at A and neither gets the better of the other as they push each other, they are shoved off the sides of the rectangle, and being deflected, they get carried off along the cross-section AD.[68]

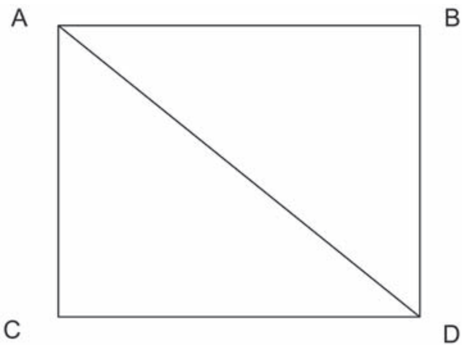

Figure 1. Motion along cross-section.

> **342a30-3** But all these occur below the moon. An indication of this is the fact that their apparent speed is similar to that of things thrown by us, which, because of being close to us seem to exceed the stars, the sun, and the moon in velocity, by far.

The childish assumption of those who believe that the motions of shooting stars are the runnings of real stars[69] can also be refuted on the basis that all the visible stars among the fixed stars have been documented by the astronomers from the first to the sixth magnitude,[70] and they are seen to be always the same and disposed in the same way, and remaining in the same places continually.[71] But

Aristotle now proves this by the apparent speed of their motion. For things thrown by us, he says, such as stones, arrows, javelins, because they are close to us seem to us to move faster than the stars themselves, and it is not possible to say how much slower their speed is. In the same way too the shooting stars, because they shoot a great deal lower than the moon and close to us, seem to us to move faster than the stars because they traverse our visual field more quickly.[72] For since our sight-streams proceed conically from the pupil of the eye as a point, the further the rays proceed beyond our eyes, the farther they diverge from the middle and the more they widen the cone.[73] So moving objects that are closer to us, because they travel through the smaller distance between the visual rays, traverse more quickly the angle subtended by them, which is where the discernment of visible things takes place, and for this reason they seem to be fast-moving. But objects that are more distant travel through the 67,1 larger distance between the sight-streams, and the farther away they happen to be the greater [the distance between the rays]. For this reason they cross the angle subtended by the sight-streams in a greater time. So, since, as I said, the discernments of visible objects take place in that angle, the objects that traverse the distance between the sight-streams more quickly seem to be faster, while those that do it the other way [i.e. less quickly] seem slower. But invariably distances that are further from the eyes always make the distance between the emitted sight-streams longer. This is why, as I said, it takes more time for the moving object to traverse a greater distance. It is plausible, then, that objects that are moving further from the sight-organs seem to move slower, and those closer, faster. This is why very distant objects seem to be almost non-moving: witness the fact that the fixed stars which are the swiftest of all seem stationary to the observers because of the excessive distance from us.[74] Having extended his discussion of the shooting stars thus far, he passes on to other effects that take place in the sky.

Chapter 5

342a34-b5 Sometimes on a clear night many strange phenomena seem to be formed in the heaven, such as 'chasms', 'trenches', and blood-red colours. The cause is the same in their case too. For since the air above has been shown to be condensed[75] in such a way as to be ignited, and the ignition sometimes is such that it seems that a flame is burning, sometimes as though 'torches' or 'shooting stars' are in motion, there is nothing incongruous if this air, thus condensed, should be coloured in different colours.

Having given the causes of all the phenomena set out earlier, i.e. flames, ‘torches’, ‘goats’, ‘shooting stars’, and the different motion of these, he now passes on to others, related to these, which he now sets out, i.e. ‘chasms’, ‘trenches’, and differences of colour. For air appears to assume colour, sometimes blood-red, sometimes purple, or crimson, or whatever other; and there seem to be some kind of ‘trenches’ and ‘chasms’ in it; none of these is in reality[76] the way it appears.

Why he joined these with the ones discussed previously, he himself has explained: for, he says, the cause of all these is the same. Now, it is manifest that they have something in common, but they also must have a difference, because otherwise they would not have been other [than those]. For the ones discussed earlier are in reality such as they appear to be; whereas the ones to be discussed here are such [viz. as they appear] only to the extent of appearance and seeming.[77] For neither are there any colour differences in the air, nor does air assume colour generally, nor do ‘chasms’ and ‘trenches’ arise in it, as it is one and continuous, and does not have any interval between its parts, since it has been shown that void is not one of the things that are possible.[78]

Such is the difference between these and those. But on the other hand they do share something in common with each other, because the formation of clouds and the ignition of air is the cause of all these. But there is also a common feature with the ones discussed above in respect of the brevity of time. Both those and these dissolve quickly because of the fine texture of the underlying matter.

Some people have thought that ‘trench’ and ‘chasm’ differ in breadth, the ‘chasm’ being broader, and the ‘trench’ narrower.[79] This, however, is not true, but we shall prove from Aristotle’s own words that the difference of these is in depth, ‘chasm’ having a great depth, and ‘trench’ a small one.[80] And the common habit and the usage of the ancients also intend this. Thus, Hesiod says about chaos ‘big chasm, not even in a whole complete year will the ground be reached, if once the man were within the gates’.[81] And the poet says about Alexander: ‘if only the earth would open again for him; for the Olympian has fed us with a lot of misery’.[82] And another ‘trench he dug a cubit this way and that’.[83] And the author of the *Argonautics* again, ‘he dug then a trench in the ground one cubit deep’.[84]

That the cause of all these is the same is clear, he says, from what has been agreed upon. For if the air in the upper region, i.e. the tinder, manifestly is ignited, and the variation of ignition causes the differences we have mentioned – flames, ‘torches’, etc. – what wonder if because of the same ignition the air also is coloured in manifold ways, or rather, seems to be [so] coloured because mist and fiery substance mix with our sight-streams, as we shall prove, which is why such phenomena are seen only at night?[85] For during the day the sunlight both conceals the [fiery] substance and illuminates the misty air, or rather, for the most part dissolves the mist.[86] But a clear [night] is needed, he says, for the appearance of such colours, that is, calm weather: for the motion of the winds scatters the mist and dissolves it right away, thus not allowing for the mentioned effects even to be formed.

And once again we shall understand 'in the heavens' to mean 'around the heavens', i.e. in the tinder. For this is said in relation to the popular opinion, according to which such effects are thought to be formed in the heaven.

> **342b5-14** For the reduced light shining through a thicker medium as well as the air taking on the reflection will produce a variety of colours,[87] most of all purple or crimson because these appear for the most part from the mixture, by superpositions, of fiery and white, as the stars rising and setting whenever it is hot weather and through smoke. And [the air] produces [colours] by reflection, when the reflecting medium is such as to receive not the shape but the colour. And the cause of the brief duration of these effects is that their condensation is short-lived.

Of the things formed between the earth and the heaven some are real entities[88] which exist in reality the way they appear, I mean flames, 'goats', 'torches', about which he has already spoken before, as well as snow, hail, and rains.[89] Others are mere impressions and false image-making, being by nature not such as they appear, such as 'chasms', 'trenches' and colours that seem to form in the air, of which he now sets out to treat; such are also the images[90] in our region, being only impressions. And there are some that are somehow mixed, being in one respect really subsistent and in another mere impressions, for instance, some 'shooting stars' formed by burning: their fiery nature is a real subsistent, but their local motion is merely seeming, as we have already demonstrated previously.[91] Effects of this kind take place also in our region, for instance, an oar dipped in water seems to be bent: for that is a mere impression, whereas the fact that it appears to be under water is true reality. Some pictures are like this, where some things appear to be set back, and others set forward and sticking out, whereas all are on the same surface. Painting of these things is a real entity, but the fact that some of them seem to be set back or sticking out is a mere impression.

So, having discussed in the preceding the effects which have true existence and the 'mixed' ones, he now sets out to treat of the things which are seen only to the extent of seeming. These are divided into two kinds: one kind are called 'transparencies', as many as are formed into images through the transparent medium of the clouds, for instance, the various colours in the air, while the other kind are called 'impressions' homonymously with the genus,[92] as many images as are seen due to the mirror-like reflection of our sight-streams falling onto the sun or the moon or one of the stars or on the fiery formations that arise in the air, such as halo, rainbow and mock sun.[93] So, the causes of all these are two, [one] the transparency of clouds, whenever a fiery formation is formed from above vertically towards them, and second bending back of our sight-streams from the denser clouds onto a fiery formation positioned sideways towards the clouds, or the sun itself, or some other star.

The first [class of effects], that is the appearances due to transparency, come about in the following way. When a cloud passes under some fiery formation that arose in the tinder, the cloud itself being not very dense, but finer and having a little bit of transparency, just enough for the colour of the conflagration lying vertically above the cloud to appear, but no longer for its shape and magnitude, then it seems that various colours are formed. But the conflagration must be moderate, for when it is big, it happens to dissolve the cloud. So, when the formation and the position of these (i.e. the cloud and the conflagration) relative to each other is like this, our sight-stream
70,1 moving through both and mixing in itself the blackness of the cloud and the brightness of the conflagration presents an appearance which is bloody or red or crimson or purple, or other colours – because as the bright and the black vary in degree, so, accordingly, varies the mixture of them which comes about in our sight-streams – then there comes about a motley variety of colours.[94] Something of this sort also happens at the rising and setting of the sun, the moon, and other stars, whenever the air at the horizon becomes misty; for at those times too there comes about an appearance of different colours, sometimes red and bloody, when both the mist is denser and the fiery substance purer, at other times yellow and as it were golden, when the mist is finer, and different at different times depending on the degree of density of the air and the amount of conflagration, and on the relation of these two to each other. It is hard and in fact impossible for us to measure this kind of mixture from which various colours come to be. But that these do come to be by the mixture of contraries is clear from the fact that artists produce many varieties of colours by mixing them. Further, flame kindled from moister wood seems red because thickness and blackness of the smoke is admixed to the brightness of the fire. And from dry wood both the smoke is finer and the colour formed from the mixture of the smoke and the brightness of fire is more yellow.

The second mode of this kind of appearance of colours in the air is the one that occurs by impression from reflection of our sight-streams. In this way, the constitution of a cloud must be dense and neither transparent nor unified and again continuous, but broken into tiny particles of vapour, like fine raindrops, and the conflagration must be not perpendicular but sideways towards the cloud,[95] and

they must be positioned towards each other so that our sight-streams that are falling upon the cloud will be reflected and transferred onto the conflagration or onto the sun or the moon. For when there is a reflection from tiny 'mirrors' in the cloud we seem to see in the 'mirrors' the colour of these [fiery bodies], but no longer their shape and size because of the smallness of these [reflecting particles].[96] Something like this obviously happens also with the raindrops, whenever the sun appears in a clearing, and when they row at night,[97] with water being similarly broken into tiny particles.[98] For we see only the colour of the sight-streams falling on [these particles] and reflected onto the stars,[99] but no longer their shape and size because of the smallness of [the reflecting surface of] water. And the same effect takes place with our mirrors of a very small size. For in the third part of this work he proves that the rainbow too comes to be in this way, when a thick cloud is formed towards the very horizon, while in the other part of the horizon the sun appears in a clearing and our sight-streams being reflected from the cloud onto the sun 71,1
produce a representation of the colours of the rainbow. We shall learn there what the philosopher has to say about the number of its colours, their difference, and the size of its circles.[100] For now let us pass on to the examination of the text.[101]

> **342b5-7** For the reduced light shining through a thicker medium, and the air taking on a reflection produces a variety of colours.[102]

He announces the two aforementioned modes of impressions produced by apparent colours. (a) The mode of transparency is indicated by the words 'for the reduced light making appearance through a thicker medium'. 'Thicker' is to be taken as referring to air, meaning not 'through a thicker cloud', (since the cloud must have a moderate transparency in order that the light of the conflagration could pass through it), but 'thicker relatively to the transparency of the air'. He put it well saying 'reduced light': for if it were big it would completely overpower the cloud and undo its constitution, so that the condition would not be formed. (b) The second mode he makes clear in the words 'and the air receives reflection'.[103] By the reflection that the air receives he clearly means the reflection of our sight-streams, not that the substance itself of air is reflected.

> **342b8-9** Most of all the purple or crimson because these appear for the most part from the mixture, by superpositions, of fiery and white. [104]

Not from the mixture of fiery and white with each other, but of each of these with the black. For white when mixed with black becomes

grey; while in order for it to become crimson it is appropriate that the fiery be mixed with the abovementioned. What then is the philosopher's meaning? He says that the mixture appears as purple or crimson for the most part because the smaller amount of black present in the mixture causes crimson and the deeper black yields purple. And let's count along with black also the dark blue as that which makes the result of the mentioned mixture shine forth. In a mixture of colours it is red that corresponds to fiery. And artists make the mentioned colours using this kind of mixture. He says that this mixture comes to be 'by superpositions', meaning not the mixture of the blackness of the cloud itself and the whiteness of the stars, nor again the fiery colour [of the stars] with the blackness of the cloud, but that a mixture of the colours which appear to us through the air arises in the superpositions of our sight-streams under the cloud, so that the medium is not affected, but the effect is formed in our apprehension and perception of mixed [colours].[105] And he called it 'superposition', because we do not apprehend colours as pure, but our apprehension of them, in which they are mixed, involves the superposition [of our sight streams reflected] from the cloud and becomes dim. For that the air which serves the colours is not affected by them is clear from the case of rays carried through the coloured
72,1 glass: in the air through which rays appear the colour of the glass does not appear, but it does show through in the solid onto which they fall, be that a wall, or the ground, or any other.[106]

> **342b9-11** As the stars rising and setting whenever the weather is hot and through smoke.[107]

'Whenever it is hot weather', he says, i.e. during the southerly winds, for the air around the horizon becomes more misty. For since the southerly wind is smoky it absorbs a great quantity of vapour, but not being strong enough to carry it away it, because of the gentleness of its heat, makes the air misty and thick. Therefore the stars that appear through this seem to be crimson, as also does the flame showing through the smoke of damp logs.

> **342b11-13** And [the air] produces [colours] by reflection, when the reflecting medium is such as to receive not the shape but the colour.

This is the second way.[108] For if someone takes some small part of a mirror and holds it facing the sun, the shape of the sun and its size do not appear in the mirror, but only its colour and light. But even if the [whole] mirror were broken into small [pieces], similarly only colour appears through all its fragments, as we have said is the case with the raindrops.[109] So, this kind of effect takes place in the clouds, namely, their parts are scattered in small pieces, and particularly when [the cloud] is [in a condition] already suitable for the coming-to-be of water, when it does present such appearances. Therefore they do not indicate either shape or size of the conflagrations, but present only the appearance of the colour.

'The cause of the brief duration of this[110] is that the condensation is short-lived'. Fine and dry papyrus or tow catches fire quickly and preserves the flame for a short time because the matter is used up faster (for this is made clear by 'is short-lived'), but wood once kindled remains [burning] for a long time because of its density. It is the same with the aforementioned conflagrations as well as with lightning. Their matter, being fine-structured and quickly used up, goes out, whereas comets being of thicker matter keep their conflagrations going for a longer time.

> **342b14-18** Light breaking out from blue and black makes chasms seem to have depth. Also 'torches' often fall out from circumstances like these, when there is more condensation. But when it contracts still [more],[111] a chasm appears.

Now, the appearance of blood-red and similar [colours] occurs either through the transparency of the clouds or by reflection from our own eyes.[112] But the appearance of 'trenches' and 'chasms' happens not in this way, but when light is occulted in the middle by the thickness of the cloud. The cloud that occults the light in the middle must be exceedingly thick and not completely transparent: in this way it gives an appearance of hollowness. For the white and the shining are such as to scatter our sight-streams because they have an acute activity.[113] That is why when they produce a swift effect in the sight-streams, these latter also quickly take up the effect in return: for something that is affected more quickly is also quicker to take on the affection. The black, by contrast, since it is such as to draw the sight-streams together,[114] causes the slowness of their motion (contrary [characteristics] must belong to contraries), and is therefore slower to take on the affection. So, when some conflagration is produced, and some dense non-transparent cloud comes to be in the middle of the conflagration in such a way that it does not occult the whole of it, but only the air that is in the middle of it, just where the cloud has been formed, since the parts around the conflagration are pure and not occulted by the cloud, in such circumstances it happens that the middle of the conflagration not being seen through the black gives an appearance of hollowness.[115]

This is also why things seen from afar appear black: because our sight-stream does not sufficiently reach them. And if you put white and black on the same surface and look at them from afar, the white will seem closer and the black farther. And the artists, knowing this effect, when they want something to look hollow, e.g. a spring or water cistern or a trench or cave or something of this sort, paint it with black or dark blue. Conversely, for things they want to appear projecting, e.g. maiden's breasts, or a stretched hand or horse's legs, they blacken the area around this part, so that while these [surrounding parts] appear hollow, what is drawn in middle of them will be thought of as sticking out.[116]

So if the cloud is less condensed, then there appears to be a 'trench', whereas if it is exceedingly dense and therefore blacker, a 'chasm', and the more it is blackened the greater the depth appears to be.[117]

He said 'the light breaking out', meaning that it is torn by the cloud, and because the continuity is severed through the superposition of the black or dark blue onto the middle.

> **342b17-18** Also 'torches' often fall out from circumstances like these, when there is more condensation. But when it contracts still [more], a chasm appears.

Circumstances like what? – The formations mentioned above, in which 'trenches' and 'chasms' appear. For when this cloud is more condensed, and a certain part of the conflagration is enclosed in its middle, that [part], being compressed by the force of density [of the cloud], is squeezed out and moves downwards. And if, he says, it contracts to a greater extent, a 'chasm' seems to develop. So, the black of the cloud in the middle of the fiery formation produces an appearance of a 'trench'. When it contracts still [more], it becomes more black, and what is more black gives an appearance of greater depth. He called this 'chasm'. So he distinguished 'chasm' from 'trench' as that which is much deeper.[118]

74,1 > **342b18-21** In general, white in black produces many varieties [of colour], for instance, flame in smoke. During the daytime the sun prevents [their appearance], while at night other colours except the crimson do not appear because of the same colour.

White, he says, and black (and he is now using the word 'white' for 'bright')[119] in a certain kind of mixture produce many different colours according to the intensification and relaxation of each of them relative to the other,[120] e.g. crimson, leek-green, purple, red, and any other of this sort, whose formula for the proportion is irrational.[121] As an example of these he gives fire which is seen through smoke and manifests a great variety of colours, different at different times depending on the quality of the smoke arising from the different matter of the things burnt. So, he says, of these different colours, those that are fiery do not shine through during the daytime because they are eclipsed by the sun to which they are similar, while those that bend towards black are apparent to all. But at night, by contrast, those that are white and fiery shine through, while those that are in the black direction are all concealed, i.e. sea-purple, purple, leek-green, dark-blue. He says crimson alone shines forth, for there is more white in it, and more black in others. Thus, we see crimson appearing on the horizon also when the sun is just set, because the air at that time is somehow lightly misty and our sight-streams reflected from the mist onto the sun produce appearances of this sort due to a mixture of colours. It is for this reason that drawing in black colours is done on white material, whereas drawing in white[122] or gold lettering, conversely, on black. For the contrary is more clearly seen on its opposite, whereas the like is hard to discern on the like, as when you make a drawing in white on some white body, or write in black on black. Hence those clad in black are more difficult to discern at night than those clad in white, and during daytime vice versa those clad in white, if they happen to be right in the sun, provide a dim perception.

> **342b21-4** As to the shooting stars and conflagrations and other such apparitions, the ones that produce swift impressions, we must understand that these are the explanations.

Everything said in the beginning is being brought to a conclusion as Aristotle announces their common feature, on the basis of which he provided a coherent doctrine about all of them, namely that all the mentioned phenomena produce fast changes, i.e. not lasting for a long time, as comets do [for instance], but dissolved in a short time. So, we must regard the explanations for their occurrences as being those we have mentioned.

And in saying about all of them in general 'of such apparitions the ones that produce quick impressions' he seems to be saying that 75,1 all are images. So either he simply called the phenomena 'apparitions' rather generically, or [he meant] that although shooting stars do have reality, nonetheless something of appearance is implicated in them too, as we have said. For the motion of those shooting stars that come about by kindling rather than throwing is apparent motion rather than real (*huparkhousa*), since what was moving was not one thing, but some matter, different each time, taking part in kindling.[123] But also in the 'goats' the flames kindled at the sides, which make the impression of hairs, have apparent and not wholly genuine continuity in relation to the whole conflagration.[124]

Chapter 6

> **342b25-7** As to the comets and the so called Milky Way, let us discuss them after scrutinising first the views of others.

Before this Aristotle has spoken about the things producing swift transformations, those that appear the way they really exist, those that are mere appearances, and those that are combinations of both existence and appearance.[125] Now he discusses the processes lasting for a longer time, which are not apparitions: for the effects that are seen as a mere appearance and seeming are quicker to dissolve. About the halo and rainbow which, while being themselves impressions, require a laborious explanation, he teaches in the third book.[126] What he explains now is the comets and the so called circle of the Milky Way.

And as it is the philosopher's custom to proceed about every inquiry to do with the study of nature, so he proceeds now with a preliminary examination of the opinions of the ancients concerning the proposed subject and refuting the ones that are not sound, and then expounding his own conception about the subject of inquiry.

> **342b27-9** Now, Anaxagoras and Democritus say that the comets are a conjunction of planets,[127] when because of coming close to each other they seem to touch each other.[128]

Clearly, [a conjunction] of the five wandering [stars] at once. These are: the so called planet of Kronos [viz. Saturn], the one of Zeus [Jupiter], the one of Arês [Mars], the one of Hermes [Mercury] and the one of Aphrodite [Venus]. They did not count in the sun and the moon, for indeed the refutation of that was obvious. So, when, they say, these [planets] draw near to forming this[129] and seem to touch each other (for they do not *really* touch each other, since they are not on the same plane), they coalesce to a larger size and make a single conjunction, i.e. one light appears to be carried along from all of them. And I think, if someone asked them why it is that a comet sometimes appears bigger and sometimes smaller, they would say that as long as the planets have their position closer to each other, the comet seems smaller, and when they are stationed somehow apart and are not too near, it seems to be bigger, and especially when some of the fixed stars drawing near them produce a single conjunction simultaneously with them. And if we inquire about the cause of its shapes being different at different times, they would say[130] again that their different position and relation towards each other is the cause of these differences, since some of them are situated in a straight line, others sideways, being further south or north, or in whatever other
76,1 way it is possible for them to have a position or relation towards each other.[131]

> **342b29-35** Some of the Italians and[132] so called Pythagoreans say that it is one of the wandering stars, but its appearance happens over a long [interval of] time and its rising is low, as is the case also with Mercury, for because its ascent is low it leaves out many of its phases, so as to appear over long [intervals of] time.

'Of the Italians and Pythagoreans' referring to the same [thinkers], as if he were to say 'also of Italian Pythagoreans'; for it was in Italy that Pythagoras established the schools of his philosophy. So, some of them held the comet to be the sixth wandering star after the five we have just mentioned, but making shorter appearances because of being concurrent with the sun and covered by its rays, something we see happen also with Mercury. For it also appears rarely, being at a small distance from the sun. And as to why this comet too sometimes appears bigger and sometimes smaller, they will assign the cause of this to the conjunction of the fixed stars simultaneous with it: for when it appears at a time at which most fixed stars, or the larger of them, are present, it too appears bigger; while as long as it appears along with the fixed stars that are fewer in number or dimmer, it is smaller. And as regards the different shapes [of this comet], they too will explain them by its relative position which differs depending on [the position of the corresponding] fixed stars: for had they not said this, they would have received a refutation from sense perception itself.[133]

And they explain by the same cause the fact of its infrequent appearance, namely that the comet is concurrent with the sun and that it takes a longer period of time before it deviates from the sun.[134] For this is what Aristotle indicated when he said 'and its rising is low', i.e. it is removed from the sun at a short interval, as is the case also with Mercury.[135] For it is because it ascends to a short [distance], he says, that it leaves out many of its phases, i.e. because it is at a short remove from the sun that it leaves out many of its phases, i.e. does not appear often.[136] For they call the phase of the [wandering] stars their first deviation from the sun which happens after the sunset, in which [a planet] becomes clearly visible to us.[137] Thus, Mercury, because it deviates from the sun to a small degree, escapes our perception, not appearing continuously because of its proximity [to the sun]: for in order for it to be seen it must be removed from the sun at the greatest distance, such as is not to be exceeded by a greater one,[138] and the weather must be clear, and the post from which it is to be observed must be located at a big elevation. This is why, then, as I said, most of its appearances at a distance from the sun escape us. This is what he meant by saying 'it leaves out many of its phases': 77,1
for even though it should appear often at a distance from the sun rays, it does not [so] appear, because of its proximity [to the sun].[139]

342b35-343a4 And similarly to these speak also those around Hippocrates the Chian and his student Aeschylus, except that they say that [the comet] does not have its tail from itself but takes it on sometimes as it travels through the space, because our sight-stream is reflected from the moisture drawn up by it [viz. the comet] towards the sun.

Hippocrates the Chian, he says (he was a mathematician credited with squaring the circle by [method of] lunes)[140] and his student Aeschylus similarly to the Pythagoreans say that the comet is the sixth wandering star [i.e. planet], but that it does not have a tail by itself, the way the Pythagoreans mean it to. For these latter used to say that the tail is the part of the star, while Hippocrates says that the tail accedes to it from without,[141] adding as a confirmation[142] of this that it is not in every place that it can have the tail: namely, neither in the southern parts [will it have the tail] nor between the tropics and under the equator,[143] for the reason he will state further, but only in the northern [parts] where because of the high humidity it can draw vapour up into itself. Aristotle himself too believes that the stars draw vapour up to themselves, as we shall see further.[144] So, they say that our sight-streams falling upon this vapour, which the comet draws up towards itself, and being reflected from it towards the sun, look at its light in the vapour as in a mirror, and form an impression of this tail of a star. For we have shown in the case of mirrors that when [such a mirror] is positioned below, then things above appear [as reflected in it], and when it is high above the underlying things are reflected[145] (and this is also the reason why before the sunrise when the sun has to a small extent and barely surfaced out of the clouds around the horizon, the sight-streams carried downwards towards the sun which is a little bit under the earth see its light in the cloud as in a mirror).[146] In the same way too, when this vapour is positioned under the star high above, our sight-streams falling upon it and being reflected and carried down to the sun and imagining the fiery substance in the cloud suppose that they see the tail in the star.

This is why Hippocrates and his school said that not everywhere where it wanders does this star acquire a tail: namely, (a) neither when it is between the tropics under the equator or near it (for places under the equator are scorched and dried up, and there is no water which could turn into vapour the star could draw up), (b) nor again, they said, could the star take on a tail if the star and the sun were at a very great distance from each other, say, the sun being in the summer solstice or near it, and the star in the winter solstice. For whether the star is in the
78,1 summer or winter solstice, if the sun is in the other, although in each part there is a lot of moisture, the star can draw up vapour, but will not become a comet[147] when disposed in this way. For our sight-streams carried towards the vapour and reflected will not reach the sun

because of its being at a very great distance: for in the motion of planets in latitude this distance between the tropics is the longest.[148]

(c) But nor does a tail form about the star if both of them were in winter solstice or close to it, since the sun is then beneath the earth[149] and removed at the longest distance: for this star [viz. the comet] clearly appears at night time. For since the circles at winter solstice have their centre under the [visible surface of the] earth,[150] that part of them which is below the earth is greater than the semicircle, and their smaller part, which is above the [visible surface of the] earth, is diminished to the same extent to which that [viz. greater part] is increased, which is why there are times when nights are longer than days. So, our sight-streams carried towards the vapour, reflected back from it and carried downwards do not reach all the way to the sun because under the [visible surface of the earth] it goes through a longer [section on the] circumference of the circle.[151]

(d) And if both the sun and the star are in the summer solstice, at that time the centre of their [day] circles will, on the contrary, be

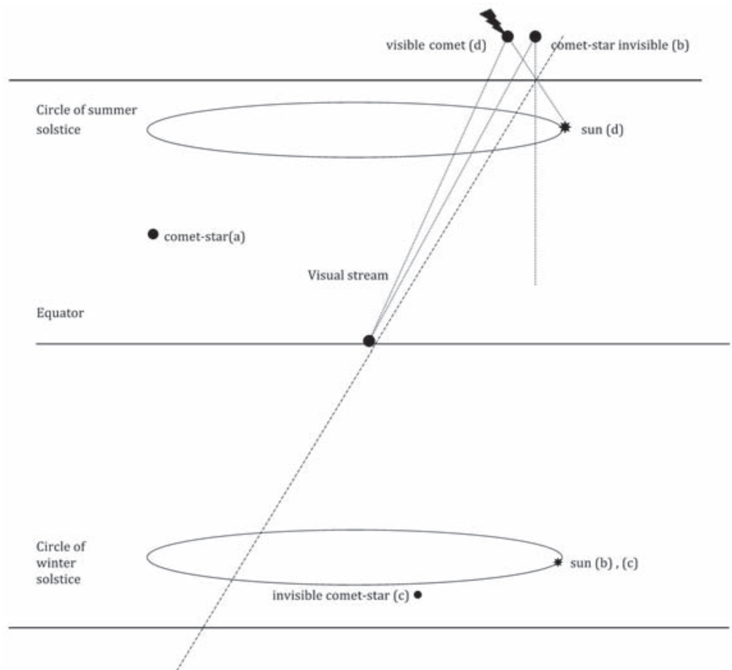

Figure 2. Hippocrates' theory of comets in Philoponus' interpretation. The comet cannot be seen in cases (a)-(c), when: (a) the comet-star is between the tropics under the equator or near the equator; (b) the comet-star is too far from the sun, e.g. when the sun is in the summer solstice and the star in the winter solstice; (c) when both the sun and the star are in the winter solstice. The only combination when the comet will be visible is (d): both the sun and the star in the summer solstice.

above the earth, the parts above the earth will be greater than semi-circle, the ones below the earth smaller, and therefore nights will be short and conversely, days longer. Therefore our sight-streams, after falling upon the vapour located above and being reflected from it, will be able to move downwards towards the sun when it is going through a smaller part of the circle's circumference which is under the earth.

Thus, according to these people, in order for a star to become a comet [lit.: 'tailed'] (i) it must be in a moister place, and (ii) the sun when it is below the earth must have such a relation to the star that our sight-streams reflected from the vapour under the star could be carried to the sun. So, if any one of these conditions is missing, the star will not turn into a comet. They too, like the Pythagoreans, say that this star is concurrent with the sun and is rarely removed from it; therefore, being covered by its rays for most of the time, it makes very little appearance, as they said in accordance with the mentioned hypothesis, and Mercury is similarly affected owing to the same reason, as we have said earlier. The idea of the argument is, then, of this kind.[152] Let us next consider the text.

> **343a4-6** And because of being the slowest in time to fall behind, it appears at longer intervals than other stars

Alexander commenting on 'being slowest in time to fall behind', says 'it falls behind in a slowest time', i.e. it goes around its own circle. For the planets are said to 'fall behind' in respect of the motion by which they are moved themselves, which is the reverse of the one by which they are carried around by the fixed sphere. And they are said to fall behind because they appear later than other planets which are not as slow to fall behind. This is what Alexander says about the text.[153] He makes Aristotle's words, which are unclear, even more unclear and explains them in a way contrary to the intended meaning of that text.

For the school of Hippocrates, trying to explain why the comet (which they take to be one of the planets) appears over long time intervals, says that because of falling behind with the slowest time and due to that reason it appears over the longest periods. But explaining what 'fall behind' means, Alexander says it is 'to traverse its own circle'.[154] But how does this explain that the comet appears over the longest time interval? For rather on the contrary, if it is supposed to be the slowest and traverse its own circle over the longest time interval, then, being distant from the sun, it should be seen all the more often and rarely become invisible.[155] For since the sun traverses its own circle in a year, and a comet in a much longer interval, it must by all means slip away from the sun and be removed from it at a very great distance, and therefore the comet must escape the sun's light and be seen often.

For instance, assume the comet completes its circle in sixty years, i.e. moves by one sign of the zodiac every five years, six degrees a year, and a half-degree a month. Assume, again, that the comet and the sun are in Aries at the same point, so that the sun traverses Aries in a month by its own motion, while the comet during the same time, in accordance with the mentioned assumption, moves by half a degree of Aries. It is clear that, having escaped the sunrays, it will be making its appearance all the time, since it is hidden by them only as long as it takes the sun to traverse this sign and one third of another, according to what Hesiod says about the Pleiades: 'some are hidden for forty nights and days'.[156] So, all the remaining time necessarily the comet will be appearing, and this will be the case every year. For Saturn also is hidden more rarely than the rest because of being the slowest. But all this is contrary to what they [viz. Hippocrates and Aeschylus] mean: for just as they say that Mercury being concurrent with the sun, and sometimes going a little beyond it, rarely makes an appearance, so too is the case with the comet. So that Alexander interpreted the text in a way that is contrary to their meaning.

What, then, is the meaning of Aristotle's text? I say that by 'to fall behind in a slowest time' he means 'to fall behind the sun after a long time'. For since it is concurrent with the sun, as they intend, it leaves it behind after the longest time interval. At that point, once it has escaped its rays, it is likely that it will become visible to us over a very long time interval. The likening of [the comet] to Mercury also agrees with this interpretation.[157]

> **343a6-7** As when it appears from the same [spot] having fallen behind by its whole circle[158] 80,1

Note that having said previously 'because of falling behind by the longest time interval' without adding 'by its own circle', he now says that when it appears from the same [spot] it has fallen behind by its own circle, so that before he meant that it rarely falls behind the sun (and therefore appears over long time intervals), but now he says that it falls behind by its own circle. So what is the claim that he is making now? That when it appears from the same spot, at which it has been seen previously, it falls behind by its whole circle, i.e. it has traversed and completed its whole circle. So, generally the appearance of the star, according to them, comes about at any time because of its greater lagging behind, but the cause of its appearance at the same spot at which it was seen previously is its traversal of its whole circle.[159]

> **343a7-10** And it falls behind both to the north and to the south. [In the place between the tropics it cannot draw up water to itself because [the area] under the motion of the sun is burnt]

'The comet', he says, 'falls behind the sun sometimes towards the north and sometimes towards the south'; for he wants to explain by this when it does form a tail, according to them, and when not. So also when he said 'because of falling behind by the slowest time', he meant falling behind the sun.[160]

> **343a10-15** But when it is carried towards the south, it has plenty of such moisture, but because the section of its circle above the earth is short, and that below [the earth] is many times longer, the sight-stream of men is unable to be carried, reflected, towards the sun, either when the sun approaches the southern place[161] or when it is at the summer solstice. [Therefore in these places it does not become a comet, whereas when it happens to fall behind towards the north, then it gets its tail because its trajectory above the horizon is considerable, and the part of the circle below the horizon is small; for in this case the human sight can easily reach the sun.]

In the places under the equator and those near it, it does not have a tail because of the excessive heat and dryness over there. And having passed over those places and moving towards the tropics and as far as them, it has plenty of water and draws up a lot of vapour from it, but in the southern places,[162] he says, since the greatest part of the circles is on the opposite side of the earth, viz. the part which the sun traverses during the night, it comes about that the sight-streams reflected from the vapour do not reach the sun below because of its great distance from the horizon below the earth.[163] In the northern region,[164] on the other hand, because the circumference of those circles below the earth is short in length, they do arrive at the sun.[165]

But perhaps (i) supposing that in the southern tropics[166] the sun at the very moment when it has set has neither traversed a great part of its orbit under the earth, nor indeed touched the line drawn to [the earth] from the centre of its circumference,[167] [it would be right to say that] at that moment the sight-streams could reflect onto the sun itself.[168] And conversely, (ii) in the northern tropics,[169] when the sun goes through a long part of the section below the earth, so as to be in its culmination[170] under the earth or perhaps surpass it to some small extent, then reflected sight-streams cannot be carried towards it.[171] So neither in the northern parts will the comet always have a tail, nor will it absolutely always[172] lack it in the southern, as is suggested by the aforementioned hypothesis.

> **343a20-2** There are impossibilities in all these views, some of which apply generally, others to some only.

Here he next turns to the refutation of the stated hypotheses. Of the incongruities following from these hypotheses, he says, some are common to all across the board, others are specific to each. And for now he sets out the ones that follow commonly from all, i.e. those that say that the comet is a conjunction of all the planets simultaneously, those that say that it is one of these or some other wandering star different from the five known to us, those that hold that it has its own tail, and those that take it [tail] to come about externally to it.

> **343a22-6** First to those who say that the comet is one of the wandering stars; for all the wandering stars in a circle fall behind[173] within the zodiac circle, while many comets are seen outside this circle. Further, more than one comet has frequently appeared simultaneously.

The proposed argument is a common refutation both of those who say that the comet is a single conjunction of the five planets, and if someone were to say that it is a single planet, viz. another one beside the five planets known to us. For the five planets, he says, occupy the zodiac circle, and move within it never going beyond it either to the north or to the south, whereas the so called comets sometimes appear to the north of the zodiac, at other times to the south.

Further, often more than one comet has been sighted simultaneously, but all the ancients always systematically treat[174] of the comet as one. And more importantly, whether just one comet appears or more, it is possible to count all the planets and see that each appears in its proper place. Neither then is a comet a conjunction of all simultaneously, nor one of them.[175] But nor is it a different planet 82,1
beside these [viz. known] ones, wandering as it does and surpassing the zodiac circle. First of all, all [the stars] which are carried by [a motion] contrary to that of the fixed [sphere], which we therefore call planets [i.e. wandering], do not go beyond the zodiac. Furthermore, how do they make sense of the comet's appearing over long time intervals? Is it not because it is concurrent with the sun and covered by its rays?[176] Then it also, together with the sun, itself occupies the zodiac circle: for neither the northernmost nor the southernmost [stars] are hidden by the sun. Why then do the comets make their appearance even beyond it [viz. zodiac circle]?[177]

And perhaps those who explain [comets] by conjunction [of planets] will respond to the difficulty of several comets by a probable argument that it is possible for, say, three planets to come together with each other and produce one conjunction, and for the remaining two again another one, so that two comets will come to be. What will they say, then, if three or more [comets] appear, and these surpassing the zodiac, at the same time as the five planets known to us appear not as coming together, but often even maximally distant from each other? Moreover, the comets are clearly seen to set bit by bit, and in much the same way as fire is extinguished little by little due to the lack of wood. And they also often change shapes, as we have observed ourselves, something none of the stars undergoes, fixed or wandering.[178]

> **343a26-31** In addition to this, if they have tail because of reflection, as Aeschylus and Hippocrates say, that star should have sometimes appeared also without a tail, as long as it falls behind in other places as well, but does not have the tail everywhere; but as things stand none has been sighted apart from the five stars.

Aristotle says this only against Hippocrates and his student Aeschylus. For if, as they hold, the appearance of a tail arises from reflection, and our sight-streams cannot be reflected from vapour towards the sun everywhere, this star will not have a tail always. So, he says, it should have appeared somewhere in other places without a tail. For if it lags behind in other places as well in which, as they say, it cannot have a tail because our sight-streams cannot be reflected towards the sun everywhere,[179] why does this wandering star not appear in other places without a tail, simply as a star and nothing more? But as things stand, he says, apart from the five planets, no wandering star appears anywhere. So much, then, against those.

And against those who say that it has its own tail Aristotle has not made any objections, since this is manifestly incongruous: for the argument is absurd. Why does it alone in contrast with the five have a tail? If it is one of the five, why is not even one of them clearly seen with a tail? And if it comes to be from a conjunction of all [five], while none of those has a tail, where does a tail come from in what has come to be from their conjunction? They might say that it gets a tail by emitting sparks, for the brightest stars appear to be of some such kind, as the Dog Star or Venus, which send rays from all sides which surround them as some sort of a tail. But a condition of this kind is clearly an illusion of our sight,[180] and it is not the case that some little bodies are hanging down from them on all sides. For in the case of a lamp too the same appearance is presented to the weaker eyes in the moister air: so such a tail is not their own.[181]

> **343a31-5** And all of these [viz. planets] are often seen together in the sky above the horizon. And whether all of them are manifest or not all of them appear, but some are close to the sun, comets nonetheless often appear to come about.

This argument is particularly suitable against those who say that the comet is a conjunction of planets. For if the comet is a conjunction and gathering of all in the same place, then when a comet comes to be, in no other place should there appear any planet nor should any of them be on the other side of the earth. But as things stand now, when all of them are and are seen above the earth, and when all are on the other side of the earth, and when some of them are above and some on the other side of the earth, and when all of them are close, and when they are distant, all being at different places, still the comets do appear which are not close to any of the planets. Since this is true, it follows that the comet is not a conjunction of planets, neither of all together, nor of some.

> **343a35-b4** But nor is it true that the comet comes to be only in the northern part of the sky, and only when the sun is in the summer solstice. For the great comet[182] which came during the earthquake in Achaea and the tidal wave rose in the west. And many have already been [seen] in the south.

Again, he directs the refutation against Hippocrates and his school who say that the comet comes about only in the northern parts, when the sun occupies the same places, because there the comet can draw up plenty of moist to itself, since the places are moist, and our sight-streams falling upon it and reflected are carried towards the sun because the part of the circle below the earth is short. But[, they claim,] there are no comets either between the tropics under the equator because the places are dried up, or in the southern parts because the sections of the circle below the earth are longer than above the earth and the reflected sight-streams do not reach the sun; nor again if the sun is in the summer solstice,[183] since our sight, again because of the great distance, is not able, when it is reflected, to get from the winter to the summer solstice.

So, Aristotle refutes these false assumptions from historical records and from phenomena frequently seen. Once these have been refuted, the account of the comet formation based on them is also 84,1
refuted. When the sun, he says, was in the summer solstice, the great comet which appeared at that time rose from the equinoctial sunset [viz. from the west], so that even with the sun so far away, the comet was formed between the tropics, right under the equator. And he must indicate that the comet was the greatest, indeed of so great a size[184] that because of the plenty of matter from which, as Aristotle proves, the comets and the earthquakes and the winds are formed, many of the Achaean towns were razed by that earthquake and a blow of a tidal wave formed by the contrary winds hit the earth, as he will show.[185] And if according to Hippocrates of Chios the comet is formed from the vapour drawn up by the star when our sight-streams are reflected towards the sun, as a result of our weakened sight seeing in the reflecting surface [of the vapours] the fiery colour of the sun, then [it would follow that] there is plenty of vapour formed under the equator.[186] So if not even they themselves believe that vapour is formed between the tropics, but such a great comet was

formed there, then Hippocrates' account of comet formation is false. Again, the records of many comets [seen] in the south expose as deluded somebody who says that a comet is formed only in the northern parts. And in our own time the comet arose under the feet of Orion in the places that are southern and distant from the zodiac.[187]

> **343b4-7** Under the Athenian archon Eucles of Molon[188] there came a comet in the northern part in the month of Gamelion,[189] the sun being in winter solstice; but they themselves say that reflection at such a great distance is impossible.

The record of the big comet refuted Hippocrates' assumption according to which the comet is formed only in northern places. The current one [refutes the assumption] according to which the comet must be close to the sun, and that one of them should not be northernmost, another southernmost, for the sight-streams cannot be reflected at such a great distance. Behold, at any rate, the comet seen under the mentioned archon, which itself appeared in the north, while the sun was in the summer solstice: hence the comet and the sun were away from each other at the greatest distance in latitude. If, then, they themselves believe it is impossible for reflected sight-streams to be carried over such a long interval, it follows that in this case too their account of comet formation is proven false.

85,1 **343b8-14** A common [objection which applies both] to them and those who say that [the comet] is a conjunction, is, first, that some of the fixed stars do have a tail too. On this we should not only trust the Egyptians (although they also say so), but we observed it ourselves. Namely, one star in the thigh of the Dog had a tail,[190] albeit a feeble one; for those who looked hard at it its light would become dim; but for those who took a side look at it, without exerting the sight, it was greater.[191]

Having argued against all the mentioned assumptions of the ancients in common, and having added the incongruities that followed upon each of them specifically, Aristotle now again sets out common refutations of both those who say that the comet is a conjunction of five planets and those who say that it is one of the wandering stars, the sixth. Of these, the first said that the tail is naturally united with it, while the second claimed that it got it from outside, or rather that the impression of a tail results from the sight-streams being reflected from the exhalation towards the sun. For if, Aristotle says, some of the fixed stars also get a tail, as both the more ancient records of the Egyptians seem to claim and he himself says he has recorded a certain [star] in the thigh of the Dog undergoing this affection, then the nature of a comet is neither a peculiar one, so that it would be one of the planets, nor a conjunction of all [planets] together, since then some of the fixed stars would not undergo this affection which did not have a tail previously, for the so called tailed star among them, if star it is in truth, should have first appeared without a tail.

But why did the light of the star seem dimmer to those who looked hard at the tail of the star, while to those who took a side look at it, turning their eyes somewhat obliquely, the light seemed to be greater? Some opticians say to this that of the cone of the sight-streams emitted from the pupil (for they are emitted in the shape of a cone, as I have said before), as many as are close to the axis of the cone (the axis is clearly the midmost), are stronger than others and more impassive, while as many as are farther removed from these are weaker and therefore, being more easily affected, are quicker to dissolve.[192] Therefore they apprehend the sense-object better: for that which is more acted upon better apprehends that which acts upon.[193] This seems to be in conflict with the fact that those who extend their sight-streams direct towards the sun have them dissolved more than those who look at it with the eyes turned obliquely. But against this it is possible to say that this happens because of the incommensurability of the sunlight with respect to our sight-streams: for the excess of the agent which is likely to lead the patient towards destruction destroys also the very apprehension of the affection.[194]

So perhaps it is the same with what is sought in this case. For those who look intensely at the light of the tail and the star simultaneously both have a greater affection and, since the sight-streams are weakened by it, a dimmer discernment; while those who look with the eyes turned aside and obliquely have the resolution of the sight-streams commensurate and the apprehension more precise.

Look [at it] also in this way. If you put two lamps along the same straight line, one higher and another underlying it, and then look at them, because the sight-streams are drawn in the contrary way by the light of each of them, the discernment of sight objects is scattered, and therefore the light seems dimmer. And if you take away one of them, since the mentioned affection will no longer be present, the apprehension of the lamp light will be more precise.[195] So, when the tail was below a fixed star, the sight-streams carried towards it underwent the effect of two lamps; but if the eyes are turned aside so that [the sight-streams] are no longer carried to both [viz. the star and the tail] in a similar way (for someone who turns his eyes aside always as it were makes the sight-streams incline towards the tail since he wants to see it), since the sight-streams are no longer scattered, the apprehension of the light of the tail will be more precise.

343b14-17 In addition to this, all [the comets] sighted in our time had no setting[196] and faded away in the sky above the horizon little by little, so that neither the body of one star was left behind, nor of several.

And this is the most important sign that the comet is neither one of the other planets, nor a conjunction of them all together. For, he says, all comets sighted in our time dissolved little by little while being above the earth, leaving no star behind. And in our own time as well, we have observed many [comets] dissolved in this way and turning into different shapes before the dissolution. However, had the above-mentioned opinions about the comets been true, i.e. (a) had this [comet] been one star, it should have been seen after the tail dissolved, or (b) had it been a conjunction of all the planets gathered simultaneously in one place, again, after the comet had dissolved, all the planets should have been seen as situated apart from each other, or rather the comet should have been dissolved by their being apart, and the dissolution of the comet should have been nothing else but those [planets] being apart from each other. For if their coming together produces a comet, then, surely, it must always dissolve as soon as those are moved apart from each other. So, if when comets – those observed by Aristotle and by us, and by everyone in general – were dissolved neither one star nor several stars were seen to be left behind, and it is impossible for the stars to assume a different shape, it follows that each of these assumptions is false. And he did well to indicate that they fade away while being above the earth:[197] for had the dissolution taken place on the other side of the earth, it would have been unclear whether there is a star left behind the comet's dissolution or not.

87,1 **343b17-25** Since the great star [viz. comet] which we have mentioned earlier appeared in winter in clear frosty weather from the west during the archonship of Asteius,[198] and was not seen on the first [night] as it set before the sun did, but was seen on the following [night] as much as was possible: for it lagged behind [the sun] by the shortest [distance] and set immediately; but its sheen stretched up to a third part of the sky in a leap,[199] which is why it was called 'path'. It rose as high as Orion's Belt and dissolved there.

And from the properties of the great comet, at the time of which also the earthquake happened followed by tidal wave, he derives the same persuasive evidence that the comet is neither one of the planets nor a confluence and conjunction of all at the same time. As it was a custom of the ancients to mark these effects, so he himself also records the facts concerning that comet.[200] For he says that he saw it

on a winter evening, in a frosty and clear weather, and on the first
evening it was not seen, viz., on the evening on which it was formed, 15
'because it set before the sun' or, presumably, at the same time with
it. But the evening on which it was seen was the second evening of
its formation and the first of its appearance. On it he says he saw it
above horizon for a shortest time; for it was in the west, therefore
when the sun set, the comet followed it shortly. For the comets are
moved along with the tinder and the air below it (the part which does 20
not stagnate between the mountains), and those move along with the
heavens.[201] But even though it set, he says, its sheen jumped over the
horizon to such an extent that after illuminating one third of the
hemisphere above the earth it set, most likely, in Aquarius, and its
light traversed two signs, Pisces and Aries, for that is a third of the 25
sky above the earth with those that rise next to them on both sides;
so great it was both in size and in power. But what is the basis for
saying that it was formed on the first evening of its appearance? He
inferred [this] well from the fact that after it has already set, its ray
made such a great leap as to illuminate one third of the sky above the
earth. Thus, on the basis of the fact that its ray does not leap over the
horizon prior to this day, he infers that it has been formed before its 30
one appearance. For their [comets'] kindling happens gradually and
not at once; it follows that it was formed before the appearance, but
did not appear because it has not yet set apart from the sun, and
possibly also because it has not grown big enough.

He says 'in a jump', i.e. the speed of movement of its rays has
become so great as to be similar to a jump. 'Which is why', he says, 'it 35
is called path', [viz.] its light traversing the said distance, being so
called either because of the speed of movement or because it colours
that place in the manner of a path, as it is said in the *Argonautics*:
'great roads were coloured white, as a lightning seen across the green 88,1
plain'.[202] The comet appeared in winter frost and set simultaneously
with the sun; consequently, the sun was in winter solstice or close,
and the comet concurrent with it. So if we assume that the sun was,
say, in Capricorn, and the comet appeared for the first time when it 5
has set, it is clear that it was then in Aquarius or close to Pisces. 'It
rose', he says, 'as far as Orion's Belt', i.e. it set apart from the sun
lagging behind it by more than three signs, Pisces, Aries, Taurus, and
some part of Gemini, as Orion's Belt, under which that comet passed
before being dissolved, is under these. And Orion's Belt lies right in 10
the southern tropic: therefore the comet has been formed in the
southern hemisphere. For although the air and the tinder, in
which the comets must be formed, move together with the heav-
enly bodies still they are not entirely equal in powers with them:
therefore the comet set apart from the sun lagging behind as far
as Orion's Belt.

343b25-8 Democritus, however, has worked hard[203] for his own opinion; for he claims to have seen some stars after the dissolution of comets. But [viz. in order for his argument to work] this should have taken place not sometimes, and sometimes not, but always.

Since one of Aristotle's refutations here was that when comets are dissolved no star appears to have been hidden by them, he says, 'however' Democritus applies himself hard [to argue] for his own opinion and claims to have seen just this happening. But, Aristotle says, this should have been taking place always, if a comet were to be one of the wandering stars, but as things stand now, while comets come to be many and often, we have never seen this happening.

It is possible to respond to him [i.e. Democritus] in another way too, namely: although Democritus believed to have seen this, in order not to deny his sense perception altogether,[204] I say that the man was misled.[205] For it is likely that some of the stars that are screened off by a comet as by a cloud, appear when the comet is dissolved, just as when a cloud is dispersed the stars appear which were until then concealed behind it, and Democritus decided that a comet is dissolved into the stars because he did not consider attentively what was happening. I also think that the stars that appeared to him, which had been screened off before, were in fact fixed; for had they been planets, proving his own opinion he would have said which ones.

343b28-32 In addition to this, the Egyptians too say that planets have conjunctions with planets[206] and with fixed stars, and we ourselves have seen the planet Jupiter going over a certain
89,1 star in the Gemini and hiding it completely, which did not bring about any comet.

Again he argues from recorded facts that a comet is not a conjunction of stars. For, he says, both the Egyptians had observed, and he himself has seen some of the planets forming a conjunction, sometimes with planets, at other times with fixed stars, in such a way as to occult and make them invisible, and yet a comet was not formed from them. Consequently, a comet is not a conjunction and joint appearance of the stars.

343b32-344a2 This is clear, further, from reason: for the stars, even if they appear to be greater and smaller, still by themselves seem to be indivisible. So, just as had they been indivisible, they would not have made a bigger size when being contacted, so too even if they are not, but appear to be, indivisible, when they are in conjunction they do not appear to be any bigger in size. [Though more could be said, these arguments suffice to show clearly the falsity of the mentioned explanations.]

He lays down this last refutation of those who take a comet to be a conjunction and joint appearance of the stars; but the refutation is not from facts, as the preceding one, but from reason and demonstration based upon it. For if, he says, some of the stars appear as small, others as big, still each considered by itself seems to be as good as indivisible, with respect to sense perception; so small do they appear. So, just as things that are indivisible by nature, I mean the points, when they are conjoined do not produce a size, in the same way too things that seem to be indivisible to sense perception because of their smallness, such as the stars, even when they are conjoined, do not produce a perceptible size. And if they appear to the observers to be indivisible, then when they are brought to a conjunction they cannot make a size as big as that which the comets seem to possess – for some of them have been seen stretched over not one, but oftentimes also the second sign.[207] Having, up until now, refuted the beliefs his predecessors had about the comets, he from now on explains his own views about them.

Chapter 7

> **344a5-8** Since we think we have given a sufficient demonstration in accordance with reason about things inaccessible to perception if we have arrived at what it possible, then from the evidence available one could assume that the following is largely the case with these things [we are considering, i.e. comets].

Aristotle next passes on to his own explanation of comet formation and announces the way in which the study of them is to be pursued. Since the cause of their coming to be is hidden from our senses, he says, those who are producing an account of them and all such matters and are willing to investigate their natural causes, must give such accounts of them that will not entail anything impossible or contradictory to evidence. What he says is the following. If we bring our accounts of the comets to what is possible as far as the evidence is concerned, so that nothing impossible follows from them (as it does from the theories of comets stated by our predecessors), but on the contrary, our accounts are in accord and agreement with the facts – if this is the case – then we shall be stating the explanation as far as the evidence is concerned.

> **344a8-10** We have assumed that the first part of the world around the earth, as much as lies beneath the heavenly rotation, is the dry and hot exhalation.

He has already said before that two kinds of exhalation are going up from the bottom, one from moist bodies, vaporous, and another from dry ones, smoky, which he termed ‘tinder’, as being suitable for kindling.[208] There is no account of the vaporous one, either in the present section or in the preceding argument; for the smoky exhalation alone is the cause of these [i.e. the comets] in the sense of matter. So, this smoky exhalation, i.e. the tinder, and a large part of the air below it, which reaches from above down to the tops of the highest mountains, are dragged along by the rotation of the heavens, and are themselves moving along in a circular motion. But he has said before that motion heats.[209] So, when there is found a dry exhalation of such constitution as to be neither too fine and feeble and easily dissolved, nor thick and dense to such an extent as to be difficult to kindle, but somehow in the middle between these two [states] and suitably mixed, such exhalation, Aristotle says, when heated to more than its inherent natural temperature by the motion of the surrounding bodies and its revolution with [these bodies],[210] is kindled and produces a comet. When it has finer texture, it is quicker to catch light, but is extinguished at once like fine tow, and when it is thicker than the constitution conducive to the generation of a comet, the motion is not sufficient to kindle it. So the thicker wood is not good for kindling, whereas the undershrubs which catch light more easily are consumed faster and the flame vanishes. But this kindling, or [rather] its cause, must be in the right measure so as not to destroy the matter at once by its intensity, on the one hand, and on the other, not to be unable, because of faintness, to have an effect on and to prevail through the whole of it.[211] And the comet when kindled keeps the flame for some time without being consumed; for the comets differ from all the previously discussed conflagrations, flames, ‘torches’, and ‘shooting’ stars in this, namely, that they are long-lasting, while these latter are quenched at once after being kindled. The cause of endurance is the thickness of the matter, as well as the exhalation which is added to the comet from above, in the same way as one preserves the flame by adding wood to the fire or oil to the lamp until the supply of matter runs out. Our teacher[212] too said that he had seen a comet of which one part was faint and less inflamed, and another exceedingly bright: it is clear that these [latter parts] are quicker to dissolve because of the intensity of the burning, but the faint parts last longer because the conflagration is milder.

‘We have assumed that the first part of the world around the earth, as much as lies under the heavenly rotation, is the dry and hot exhalation.’ This he already dealt with when he explained the order of the five elements, that immediately next to the spherical bodies goes the tinder, and the third after it air, after which water, and the last of all the earth in the middle one.[213]

> **344a11-13** This [viz. dry exhalation] itself, along with a large part of the adjacent air beneath it, is carried along around the earth by translation and motion [in a circle].

By a 'large part of air' he means the air extending down to the top of the highest mountains, which, when it becomes stagnant, is not pulled along by the bodies moving in a circle, being impeded by the surrounding mountains.[214] So, he means that the revolution of these two bodies is forced. And how can what is forced and contrary to nature be unceasing? But about these matters we have said enough elsewhere.[215]

And [he says] 'being carried along around the earth' meaning 'around the earth as a centre'; for he has proven that the earth together with the water it holds and the stagnant air is the centre in relation to the fixed [sphere].[216]

> **344a13-15** Being carried and moving in this way, where it happens to be suitably mixed, it often catches fire, for which reason, as we say, scattered shooting stars also come to be.

The dry exhalation, he says, being carried 'in this way', i.e. being carried about with heavenly bodies, 'where it happens to be suitably mixed', i.e. suitable for kindling, neither too fine or loose-textured nor, the other way round, dense or thick, always catches fire. And he has demonstrated that the 'running' stars which they call 'shooting' come to be from it.

> **344a16-23** So, when an incipient fire due to its downward motion falls into this kind of thickness – the fire neither so excessive as to lead to a quick and nearly total combustion, nor so weak as soon to be quenched, but stronger and capable of having a considerable impact – and at the same time a suitably 92,1
> mixed exhalation happens to rise upwards, this comet comes to be, shaped in the way the exhalation happened to be: if equally in all directions, it is called a comet ['long-haired'], if lengthwise, a 'bearded' star.

After explaining what kind of right proportion the matter must have in order to be kindled so as to bring about a comet, Aristotle now says of what sort the efficient cause must be, which he called the 'incipient fire', namely, that it too has to be balanced in such a way as neither to burn up the matter too soon by its intensity, nor to be quenched by it because of its feebleness and faintness. So, it is clear that he calls 'the incipient' the first portion of the exhalation that catches fire. And where this incipient fire comes from, he said many times, namely, due to the motion from above.[217] For if the kindling is of some very abundant and strong kind, it will quickly burn up and consume the matter, and will proceed over a long distance burning it. This makes not comets, but flames about which he has already written,[218] in much the same way as when a very big flame gets into a small number of vine-branches or into tow – for it scorches them faster. And if the incipient fire is feeble, on the contrary, it is quenched because of being stopped by the matter, [thus] being rather acted upon by the matter and not able to have any significant effect on it, in the same way as when a small flame gets into a large amount of oil or a big pile of wood (either in quantity or in close packing) – for such are hard to work on. Therefore the incipient fire too must escape each of these extremes and be some sort of a mean [state], neither prevailed upon by matter nor exceeding it too much; being in this state, it will produce a comet.

But also, he says, other matter must rise up from the lower region, suitably mixed, i.e. fit for kindling, in order to make up for the consumed matter of the comet and provide the productive power with a supply to work on, so that the effect will persist longer.

The constitution of the comets is of some such kind. Now, in a more general way they call the whole genus of this kind 'comets'. At any rate, Aristotle in the beginning of the account said 'about the comets or[219] the so called Milky Way'. But in a more specific way, each of these too received a name proper to the shape of the exhalation. For if the exhalation is spherical in shape and happens to have slight formations of this sort appended to it outside, this shape is called 'comet', i.e. 'long-haired' [star], in a more specific way, since it looks like hair. In an expanded sense, they call so all the rest; but the one whose shape is merely oblong is called 'a beam', the triangular one is called 'bearded', some other sort 'jar-shaped', and so on, each being called differently, for different reasons, in accordance with the shape.[220]

344a23-33 And as this kind of motion seems to be the motion of a star, so too a similar [state of] rest seems to be the rest of a
93,1 star. What happens is similar to when someone pushes a torch into a large chaff-heap or drops an incipient fire into it. For the path of the stars is apparently similar to this, as because of the suitable disposition of the tinder it spreads quickly lengthwise. But were it to stay and not die away when spreading where the tinder is thickest, the terminal point of the path would become the starting point of motion [of the comet]. The long-haired star [comet] is of this sort, like a path of a star, and having in itself the limit and the starting point.

Aristotle now also explains the difference of comets and shooting stars from each other. He says, just as the motion of this kind of exhalation, formed and kindled in the way described, seems to be a path and motion of a star which is called 'shooting', so too the resting state of such kindling seemed to the observers to be the resting state of a star, and this [latter kind of stars] are the comets so called in a more generic sense. And again he explains the effect that arises with the help of an example. For it is just as when one pushes a torch into a chaffs-heap, or a small incipient fire, like a spark, falls into it, and kindles some small bit of these, the part of the chaffs that was kindled first spreads over to the next, and this to the one after it, while the first to be kindled is extinguished because of the fine texture of the matter, and so on, until everything suitable has been kindled and there is no longer anything being kindled. To those who stand close by, it is clear how this comes about, but to those observing this from afar it seems to be motion and a path of a single flame. The very same thing happens with the shooting stars: 'because of the suitable disposition of the tinder', he says, i.e. its suitability for kindling, one part of it being kindled after another continuously, and when the one which is kindled earlier extinguishes because it is consumed easily, it seems that one star runs along a certain [distance].[221] Now, the starting point of the seeming motion is where it started burning, and the end is wherever it stops because no more matter is left suitable for kindling. And if some thicker and denser matter comes across the running flame, which can sustain the form of the fire, then this is the [final] limit of the shooting star, and the starting point of the comet.[222] For the flame remains in it for some more time both because of the large amount and density of matter and because of the exhalation with which the comet is provided in good quantity from below and which is added to it like nourishment and makes up for the parts of kindled matter that have been dispersed.

And 'the terminal point of the [star's] path is the starting point of the motion' means: the end of the path of a shooting star (it reached its end where it encountered the density of matter) is the starting point of the comet's motion, i.e. the point where its matter starts to burn: for in it too the earlier [burning part of matter] spreads over the next and in its motion kindles what is suitable, but because of the 94,1 density of matter neither is the next part easy to kindle, nor does the earlier [burning part] readily die away, and therefore no impression of motion comes to our attention. So, he said 'the starting point of motion (*phora*)' either referring to the starting point of the motion of the comet along with the universe,[223] or simply the beginning of its existence and the plentiful supply of matter. For when a lot of fruits are born we do speak of a large crop, and similarly in the case of worse [proceeds] Menander:

> 'For it's been a pretty crop (*phora*) of this for whatever reason'.[224]

Concluding the discussion, he says 'the comet-star is of this kind, as a path of a [shooting] star, having in itself the limit and the starting point'. The comet, he says, is like a path of a star, i.e. it is a shooting star which has in itself the starting point and the limit of burning which remains in it and is not quenched; for in the case of the shooting star that which is kindled is extinguished at once. For things that have their being in change[225] are of this kind, namely they have neither the starting point nor the limit of their motion in themselves. For all change has its being in coming to be and perishing, and there is no part of it which persists, just as there is no such part of time, or of perishing.[226] But the comet has in itself both the first and the last kindled [parts] as persisting and being preserved. So, the comet is a shooting star that does not move but remains at rest and has in itself the starting point and the limit of ignition.

> **344a33-b8** So, when the starting point of condensation is in the lower place itself, the comet appears by itself. But when the exhalation is formed under one of the stars,[227] fixed or wandering, by the motion of the latter, then one of them becomes tailed. For the tail is not attached to the stars themselves, but like halos which appear to follow after the sun and the moon, even when these latter move from place to place, when the air is so thickened that this effect is produced under the course of the sun, in the same way too the tail is a kind of halo to the stars. But in one case [i.e. of the sun and the moon] the halo is of a given colour due to reflection, while the colour of these [i.e. comets] is such as it appears.

Since some comets come to be without and some with[228] the stars, not just the planets, but also fixed stars, Aristotle here recounts the difference between them. So, when, he says, the aforementioned exhalation is formed in a place below, not near the stars, it by itself, without a star, becomes a comet in the way described. But when the stars too by their motion draw to themselves the exhalation of this kind, when this exhalation happens to catch light due to the aforementioned causes, the star seems to become a comet.[229] And it is also possible for matter to be formed closer to the upper body, but not have any of the stars on the vertical line above it, in which case too the comet comes to be by itself.[230] But if such exhalation is burned along one vertical line underneath any of the stars, our sight not being strong enough to attend to the difference between it and the star, i.e. to the space between them, thinks that the star and the tail are in one and the same plane, and therefore it imagines that the star has become a comet.[231] But this is not how things are in reality, he says, as the tail does not [reach up] to the stars themselves, but is much lower, although still underneath them. And he gives as an example of this the halo formed around the sun and the moon, although he has not yet shown what kind of thing that is.[232] So, as the halos seem to be in the same plane as the sun, e.g., or the moon, but are not in these [planes], but underneath them, in the same way it comes about in the case of the tail formed under any of the stars.[233] This, then, is one thing that both halo and comet have in common. And he names another, namely that both the halos are moved along with the sun and the moon, and the tail with the stars. But they differ in that the halo because of the reflection of sight-streams from the cloud surrounding the sun or the moon has not a colour that really exists, but only an appearance of a colour, whereas the tail of a comet does have the colour with which it appears, since it is the kindling to the underlying matter.[234]

What causes the halo to seem to change place simultaneously with the sun or the moon, and the tail with the star of which it is a tail? Aristotle says it is the thickening of air everywhere in the same way, and therefore the possibility for our sight-streams to make an equal reflection from each of its parts. And as he said 'so that this effect is produced under the course of the sun', the same is also the case with the tail. For if the exhalation is uniform everywhere, nothing prevents [the part of it] from which the star has moved away to be quenched, and for another [part of exhalation], at which the star arrives, to be kindled by its motion, if he is right in saying that the exhalation is formed by the motion of one of the fixed or wandering stars. So perhaps it is true, that if the tinder with a large quantity of air under it is carried about with the heavenly bodies, and the comet is something that really exists, namely a condition of the air that moves along with the whole, it is plausible that it is carried about with the bodies of which it is a condition, but not moved; and it is not the star that pulls along the tail, but the fixed sphere pulls the tinder and the air, together with the conditions formed in them.[235]

> **344b8-17** Therefore when such condensation [of exhalation] comes about in connexion with a star, the comet must appear as moving with the same local motion with which the star is carried. But when a comet is formed by itself, then it seems to be lagging behind. For such is the motion of the [part of the] universe around the earth. In effect, this is the strongest indication that a comet is not some reflection like a halo which comes to be in relation to a star in the pure tinder nor, as the school of Hippocrates claims, in relation to the sun, namely that often, and more frequently than around some particular stars, a comet comes about by itself.

Further, he announces the difference between the comets, those that come to be by themselves and those that are formed under one of the stars and make the star itself into a comet. The latter, he says, are carried by the same motion as that of the star, and do not lag behind it at any time. On the other hand, the comets formed by themselves, without a star, lag behind the motion of the heavenly bodies. Alexander states the cause, namely that the world around the earth does not move at the same speed as the heavenly bodies nor follows them evenly. It moves in this way not in accordance with nature, but is clearly dragged along by force, contrary to nature, by the prevailing strength of that which pulls it.[236] This is what Aristotle relates about what happened to the great comet: that it stayed behind.[237] We can assume on the basis of what he is saying that the sun then was in Capricorn, and the comet was in conjunction with it before being sighted, but when it first appeared, it lagged behind the sun in Aquarius for the rest of the time (for how would it have made an appearance had it not been behind the sun?). Since Aristotle says, again, that it rose up to the Belt of Orion, which is under Gemini, and dissolved when it had arrived there, we can infer that it lagged behind by four signs, Aquarius, Pisces, Aries, Taurus. Consequently, it lags behind by this much also with respect to the motion of the whole heaven, moving slower, because the tinder, in which the comet has its existence, is pulled along with the heavens by force.

Surely no student of nature would ask: 'How do we know that the comet did not move faster and run into the sun [passing] through the eight preceding signs, Capricorn, Sagittarius, Scorpio, Pisces, Virgo, Leo, Cancer, Gemini?'[238] First, it is ridiculous that a comet which is pulled along with the fixed sphere and together with the tinder should have such a great speed. Secondly, the comet running back in the Capricorn would have become invisible, because it would be in conjunction with the sun, and as it deviated from the sun and went past Sagittarius and Scorpio it would most likely appear at dawn only. But as things stand, it first appeared after sunset, being clearly in Aquarius, and until its last setting it kept appearing after sunset, until having arrived under the belt of Orion it was dissolved.

In addition, it is impossible that things pulled along with something by force should move faster than that which pulls them (for they have no motion of their own), but they either move at the same speed with it, if nothing counteracts, or always[239] lag behind, unable to keep pace in continuity[240] with that which pulls, as I think was the case with the comet under discussion. And if in general the [part of the] universe around the earth is pulled along with the heaven by force, I think, it follows that the comet always has periods of rest and is left behind in motion.

Now, this is manifest. If according to the Platonists it is natural for the totality of the elements either to rest or to move in a circle,[241] and therefore the tinder is carried in a circle not by force but naturally, it follows that the tinder has it out of its own nature to lag behind the fixed sphere, moving slower than it, just as the speeds of the heavenly bodies are not equal either, but some move faster than others, others slower. Now, perhaps Aristotle also alludes to something of this sort when he says ‘for such is the motion of the [part of the] universe around the earth’, viz. the motion of the tinder and the non-stagnant air, namely, not to move at the same speed as the universe, but to lag behind. So the tinder lags behind the heavenly bodies not because it is pulled along by force, but because it has a nature of this kind, since if it moved in this way by force and against the nature, then it would be in the state against nature for the whole of the time, and would never happen to be in accordance with nature, which is impossible.[242] This, then, is also the reason why the comets lag behind with respect to the motion of the heavenly bodies. For they do not move by themselves, since they are a condition of air or tinder. So, since what underlies them [i.e. air or tinder] lags behind the heavenly bodies, there is every necessity that they themselves lag behind as well.[243] From this it is clear that their motion is not supernatural, as Damascius says elsewhere,[244] which we have refuted; for it would not have been so easily affected.

This, then, has been explained sufficiently. But why the comets formed in connexion with the star run at the same speed as the star and do not lag behind, neither Aristotle nor Alexander explained, except that Alexander simply made a casual remark to the effect that ‘[because it, viz. the star] provides a cause of the exhalation’.[245] He should have said, then, in what way it provides a cause of the exhalation; for Aristotle gave no explanation. At this point someone might say, I suppose, that a comet formed below[246] is made up by the matter that is denser because it is admixed to the bodies below, whereas a comet formed near the stars is of finer-textured and fiery matter, because it is close to the bodies above. Therefore it is plausible that the former lags behind because of the heaviness of its matter and its resistance to that which pulls it along, whereas the latter follows along because of its fine texture, since nothing counteracts the compression produced by that which pulls.[247] This is highly credible, but will not be found true by those who examine the nature of the subject matter. For since the tinder and the non-stagnant air are continuous, they also produce a motion that is not split into parts but is single and continuous, whether it moves by itself or is pulled along in the heavens. This is why the conditions [viz. of tinder and air] themselves revolve, as the comets also clearly show, which set and rise many times in the same way as stars. If, then, comets are a condition of the tinder, and come to be different in its different parts which are continuous, how is it possible, if the whole is continuous and produces a single motion, for one of its parts to run at the equal speed with the heavenly bodies and for another to lag behind?[248] So, since neither the philosophers mentioned above explained the phenomenon, nor generally anyone else at all was capable of finding their cause, I think, one must make multiple observations of all these things, to see if it is the way Aristotle said it is, and if it appears to be the case, to see, again, whether what is happening is just a phantom and visual illusion and not the truth. For perhaps the comets which are near the stars, because they move along a long circumference and with a motion which does not deviate much, i.e. in an obvious way, from the stars, are believed to run at an equal speed with them, while those that are below, by contrast, move along a short circumference and seem to be faster in deviating from the stars that were previously above them on the same perpendicular line [to the surface of the earth].[249] The star-gazers can observe a similar phenomenon in the case of the fixed stars, namely the motion along a longer and a shorter circumference.[250]

> **344b12-17** For this is the strongest indication that a comet is not some sort of reflection like a halo which comes to be in relation to the star in the pure tinder nor, as Hippocrates says, in relation to the sun, namely that often, and more frequently than around some definite stars, a comet comes about by itself.[251]

Now Hippocrates, just as he explains the halo as a reflection of sight-streams onto the sun,[252] also states that stars become long haired [i.e. comets] because the exhalation reflects our sight[253] onto them.[254] Moreover, Aristotle himself invoked the halo as an example when discussing the tail. So, lest someone should think[255] because of this that Hippocrates is correct in claiming that the tail comes to be from reflection of our sight-streams onto the star as the halo from the reflection of our sight-streams onto the sun, Aristotle refutes this supposition in what he says right now, namely that the comet often lags behind and is formed by itself for the most part, and more rarely in connexion with a star. For if the tail came to be as a result of sight-streams being reflected onto one of the stars, as halos do [as a result of sight-streams being reflected] onto the sun or the moon, it would be impossible that it would have ever formed by itself without a star, just as a halo cannot be formed by itself apart from the sun or the moon; but as a matter of fact, this happens often.

Further, a halo comes to be in the misty air, and our sight-streams falling into it are reflected onto the sun and the moon; but the comets come to be in the clean tinder, for which reason reflection is impossible.

Again, a halo does not abandon the sun or the moon, but keeps pace with the [star] under which it is formed, but comets do happen to abandon [their stars]. The tail is not formed in the same way as the halo, by reflection.

Since (a) from the fact that the halo does not fall behind [its star], and the comet does fall behind, Aristotle concluded that halo is not the same condition as comet, but said that (b) a comet formed under
99,1 one of the stars does not lag behind the star, somebody might derive

from this an opposite conclusion, namely, that according to him the tail and the halo are the same condition. If this is false, it would not be true that the tail formed around the star does not lag behind it.[256]

Aristotle's words[257] should be understood with transposition, as follows: 'For this is the strongest indication that the comet is not some sort of reflection which comes about in relation to the star itself, as Hippocrates and his school claim, just as [they claim that] the halo too [is some sort of reflection] to the sun that comes about in the clean tinder.'[258] And it is clear that the particle *mê* (not) after the conjunction *kai* (and) is superfluous.[259] And what 'this' is, he then clarifies by adding that the comet often comes to be by itself, viz. more often than under some definite stars, punctuated with a comma after 'often comes to be by itself',[260] in order to give the sense as follows: 'the comets come to be by themselves more frequently than around some fixed stars or planets, as he said before'.[261] And he called these 'definite' in contradistinction to the comets, since these latter are also called 'stars'.[262]

> **344b17-345a5** We shall explain the cause of the halo later. As to their fiery constitution, one should regard it as a sign that their constitution is fiery that their increased quantity signals winds and drought. For it is clear that they come to be because of the abundance of this kind of effluence, so that the air must be drier and the evaporating moist must be dissolved by the abundance of hot exhalation, so that it does not easily condense into water. [But we will speak more clearly about this effect in due time in the discussion of winds.
>
> So whenever the comets are dense and many, the years are clearly dry and windy, but when the comets are rarer and feebler in magnitude, the effect is not similar, although some excess of wind, either in duration or in strength, comes about for the most part. Thus, when the stone fell from the air at Aegospotami, it had been lifted by the wind and fell during the daytime; at that time also the comet appeared in the west.
>
> Again, at the time of the great comet, the winter was dry with strong northerly wind, and the tidal wave arose because of a conflict of winds: for inside the gulf, the northerly wind prevailed while outside it a southerly gale was blowing.
>
> Again, in the archonship of Nicomachus, a comet appeared for several days in the equinoctial circle, not rising from the west, which coincided with the storm at Corinth.]

Aristotle said earlier that the matter of the comets is dry and hot, so now that he has completed the account of their formation, it makes sense for him to go on and prove what he had already adduced as agreed, viz. that the material constitution of comets is fiery. Thus, the year when more comets appear turns out dry and windy. It is clear that many comets formed [in such a year] because their matter has been plentiful, i.e. the dry and hot [exhalation] which vaporises, disperses and transforms into itself the other, moist, exhalation, from which rains, hail and snow come about; for when one of the contraries prevails, the rest becomes the same as the prevailing one.[263] It is plausible, then, that that year is dry 'because of this kind of effluence', i.e. the dry exhalation; for when the earth is heated, the part of it which has been made fine-textured by the heat is separated from it and carried upwards. And since the same matter is the cause of winds, as he will show further on, it stands to reason that the year is also windy. Aratus in the *Signs* also said this as follows:[264]

100,1 It is to be hoped that the stars above will not[265] be always recognisable,
and that there will not be one or two or more comets,
for many comets mean a dry year.

Since the shooting stars also have the same matter, as we have said earlier,[266] the abundance of them is also, again, the sign of winds, as Aratus also, again, indicates:[267]

When through the dark night the shooting stars
fly thick, and their track behind is white,
expect a wind coming in the same path.
If other shooting stars confront them,
and others from other quarters dart
then be on thy guard for winds from every quarter.

So, if this is said correctly, I believe, it is clear then that the more numerous and uninterrupted the comets are, the drier and windier those years turn out. If the comets are fewer, smaller in size and less frequent, that year, he says, will proportionately have a smaller than the first, but still an excess of wind, either in force or in duration. For it either blows most of the time because of a large supply of matter, or winds become strong and violent because of its concentrated movement. Again he makes the records witness to his argument, namely, the stone raised to a height by the force of wind <and thrown back again>[268] by its innate weight in the Aegospotami, clearly, when the wind set back and was no longer able to hold the stone up for a long time,[269] and moreover, the earthquake which happened after the great comet, and the tidal wave which arose from the contrary winds, as will be shown in the chapter on earthquakes.[270]

> **344b36-7** For north wind prevailed in the gulf, while outside the strong south wind was blowing.

That it is the cause of floods, he will explain again in the discussion of them.[271]

> **345a5-10** The reason why the comets come to be neither in large numbers nor often, and more outside than inside the tropics, is the motion of the sun and the stars, which not only separates the hot, but also dissolves what is condensed. But the chief cause it that most of it [the hot] collects in the area of the Milky Way.

He enquires both in general, why comets do not come about continuously, and more specifically, for what reason those that come to be do so more outside than inside the tropics. And the cause of these facts is one and the same, namely that the motion of the sun and the stars not only generates the mentioned exhalation by heating the sublunary area, but also, through the intensification of the heat, rarefies this same exhalation and thins and completely scatters it. And we have said that for the coming to be of a comet a thicker exhalation is needed.

But if this is the reason why the comets do not come to be continuously outside the tropics, then so much more will they not be formed between the tropics, since the sun and the planets rule there.[272] That is also why the earth under the equator and near both tropics is scorched and uninhabited. And he adds yet another cause, namely that much of the matter of this kind collects in the area of the Milky Way. Whether this is said well or not, we shall show in the discussion of the subject.[273] But since in general he believes that much of the matter of the comets collects in the area of the Milky Way, assuming that both are of the same kind of matter, once the matter is known, he naturally passes from here to the account of the Milky Way itself, enquiring how it comes to be, and by what cause, and what the Milky Way is. In accordance with his habit, he again starts by expounding the ancient beliefs about it; and he says that there have been four main accounts of it among the ancients, each of which he presents.

Chapter 8

> **345a11-25** [Let us now say how and why the Milky Way comes to be and what it is. And let us again first discuss the views of others about it.] Now, some of the so called Pythagoreans say that it is the path of one of the stars fallen out at the time of Phaethon's legendary death, others say that the sun was once carried along this circle, in such a way that this place has been

completely burnt out or has been affected in some other way by its motion.[274] [But it is absurd not to agree that if this is the cause, then the circle of the zodiac should be affected in this way too, in fact, even more so than the Milky Way: for all the planets move in it, not just the sun. And this circle is clearly visible to us: for we can always see half of it during the night. But it is clear that it is not affected in this way at all, except when a part of it overlaps the Milky Way.]

The two opinions set forth earlier which are fabulous and made up by poets are in the tradition of Pythagorean myths. The fiction about Phaethon is celebrated in many places in poetry, that he was young and eager to drive the chariot of his father Helios and when he got to do it, he drove it more youthfully than wisely, applied, according to the poet,[275] his whip without thinking and burnt out many a part of the world, amongst which the torrid zone,[276] as well as, according to the Pythagoreans, the Milky Way which now still reflects the colour of the fire that happened then and of the stars that have fallen in that place.

Other Pythagoreans again say, on the other hand, that the sun once used to go around this circle, not the zodiac, as it does now, but that of the Milky Way, which, having thus been set on fire, made this colour. And I think that these too followed a myth, the one made up about Atreus, that because of him the motion of the sun turned in the direction contrary to that in which it is carried now. 'For', says
102,1 Euripides,[277] 'she [Eris] turned the sun's winged chariot about, adapting the westward path in heaven towards Eos who drives her steeds alone,[278] and Zeus turns about the course of the seven-track Pleiade onto another path'.

Now, concerning the former mythological account, Aristotle does not even deem it worthy of a reply. Concerning the second, however, he adduces a concise refutation, since it does somehow touch upon natural science, no matter in what way, namely, that the places through which the sun, hot and fiery as it is, is carried, must be affected in some way by it. So, what is the refutation? That the circle of the zodiac, through which the sun is carried now, must be affected in the same way and that it must be coloured like the Milky Way, and all the more so because along with the sun, the five planets and the moon are also carried through it. But it does not seem to be subject to any such condition. Although we see its semi-circle at any time of the night, we do not observe any such condition occur in it, except, he says, if some part of it connects with the circle of the Milky Way; and it connects in the Gemini and Sagittarius. But if the condition were of the zodiac due to the sun's motion through it, the whole circle should have been affected in this way. Now, some people resolve the myth of Atreus as follows. Atreus, they say, who was an astronomer, was the first to show people that the motion of the seven planets proceeds in the direction opposite to that of the universe, and from this the myth made its entrance that because of Atreus the god turned about the motion of the heaven into the opposite direction.[279] And I think that the 'course of the seven-track Pleiade' is said on account of the seven planets: for the so called Pleiades are only six, as Aratus said,[280] and this is apparent to those who look at them.

The myth of Phaethon, to unfold it in a way that suits the study of heavenly phenomena, seems to me to hint at the formation of a comet which once came about and which they say is a child of the sun: for it comes to be from the fiery matter evaporated by the sun. And he desired to drive his father's carriage because it is carried by the same [path] as the sun. And his disorderly motion and that he did not keep pace with his father indicates that the comet did not move at the same speed as the sun, nor preserved the order of its movement, because the comets lag behind the sun and because the matter of sublunary things is disorderly, since these latter cannot display the good order of the heavenly bodies. And that the parts of the world through which its movement proceeded, were consumed by flame is in agreement with what is said about the comets, namely that they are signs of droughts and excessive heat of the air below the moon. It is possible that at the time in question many comets, shooting stars and meteors were formed, from which the myth not unlikely had its origin.

> **345a25-31** Anaxagoras and Democritus[281] and their pupils say that the Milky Way is the light of some stars. For the sun, when it is carried beneath the earth, does not shine on some of the stars. The light of all the stars on which the sun shines is not visible to us (for it is impeded by the sunrays); but of all those that are screened off by the earth so that the sun does not shine on them, the Milky Way, they say, is their own light. 103,1

Aristotle now states the third view on the Milky Way which is as follows: when, he says, the sun at night is beneath the earth, clearly of the stars above the earth there are some which its light does not reach, but some which it does reach. Now, it conceals with its greater light all the stars which it reaches and they are not seen, just as in the daytime, of course, it hides all the stars above the earth, for which reason we see none of them. But as for those stars which its rays do not reach because of the interposition of the earth, the sun does not hide their light, and this light is the so called Milky Way. He produces the refutation of this view as follows:

> **345a31-6** It is manifest that this, too, is impossible. For the Milky Way is always the same amidst the same stars (for it appears as a greatest circle[282]), whereas the things on which the

sun does not shine are always different because they never remain in the same place. So the Milky Way should have changed its position when the sun changed its; but as things stand this obviously does not happen.

If the Milky Way, he says, were the light of the stars which are not hidden at night by the sun because of being screened off by the earth, then, since the fixed stars always occupy the same place, whilst the sun in its own motion comes at different times near to some stars and moves away from others, it will neither always hide away the same stars with its own light, nor will the same stars be continually screened off by the earth. For the shadow is cast on the things that are on the opposite side of the source of light; and if because of the sun's changing place from one set of signs to another not always the same part of the earth is illuminated, then it is as it were absolutely necessary that also the fixed stars which are in the shadow are not continuously the same, but different fixed stars at different times. For since the sun does not always move with the fixed sphere, but also has its own motion, it is absolutely necessary that also the cone of a shadow should be different at different times and therefore not occupy the same position in relation to the fixed stars, just as the sun itself does not.[283] But as things stand, we always see the same Milky Way, always under the same stars and in the same places. Moreover, each of its parts appears always to be the same, and where it is dim, it never becomes brighter, nor does it become dimmer where it is bright, and where it is simple and where it is convoluted,[284] it always
104,1 appears this way, undergoing no alteration because of the sun's relocation. Now, this is the first refutation; and he also adds the second one.

345a36-b9 Moreover, if what has been shown by the theorems of astronomy[285] is right, and the size of the sun is greater than that of the earth, and the distance from the stars to the earth is many times greater than <from the sun>,[286] just as [the distance] from the sun to the earth [is many times greater] than from the moon [to the earth], then the vertex of the cone formed by the rays of the sun will fall somewhere not far from the earth, nor will the shadow of the earth, which we call night, reach the stars, but it is necessary that the sun shines on all the stars, and that the earth screens off none of them.

Aristotle refutes the hypothesis just set out directly and indirectly. He first used the indirect refutation when he allowed [hypothetically] that some of the stars are screened off by the earth, as if the cone of the shadow stretched, according to them, to the fixed sphere and as if some of the stars fell into it, in the way this happens with the lunar eclipses, when the moon falls into this cone and therefore, during this time, does not receive the sunrays; this is why it is eclipsed.[287]

But next using a direct refutation, he accuses them of ignorance of astronomical theorems, since they think that the shade cast by the earth goes all the way up to the fixed sphere, so that some of the stars are screened off by it and do not, for this reason, receive the sunrays. For in the astronomical theorems it is proven, first, that the sun is a hundred times, or simply many times, greater than the earth,[288] and that therefore the shade cast by the earth is of conic shape.[289] For it happens in this way whenever a smaller sphere is illuminated by a greater one, whilst the rays of the sun which extend beyond the earth converge little by little: they proceed up until they come together in one point and dissolve the shadow.

So, they [theorems] say that this cone reaches only as far as the sphere of Mercury and does not extend beyond that, so that nothing above it is in the shadow, but everything always receives the sunrays.

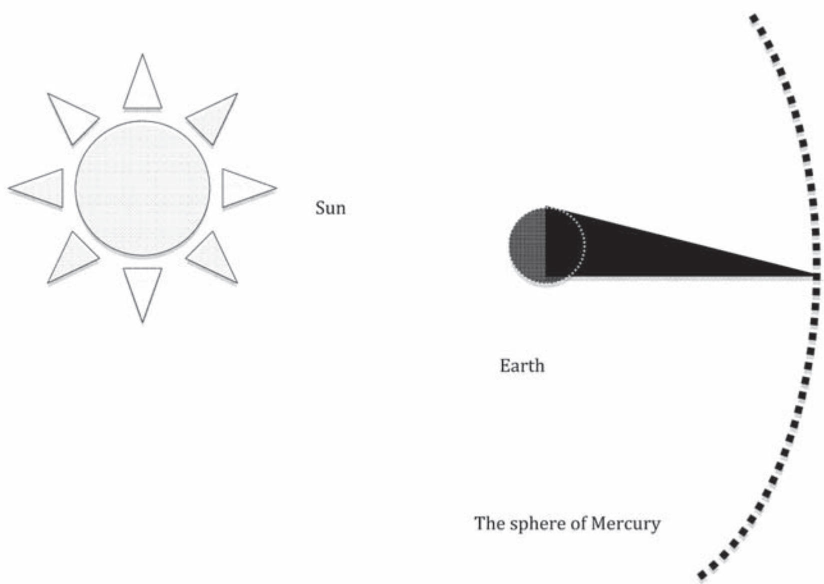

Figure 3. Earth's shadow does not reach beyond the sphere of Mercury.

And also this is proved [by the astronomers], that the distance from the centre of the earth to the lunar sphere is equal in length to 60 times the distance from the centre of the earth to its surface. And the sun is removed from the earth 1210 times this distance.[290] So, if you subtract from this the 60 from the centre to the moon, there remain the 1150, by which distance the sun is removed from the moon. So, the distance from the moon to the sun, which was 1150, is

105,1 less than 20 but more than 19 times greater than the distance from the centre to the moon, which was 60. And the cone of the earth's shadow goes only as far as 268 times this distance, i.e. the distance from the centre of the earth to its surface.[291] Hence, if we subtract 268 from 1150, the remainder will be 882, which is the distance from the sun to the limit of the earth's shadow. How long then would [the distance] be [from the edge of the shadow] to the fixed [sphere] which is separated by three other spheres in between (the one named after Mars, the one of Jupiter and the one of Saturn)[292] and which astronomical methods are not even capable of calculating because of its ineffable and exceeding greatness? So, nothing at all beyond the sphere of Mercury is overshadowed. So much the more, therefore, is the fixed sphere free of this, but rather all spheres throughout receive sunrays. For the sun, Aristotle says, must shine on all the stars, and none is hidden from it. Hence, those who say that some of the fixed stars are screened off by the earth are naïve and completely incompetent in astronomical methods.[293]

> **345b9-22** There is, further, a third assumption about it. For some say that the Milky Way is a reflection of our vision to the sun, just as the comet was.[294] But this also is impossible. For if that which sees and the mirror and all the whole object seen are at rest, the same part of the image would appear at the same point of the mirror. But if the mirror and the object seen are in motion, remaining at the same distance from that which sees, which is at rest, but neither moving at the same speed, nor [always] at the same distance [from each other], it is impossible for the same image to appear in the same part of the mirror, etc. [But the stars revolving in the circle of the Milky Way are in motion, as well as the sun towards which there is the reflection, while we are at rest, and they are removed at the same and constant distance from us, but not at the same distance from each other.]

Others, Aristotle says, say that the Milky Way is a reflection of our vision to the sun, and that what is reflected is our sight-streams, and that the thing in respect of which the reflection happens is the sun. It is clear that the thing from which the reflection has its beginning is the circle of the Milky Way, but what, they say, is underlying this colour, Alexander did not tell us. Sometimes he says that it is the exhalation, when claiming: 'He says that there is a third opinion about the Milky Way which says that the Milky Way is a reflection of our vision having its beginning in some exhalation and being directed to the sun as a mirror'.[295] However, in all cases that *from* which the sight-streams are reflected is the mirror, not that *to* which
106,1 they are carried when they have been reflected, i.e. that which is seen

and which presents its appearance in the mirror. If, then, the colour of the sun is that which appears in the mirror, i.e. in the exhalation, and produces the Milky Way, then the sun is not a mirror but the object of sight.[296]

Again, towards the end of the refutations of this hypothesis Alexander says that the fixed stars which are the Milky Way are the mirror, to quote: 'The stars in the circle of the Milky Way, which they take to be the mirror, move, and the sun, which they say is seen in the circle of the Milky Way, also moves, since the reflection is directed towards it'.[297] And our teacher Ammonius the son of Hermeias explicated it in this way: for since the moon receives the light from the sun, the light that we see on the moon is not its own, but it is the light of the sun that is visualised on it like in a mirror. For during a lunar eclipse the moon's own smouldering light appears.[298]

Aristotle posited this hypothesis, which is the fourth, as the third, either because he combined the first two into one, since they are both Pythagorean, or because he did not think the first one worthy of an objection;[299] thus, it was reasonable that he counted the remaining three.

Against this hypothesis it is easy to reply that the stars in the Milky Way are not a mirror, and that neither the sun, nor yet the colour of the Milky Way appear in them; for they clearly exist as distinct from the Milky Way. (And Aristotle directed his refutation of the hypothesis at issue also against those who assume that stars are a mirror, when he said that also this hypothesis is impossible.) For (i) it is necessary that if the images of things that are seen as a result of reflection continually appear to be the same and undergo no displacement whatsoever, then all their causes must also be unmoved, i.e. that which sees and what is seen and the mirror, from which the reflected sight-stream is carried to the visible object. (ii) But if any of these are displaced (either some or all of them), the image also immediately appears as having been displaced, being at different times in different parts of the mirror. (iii) And if all are moved at the same speed and keep preserving the same relative position towards one another, the reflected image comes about again in a similar way.[300] (iv) And if the object of sight, along one [and the same] perpendicular line in between travels farther away from the mirror, the image appears in the depth of the mirror; and if it gets closer, the image will rather seem to float on the surface of the mirror.[301] The experience of these things is readily available to everyone. Since these things are true in this way, let us proceed to our topic.

Our sight is practically unmoved.[302] For the whole earth, on which we stand, is a centre and point in relation to the sphere of the fixed stars on which the heavenly bodies move in a circle.[303] But all the things being in a circle around the centre are equally far removed from the centre; hence the stars are equally far removed from our

sight. But neither the mirror (i.e. the stars), nor the object of sight (i.e. the sun, towards which the reflection is directed), remain unmoved, nor do the stars always preserve the same relative position
107,1 towards the sun, even if they preserve the same relative position towards us. Consequently, the Milky Way would not appear to us as having the same relation and remaining unmoved in the same place, rather it would have moved together with the mirror and the object of sight. But as things stand, it is completely the contrary: we do not see any change happening to it, neither in place, nor in quantity, nor in quality, and it is not seen to have any other different disposition; therefore the Milky Way did not receive its existence from the reflection of sight-streams.

> **345b15-19** And if the mirror were in motion and the object of sight remained[304] at the same distance from the eye, which is at rest, but not at the same speed with each other nor always at the same distance from each other, it would be impossible for the same image to be in the same part of the mirror.

Aristotle moves the mirror (viz. the fixed stars) and the object of sight, (viz. the sun), not at the same speed nor always at the same distance. He maintains that each of them, the fixed stars as well as the sun, has the same distance from the observer (viz. us), but points out that they do not move at the same speed with the movement with which each moves by itself. For the sun moves with its own movement faster than the rest; so the sun because of its own motion must fall behind the fixed stars and be at different times in different places alongside them.[305] Therefore it also does not always hold the same distance to each of them nor remain in one and the same place. Thus, the sun and the fixed stars are not at an equal distance from each other, but both keep an equal distance to us, the observers, because we are in the centre of the universe, i.e. on the earth. Having shown this, he added:

> **345b22-5** For the Delphinus[306] sometimes rises in the middle of the night, sometimes at dawn, but the parts of the Milky Way remain the same in each case. And this should not be the case, if it were a reflection, and not an affection occurring in those places.

That fixed stars do not move at a speed equal to that of the sun, he proves with the help of one of the fixed [constellations], namely the Delphinus.[307] For this sign sometimes rises at midnight, viz. when the sun is in its zenith beneath the earth, and sometimes at dawn, viz. when the sun rises immediately after it; at other times it rises when the sun sets, being at maximal distance from it, namely, by the whole diameter of the universe. The same holds true of each of the fixed stars. It is thus clear from these facts that the fixed stars do not move at a speed equal to that of the sun. For were this the case, each of the fixed stars would always rise at one [definite] moment, say, at midnight or at dawn, or at sunset, or at any other time. But if they make different retreats from and approaches to the sun, it follows that the motion of the fixed stars in relation to the sun is irregular. But nonetheless at each moment the Milky Way apparently has no difference whatsoever in relation to itself, as it would always have were it a reflection. If it is thus not a reflection, then the Milky Way 108,1 is a condition of those places in which it is seen to exist.[308]

> **345b25-8** Further, at night those who observe can see the Milky Way reflected in water and mirrors of this kind: but how can sight then be reflected to the sun? [From these arguments it is clear that [the Milky Way] is neither a path of any of the planets, nor the light of the invisible stars, nor reflection; these are practically all the alternative views received so far.]

This is the last refutation, and a very clear one, of those who say that the Milky Way is a reflected image and not a real condition of the underlying body. For when we look into water at night we see in it the Milky Way, or rather its reflection and image, just as we see the other stars in this way, because our sight-streams are reflected from water to us. For it is unreasonable and impossible to say either that our sight-streams are reflected from water to the sun, or that they are first reflected to the stars, and that afterwards there is another reflection from them to the sun.[309] For in this way the sight-streams would be exhausted by huge distances and by the amount of reflections, and rather they would not be able to reach the sun, least of all if it is in zenith beneath the earth.[310] It is clear, then, that it is not a reflected image but something real. Hence, just as in the case of the stars which are reflected from water, so too in the case of the Milky Way: our sight-streams which are reflected see the reflected image of the Milky Way in the water. Having in this way refuted the theories of his predecessors about the Milky Way, he now expounds his own.

> **345b31-6a6** But let us[311] start our explanation by recalling the first principle we have laid down. For it was said earlier that the outmost part of the so called air has the power of fire, so that, when the air is divided by motion, a condensation is separated out of the same kind as the one which, on our view, constitutes the comets. We must thus understand that the same thing happens there as in the case of comets, when such a separation does not happen by itself, but under[312] one of the

> stars, either under a fixed star or under a planet. For in this case they [i.e. the stars] appear as comets because their motion is accompanied by a condensation such as that which [accompanies] the sun, from where originating, we say, because of reflection, the halo appears, when the air happens to be mixed in this way.

Intending now to explain his own view concerning the Milky Way, Aristotle recapitulates again what was said earlier about the smoky exhalation, namely that when the so called air reaches from the earth up to the inner surface of the lunar sphere (for the common usage calls this whole 'air'), its outmost part, near the moon itself is dry and hot, and suitable for ignition, which is why it is called 'tinder'. As the circular motion of the heavenly bodies separates off from it [viz. tinder] certain formations, the denser part which is most heated by their motion and coloured in this way becomes a sort of tail. Either, then, he says that this separation from the air is such a formation, or that when two exhalations are rising up together the motion of air happens to dissolve the vaporous exhalation, whereas the hot and dry exhalation, when it is raised up, becomes the matter of comets and the Milky Way. Some of the comets, we said, are formed by themselves without a star, others are formed under certain fixed stars which draw such matter towards themselves. From this matter they get a 'tail' which lasts as long as they have sufficient density to sustain the flame and as long as the supply of this kind of exhalation is brought to them from below.[313]

Hence, the same as what happens in the case of individual fixed stars, namely that a 'tail' is formed under them in the way we have assumed, must also happen in the case of many stars at once, and the tail must be formed around the whole circle of the stars, and this is the Milky Way. Thus, it is a great tail stretching under many stars. For, he says, just as our sight-streams reflected from the mist stretching over the sun or the moon produce the reflected image of a halo on them, in this way too the above-mentioned dry and hot formation, by stretching over the entire circle of the stars produced the Milky Way, except that it did not produce a reflected image like the halo, but something real that has such a colour, as we have proven.[314] And since the tinder is carried about with the moving circle, it is reasonable that also the Milky Way, which is a condition of the tinder, moves along with the universe, since a tail formed in alignment with the star is carried around together with the star and seems to be its tail. The same happens also in the case of halo. For whenever the whole of the air underlying the sun or the moon is blended in such a way that the reflection of sight-streams can be produced starting from each part, it seems, because of the continuity of reflection, that there is one halo which is carried about with the sun.[315]

One will be well advised to pay attention to Aristotle's text here where he says 'but under one of the stars, either bound or wandering' (346a1-2), meaning by 'bound' fixed. For Aristotle does not mean, as Ptolemy does, that the stars themselves move in circle around their own centre,[316] but that, being bound to their own spheres they by themselves are completely unmoved. For he wrote this same thing also in the second book *On the Heavens* so: 'Since, then, it is not reasonable that either both move or the star alone, it remains that the circles move, whilst the stars are at rest and are carried along being bound to their circles'.[317] If he thus means that the fixed stars are bound and remain each in their own sphere, being carried by them, how did he set apart the planets from the 'bound' stars as if the former were not bound in their own spheres but were moving by themselves?[318] For he said that it was impossible that both move, i.e. the circles and the stars belonging to them. If, then, also the spheres of the planets move, the planets must also be bound to them and be carried by them, not moving with their own motion. Since this is indeed the case, it was not reasonable for him to contrast the bound with the wandering stars, as these latter, too, are bound in the same way to their own spheres.

> **346a6-9** We must assume that what happens to one star is also the case with respect to the whole heaven and the whole upper motion. For it is reasonable to assume that, if the motion of one star [produces such an effect], the motion of all the stars should also produce such an effect and set [the air] on fire [and dissolve it because of the size of the circle].

Alexander says that Aristotle here calls the fixed sphere 'heaven'. For this, he says, he made clear by saying 'and the whole upper motion'.[319] But I think that the addition refers to the whole substance moving in a circle, I mean the whole which includes eight or perhaps nine spheres, as Ptolemy thinks.[320] For saying 'the whole upper motion' rather seems to be indicative of this. Moreover, also the words before this passage: 'but by one of the stars, either bound or wandering' cover the whole substance of heaven: for he means that not only the fixed stars but also the planets attract this kind of exhalation. It was customary amongst the ancients to call the whole world 'heaven', as Plato did: 'which we named the heaven or the world'.[321] Aristotle called the work which treats of the whole world, *On the Heavens*, in this way. And in a more specific sense, again, they call 'heaven' the systems of eight or nine spheres, and in addition to this in the most special sense the fixed sphere alone.[322]

The conclusion drawn from this is the following: it is plausible that what happens to one star, i.e. drawing towards itself the above-mentioned exhalation, and the emergence of the comet due to this [exhalation], also happens with respect to all the stars and that a single 'tail' lies round the whole circle, when each star draws in the underlying matter, and that because of the continuity of the exhalation, a single 'tail' for all comes to be, which we name 'the Milky Way' because of its colour. For if the motion of a single star sets on fire and ignites this kind of matter, how much more can all stars together do the same?[323]

> **346a10-11** Moreover, especially in a region where the stars happen to be the most dense, most numerous and the largest in size.

And this constitutes a probative sign[324] that the Milky Way is a comet formed from the above-mentioned exhalation functioning as its material cause. For where the stars are largest and densest, there the
111,1 Milky Way appears to be abundant and brightest, and its circle is convoluted. For because of the heat coming from the stars a lot of exhalation is being gathered there, from which the comets are formed. And where the stars are neither big, nor numerous nor dense, there the light, too, is weak and dimmer, and the circle is without convolution.[325]

> **346a11-16** Now, the zodiac circle dissolves such a formation because of the motion of the sun and planets, for which reason most of the comets come to be outside the tropics. Further, no tail is formed either around the sun or the moon: for they dissolve such a formation before it can take shape.

Since he said earlier about the Milky Way 'what happens in the case of one star, this we must assume also to happen in the case of the whole heaven and the whole upper motion',[326] and since the Milky Way completes only one single circle, he now resolves the difficulty which was raised earlier, namely, why there is no Milky Way in every part of the heaven where bright stars come together. Now, he says that in the zodiac, where the wandering stars, and the moon and the sun move, it is not possible for a 'tail' or Milky Way to take shape, for the abundant heat attenuates the matter and destroys it completely. For it has been said that, in order to be ignited, the matter must have proportionate density, since neither what is exceedingly fine nor what is very dense is suitable for kindling. For the former is dried up before it catches fire, and the latter cannot be reached by the agent. It is a probative sign of this that no 'tail' is formed around either the sun or the moon. It is reasonable, then, to assume that [none is formed] under the circle in which they move.[327]

346a16-23 This circle, in which the Milky Way appears to the observers, is the greatest circle and is also positioned so as to extend far beyond the tropics. And in addition to this, the place is full of stars, largest in size and brightest, and also of the so called scattered stars (one can see this clearly with one's eyes), so that, for all these reasons, all this formation is continuously always gathered there. [It is a sign of this that the light of the circle itself is stronger in that half of it which has a duplication: for the stars in it are greater in number and more densely packed than in the other one, so the light is produced by no other cause than the motion of the stars. For if it is formed in the circle in which most stars are placed and, moreover, in the part of that circle which seems to be particularly packed with stars, both in terms of their size and number, it seems reasonable to assume that this is the cause of the phenomenon.]

Aristotle has already shown why the Milky Way is not formed under the zodiac circle; now he explains why it is formed in this one.[328] Because, he says, this circle is the greatest, cutting the sphere in two,[329] and because it extends far beyond the tropics, i.e. because it falls outside them, and therefore is not subject to the same condition as the zodiac. For since none of the planets and neither sun nor moon move through it, the exhalation carried there is not dissolved. 112,1
Moreover, it is full of the largest and brightest stars, so that a massive exhalation can be drawn from them, without being completely destroyed. For the hot does not prevail in these regions to the same extent as in the zodiac, which is why below it, the zone of the earth is torrid and uninhabitable.

Now, this is all highly plausible. But how is the fact that the circle of the Milky Way is the greatest helpful? For the zodiac and the equator are of the same size, as well as every circle that cuts the sphere into two.[330] Now, I say that the stars carried along the greatest circles move, insofar as they are carried about with them, faster than the stars that move along smaller circles. For since the revolution of all the heaven is a single one, and since within the same period of time all the circles in it, both large and small, return at once, there is every necessity that the larger circles move faster than the smaller ones, and the speed of their motion, too, increases to the same extent at which they exceed the others in size, so that in this way there is a revolution of all circles together. Aratus also said this about the stars located in the equator, which is the largest [circle]:

There too are the paths of the Ram, the swiftest
because it speeds round the longest circle
and yet does not lag behind the Bear Cynosura as it runs.[331]

That is to say, Aries does not, because of the size of its own circle, lag behind Ursa Minor, which is rotating in the smallest circle, in the revolution of the motion of the universe, but they make a full revolution within the same time. This happens clearly because of the speed of the motion of Aries. Thus, if the motion heats, and the heat draws the exhalation, it is clear that the faster motion heats more, and the greater heat produces more exhalation.

When I say that the stars in larger circles move faster than the ones in smaller circles, I mean the circles with which they are carried about. For the stars located on the zodiac do not move faster than the others (although it is the greatest circle), because not all of them move along its middle line.[332] At any rate, the stars near the signs of the tropics, Cancer and Capricorn, are slower than all of those others that are closer to the equator; for the latter move on longer parallels, while those which are in the signs of tropics move on shorter ones.[333]

And having said that the place of the Milky Way is full of the largest and brightest stars he added 'and also of the so called scattered stars', meaning that the former are not scattered but formed in an image, while the latter are randomly dispersed and not imprinting images. Aratus too calls such stars in the same way:

> Other stars, lying scattered below the Water-pourer,
> hang in the sky between the celestial Monster and the Fish.[334]

113,1 This is also made into a sign that the account of the Milky Way is well stated.[335] For this whole circle, he says, is full of the largest and brightest stars, in particular of the so called scattered stars, and in one of its semi-circles, in which there is abundant light in the Milky Way and brighter light which has duplications, the stars are denser than in the other semi-circle, and larger and brighter, whilst in the other one, where the stars are not of this kind nor as dense, also the Milky Way is weaker and dimmer and is without convolutions. It is clear, therefore, that the stars are the causes of the Milky Way.[336]

> **346a31-b10** Consider the circle and the stars in it on the diagram. The so called scattered stars cannot be marked on the sphere[337] in this way because none of them has a completely clear position, but they are clear to those looking up at the sky. For only in this circle the intervening spaces are full of such stars, while elsewhere they are manifestly absent. Hence if we accept the cause of the appearance of comets as stated above as reasonable, we must assume that the same holds true of the Milky Way. [For the same effect, viz. the tail, which in that case [i.e. of comets] takes place around one [star], occurs in a certain circle, and the Milky Way might be as it were defined as the tail

> of a great circle produced by condensation. (Therefore, as we have said before, the comets do not come about in great numbers or often, since this kind of formation has been and continues to be separated with each revolution always into this place [i.e. into the Milky Way].)]

And with the help of a drawing he visually presents what has been said, depicting the Milky Way as it is positioned in the heaven, where it is simple and where it has convolutions, and in each of its parts those stars that are formed in an image. But since there are also some scattered stars between them, which it was not easy to draw because of their disorderly position, one should not, he says, consider them on the diagram, but by looking at the heaven itself. For you will see many scattered stars settled between these, which the ancients found hard to form into an image. For, he says, the whole space between the stars formed in a shape in the Milky Way is full of the scattered stars, while in other circles the space in between appears void and starless. Having said this he concludes his account by saying that if we accept the cause of the comets as discussed, it is reasonable to assume that the same is the cause of the Milky Way. Consequently, if, he says, somebody were to define the Milky Way he would say 'the Milky Way is the tail of the great circle which exists because of the abovementioned exhalation' [346b5-6].

These are Aristotle's opinions about the Milky Way. But his account contains many incongruities and impossibilities and merely arbitrary statements. For, if the Milky Way were, like a comet, a condition of the air, why is it always the same, never becoming 114,1
different either generally or in some of its parts, nor increasing in either length or width, nor diminishing, not changing its position or shape, nor becoming simple in the places where it is convoluted, nor vice versa receiving a convolution where it is simple, as a quantity of matter which is formed at different times in different of its parts, which is obviously happening with comets, as he says, which are formed out of the same matter as it?[338] In general, we see a great many changes happening in the air over a short period of time, the cold often taking the upper hand in warmer places, as well as the hot in colder places. How, given this, could it be plausible [to assume] that in such an unstable stuff as exhalation, the same [exhalation] is permanent in the Milky Way alone, without there being any difference ever, but the exhalation appearing to be the same quantitatively and qualitatively, and being in the same position and order as the stars, without any change whatsoever affecting it? This does not seem to be the case with anything in the sublunary world, not even in the case of the comets themselves in question, which are the subject of our discussion: for they are neither arising always in the same place, nor are they of the same size or shape, nor is the position of their parts always the same.

If it is because of the multitude of stars in Sagittarius and Gemini that the Milky Way is the most translucent, why is the same not the case with Orion, where there are many stars largest in size, or also under the Bears?[339] Why is it that, although the sun and the moon and the rest of the planets move around and are at different times in different parts of the zodiac, no change at all ever happened to occur in any part of the Milky Way, more to the north or to the south? This despite the fact that the sun's relocation northwards and southwards causes a very great difference in the air, by withdrawing from some of its parts and approaching others. Why then does the sun not even produce a chance change only in those parts of the Milky Way which it approaches or again from which it withdraws, but the exhalation in each of its parts is always the same in quantity and quality and colour? For what always remains and is always in the same state does obviously not at all belong to any body below the moon, but only to the heavenly, if to any body at all.

Furthermore, there is another proof[340] ready to hand, to wit that the Milky Way is not a condition of the air, but lies far beyond these things and that its specific quality belongs to the body of the fixed sphere itself.[341] For were it a condition of the air, it would be causing 'settings' and 'risings'[342] of the stars below which it passes, e.g. as when a cloud runs under the sun, it does occult it from the point of view of some people and impede their sight of the sun, but to others who inhabit the regions further on it does not cover it completely, but they see the whole of it clearly, facing the particular position which the cloud has in relation to both our sight-streams and the sun itself. The same takes place in the case of the moon and the other stars, when the cloud moves in front of them.[343] This happens also in the case of solar eclipse, when the moon which lies below the sun occults 115,1 it. For it does not occult the sun completely and everywhere, nor does it have the same position in relation towards those for whom the sun is occulted, but also makes a difference depending on the place where it occults the sun, so that the whole of the sun appears covered by the moon to some people, but to others not the whole of it [appears covered]. Moreover, there are some [places] in relation to which it only occults the middle[344] parts [of the sun], whereas the outer periphery is seen in annular shape, when the moon is near the earth. Thus, were also the Milky Way below the stars, as a condition of the exhalation, it would be causing the 'risings' among the stars concealing certain of them from some of us but not from others. In general, if it were below the stars, either fixed or wandering, then, since the signs at which the zodiac and the Milky Way intersect are Sagittarius and Gemini, each of the planets appearing there would have to be coloured by the Milky Way.[345] Furthermore, each of the fixed stars which are located perpendicular to certain parts of the Milky Way would have to be affected in the same way or even be completely concealed by it.[346] For, as the Milky Way is the tail of the entire circle of stars, so it is reasonable that each of the stars constitutive of that circle has some such condition.[347]

[348]We think that <this account is a> myth <similar> to the one that says that this circle was formed of Hera's milk, when Heracles despite her will was sucking her milk without her noticing it (for Athena, he says, brought him in to her while she was sleeping, so that he would drink [from her milk] to become immortal), Hera because she felt a sudden pain, suddenly pulled out her breast [from him], and out of the spilt milk, this circle came to be.[349] For neither is the milk being spilt continually, nor is the number of ascending and descending souls always the same, so that also their radiant bodies would [always] fill the same space, never leaving the space empty or overcrowded.

Aristotle's account based on natural science also contains an element of fairy tale no less than those myths, since it assumes that there is an everlasting condition in the exhalation, whose being has neither a beginning nor an end, something that is not observed as happening with any of the elements, since even their substance comes to be and perishes part by part. If now no part of an element is without a beginning and end, how can the Milky Way be, given that it is in a small part of the tinder, since the world [viz. as a whole, but not any of its parts], according to the Stagirite, is everlasting? But if he says that also in the Milky Way something comes to be and something perishes, as we said would happen in the case of the matter of the comets and in that of nourishment, namely that what is destroyed is replenished by additionally incoming stuff, [it should be replied that] no such thing appears always to be disposed in the same way, nor is any of them capable of remaining unaffected, but instead they are subject to most numerous alterations and variations, being diminished and increasing, which does not happen to the Milky Way.[350] And it was well said by the Philosopher that no one should agree with someone who says what does not appear to be the case either always or for the most part.[351] If, therefore, none of the things in local motion always remains disposed in the same way, but instead variously changes, and if the Milky Way neither has, nor will ever change, as long as the universe exists,[352] it follows that it is not a condition of the air, nor of the tinder being produced by the dry exhalation. For all the things that come out of it [i.e. the dry exhalation], flames, shooting stars, trenches, comets, thunderbolts, winds, and generally what happens in the sky, are easily changed and patently come to be and perish, while the Milky Way is subject to none of these. Hence, it seems that it is a real condition of the heavenly body, inseparable from it. Just as it is not possible to state the cause of the difference between the stars in terms of their size, colour and position, and in terms of their mutual relation and order, nor [to state the cause] of the difference of the motion of the spheres, i.e. why some are carried eastwards, and others westwards,[353] or why some of them move faster and others slower, in the same way it is not possible to state the cause for the Milky Way, i.e. to what purpose this condition accedes to a part of that being as its attribute *per se*.[354] For since no difference is or comes to be in the Milky Way, it is false to claim that the stars with their motion heat the air and the tinder, and draw in from them the matter of both the comets and the Milky Way. For since such a separation (*ekkrisis*) is irregular, it would be impossible for the Milky Way not to be irregular to a great extent too, both in quality and quantity, since matter that is carried upwards from below is itself irregular.

How should the stars, removed at a distance so great that it cannot even be expressed in theoretical terms,[355] act upon the things below the moon, in such a way that this great amount of matter would continually be carried upwards, remaining always the same, in winter and summer, in autumn and spring, without there being the tiniest difference in the Milky Way – a state of affairs which is impossible in things mortal, as is also shown by the comets which, according to Aristotle, have the same matter as the Milky Way?[356] Yet, when earlier inquiring from which of the heavenly bodies the sublunary things are heated, he said that only the motion of the sun was the cause of this, and neither the fixed stars nor any other of the heavenly bodies. Why, then, does he say that the stars are causes of the matter of the processes in the sky, in that they, by means of using their heat, draw from the sublunary region into themselves such a great amount of matter [that it is enough] to make not only the comets, but also the Milky Way? Why do they make the comets different at different times, but make the Milky Way always the same, having no beginning and no end, nor undergoing any change, either big or small – if we give to the stars at all any motion of their own, by means of which they heat the air and the tinder. But even if, in general, it were granted that they heat only by means of the quality and do not act by anything else, as we have proven to be the case with the sun,[357] in this way also according to Plato the stars have their formation for the most part from the substance of elemental fire, and the Philosopher's account has been caught in its own snares.[358]

And Damascius also disapproved of Aristotle's theory of the Milky Way [on the grounds that] neither is its matter exhalation, nor is it formed in the sublunary region.[359] For none of the conditions produced out of exhalation in the air and tinder always appears to be the same nor is any of them formed in the same place, but [all of them] undergo numerous transformations and are formed at different
117,1 times in different places. But the Milky Way is always the same and in the same immutable position, cutting through the zodiac circle in Sagittarius and Gemini: it would not appear in this way if it had its

formation in the region around the earth and did not belong amongst the heavenly bodies.[360] Moreover, if it had its formation in the aether, and if the aether in its motion lags behind the motion of the heavenly bodies, the Milky Way would also have had to lag behind their motion. But as things stand, it does not lag behind any of them, so its formation is not in the aether, but belongs to the heavenly bodies.[361]

After refuting with these and similar arguments Aristotle's hypothesis of the Milky Way, Damascius well appropriates Empedotimus' hypothesis about the Milky Way, calling it a fact not a myth.[362] For, Empedotimus says that the Milky Way is the path of souls which pass through the heavenly Hades. And it is not astonishing, says Damascius, if also souls are purified in this circle of heavenly becoming.[363] And it must be conceded, [he says] that the heavenly circle itself is a divine arrangement, either formed by Hera's milk, as the myth says (and this is why it is fit to relate it to the ascent of the souls, and its meaning is that a soul does not ascend from the world unless it has sucked in from Hera's milk, i.e. unless it lighted on the Goddess' providence which is spread in that milk), or arranged in a different way known to the gods.[364] This, then, is a certain disposition of the heaven, imperishable, starry, appearing milky due to the close spacing of small stars.[365] But it is not reasonable, he says, to claim that it is soul-vehicles, since its constitution appears so bright and star-like, and always the same and in the same way. Why not the souls of daemons, why not of the gods in the first place? For this special property also must have its origin from gods. Particularly if it has been shown to be a part of heaven, how is it not god and full of gods, since it fills the visible heaven?[366] This [has been said] verbatim by Damascius, who judges the Empedotimus myth to be a true account. Just as he was well aware of the objections to Aristotle's theory, he should also have examined each point in the myth, whether it belongs to the nature of things. For natural things, which are the subject [of this study] should also be given natural causes.

And he [Empedotimus reported by Damascius] says: 'The Milky Way is the path of the souls which pass through the heavenly Hades'. Thus, if they pass through the Milky Way, the latter would be the heavenly Hades. But how could it be Hades, while being so full of light? Moreover, if the souls are purified there, it is clear that they ascended without being purified. Hence, with their mortal vehicles: but it is impossible that a mortal body should accompany them, since they are imperishable. And, at any rate, you yourself[367] said 'the soul does not ascend from the world unless it has drunk from Hera's milk, i.e. the Goddess' providence which is spread in it.' So you ought to have spelled out what this [providence] is as opposed to the one that comes from the other gods, rather than discoursing about gods in meaningless words, or rather quacking. Note however that Plato

118,1 does not mean by Hera anything other than air. For if, he says, you continuously exchange the letters of the word 'Hera', until the A is taken as the beginning of the name, the *'(H)êra'* becomes the '*aêr*', and even shorter, by re-positioning the alpha '*(H)êra*' becomes '*aêr*'.[368] Therefore the air when it is rubbed generates Hephaestus, that is, fire, Hera being the mother of Hephaestus. It is plainly absurd of those looking for the cause of the Milky Way, which is perceptible, to turn to allegory out of fear to confess their ignorance, lest they should blush. [Damascius] himself, at any rate, aware of the fiction of this incongruous divine discourse turned to a natural explanation, although he picked the one that is implausible: for he says that the Milky Way is a certain disposition of heaven, imperishable, starry, and forming the Milky Way by the close spacing of small stars.[369] However, the light of the Milky Way is much brighter than the light of even no mean stars – so that [had this been true] the shape of those stars would not have escaped our notice.[370]

But, as though having himself demonstrated this to be the case, he reproaches those who say that the Milky Way consists of soul-vehicles as he claims that its constitution is bright and star-like. But this is not necessary.[371] For those who assume that the Milky Way consists of the vehicles of our souls also say that they are made of the substance of heavenly bodies, and therefore in fact call them star-like and radiant, eternally attached to our souls and ascending and descending along with them. And if according to him also the souls running about with their individual vehicles have passage pretty much everywhere, I don't know why they should stick to that beaten road.[372] Indeed, this very objection of yours, 'why is it the road of human rather than daemonic souls, why not of gods in the first place?' is a sign that you speak knowing none of these things, but only do not seem ignorant of what presents itself to your imagination.[373] However, it is reasonable to keep what has been well said by Aristotle in the introduction: 'In some of these cases we merely raise the question, other points we understand to some extent.'[374] Let us therefore also give here a limit to this division and move on to the next [topics] from a new start.[375]

Chapter 9

> **346b10-15** Now, we have explained the processes in the part of the world around the earth, which is continuous with the [heavenly] motions,[376] that is, the shooting stars and burning flames, comets and the so called Milky Way: for these are practically all the apparent affections that come to be in this region.

Aristotle has already explained earlier on several occasions that two exhalations are carried up from the lower region, into which sublunary bodies are dissolved due to the revolution of heavenly bodies, and particularly the motion of the sun.[377] From the bodies that are dry, the smoky exhalation is formed, which is hot and dry. From bodies that are moist, comes the vaporous exhalation, which is also, moderately, hot,[378] since it has been released from water because of the heat, but also moist, and in that respect maximally opposed to the other one. The former, which is fiery, rises higher up and comes in contact with the bodies moving in a circle, and the tinder comes to be from it, while the latter is heavier and therefore settles below the tinder.

So, having discussed the effects that come to be in the tinder from the first [i.e. smoky] exhalation, that is, the shooting stars, flames, comets and the Milky Way, he now proceeds to explain the effects that come to be from the other [i.e. vaporous] exhalation in the region below the tinder, i.e. in the air itself, rains, hail, snow, dew, rime. Having said 'of the things that happen in the part of the world around the earth', since so far he has not explained all the sublunary phenomena, but only the properties of the tinder, he did well to add 'continuous with motions', that is, with bodies moving in a circle, calling them so because of their continuous and uninterrupted motion.[379] For, although the sublunary bodies also move, the bodies that are light upwards, the heavy ones downwards, yet they do not move so continuously as not to be interrupted at any time: for they also have rest, when each occupies its proper place.[380] And he said the effects are 'practically all' referring to those that come to be out of [certain] shapes, among both the comets and the flames. Thus, in this latter case he mentioned the 'torches' and 'goats',[381] and it stands to reason that there are more other shapes with respect to the position of the exhalation, and similarly in the case of comets.[382]

> **346b16-19** Let us discuss the region which by its position is the second after this, and the first above the earth. For this is the common place of water and air and the processes that accompany its[383] coming to be above [the earth]

For the whole region after the tinder down to the earth is common to air and water. For water is formed in air, e.g. rain, as well as air in water, as the bubbles formed in it make plain, and air extends down to the surfaces of both earth and water. He will explain the effects in air and water, both on earth and below the earth's surface. But since the current subject is to do only with the processes in the air, it was necessary for him to add 'and the processes that accompany its coming to be above': for rains and snowfalls and hail and dew and rime, about which he now explains,[384] happen in the parts of the air that are higher above, and he now intends to explain their principles and causes.

> **346b20-3** The moving, ruling and first of the principles is the circle in which the motion of the sun, which separates and combines by becoming closer or farther [from the earth] is manifestly the cause of coming to be and perishing.

He normally means by moving cause and principle the efficient
120,1 cause; and this [he says] is the circle. And he calls 'the circle' either generally the circular motion of the heavenly bodies, or the zodiac circle, as is clarified in what he added next: 'in which', he says, is 'the motion of the sun separating and combining' sublunary bodies. For the sun, when approaching, heats the things it approaches, and with its heat separates them by thinning them down completely from a denser state. Not only does it turn liquids into vapours, as we see happening in the case of things boiled, but it vaporises even the solids,[385] that is the earth, and this again is obviously the case in all fumigations.[386] And conversely, when it withdraws, it cools and combines things that were separated, and transforms them to a denser state,[387] their transformation running in the opposite direction, just as the motion of the transforming agent.

And he did well to call that [cause and principle] ruling and first. For the proximate[388] and secondary cause of some processes in the air is the heating produced by the sun's drawing near, of others the cooling produced by its withdrawing away from these and destroying the heat which it had given [them] by its presence. Since, then, circular motion causes also the more proximate causes, it is reasonable that he called it the first among the causes. Or 'the first' should be understood generally as 'efficient', since matter also is the cause and principle, however, not the first, but the second, as a co-cause.[389] For in the case of the coming to be of a house, say, the matter also is a cause, i.e. stones, wood, and their accessories, as well as the builder, but the first cause is the builder, and those are second, as co-cause. For the efficient cause prepares the matter itself: stones and wood are the matter of a house not without qualification, but when they are prepared in a particular way. In the same way, then, also the proximate matter of the processes in the sky is not the moist and dry bodies, but those of them that are combined and separated in a particular way. For the cause of combination and separation is heating and cooling, and the cause of these is the sun approaching or withdrawing, and the cause of the sun's approaching and withdrawal is its course and motion along the zodiac circle. Therefore, the first cause is the circle, but the first as far as natural things are concerned. For if somebody ascends to the cause of the motion in a circle, he looks for a cause which is transcendent, not natural. But the task of a student of nature is to give natural causes.

Having said, again, 'the motion of the sun which separates and combines by becoming closer or farther', he ought to have added 'is the cause of the effects in the sky' which are the subject of the present investigation of natural causes, but instead he says, ascending to a more universal level, 'is the cause of coming to be and perishing'. For the sun's motion is the cause not only of the things which are being currently discussed [i.e. not only of meteorological processes], but of all the processes of coming to be and perishing. The sun approaching is the cause of coming to be because (i) at that time the generation of fruits is completed and every individual receives its proper end, I mean, form (for the animals too reproduce most at that time),[390] or (ii) because from fruits there comes nourishment, and from it comes life, and the seed is the cause of succession.[391] But when it withdraws, it produces perishing: for at those times almost everything decays and stops budding and coming to be. For, as the hot is the cause of life, the cold is the cause of perishing. And if you want to give a more universal and uncontroversial account, say that the sun when it approaches is the cause of coming to be, because it then transforms denser and heavier bodies into finer and lighter ones, and it is the cause of perishing when it retreats since conversely it makes the bodies that are fine-textured and light over into thicker and heavier ones.[392] For light and fine bodies embrace the heavy ones from outside and as it were contain them, and what contains and arranges is the form, while what is contained is matter.[393] But coming to be is the transformation from matter to form, while perishing is dissolution into matter of what has form. Therefore the transformation of the heavier to the lighter is analogous to coming to be, and conversely the transformation of the lighter into heavier is perishing. But because of the article it is possible to take 'the cause of coming to be and perishing' as referring not universally to all coming to be and perishing, but of rain, snow etc. And I think he indicated this in what follows, saying:

> **346b23-31** While the earth stays, the moist around it evaporates under [the action of] the sunrays and the other heat coming from above, and is carried upwards. But when the heat which caused the moist to rise leaves it, being partly scattered towards the upper region, and partly quenched by rising farther up to the air above the earth, the vapour is cooled and condensed because of the departure of the hot and because of the [altitude of the] region, and water comes to be from air; and when it has come to be it is carried back towards the earth.

Since he said that the sun's motion is the cause of coming to be and perishing of the conditions in the air which are being discussed, Aristotle now states in what way it is their cause. And if he said earlier that the earth also produces the dry exhalation when it is dissolved by the heat,[394] why does he say here that the water around it vaporizes and ascends, 'while the earth stays', as though it is not dissolved and carried upwards? For if one were to understand 'stays' as referring to the totality of the earth, then water too, taken in its totality, likewise stays the same.[395] Perhaps, then, because he previously was explaining the effects produced by the dry exhalation, and now wants to explain only those that belong to the moist one, therefore he left the earth out of the account. 'While the earth stays' is to be understood as though it remains unchangeable as it were theoretically or hypothetically.[396]

So, the moist around the earth, he says, 'evaporates by the sunrays and the other heat from above and is carried upwards.' He did explain how the heat comes to be from rays, namely, that the air trapped up between their reflections is heated by their motion and
122,1 friction, the way the air is also affected in the stones which they use to kindle fire, being trapped by them and thinned by their friction; and like the air between the rays reflected from water or burning mirrors or some other smooth and shiny[397] bodies.[398] But what kind of heat does he mean by 'the other heat from above' if not the one which is passed in a qualitative way from the sun and the stars to the bodies next [to them]? For the heat is also passed from fire to the bodies next to it, as in the case of things boiled it is passed to the cauldron first, then from it to the dry or moist bodies next to it, and in baths, first to the bricks, then to the air next to them, and from it to the bodies embraced by it. This directly proves that the substance of the sun and the stars is hot, and therefore is the substance of fire as Plato believes,[399] and not fifth substance as per Aristotle's view, unless someone says that the heat from above is the one that is imparted to the air by the tinder: for it partakes of coldness from below, from both earth and water.[400]

So, he says, after the vapour has been carried away and removed farther from the earth, the heat leaves it and it cools down; and it leaves it in two ways. Some of the heat is released from the heavy watery substance it ascends with, is scattered and moves without impediment by its innate lightness to its own totality,[401] i.e. the tinder; and some of it lags behind, obviously, being in small quantity and lacking tension[402] because it has risen so far above the earth, so that coming to a cold region it is completely extinguished. For that region, as he has already said and will shortly say again, is cold, since the reflected rays are separated by a huge distance and can no longer heat with their motion and friction the huge mass of air in between.[403] And because of the departure of the hot, and because of the [height of] that region, the cooled down vapour again comes to be water from air, and having turned into water is carried towards the earth. For as the vapour which has come to be from water rarefied by heat leaps towards the sky, so, conversely, vapour cooled and condensed above runs back towards the heavy bodies, viz. the earth and water.

346b32-3 The exhalation from water is vapour; the formation of water from air is a cloud.

Someone might reasonably raise a difficulty against this: if water and air transform into each other, why is the middle state between them not one, nor the path [of transformation] one and the same, but if the water transforms into air, it transforms through vapour as a middle state (for he says that it must first become a thinned vapour, and then, from it, air); whereas if, conversely, the air comes to be water, the air becomes not vapour first, but cloud? For the path between the contraries which pass into each other must be one. For instance, if the hot is transformed into the cold, it does not become cold at once from being extremely hot, but it must first become tepid, then from 123,1 this a pure cold. Similarly, if something cold were to become hot, it first becomes tepid. Again, if white and black are transformed into each other respectively, the middle state of the transformation of each one into the other must be the same colour, namely grey. And if a thing above and a thing below are to yield to each other in turn, they will assume their mutual places [by going] through a middle state.[404] Why then, in the mutual transformation of air and water, is there no single middle state, but water is transformed into the air through the middle [state] of vapour, but comes to be water [again] through the middle state of cloud? Let us reply to this that the transformation from air to water also first produces vapour when air is moderately condensed, and the vapour as it condenses further becomes water. The cloud is not a condition of a different nature, but a condensation and settlement of a large mass of vapour. Why then does the vapour formed in the transformation from water into air not first condense into a cloud but directly turns to air being thinned? I would say that the vapour which has come to be from water below and is small in mass cannot wait below for the vapour to grow big in mass, get condensed and become a cloud, but rather ascends straightaway.[405, 406]

Chapter 12

***[407]**348a20-3** But in the very high places hail falls very infrequently; and [on Anaxagoras' view] it should have [fallen frequently], just as we see that the snow falls mostly in high places.

Here follows the refutation of Anaxagoras' view, and so far to the effect that the hypothesis militates against the evidence. For hail is not seen in the highest places. And yet, had Anaxagoras been right, it should have been formed rather in those places where the cloud is pushed. And it is obvious that the snow comes down from the higher mountains. Hence, Anaxagoras' hypothesis is false and in conflict with the evidence.

> **348a23-30** Further, the clouds are often seen carried with a great noise close to the earth, so that those hearing and seeing them are frightened of something bigger impending. But when such clouds are seen without noise, there falls a lot of hail, and the stones are of incredible size, and their shape is not round, because their travel was not long since the freezing took place close to the earth and not as they [Anaxagoras' school] say [viz. high above it].

This is to indicate that hail is not formed far from the earth, as
124,1 Anaxagoras believes. For often, he says, the clouds have been seen closest to the earth carried with a great din, obviously, because of extraordinary thunders, which frightened those hearing them beyond measure and made them lose hope because of the fear of some forthcoming hardships. And when such clouds were seen without the din around the earth, they were at once followed by hail of such a size as is hard to believe for those who hear reports of it, and its shape not round. All these are signs that it has been formed close to the earth. For great din indicates the closeness of clouds. For when the first stroke is from far away, and its distribution towards us is carried out part by part, the volume of the sound is reduced by the distance, just as the apprehension of the objects of sight which happens through the long interval of the transparent is blunted as it proceeds: for neither is the transparent capable of carrying the colours over long distances, nor is the milieu conducting sound [capable of carrying] the sounds.[408]

And the size and the fact that it does not have a round shape indicate coming to be close to the earth. For its dissolution is easy given that the time or the place is warmer. Now, had it been carried from afar, it is plausible that some of its protruding parts would have been wasted away, and become smaller than they have been at their initial formation, but being carried from a small distance, they remain without dismantling, and therefore appear bigger.[409]

The cause of its not being round is the same. For having completed a long way from far away, with its extremes being beaten off by friction against the air, it becomes spherical as a stone pushed by somebody from the top of a mountain and having its excesses ground down and become, as Homer says, 'a round boulder',[410] and the stones which are brought by the backwaters in the sea. But being moved from a short distance, it remains unaffected as it was initially formed, without becoming round-shaped. And the apprehension of our sight itself is able to discern the clouds that are closer to earth, when some of them seem to be laid over, and others running beneath, but not in the way those people say.

> **348a30-1** But it is necessary that under that which is the main cause of freezing there be the largest hailstones.

He has proved by the earlier arguments that the formation of hail happens closer to the earth and not, as Anaxagoras held, in the region above. For if the region above, which is colder, produced hail, it should have been the case that from higher places there is more abundant hail with larger hailstones: for the nearer the effect is to its efficient cause, the greater it is. But as things stand, obviously the contrary is the case. For from the regions close to earth the hails come more abundant and with larger stones not round-shaped, because not beaten around in their descent; this is because they do not travel a long distance. Having thus refuted the view of Anaxagoras, he then explains his own views concerning these matters.

> **348b2-12** But since we note that hot and cold have mutual replacement,[411] which is why the subterranean places are cold in warm weather and warm in frosts, one should think that the same takes place in the region above, so that during the warmer seasons the cold, being replaced inwards because of the surrounding heat, sometimes produces quick water from the clouds, and sometimes hail.[412] Therefore the raindrops get much larger on the warm days than in winter, and water torrents are more violent; for they become more violent when they are more sudden, and they are more sudden because of the rapidity of condensation. 125,1

He put forward a certain axiom of the cause of the processes that take place during hail, which is both known and often stated by him. For since the cold and the hot reside in the sublunary region, they happen to undergo mutual replacement in the course of a conflict; for the contraries cannot be together at the same time, and therefore they usually give place in turn. For in the summer, when the atmosphere is heated, the cold retreats into the depth of the earth, and therefore the caves and the deep water are then cold. In winter, on the contrary, when the atmosphere becomes cold, the air and water under the earth become warmer. And the wisest poet says about water in the depth in agreement with the evidence: 'it is heated by the setting Pleiades, but when it is their turn to rise, it gushes forth, like ice, from a hollow stone.'[413]

And it is not the case, as somebody might suspect, that this is thought to be the case relative to our perception. For someone might say, while these, i.e. summer and winter, are similar, in summer

because we are excessively heated from the atmosphere, the subterranean [things] seem to be cold, and in winter because we are excessively chilled, they seem to be less cold, so that they are in much the same state in winter and summer, but we, because of the affections that are imparted to us from the atmosphere, err in distinguishing between them. What shall we say then? That this supposition is false, and the mutual replacement of the hot and the cold is very true indeed. For we see clearly that in winter the caves and the depths of the wells emit vapour, since the hot in the depth evaporates the moist from there. For where would the sending up of vapours come from, if the hot enclosed there were not the cause of the process? But with the animals also in summer the inner parts are cold, and in winter rather hotter, because in summer we absorb less food and concoct it slower and in a less well ordered way, but in
126,1 winter we both use more food and concoct it in accordance with proportion.[414] Therefore northern bodies are larger and more vigorous,[415] since they have the innate heat enclosed [inside them] (because of the thickness of the surface of their body due to cold) which increases the concoction of food, and the absorption and the addition to the size. Now, these processes are at their strongest in the prime age; but when it passes the mark of the prime and heads towards old age, their innate heat is therefore also diminished, since in winter they have a lot of cold, it is more easily extinguished, and therefore their bodies decay and perish quicker, and it is extremely rare that one can see an old man among them. Hence a certain proverbial saying customary among us about those who have not acquired a good end 'he got the Goth's end'.[416] For with the word 'Goths' they usually referred to all the northern barbarians. Thus in winter our innermost is hotter, so that we see a lot of vapour coming out through our mouth, and a lot of smoke is sent up from the excrements, as does not happen in summer. Therefore it is in every way true that the hot and the cold replace each other.

And it is worth considering this mutual replacement in a more systematic way, to understand what exactly comes to be and how it comes to be. One should not think that this hot in a deep place, I mean residing in the subterranean body, in summer leaves its peculiar substrate and finds itself outside heating the atmosphere, while the cold from outside, in the meantime, enters inside [the earth] and chills the bodies in depth, and in winter vice versa, the hot from outside relocates to the depth, and the cold in depth goes outside and chills the air outside.[417] For it is impossible that inseparable qualities of bodies should pass from one substrate to another, because in that case they would have a separable substance. For subsisting in their own substrates they perish when these substrates become unsuitable.

So, what happens is as follows. In winter, when the outside air and the surface of the earth become dense,[418] the heat which is deep inside is not dispersed by a continuous mutual transformation of the elements owing to the density of the surrounding elements, but rather is collected inside, and as it becomes more massive, it heats the subterranean air and water. In summer, on the other hand, when the passages of the earth are rarefied by the heat of the sun, the heat deep inside is dispersed, since it naturally follows the tendency upwards, and when this happens, what is left behind [i.e. the inside of the earth] necessarily cools down. The same process happens also in our bodies, namely, in winter the innate heat, which is enclosed inside due to the density of bodies outside caused by cold and which because of this is becoming more and more massive, heats the depth, and thus the hot never fails to display its activities; in summer it gets dispersed because of the loose texture of bodies, for which reason the depth is cooled down due to the lack of it or, to put it more precisely, becomes less hot. This, then, is what happens deep inside. What takes place in the bodies on the surface of the earth is clear to all. For the sun, as it approaches in the summer heats the bodies that surround [the earth], and in winter being maximally removed from them does not pass on to them enough of its own heat, so that the cold bodies, viz. earth and water, cool down the air by the vapours they emit; and it, when it is excessively chilled, being fine-textured, in turn chills the bodies that chilled it, and they in their turn chill the air again, and in this way they mutually intensify their respective coldness, as we have already demonstrated in the preceding.

One must believe that the so called mutual replacement of the cold and the hot is of this sort, because when things outside are heated things inside are cooled, and on the contrary when things outside are cooled things in depth are heated. One should believe, then, he says, that this is the mutual replacement of the hot and the cold, and that it comes to be in the region above, where the clouds are formed, when the place or the time is warmer: for being replaced in turns by the warmth of the atmosphere, the coldness present in the cloud retreats into its depth, and then, having become more concentrated inside, more rapidly transforms the vapour inside the cloud into water. This is why also the rains which happen during such seasons or in such places come to be because of the rapid thickening of the cloud, and drops are larger because a large mass of vapour is transformed at once and their motion is easy, since their downward momentum is greater because of their [larger] size. Since, then, water comes to be in this way and is carried downwards by its innate downward momentum, the coldness which transforms vapour into water, which is still present in it to a great extent, solidifies it quicker than the momentum which carries it downwards. So, water as it is carried downwards at once freezes and makes hail. And this is what he means by saying ‘sometimes produces quick water from the clouds, and sometimes hail’: for inside the cloud it makes water quickly thickening the vapour, and when it is carried down outside [the cloud] or even when it is still inside, being water and solidified, [it makes] hail.[419]

348b12-17 And this very thing happens in the way that is contrary to that described by Anaxagoras. For he says that it is affected in this way when it rises to the cold air, while we say that it is when it descends into the hot air, and it is most affected when it descends most. And when the cold is removed by the external heat still further inside, making water, it solidifies it and hail comes to be.

Our account, he says, proceeds from assumptions contrary to those of Anaxagoras. For he said that hail comes to be when a cloud is formed in the upper region which is chilled, while we say, on the contrary, that hail comes to be when a cloud is formed in a lower region, which is hot, and [that] when the environment is hotter and the cold, compressed by the external warmth, is replaced by turns further inside, so that it becomes abundant deep inside, water is rather coming to be, and when the compression by the cold is inten-
128,1 sified, water, being solidified, at once becomes hail.

348b17-22 And this happens when the freezing [of water] is quicker than its falling down. For if it is carried down in a given time (t_1), but the coldness being intensive freezes it in a shorter time (t_2), nothing prevents it freezing when up in the air, if freezing happens in lesser time than downward motion.

He here resolves the difficulty which was raised, namely: if hail is frozen water, how does it freeze in the air? For if freezing happened before water came to be, the result would have been snow not hail. But if water froze after it came to be, how long does water stay in the air until it freezes? So, he now explains how this can be the case. Since it is manifest that both the downward motion of water and its solidification by cooling take time to occur, therefore, when the time of water's downward motion is longer than the time during which it freezes, the water freezes and becomes hail. For instance, if the downward motion requires three lengths of time, and the freezing just one, because of the intensity of the coldness which solidifies it, then it happens while the water moves downwards during the time of one length it freezes and becomes hail, and in the remaining two lengths it is the formed hail that is moving, and thus none of the raised difficulties are in conflict with the formation of hail.

And from this you also have the reason why in the region close to earth there is no analogue to hail in the way in which dew is the analogue of rain and rime is the analogue of snow:[420] for the freezing of the dew so that it would become ice could not possibly have happened quicker than its downward motion, because the distance is too short, but the dew falls out before it can freeze.

Someone might reasonably raise a difficulty here with regard to the way in which water freezes when it has started moving downwards: whether it does so when still contained in a cloud, or whether it freezes when it has left the cloud and is outside it? But the hotter air is underlying it outside and therefore coldness collects deep inside the cloud, having exchanged places with the external heat and having condensed the vapour in the cloud into water.[421] If, however, the water present in the cloud freezes and thus makes yet another change, into hail, first, why did water remain in the cloud for a time enough to freeze instead of being immediately carried downwards by its innate weight? Second, why is the hail formed outside the cloud not melted by the surrounding hot air, through which it is carried downwards? To this it should be said that the cloud is not without depth,[422] but has a certain, and no small, depth, which is why it occults the sun, and thunders break out,[423] and it rains heavily. So, the water which passes through this depth is solidified by the coldness which is still abundant in it even after [it has left] the cloud, and being frozen it is not melted by the surrounding heat because of the short distance.[424] Therefore, even though it does associate with the hotter air, it remains frozen; for it is brought down before it melts. For each transformation needs a proportionate amount of time. So, [hail] is brought down before it is affected in any way by the air. Thus, the snow, which undergoes the strongest freezing, can often last through the whole time of the summer and is not easily melted even when it associates with the hottest air, and some ice can even be completely petrified;[425] but hail, whose degree of freezing is softer, melts directly as it falls out. It is not at all unreasonable that it melts while still moving downwards, either all of it, or the more suitable parts, which is why not all of it is similar in size, and often the water of the melted part is carried down along with the hail.

Someone might also raise the following problem: why, when the coldness is pushed along into depth by mutual replacement, does vapour not immediately freeze and become snow, but first freezes and is transformed into water, then the water freezes and becomes hail? Now, we say that although there is some considerable amount of coldness in the cloud, it is still not the coldness which in winter completely freezes vapour and makes snow; for it takes very strong coldness indeed to freeze the vapour, which is hot, before it is condensed into water. And because the water of the hail is pre-heated by the force of the surrounding [air] it is made more susceptible to freezing; for those waters that are pre-heated are particularly easy to chill.[426]

> **348b22-30** And the nearer [the earth] and the closer-knit the coagulation, the more violent the showers and the larger the drops and the hailstones, because they are carried over a short distance. For the same reason the large drops do not fall thickly.

When, he says, the coldness is of some strong kind, and the place in which it is close to the earth, because of the intensity of the coldness the density of vapour becomes closer-knit. Therefore the drops also are larger, and the showers are more violent because of the very size of the drops which move faster. For the small drops, of the kind that are formed in winter, being less heavy, have a gentler motion. And the drops are larger not only because of this, but also because they do not get scattered when carried down over a short distance; for they arrive at the bottom before being scattered. For when they are carried down from height, they are scattered midway. At any rate, if you empty a pot of water from a height, water will immediately disperse and travel down in small drops; but if you pour it out from a short distance, water will go down more at once and in bigger parts.

130,1 But why are the hailstones also the largest? First, because the raindrops, which when frozen make hail, are large; further, also because they are not broken down [as they would] moving from a greater height, nor melt [as they would] associating for a long time with the hot air, as it happens with things moving down from height. But why are the drops not dense, but rather rare? Perhaps because they are large as a result of abundant vapours rapidly condensed into one, or because the transformation takes place not far from the earth: for the water which comes to be all the time is immediately carried downwards, before [another portion of water] is transformed. But if the transformation were to take place in the higher region, only as soon as the water which has been formed first went down, does the one that has been transformed after it follow, and this one is in turn immediately followed by the next [portion], and so on, and therefore it is quiet.

> **348b26-30** Hail is rarer in the summer than in spring or autumn, though commoner than in winter, because in summer the air is drier, while in spring it is still moist, and in autumn it already begins to become moist. And sometimes, as has been said, hailstones happen in the late summer for the same reason.

He himself adds and resolves the difficulty which one might raise concerning the cause of hail as stated by him, i.e. the mutual replacement of the hot and the cold, namely: why do hails not happen in the summer when there is the heat which causes the mutual replacement of the cold? Because at that time the material cause, i.e. the moisture, is missing, from which the exhalations come to be. For the summer is drier and hotter than all the seasons, and the spring is moist and hot, moist because it succeeds the winter, hot because it is nearing the summer; and both these [elemental qualities] are needed for the formation of hail. And autumn is characterised by both the dry and the cold, having the former from the summer and the latter from the nearing winter at its door; however it has not got rid of the heat completely, for it succeeded the summer. As for the winter, it does have the material cause, being abundant in the moist, but lacks the hot, which was the cause of mutual replacement for the cold. And in the late summer, he says, hails sometimes happen, which is the end of summer, since it, on the one hand, does still retain the heat of the summer, even if not in such a vigorous way, and since on the other hand this season is not completely rid of the moist, so that the rains are frequent during it. For this season passing its heat over to the summer receives from it in return a moderate moisture; which is why, although rarely, hails do still happen in it.

> **348b30-4** If the water has been previously heated, this contributes to the rapidity with which it freezes: for it cools more quickly. Therefore many people when they want to cool water quickly first put it in the sun. 131,1

He invokes the common experience of everyone to witness that things that are pre-heated cool down better. The reason is that nothing is naturally apt to act upon or be acted upon by its like. For the contraries act upon and are affected by each other. And the water which has been a little pre-heated and placed in the cold air is better affected by the cold as the contrary [of the hot] than if it has not been heated. And furthermore, the hot refines the texture of things heated and makes them looser.[427]

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Notes

1. 54,7-8. 'The fiery substance which is not fire'. On the distinction between fire in a strict sense and fiery mixtures, see Introduction, pp. 4-5.

2. 54,9-12. *hê poiêtikê toutôn aitia*: the productive (or efficient) cause of all the things in the sublunary world, whose material cause is the four elements.

3. 54,18-19. 'In the sky' always translates *en tôi meteôrôi*, while the word 'heaven' is used to render *ouranos*.

4. 54,20. 'Running stars', *diatheontes asteres*, the same as 'shooting stars', *diaittontes*, a generic term for meteors. See Introduction, pp. 17-19.

5. 54,21. 'Torches', *daloi,* meteors of a particular shape; see n. 38 at 59,33-6 below.

6. 54,21. 'Goats', *aiges,* meteors of a particular shape, see n. 40 at 59,36-60,12 below.

7. 54,23-4. Exhalations: see Introduction, p. 4.

8. 54,26-7. 'The opinion of the many': *hê tôn pollôn doxa*, not in a pejorative sense, but in accordance with Philoponus' doxography, according to which Aristotle is in the minority with his theory of a permanent indestructible heaven (see Introduction and vol. 1, p. 9).

9. 54,28-9. Homer, *Iliad* 14.192.

10. 54,39. 'That have been enumerated', viz. by Aristotle under the previous lemma (burning flames, 'shooting stars', 'goats' and 'torches').

11. 55,7. 'The matter of composite [substances] changes when their forms change (*tois eidesi sunexallattetai*)'. Philoponus seems to refer not to the changes which occur in the course of one process of transformation, but to the covariation of matter and form, so that each natural kind (genus or species) has the matter appropriate to this kind and distinct from common matter. This point is used in the definition of the generic matter of the sky phenomena that follows.

12. 55,13. 'In the way that was described', in *Meteor*. 1.3, see vol. 1, pp. 70-84.

13. 55,18. 'Each of these is hot': this is Philoponus' reading of Aristotle, *Meteor*. 1.3, 340b28; see vol. 1, p. 66 and n. 162.

14. 55,18-21. Philoponus invokes here Aristotle's theory of change as presented in *Phys*. 1.7-9 and his theory of elemental qualities (*GC* 2.3): in the alteration with respect to a particular quality, it should be replaced by its privation; in the case of elemental qualities, the hot and the cold are mutual privations (as are the moist and the dry).

15. 55,21-7. The discussion is supplied by Philoponus, who probably follows Alexander (see next note). Aristotle makes no indication at this point concerning the elemental qualities characterising the two kinds of exhalation. Elsewhere (360a23, cf. 367a34) he refers to the moist exhalation (*atmis*) as wet and *cold*. See vol. 1, p. 66 and n. 162 on the reading at 340b28. However, all ancient commentators (Alexander, Philoponus, Olympiodorus) assume that both exhalations are hot, differing only in respect of moist and dry.

16. 55,32. 'Elsewhere', cf. *in GC* 224,12-32. Philoponus' analysis both here and in *in GC* most probably goes back to Alexander's commentaries, cf. Alexander *in Meteor*. 20,9-12 as well as *Mant*. 8.

17. 56,12-14. 'The wholes (*holotêtes*) of the elements' are the absolute masses of the elements within the cosmos. Philoponus discusses this principle in detail in his commentary on *GC* 2.6-7.

18. 56,16-17. On contact as the mechanism of acting and being acted upon, see Aristotle *GC* 1.6-7 and Philoponus' commentary (Williams 1999a).

19. 56,19-20. Touch or contact (*haphê*), according to Aristotle, is not a symmetrical relation (see *GC* 1.6, 323a22-34, cf. *GC* 1.7, 324a24-b13).

20. 56,24. 'As he said earlier too', *Meteor*. 1.3, 340b23, cf. *GC* 2.3, 330b25-31.

21. 56,23-5. On the strict and loose use of 'fire', see vol. 1, pp. 4, 64.

22. 56,29-31. 'We habitually apply to the class the name of [its member that is] more familiar to us, [on its account] calling the whole set [of different phenomena] "such and such"' (*dia touto to genos onomazein eiôthasin ek tou gnôrimôterou hêmin, to toiouton holon prosagoreuontes sustêma*): i.e. we use the term 'fire', the name of the most familiar member of the class, generically and call this whole class of phenomena enumerated above 'fiery' (*to toiouton*), viz., on account of fire. Thanks to Catherine Osborne for querying the sentence.

23. 57,18-19. Philoponus may be alluding to Aristotle's definitions of contact and continuity in *Phys*. 5.3 (227a7, 10-15).

24. 57,22. 'Persuasive evidence': *pistis* (cf. Aristotle, *Rhet*. 1356b6-11)

25. 57,24-8. Philoponus here follows the example discussed by Alexander, *in Meteor*. 22,1-10. Alexander points out that the fire is transmitted from the burning upper to the extinguished lower lamp through the sequence of ignited continuous parts of the smoke, although it may appear that the burning fire is moving down.

26. 57,28-32. Philoponus' own example, illustrating the same point he made earlier, that the smoky substance is inflammable and can be set on fire by a minor ignition.

27. 57,34. These lines are not printed by Hayduck as a lemma, but they are probably a lemma.

28. 57,36. On intensification and remission of qualities, cf. Philoponus *in GC* 259,15-17; 262,1-9.

29. 58,1-3. These lines are not printed by Hayduck as a lemma, but they are probably a lemma.

30. 58,3-8. It is not clear whether this difficulty was raised by any of Aristotle's readers or critics (for a modern version, see Wilberding 2006, 228). Alexander assumes that the presence of dry exhalation in the tinder sphere is regular, but its density varies over the volume it occupies, and this is the cause of the fiery processes in the sky discussed in *Meteorology* 1 (see Alexander *in Meteor*. 33,2-24). Philoponus' explanation here is along the same lines.

31. 58,14-15. Philoponus is comparing the tinder layer with a living organism where different parts have different resilience towards the heating that happens against nature. This kind of heating is discussed as the cause of diseases by Hippocrates and later Galen, in terms of the humoural theory to which Philoponus is also probably referring here. Cf. Galen *in Hippocratis de natura hominis*, 21,29-23,14 Mewaldt = XV 38-40 K.

32. 58,23-4. By the sun's retreating (and drawing near at 58,26) Philoponus means the sun's movement along the circle of ecliptic which accounts for its varying distance from the earth.

33. 59,11-13. These readers of Aristotle would interpret length and breadth as astronomical coordinates of right ascension and declination. This suggestion might be made in the course of the seminars in Ammonius' school; Philoponus himself uses this terminology when discussing the motion of comets (see 1.6, 78,5 below). Alexander also mentions such interpretation in his *in Meteor*. 27,26 (for this meaning of length and breadth, cf. Strabo *Geogr*. 2.5.9.7, 3.1.3.3-4, 12.3.39.30). A consequence, as Philoponus points out, would be an introduction of the third co-ordinate of a tridimensional formation, 'depth', defined on the basis of its distance from the centre of the universe (see next note).

34. 59,26-9. There is no evidence of calculations of the distance to the shooting stars in ancient astronomy, the task apparently formulated and performed in Arabic astronomy by Al-Kuhi, see Van Brummelen and Berggren 2001/2.

35. 59,21. Philoponus' explanation of the usage of 'length' that he suggests is that in the things that have form, either natural (such as a human being or a tree) or artificial (such as a house or a column) the names of the 'dimensions' are fixed by the form of the object in question (e.g. the greater dimension of the tall objects would be referred to in terms of 'size'). In the case where there is no fixed usage with respect to dimensions, we tend to call the greater surface dimension 'length'.

36. 59,23. 'Sight-streams', *opsesin*, see Introduction, p. 6.

37. 59,30-3. 'Flame', *phlox*, a generic term for bright fireballs.

38. 59,33-6. 'Torch', *dalos*, a bright meteor of a most familiar shape: nucleus and a straight bright trail, cf. Heidarzadeh 2008, 8.

39. 60,8-9. 'Torch' here translates *dalos*, and thus refers to a sky phenomenon, not a real torch.

40. 59,36-60,12. 'Goat', *aix*, a bright meteor 'fragmenting severely along part of its path' (McBeath 2006, 144; cf. Heidarzadeh 2008, 8).

41. 60,13. For the structure of the sentence, see Textual Questions 1.

42. 60,12-15. This would be the case, had 'length' meant geographical length, i.e. (as Philoponus understands this) the intervals oriented from east to west.

43. 60,19. 'Lengths': Philoponus' text has *mêkê*, where some manuscripts of Aristotle (E (corr m 1), W, N) read *merê*, 'parts'. See Textual Questions 2.

44. 60,34. 'To its own totality' (*mekhri tês idias holotêtos*), i.e. to the place where its own element is collected around the earth. Philoponus is avoiding a mention of the 'natural place' to which this corresponds in Aristotle's system.

45. 61,5-6. 'Due to the aforementioned cause', i.e. to the being surrounded and blocked by the cold air, as at 60,35-61,1.

46. 61,7-15. The point of this explanation seems to be to show why in some cases there is no 'remainder' (meteorite) after a meteor.

47. 61,15-16. See 57,22 and n. 25 above.

48. 61,24. The reference is to the parallel drawn in the same example at 57,22 above.

49. 61,31. 'Fibre of a papyrus' (*khartou inarion*): perhaps a local (Alexandrian) reference to papyrus as a plant rather than a writing material.

50. 62,3. 'Scattered, as has been said, in all directions': an imprecise reference to the lemma 60,19-20 (341b32-3): 'scattered … in many directions' (*pollakhêi*).

51. 62,12-13. cf. 60,35-61,1 (because it is prevented by air).

52. 62,30-31. 'It finally catches fire': it catches fire because of the concentration of heat and 'local' friction created by the strong motion of 'squeezing out'.

53. 62,36-7. This principle (reflected rays heating the air) is used by Aristotle himself when he explains why no clouds are formed in the upper region in *Meteor*. 1.3 (340a19-33**)** and attributed by him to Anaxagoras in *Meteor*. 1.12, 348a14-20.

54. 63,16. i.e. by kindling and by squeezing.

55. 63,19. 'Throwing', *rhipsis*. Aristotle defines 'throwing' in *Phys*. 7.1, 243a20-b2 ('throwing [occurs] when the mover causes a motion away from itself more violent than the natural locomotion of the thing moved, which continues so long as it is controlled by the motion imparted to it', tr. Gaye & Hardie). Philoponus points out the serial nature of motion in the case of kindling which makes it different from throwing.

56. 63,21. 'With the lamps', see nn. 25, 47 above.

57. 63,25. 'The connective "or"' of the lemma (Aristotle, *Meteor*. 343a7). 'Connective', *sundesmos*, i.e. conjunction. 'Disjunctive', *diazeuktikos*, for definition see Dion. Thrax, *Ars gramm*. 1.1.90.1.

58. 63,32. 'Even though fire in accordance with nature moves upwards.' These words are not present in the MSS of Aristotle (see Textual Questions 2).

59. 64,10-11. 342a21-2.

60. 64,20-2. 'With the other [kind] of shooting stars', i.e. with those discussed in the first part of the chapter (*Meteor*. 1.4, 341b6-35).

61. 64,20-2. Philoponus refers to the mechanism of ignition 'by transmission' just discussed in his commentary. Aristotle does not treat this subject extensively, but the explanation is elaborated in detail in Alexander's commentary, *in Meteor*. 20,12-22,10.

62. 64,32. This lemma ends with 'and so on'. The sentence supplied fills the gap between this and the next lemma, but the real scope of the lemma seems to be to the end of the chapter. Aristotle does not discuss the distinctions between the two types of shooting stars, providing rather the points that are common; Philoponus elaborates by drawing a series of distinctions with respect to each point.

63. 64,33-5. In Olympiodorus' *theôria* corresponding to this passage (38,26-39,16) we find a very similar set, including four rather than five distinctions (missing is Philoponus' (iii), which in fact repeats the main distinction between the two kinds of shooting star), and listed in a different order. Just as in Philoponus, it announces the number of differences first: 'The first [kind of] shooting star differs from the second in a fourfold way: (i) efficient cause; … (ii) many vs. one; (iii) manner of motion: linear progression for the first type, 'oblique', i.e. changing direction under he force of squeezing out, for the second type; (iv) place: higher up for the first type, lower down for the second type. In both cases, it seems, Ammonius' lectures are the common source.

64. 65,21. 'Cold', *psukhras*: Alexander actually speaks about 'cooled' exhalation (as Philoponus himself indicates citing more precisely in the next sentence); both Alexander and Philoponus consider both types of exhalation to be essentially hot, not cold.

65. 65,20-5. Alexander, *in Meteor*. 22,29-23,4. The addition concerning north-south and east-west directions is made by Philoponus, as well as the discussion of the smoky exhalation.

66. 65,32: 'The other position', *tês loipês theseôs*, has to refer to the westward motion, unless Philoponus wants to include the 'mixed' cases (e.g. from south-west to north-east etc.).

67. 65,36-66,3. We have to imagine the ants who are not trying to avoid collision, but follow their respective paths and run into each other mechanically. Notably, Philoponus is not interested in the physics of impetus here but only in the geometry of their motion.

68. 66,3-17. We have to assume that the ants move on the inner surface of the rectangle's sides. On the possible source of Philoponus' discussion in [Aristotle] *Mechanics* 1 848b9-23, see Introduction, p. 9 n. 42.

69. 66,22-3. Who are these naïve believers? One might imagine that in the Academy the possibility of a permanent 'star traffic' was envisioned as part of the doctrine of heavenly soul-vehicles. Plato says in the *Timaeus* 42B-D that incarnate souls have star-vehicles. The doctrine of soul-vehicles does get some credence among contemporary Platonists (cf. Philoponus' debate with Damascius at 116,36-118,26 below), so this could be the target of Philoponus' criticism here. Notably, Olympiodorus' discussion of this text also contains a warning: 'lest somebody think that they are up above in the region of the stars' (43,20-2). Alexander presents this passage as an argument showing the sublunary origin of the shooting stars (23,13-18).

70. 66,23-5. This is the range of magnitudes used by Ptolemy in his star catalogue in *Almagest* 7.1-8.1 (see Toomer 1984, 16).

71. 66,25-6. Philoponus makes no mention here of the precession extensively discussed by Ptolemy in book 8, at the beginning of his treatment of fixed stars (possibly because it has no immediate relevance to the contrast between the fixed stars and the shooting stars), but cf. nn. 305, 307, and 308 below and Introduction, p. 16.

72. 66,32. 'Visual field' translates *opseis*, further rendered as 'sight-streams' and 'sight-organs' (see n. 36 ad 59,23 above and Introduction, p. 6).

73. 66,35-67,12. Aristotle points out that closer objects seem to move faster and distant ones slower, but does not argue for it (nor does Alexander in his commentary). Philoponus himself supplies the argument he attributes to Aristotle. The argument is based on the physical interpretation of the visual rays hypothesis of the geometrical optics. The idea is that since our sight-streams form a cone and since the base of the cone is larger than any of its sections, it should take more time to traverse, other things being equal. A very concise version of a similar argument (mentioning only the peak but not the cone) is found in Olympiodorus' *theôria* as an explanation of the way two types of shooting stars differ in terms of location (the burning ones being farther from earth, the hurled ones closer). For a more detailed account of the principle in question (remote objects move slower, those near us faster) Olympiodorus refers his reader to a theorem of optics in the treatise *On Sight* (*P. opseôs*). (39,1-16).

74. 67,11-12. The idea is that the fixed stars only seem to be stationary because the base of our visual cone is so large that they never get to cross it while we are observing; but in fact they are moving at the highest speed.

75. 67,18. 'Condensed' (*sunistamenos*) or 'settled': hardly a reference to any particular process of condensation (cf. Lee ad loc.). The important point for this argument is that some parts of air get a certain dense texture which makes them into suitable matter for various sky phenomena.

76. 67,28-9. 'In reality', *kath'huparxin*, literally, 'in existence', as opposed to being in concept only. See Introduction, p. 5.

77. 67,32-4. This difference is pointed out by Alexander *in Meteor*. 23,23-7.

78. 67,35-7. For Aristotle's arguments against the existence of void, see

Physics 4.6-9. Philoponus' position is different from Aristotle's (for his criticisms of Aristotle's arguments, see his *Corollary on the Void* in Furley and Wildberg 1991), but as long as he agrees that there is no void separate from things, the fact that this has been proven is relevant in the analysis of the sky phenomena.

79. 68,5-6. 'Breadth' and 'narrowness' are meant as physical, not logical, characteristics.

80. 68,7. 'From Aristotle's own words': 342b17-18, see below 73,30-8.

81. 68,10-12. A description of Tartarus in *Theogony* 740.

82. 68,12-13. Homer, *Il.* Z 281.

83. 68,13-14. Homer, *Od.* K 517.

84. 68,14-15. Apollonius of Rhodes, *Argonautica* 3.1206.

85. 68,20-3. See Textual Questions 1.

86. 68,22-4. Two different explanations in one, none particularly dependent on the sight-streams hypothesis.

87. 68,31-2. In order for the sentence to construe, we have to supply *poiêsei*, 'will produce' as a predicate of 'light shining' in the first part of sentence. The meaning will then be that a variety of colours is produced as a result of each of these processes (i.e. the light shining through and the air taking on colour). This is how all ancient commentators seem to take the text (so too Lee; for a different reading, cf. Thillet).

88. 69,3. 'Entities' renders *hupostaseis,* literally 'existent things', as opposed to mere appearances. On this classification, see Introduction, pp. 5, 9-10.

89. 69,5. For the text, see Textual Questions 1.

90. 69,9. 'Images', *eidôla*, for this meaning, cf. *Plato,* Rep. 546A7.

91. 69,12-13. See 61,7-24 and 66,22-67,14 above.

92. 69,22. Aristotle does not introduce a formal classification at this point, although he distinguishes between the two kinds of effect: those caused by the refraction of the light passing through a transparent medium and those caused by reflection. The implicit distinction between 'transparencies' (*diaphaseis*) and 'impressions' (*emphaseis*) is drawn already in Theophrastus *On Stones* 30.3. The genus of Philoponus' classification, *emphasis*, refers to an impression by contact with real existence (*huparxis* or *hupostasis*), while its species which has the same name is only homonymous with the genus and refers to reflection. The difference between the processes of reflection and refraction is stated in Ptolemy's *Optics* 3.2, cf. 5.1. Olympiodorus (44,15-25) speaks about the difference between *diaklasis* and *anaklasis* which does sound closer to Ptolemy's distinction (although we do not have a Greek text of the *Optics* to compare exact wording). Alexander speaks of the effects of 'superpositions' (*epiprostheseis*) vs. reflections (*anaklaseis*) (24,3-13).

93. 69,23-6. Philoponus refers to the reflection of our visual rays from the parts of exhalation that obtain mirror-like properties due to a particular elemental constitution. This is in accordance with Aristotle's explanation of rainbows, halos and mock suns in *Meteor*. 3.2-5.

94. 69,38-70,6. When Alexander speaks of 'mixture' ad loc. (24,18-19), he means that the colour is produced by the mixture of the black colour in the air and the brightness of the source of light; similarly with the effects at the rising and setting of the sun: there is no suggestion of any role played by the eye-rays in the mixing.

95. 70,25. 'Not perpendicular but sideways towards the cloud', Philoponus probably means that the light must not pass through the cloud as in the first case (so as to mix with our sight-streams), but our sight-streams must be reflected from the surface made by tiny particles of vapour, towards the source of light. The resulting colour will be thus produced by reflection (cf. Aristotle's explanation of the rainbow colours in 3.4, 374b7-34).

96. 70,29-30. Cf. Aristotle, *Meteor.* 3.4, 373b17-19.

97. 70,32. See Textual Questions 1.

98. 70,30-3. The two examples from our close environment are supposed to illustrate the mechanism of sky phenomena (see 69,13-19 above). The point (as Philoponus spells out again below, 72,11-21, see n. 109 below) is that the reflections preserve the colour, but not the shape or the size of the reflected object. Both examples are found at this point in Olympiodorus 48,17-22 (with the example of the sun being more complex, distinguishing seeing the sun in a clearing vs. in a shadow). Alexander (24,20-6) only mentions the case of raindrops and compares it with rainbows. In 2.9, Aristotle reports that the example of rowers by night was used by Cleidemus to explain lightning as a mere appearance (370a10-17). The example of (daytime) rowers is used by Aristotle himself in the discussion of the rainbow in 3.4 (374a29-32).

99. 70,34. 'Stars', *ta astra*: it is not clear whether this includes the sun, and thus the first example, or only refers to the second example; technically the inclusive reading is not impossible.

100. 70,37-71,4. Aristotle discusses rainbows in *Meteor*. 3.4. 'We shall learn there' (*akousometha*) must presuppose at least Philoponus' intention to write a complete commentary, if not the already existing commentary. Alexander makes the same reference at this point (*in Meteor*. 24,24-6).

101. 71,4. The following four lemmata are parts of the current lemma which presumably sets out the *theôria*, general survey and analysis of the main argument. The division into *theôria* and *lexis* is standard in all of Philoponus' commentaries, but textual analysis is more often incorporated under the same lemma with the *theôria*, without the repetition of the whole sentences from the main lemma. However, there are exceptions to this common pattern (see Kupreeva 2005, 1-2).

102. 71,5-6. This is not printed as a lemma by Hayduck but is likely to be one. See previous note.

103. 71,14-16. The mode is discussed below at 72,11.

104. 71,17-19. Not printed as a lemma by Hayduck, but is likely to be one.

105. 71,28-34. Philoponus' explanation of superpositions and mixture clearly differs from the explanations given by Alexander and Olympiodorus (see Introduction, pp. 10-11).

106. 71,37-72,3. That the air does not get coloured by the rays passing through it is supposed to emphasise Philoponus' point that the colours get mixed only in our apprehension which projects them onto the objects (viz. the tinder).

107. 72,3-5. Not printed as a lemma by Hayduck, but is likely to be one. See n. 101 above.

108. 72,11. The way (b) mentioned above, see 71,6 n. 103.

109. 72,16-17. See 70,24 and n. 98 above.

110. 72,22. 'This', *touto*, where Aristotle's text (in the lemma at 69,1 above) has plural 'these', *tauta*. An example of reduplicate lemma (see vol. 1, p. 2).

111. 72,32-3. See 73,29-30 and n. 117 below.

112. 72,34-6. See 67,15 and 71,6 above.

113. 73,2-5. Definition of white as 'colour dispersing sight' is used by

Aristotle in *Top.* 3.5, 119a30 as an example, taken over by many of his commentators. Philoponus here gives a physical interpretation to this statement.

114. 73,6-7. The claim that black is drawing sight-streams together is reported as Aristotle's example by Simplicius *in Categ.* 107,8-9.

115. 72,34-73,14. This is Philoponus' explanation of the black 'folds' seen on the coloured 'surface' of the aurora.

116. 73,17-23. The same reference to the effect and the artists in Alexander (25,8-13) and Olymiodorus (44,33-45,10).

117. 73,23. This is Philoponus' explanation of the difference between chasm and trench on the basis of Aristotle's own words alluded to at 68,6-9 above. The text on which Philoponus bases his interpretation is the last sentence of the next lemma (342b17-18): 'when it contracts still [more], a chasm appears'. Philoponus seems to take 'still more' as relative to the 'trench', although the trench is never mentioned by Aristotle in this passage; see next note.

118. 73,37-8. 'Much deeper', *mallon bathuteron*. Philoponus' explanation of the distinction between the two types of aurora borealis, 'chasm' (*khasma*) and trench (*bothunos*) is the exact opposite of the one given by Alexander, who describes the 'trench' as being deeper due to the prevalence of the black (*in Meteor.* 25,19-22); Olympiodorus agrees with Alexander.

119. 74,4. *leukos* means either white or bright. In his discussion of colours Philoponus draws on Aristotle's explanation of rainbow colours in *Meteor.* 3.4.

120. 74,5-6. 'Intensification and relaxation of each of them': of white and black. On the colours being composed of white and black either in accordance with proportion or without proportion ('by greater and less'), see Aristotle, *De Sensu* 442a12-25.

121. 74,6-7. Presumably, the colours with rational formula are the seven mentioned by Aristotle, while those whose formula is irrational are 'between these' (*De Sensu* 442a20-5).

122. 74,22. 'Drawing in white', *leukographia*. The LSJ entry gives a translation 'painting in white' citing this place in Philoponus as its only source. The Greek corpus (TLG online version as updated on 2009-02-11) has two more occurrences of this word: Elias *in Porphyrii Isagogen* 56,16 and Elias *in Categ.* 158,26. Elias (*in Porph. Isag.*) draws a distinction between coloured painting as the complete form of painting and *leukographia* and *skiagraphia* which are as it were 'under' this kind of painting. The same contrast is indicated in Aristotle's *Poetics* 1450b2 where the distinction is drawn between the 'most beautiful colours' and 'a simple black-and-white sketch' (*leukographêsas*). So probably the word refers most often to the sketch made in chalk of white clay.

123. 75,6. See 63,15-19 and n. 55 above.

124. 75,8. See 59,36-60,12 and n. 40 above.

125. 75,11-13. See 69,3 above and Introduction, p. 5.

126. 75,15-17. *Meteor.* 3.2-3 (haloes) and *Meteor.* 3.4 (rainbow).

127. 75,22-3. DK 59A 81, 68A92. 'Conjunction', *sumphasis*, a standard term for 'combined appearance', cf. Mansfeld 2002, 36-7 and n. 48.

128. 75,21-3. This is not printed as a lemma by Hayduck, but probably is one.

129. 75,27. 'Draw near to forming this': *eis touto plêsiasôsin*

130. 75,36. 'They would say', *eipoien* see Textual Questions 1.

131. 75,24-76,2. This is Philoponus' rationalisation of the Pythagorean position (cf. below 76,15-22).

132. 76,3. 'Some of the Italians and so called Pythagoreans': Philoponus' copy of Aristotle has 'and' omitted by most *veteres* MSS of Aristotle, but he treats it as epexegetic and in effect normalises the text with this interpretation. (For readings, see Textual Questions 2.)

133. 76,9-22. This seems to be an explanation supplied by Philoponus or one of his sources (cf. 75,30-76,2 above).

134. 76,24. 'Deviates from the sun', *parallattein auton*, i.e. before it is seen as rising. The explanation follows in the text.

135. 76,24-6. In both cases, the 'interval' refers to the angular distance from the sun.

136. 76,28-9. 'Leaves out many of its phases, i.e. does not appear often': Philoponus is explaining the astronomical term for appearance *phasis* (more technical in Greek than in the English translation) with its non-technical relative 'appear' (*phainesthai*).

137. 76,29-31. 'Phase', *phasis*, appearance above the horizon, opp. *krupsis*, disappearance below the horizon. As astronomical term, a *hapax* in Aristotle. Philoponus mentions only one kind of phases, when the planets appear as 'evening stars'. The other kind, when planets appear as morning stars, are seen before dawn.

138. 76,33-4. This means that Mercury can be observed only when it is at its greatest elongation from the sun; presumably, when the elongation is smaller, it cannot be discerned.

139. 77,1-2. Many appearances of Mercury between the conjunction with the sun and its greatest elongation from the sun are hidden from the observer by the sun rays.

140. Heath 1921, vol. 1, 182; recent summary in Heidarzadeh; detailed study of Hippocrates' theory with reconstruction, see Wilson 2008.

141. 77,13. Olympiodorus ad loc. (*in Meteor*. 45,28-30) says that the Pythagoreans consider both the comet and its tail made of the fifth element, while Hippocrates thinks that the comet is made of aether, but its tail is sublunary. This report is likely to be anachronistic; notably, Philoponus does not mention aether (and in his historiography of the question, the doctrine of the fifth element is not accepted by any early thinkers, with Indian sages as one possible exception, cf. vol. 1, pp. 9 n. 39 and 46 n. 95).

142. 77,14. 'Confirmation', *pistis,* refers here to a kind of inductive proof, weaker than demonstration, but able to confirm the results of the demonstration.

143. 77,15-16. 'Under the equator', i.e. the celestial equator.

144. 77,17-18. See n. 229 ad 94,35-95,1 below.

145. 77,22-4. Philoponus *in Meteor*. 27,31-28,23 (see vol. 1, p. 9).

146. 77,24-7. According to Hippocrates, seeing the sun rays thus reflected involves a two-leg journey for our sight-streams: first to the clouds on which, by assumption, the sun rays fall, and secondly, after being reflected from these clouds, to the sun.

147. 78,3. 'Will not become a comet' (*ginetai komêtês*), lit. 'will not become tailed', i.e. the vapour drawn up will not be sufficient to form a tail.

148. 78,5. *kata platos*, i.e. along the latitude with respect to the ecliptic (Philoponus himself uses the terminology of celestial coordinates discussing *Meteorology*; cf. 1.4, n. 33 at 59,11-13 above).

149. 78,10. 'Beneath the earth', with respect to our northern hemisphere (see Fig. 2 below).

150. 78,10-11. Day circles of the sun and the comet-planet.

151. 78,7-16. This argument presupposes that when in winter the comet-planet appears in the sky, the sun is always at the longest remove on the other side of the ecliptic trajectory, which is only true about the time around midnight. This is certainly not compatible with the claim that the planet-comet is concurrent with the sun. In fact, Philoponus raises this objection below (81,1-11). The format of the objection is similar to that of his 'own observations' in commentaries based on Ammonius' lectures (for *in GC* 2.5-11, cf. Kupreeva 2005, 2 n. 25). It is possible that this exposition of Hippocrates' theory goes back to Ammonius. Olympiodorus (46,35-47,23) gives the same arguments; note however that he says that with both the sun and comet-planet at winter solstice, 'reflection cannot take place *during the whole night* (*di'holês tês nuktos*)' (46,11-12). If the italicised clause is taken to be within the scope of negation, it can mean the same restriction as the one stated by Philoponus below.

152. 78,32. 'The idea of the argument', *tôn legomenôn dianoia*, corresponds to *theôria* as opposed to the 'text', *lexis*, as indicated.

153. 78,35-7. Alexander, *in Meteor*. 27,12-21.

154. 79,7-8. cf. Alexander *in Meteor*. 27,12-15.

155. 79,9-12. 'Being distant from the sun', as a consequence of Alexander's interpretation. Philoponus thinks that for Hippocrateans, the comet-planet is concurrent with the sun; Alexander's interpretation does not support this. But Philoponus' interpretation faces some problems of consistency as well: if the comet is concurrent with the sun then it cannot move too far from it, so the reflected sight-streams should be able to reach the sun much more often than defined by (a)-(d). In fact, if the comet-planet is concurrent with the sun, the only case where the comet cannot appear is (a).

156. 79,24. *Opera et dies* 384-5.

157. 79,30-6. This interpretation actually belongs to Ammonius, as Olympiodorus (who also shares it) informs us in his commentary, 51,9-15 and 51,29-52,2. Modern translators are divided: Lee, Strohm, Tricot, Thillet agree with Ammonius and the Alexandrians; Louis and Pepe follow Alexander.

158. 80,1-2. 'Having fallen behind by its whole circle' (*hupoleleimmenon holon ton heautou kuklon*). Lee translates: 'having completed its backward orbit'. This occurrence might have served as a cue for Alexander's interpretation of *hupoleipesthai* rejected by Philoponus (Ammonius). Philoponus' point is that the meaning of *hupoleipesthai* here is different from that at 343a4-6 because it is qualified (whereas Alexander understands this meaning as the same throughout this chapter).

159. 80,12-13. Reading *tou de eis to auto sêmeion phainesthai … to perielthein holon ton heautou kuklon*, following Hayduck's suggestion in the apparatus.

160. 80,18. See Philoponus' argument above.

161. 80,22-3. 'The southern place', *notiôi topôi*, see Textual Questions 2.

162. 80,28. 'In the southern places' here refers to the southern hemisphere.

163. 80,28-31. 'The sight-streams reflected from the vapour do not reach the sun below because of its great distance from the horizon below the earth': the power of sight-streams apparently has physical limits, as they taper off after a certain distance (cf. Wilson 2008, 148).

164. 80,32. 'In the northern region', i.e. in the northern hemisphere (during the summer).

165. 80,1-81,1. See Fig. 2.

166. 81,1-2. 'Southern tropics', reading *en tois kheimerinois kuklois* as suggested by Hayduck in the apparatus.

167. 81,3-4. 'The line drawn to [the earth] from the centre of its circumference' is the line connecting the centre of the observer's field on earth and the point on the sun's circumference at midnight; the same as 'culmination' (*mesouranêma*) at 81,6 (n. 170 below).

168. 81,1-5. These two exceptions constitute Philoponus' corrections to his (or his source's, perhaps Ammonius) earlier exposition of Hippocrates' theory at 77,31-78,23. (i) addresses the claim made under (c) above: assuming both the star and the comet are in the winter tropic, the comet can be seen for a short time before dawn and after sunset, because the distance between the comet and the sun is not too long; (ii) addresses (d): even when both the comet and the sun are in the summer tropics, i.e. in the northern hemisphere conveniently for the observer, the comet will not be seen at midnight, because the distance between the sun and the comet-planet will be too long for the sight-streams to traverse.

169. 81,5. 'In the northern tropics', reading *en tois therinois* (instead of the MSS *kheimerinois*) as suggested by Hayduck in the apparatus.

170. 81,6. 'Culmination', *mesouranêma*, refers here to the sun's perigee (see n. 167 at 81,3-4 above).

171. 81,5-8. Philoponus' second amendment to Aristotle's statement concerns the thesis (b) that comet is seen with tail during the summer in the northern hemisphere. He suggests that when the sun is near the perigee in the southern hemisphere, our sight-streams may not be able to reach it, so the optical mechanism will not work and the tail will not be seen.

172. 81,9. Either delete the *oukh* following Hayduck, or retain it but understand as emphatic (in each case, the purely negative particle is impossible).

173. 81,22. 343a24. 'Fall behind', *hupoleipontai*, here to be taken in the meaning 'travel on their own orbits', cf. n. 158 at 80,1-2 above.

174. 81,33. 'Systematically treat', *tekhnologousi*, cf. 61,7. One would like to know whether Philoponus had an independent access to any of the early sources.

175. 81,35. i.e. one of the known planets.

176. 82,4-5. On this assumption of Philoponus, see n. 155 at 79,9-12 above.

177. 82,7-8. For a plausible reconstruction of Hippocrates' theory, avoiding this and other objections, see Wilson 2008, 156-9.

178. 82,16 -17. Another reference to comet observations conducted in the Alexandrian school.

179. 82,28-30. See 77,31-78,23 above.

180. 83,3. 'Illusion of our sight' (*planê tês opseôs*), or 'deviation of our sight-stream', as Jan Opsomer suggests to me, which clearly captures the mechanism of the illusion (although Philoponus normally refers to the sight-streams in the plural).

181. 83,1-6. It is not entirely clear what effects Philoponus is referring to in the case of Sirius and Venus.

182. 83,22. 343b1. *c.* 373/372, see n. 198 at 87,3 below.

183. 83,34. 'If the sun is in the summer solstice', i.e. while the comet-planet is in the winter solstice.

184. 84,6. 'So great a size', *tosouton megas*, see Textual Questions 1.

185. 84,10. 'As he will show', *Meteor*. 2.8, 368a34-b12.

186. 84,13-14. 'Then there is plenty of vapour formed under the equator': this follows from Hippocrates' assumption that comet tail is made of vapour and from Aristotle's evidence of the comet formed near the equator.

187. 84,19-21. There are, to my knowledge, no extant Greek records for this comet. In Kronk, we find a reference to the Chinese text Wéi Shu (572) which describes the 'guest star' that appeared some time within the month of 16 November to 14 December 483. The 'star' is said to have been the size of a 'peck measure' and to have looked like a 'sparkling star'. It appeared at Shen (a, b, g, d, e, z and k Orionis). (Kronk I, 84: 483). The date, 483, is a little early for our estimated Philoponus' time, but would suit well the time of Ammonius.

188. 427-426 BC.

189. 15 January to 15 February.

190. 85,4-5. Canis Maior, see Thillet 486 n. 79, citing D.R. Dicks 1976, 265 n. 409.

191. 85,5-7. 343b13-14. Barrett 1977 suggests that this is the earliest known reference to the technique of 'averted vision' used in astronomical observations. Heidarzadeh 2008, 11 n. 33 suggests that Aristotle could be observing an open cluster M41 in Canis Maior or faint stars near the Delta of Canis Maior.

192. 85,29. 'Quicker to dissolve', *thatton diakrinomenai*. The meaning of *diakrinein* will switch to 'discern' at 85,40.

193. 85,24. See Introduction, n. 23. 'Opticians', i.e. writers on optics. Philoponus' exact source here is not clear, particularly since in most optical treatises we can find a statement that the sight-streams that are on the cone's axis have the strongest visual power while those at the cone's sides are the weakest (for references see Knorr 1985, 91-4). But the point made in the argument reported by Philoponus has to do not so much with the precision of sight, but with the sight itself being affected by a similar, but much more intensive, physical action. We can then compare Ptolemy *Optics* 2.88: 'What happens in vision, moreover, is like what happens in touch. For a given object feels softer to one whose body is harder than to one whose body is softer. Furthermore, it feels cooler to one whose body is hotter than to one whose body is cooler' (tr. Smith). In accordance with this principle of contrast, the sunrays will appear brighter to the sight-streams that are themselves weaker (and dimmer) than to the ones that are themselves stronger (and brighter). I disagree with Smith's note ad loc.: 'By analogy … to someone with an abundance of visual flux, dimly illuminated objects appear brighter than they do to someone with a deficiency of such flux' (Smith 1996, 107 n. 106): according to the principle as stated, the bright objects will be perceived as brighter by weaker sight-streams and as less bright by the stronger sight-streams – just as Philoponus describes.

194. 85,34-6. For the general principle, cf. Aristotle *De Anima* 2.8, 420a12-15, Philoponus' discussion in *in De An.* 365,2-17; and more specifically for looking against the sun, [Aristotle] *Probl.* XXXI.28, 960a21-8.

195. 85,41-86,5. Cf. the discussion of binocular vision in Ptolemy, *Optics* 2.33. Philoponus seems to adapt a simple case in order to resolve Aristotle's problem.

196. 86,11-12. 'Had no setting', i.e. no last setting. Alexander interprets 'had no setting' (*aneu duseôs*) as 'remained above the earth before the [last] setting' (*pro tou dunai huper gên ontas*) (31,12-16).

197. 86,31-4. 'He did well to indicate that they fade away while being above the earth (*huper gên ontas*)'. The phrase *huper gên ontas* belongs to Alexander (31,14) who uses it to clarify Aristotle's meaning (although Aristotle's *huper tou horizontos*, above the horizon, is close enough, Philoponus does not use it).

198. 87,3. The archonship of Asteius, 373-372 BC.

199. 87,6. 343b23, 'jump': *halma,* Lee suggests reading *hamma* ('like a cord or band') in the apparatus (following two MSS), Thillet prints his own conjecture *nama,* 'stream' (486 n. 81). (Alexander, Philoponus, and Olympiodorus all have *halma*). A modern comet historian supports 'band' (Seargent 2009, 67).

200. 87,12-3. Aristotle would be about fourteen at the time of this comet.

201. 87,19-21. On two kinds of air, moving with the heavens (above the peaks of highest mountains) and stagnant ('trapped' between these peaks), see Aristotle, *Meteor*. 1.3, 340b34-41a2 and Philoponus ad loc. in vol. 1, p. 67.

202. 88,1-2: Apollonius of Rhodes, *Argonautica* 1.545.

203. 88,15. 343b25, DK 68A92. 'Has worked hard', *prospephiloponêke*, where Aristotle text has *prospephiloneikêke* 'has championed vigorously'.

204. 88,25. This contains a methodological enhancement of Aristotle's objection (which could be accused of not doing full justice to Democritus' argument in that it does not consider possible special conditions of his empirical evidence). With his 'sceptical' argument, Philoponus pre-empts this defence.

205. 88,25. 'Misled', *peplanêsthai*, a pun: the Greek verb is also used in what became a technical term for planet (*planêtês*), a 'wandering', 'stray' star.

206. 88,34. 343b29. 'With planets', read *pros hautous* instead of *pros autous* (see Textual Questions 2).

207. 89,24-5. Meaning the comet inclusive of the tail.

208. 90,13-15. See Introduction, p. 23.

209. 90,21. Aristotle, *Meteor*. 1.3, 341a17ff. See vol. 1, pp. 15-17, 70-6.

210. 90,25. The 'surrounding bodies' refer to the concerted motion of heavenly spheres. According to Aristotle, heavenly spheres have continual regular motion, while the tinder sphere is pulled along (see *Meteor*.1.3 and vol. 1, pp. 66-8). It is not clear whether 'and' (*kai*) in 'by the motion of the surrounding bodies and its revolution with [these bodies]' (*kinêsei kai sumperiagôgêi*) could be epexegetic, i.e. whether 'revolution' in fact just specifies the meaning of 'motion' or whether it has any additional meaning. The exhalation is heated by friction, but since some of it is also carried about with the lowest sphere, this further revolution (*sumperiagôgê*) could produce its own friction against the stagnant lower air which would transmit heat downwards. Note that LSJ cites this passage under *sumperiagôgê* giving the meaning 'revolution in the same sense with', which does not seem right: the tinder certainly does not revolve in the same sense with heavenly bodies, but only together with them.

211. 90,34. 'To prevail through the whole of it', *mêde di'holou tautês epikratein*. 'Prevalence' (*epikratêsis*) is the main mechanism of sublunary elemental transformations in Aristotle's physics (*GC* 2.4). In mixing with matter, fire is supposed to prevail over the matter throughout the body of the wood in order for combustion to take place.

212. 91,3. 'Our teacher', Ammonius (Olympiodorus does not mention this comet in his commentary at this point).

213. 91,10-12. On the order of the elemental tiers, see *Meteor*. 1.3, 340b15-30 and commentary in vol. 1, pp. 62-6.

214. 91,16-18. On the two layers of air, see *Meteor*. 1.3, 340b23-31 and Philoponus' commentary in vol. 1, pp. 65-6.

215. 91,20. The claim that the motion contrary to nature cannot be unceasing is a conversion of Aristotle's deduction in *Cael*. 1.2 showing that circular motion is unceasing. Philoponus in his lost treatise *Contra Aristotelem* argued (following earlier arguments by Xenarchus) that circular motion can be natural to fire (frr. 9-17 Wildberg).

216. 91,23. 'Fixed sphere', *tên aplanê*: probably distinguished here from the sphere of fixed stars, although the earth is the centre of both spheres, cf. nn. 71, 305, 307, 316, and Introduction, p. 16. Jan Opsomer points out to me that the distinction is drawn in the same terms by Simplicius, *in Phys*. 643,32-3.

217. 92,10-11. On the heating of the atmosphere by the rotation of the heavenly spheres, see *Meteor*. 1.3, 341a12-36 and Philoponus' commentary in vol.1, pp. 70-84.

218. 92,14. See *Meteor*. 1.4. and 61,7-62,2 above.

219. 92,28. 'Or', instead of 'and' printed by Hayduck (see Textual Questions 2).

220. 92,35. Olympiodorus says that there are three different kinds of comets: the 'beam' (*dokias*) when the ignition is in length but not in breadth; the comet proper (*komêtês*) when the ignition is in both length and breadth; and the 'bearded' comet with the emissions of sparks happening in depth. (60,5-7). Seneca ascribes to the 'Greeks' a similar tripartite classification, except that the elongated comet is not called 'beam' (*trabs*), but left nameless (*QN* 7.11.2).

221. 93,9-26. See *Meteor*. 1.4 and Philoponus' discussion in chapter 4 above.

222. 93,28-30. The comet's perceptible motion in the sky is due to the 'shooting' effect, while the picture we have of its resting state corresponds to the real process of burning.

223. 94,3-4. This is the interpretation of Alexander, *in Meteor*. 34,24-9.

224. 94,7. Fr. 872 Kock. Philoponus shows his usual lexicographical interests in suggesting that the word *phora* could be used by Aristotle in its second meaning, 'crops'.

225. 94,12-13. 'Things that have being in change', *ta en kinêsei to einai ekhonta*, things whose being consists in a particular kind of change, perhaps what we might call 'processes'.

226. 94,14-16. Philoponus assimilates change (*kinêsis*) with coming to be and perishing (*genesis kai phthora*). It is not clear whether he operates with Platonic or Aristotelian categories here. Change (*kinêsis*) is very clearly distinguished from coming to be and perishing by Aristotle, but not by Plato.

227. 94,21. 344a35. 'Stars', see Textual Questions 2.

228. 94,31. 'Since some comets come to be without and some with the stars' (see Textual Questions 1).

229. 94,35-95,1. This is Philoponus' interpretation of Aristotle's claim that the stars draw up the exhalation. Philoponus' addition of the qualification 'to themselves' to the description of this 'drawing up' makes it sound Stoic. Alexander says (following Aristotle) that the stars cause the condensation of exhalation.

230. 95,2. 'On a vertical line' (*kata katheton*): one must think of a line drawn from the centre of the cosmos to its periphery; if there are no stars above the exhalation on this imaginary line, the comet is taken to be formed 'on its own'. If there is a star above, the optical illusion assigns the 'tail' to the star.

231. 95,3-6. 'Our sight', *opsis*, elsewhere translated as 'sight-stream', and here understood in the same way (see Introduction, p. 6).

232. 95,9-11. Haloes are discussed in *Meteor*. 3.2-3.

233. 95,11-13. See *Meteor*. 3.3, 372a1-17.

234. 95,19-20. 'For it is the kindling of the underlying matter', and not a reflection of sight streams, as in the case of the halo, which creates an optical illusion. For the same explanation in Alexander, see his *in Meteor*. 35,8-16.

235. 95,34. 'With the conditions formed in them', following Hayduck (see Textual Questions 1).

236. 95,20-3. 'The prevailing strength', obviously, of the heavenly spheres, as Alexander spells out in the passage cited by Philoponus.

237. 96,16-17. *Meteor.* 1.6, 343b4 and Philoponus' discussion at 84,1-19 above.

238. 96,27-9. The imaginary objection probably has a pedagogical purpose, to explain the motions on the celestial sphere. Philoponus explains that if the comet were moving faster than the sun, it would have had its first appearance before dawn rather than after sunset, and states that on the basis of physical theory such high speed is impossible for a comet anyway.

239. 96,38. 'or always lag behind, [97] unable to keep pace in continuity', *ê hupoleipetai pantôs sunepesthai kata sunekheian tôi helkonti mê dunamenos. Pantôs* can be construed either with *hupoleipetai* (my choice here), or with *mê dunamenos*, where the sense would be 'not being able always to keep the pace'. I think *pantôs* at line 97,3 lends some support for taking *pantôs* as referring to a permanent characteristic of the comet motion.

240. 96,38. 'In continuity' (*kata sunekheian*) may refer to the continuity between the heavens and sublunary cosmos (see *Meteor.* 1.1, 339a17), but it is more likely that Philoponus uses it to refer to the uninterrupted motion (cf. 97,1-3 below).

241. 97,4-5. This section gives us a Platonist reading of Aristotle. On rest as the natural state of homogeneous masses, see Plato, *Tim.* 57E, on the rotation of the spherical boundary of the cosmos, *Tim.* 33B. 'Totality', *holotês*, is the mass of the element mainly of one kind in the elemental layer within the cosmos. See n. 17 above and also vol. 1, pp. 52-3.

242. 97,12-16. Philoponus is trying to establish as a common position between Aristotle and 'the Platonists' the view that the tinder sphere (fire and upper layer of the air) moves around the earth with its own natural motion. He draws on Aristotle's text (*Meteor.* 344b11-12 = 96,1-2 in the lemma) and also argues that a contrary view, namely, that the constant motion of the tinder is forced, involves an impossibility.

243. 97,16-19. This only applies to the comets which are formed 'on their own', not under the stars. The latter class, which on Philoponus' view, do not move, are considered in the next section.

244. 97,20-1. 'Elsewhere', *heterôthi pou*. Not any known source: this may or may not be Damascius' lost commentary on *Meteorology*. On references to Damascius, see Introduction, p. 3. Wildberg 1988, 129, suggests on the basis of this passage that Damascius may have been the originator of the idea that the circular motion of the fire sphere is supernatural and that Philoponus here rejects the supernatural character of motion of the fire sphere (which he endorses in his earlier *in Phys.* 378,25-9). While this may be true if supported with further evidence, it seems clear that here Philoponus only discusses the motion of comets which should be regarded as anomalous compared to the regular motion of the fire sphere.

245. 97,25. Alexander, *in Meteor.* 35,17.

246. 97,28. 'Comet formed below', i.e. without a star.

247. 97,32-4. This is what Alexander says in *in Meteor.* 35,16-20. Effectively, this suggests a distinction between the two kinds of comet – or so Philoponus understands Alexander's claim.

248. 97,32-98,3. Philoponus points out a problem with Alexander's distinction in the light of Aristotle's view according to which the elemental layers constitutive of the sublunary cosmos are all continuous with each other and with the heavenly spheres (see *Meteor.* 1.3, 340b14-23, Philoponus in vol. 1, pp. 62-5).

249. 98,12. 'On the same perpendicular line', i.e. directly above them.

250. 98,8-14. An alternative explanation envisioned by Philoponus based on the visual effect of the different distance to the observed types of comets. Philoponus' verdict, notably, is that the question should be decided empirically, by observation.

251. 98,14-19. Not printed as a lemma by Hayduck, but apparently is one.

252. 98,19-20. 'Just as he explains the halo as a reflection of sight-streams onto the sun' (*hôs tên halô kata anaklasin tôn opseon eis ton hêlion ginomenên*). Hippocrates' theory of halos is not known and hardly relevant in this context. It is just possible to understand this sentence as saying that Hippocrates understood a comet to be the halo formed by reflection of sight-streams onto the sun (which will bring it in agreement with Aristotle's argument above), but 98,23-4 seems to give a disambiguation in favour of the prima facie reading, namely that the comet is formed by reflection of the sight-streams onto the *star*. Cf. the same problem at 99,6-7 and n. 257 below.

253. 98,21. 'Our sight' (*opsis*), i.e. our sight-streams.

254. 98,19-21. It is not clear that Hippocrates had this 'stellar' theory of comet formation. Below, Philoponus offers his reading of the lemma that suggests as much (see 99,4-14 and nn. 257-8 below). All Aristotle's arguments against Hippocratics seem to be based on the 'solar' theory of comets.

255. 98,23. 'Lest someone' (see Textual Questions 1).

256. 98,37-99,2. In this passage Philoponus seems to be raising the problem with Aristotle's account of comet as covering both the real comet (without a star) and an apparent star-comet. The formulation of the problem runs as follows. (a) The halo does not lag behind its star, while a [stand-alone] comet does lag behind [the fixed stars), therefore the halo is not the same condition as a comet; on the other hand, (b), a certain type of comet (formed under the star) does not lag behind its star. Somebody might conclude from (b) and some unstated assumptions that the halo and the star are the same condition. This conclusion is independently established to be false. Hence, by contraposition (if we do not question any other assumptions), (b) must also be false. But we know it has to be true if the phenomena are to be preserved (namely the appearance of the comet-star). Aristotle does not state this problem explicitly, but is perhaps aware of it. As a solution, he suggests in 344b13-18 that comet-star is not a comet strictly speaking, deferring the complete solution to the discussion of halo in book 3.

257. 99,4-14. This passage contains a discussion of the *lexis*. Philoponus paraphrases Aristotle's lemma, somewhat difficult in Greek, transposing parts of the sentence (see next note). For some reason he attributes the theory according to which comet is formed like a halo under the star to Hippocrates and suppresses Hippocrates' theory discussed by Aristotle so far (according to which comets are formed by reflection of the sight-streams towards the sun). Lee ad loc. follows Philoponus in attributing the theory of comets as 'astral haloes' to Hippocrates, but does not notice that the attribution comes from what seems to be a controversial reading of Aristotle's passage. Neither Alexander nor Olympiodorus attribute to Hippocrates in this passage any other theory of comets beyond the one already discussed in the previous chapter, i.e. that the tail of the comet-planet is a mere appearance produced by our sight-streams reflected from mist to the sun.

258. 99,7-8. Our lemma: 'For this is the strongest indication that a comet is not some sort of reflection like a halo which comes to be in relation to the star in the pure tinder, *nor* (*kai mê*), *as Hippocrates says, in relation to the sun*, namely that often, and more frequently than around some particular stars a comet comes about by itself.' (Hippocrates' solar theory of comets very briefly mentioned). Philoponus' reading drops *kai mê* as redundant and attributes to Hippocrates a different theory of comets and an unknown theory of haloes: 'For this is the strongest indication that the comet is not some sort of reflection which comes about in relation to the star itself, as Hippocrates and his school claim, just as the halo is in the clean tinder in relation to the sun.'

259. 99,7. 'Is superfluous': *pleonazei*; Philoponus treats this as a rhetorical device (repetition of 'not', *mê*, of the first line of the lemma).

260. 99,10. In the Greek sentence the comma is after 'often.'

261. 99,8-12. Here Philoponus' reading does not differ from everyone else's.

262. 99,12-14. Philoponus apparently takes 'definite', *hôrismenous*, in the strongest sense, as 'stars by definition', as opposed to the 'stars' of folk astronomy, which include comets.

263. 99,29-31. For quantitative 'prevalence' as the mechanism of elemental transformation, see Aristotle, *GC* 2.4.

264. 100,1-3 Aratus, *Phaenomena*, ll. 1091-3, tr. D. Kidd, lightly modified.

265. 100,1. The text of Aratus at l. 1091 has 'it is to be hoped that the stars above will be always recognisable', see Textual Questions 3.

266. 100,4. *Meteor*. 1.4, 341b6, and 54,39-55,39 above.

267. 100,7-12. Aratus, *Phaenomena*, ll. 926-31.

268. 100,21. Read *kai authis katapesonta*, as Hayduck suggests in the apparatus (see Textual Questions 1).

269. 100,21-3. The meteorite of 467 BC, which Anaxagoras was said to have predicted (DK 59 A 1, ii. 6, 9 and A 11, 12).

270. 100,25. *Meteor*. 2.8, 368a34; See also 1.6 and at 84,1-21 above. Possibly an indication of an existing or planned commentary on book 2.

271. 100,27. *Meteor*. 2.8, 368b6.

272. 101,8. 'Rule', *dunasteuein*, a political metaphor, cf. Aeschylus, *Agamemnon*, 6 (*lamprous dunastas* … [*asteras*]).

273. 101,12. *Meteor*. 1.8, the next chapter.

274. 101,23. 'By its motion', i.e. the sun's; Aristotle's text printed in most modern editions has 'by their motion' (*autôn*), which Lee translates 'of these bodies', Thillet 'of these stars'. See Textual Questions 2.

275. 101,29. Homer, *Odyssey* 6.320.

276. 101,30. 'Torrid zone', *diakekaumenê zônê*, between the tropics particularly around the equator.

277. 102,1. Euripides, *Orestes* 1001-6.

278. 102,2. 'Who drives her steeds alone', *monopôlon*, can also mean 'who drives a single horse'.

279. 102,17-20. cf. Achilles Tatius *Scholia in Aratum* 20; [Lucian], *De Astrol*. 12.

280. 102,21-3. Aratus, *Phaenomena* 257-8 ('Seven in number they are in the lore of men, although there are only six apparent to the eye', tr. D. Kidd).

281. 103,1. DK 59 A 1; 42; 80 and DK 68 A 91; for recent discussion of the doxographical sources, Mansfeld 2002, 33-5.

282. 103,16. 'Greatest' (*megistos*) circles are concentric with and of the same radius as the universe (cf. 330 ad 112,6-7 below). The Milky Way is regarded as one of them.

283. 103,29-33. If Anaxagoras' and Democritus' theory (the Milky Way is the shining of the stars in the shadow cast by the earth) was true, the position of the Milky Way would change throughout the night, with the position of the earth's shadow. But this does not happen.

284. 103,37. 'Convoluted' (*ekhon anadiplôseis*), refers to the visible bifurcation on the central disc of the Galaxy, which has the form of a helix. Ptolemy calls this *to diploun*, 'bifurcated part' in Toomer's translation (*Syntaxis* II.1, 170, 8 Heiberg).

285. 104,3-4. 'The theorems of astronomy': Thillet 490 n. 103 suggests the reference is to Aristotle's work entitled *astronomikon theôrêma a'* (following Endress 1966, 244 ad *De Caelo* 291a31-2, cf. however Thillet 76n.22 where he seems to be more sceptical about this attribution). The Greek commentators clearly treat this as a reference to the 'theorems of astronomy' in general, as a subject rather than a specific work.

286. 104,6: 'From the sun' (*to tou hêliou*) omitted in Philoponus' lemma, added by Hayduck.

287. 104,12-18. This is a summary of the previous objection (103,20-104,2).

288. 104,21-3. Ptolemy in *Almagest* 5.16 calculates the ratio between the sun's and earth's volumes at around 170. Earlier, Hipparchus *On sizes and distances*, gives the figure 1880 for this ratio. For Philoponus' purposes it is sufficient to establish that the sun is considerably greater in size than the earth. Alexander in his commentary explains, without giving any precise values, that the shadow forms a cone and that its vertex does not reach as far as the fixed stars (38,5-27).

289. 104,24. Theon of Smyrna, who discusses the shapes of shadows cast by bodies of different geometrical shape and size, also gives Hipparchus figure for the ratio between the sizes of the sun and the earth (*De Utilitate* 195.5-198.8). In the case of Philoponus, it is significant that he is aware of this connection between the relative size and shape of shadow.

290. 104,30-3. See Ptolemy, *Almagest* 5.16. The unit of calculation is earth's radius.

291. 105,1-3. Ptolemy, *Almagest* 5.16.

292. 105,7-8. Philoponus apparently assumes that there is just one sphere corresponding to each planet.

293. 105,14. Olympiodorus (68,13-29) gives rough ratios of the distances on the basis of the calculations similar to those used by Philoponus.

294. 105,15-17. 'Some say': Olympiodorus (68,30-4) takes these to be the circle of Hippocrates of Chios.

295. 105,30-2. Alexander, *in Meteor*. 38,28-30.

296. 105,25-106,4. There is no real difference between Alexander's and Philoponus' interpretations of the theory, but Alexander's sentence has typically difficult syntax which may cause misunderstandings. He says: 'Aristotle says that the third opinion about the Milky Way is the one that says that the Milky Way is a reflection of our sight from some sort of exhalation, onto the sun, [the Milky Way] being the mirror for our sight, for the sunlight seen by it' (38,28-32). Philoponus takes the sun, which is closer in the sentence, to be the subject of 'being the mirror', but it should be clear from the sentence that it is 'the Milky Way' that must be supplied (otherwise the sun will be the mirror for the sunlight, which makes little sense).

297. 106,6-9. This is an imprecise quotation of Alexander, *in Meteor*. 40,3-7. Alexander's text says: 'But the stars that are in the circle of the Milky Way move, *that is, the mirror – for if the circle is around them, and they move, the circle, which they consider to be the mirror*, also moves and the sun, which they say is seen in the circle of the Milky Way, also moves, since the reflection is directed towards it'. Alexander thinks that the Milky Way is the mirror, but as such it moves because of the motion of the stars under which it lies. We don't need to assume that Philoponus had a different text of Alexander: he could be paraphrasing the correct text which is again difficult and could be misleading.

298. 106,9-13. Ammonius seems to adopt a theory similar to the Stoic theory of the moon's own light in order to present the reasoning behind the 'reflection' theory of the Milky Way. The Stoic theory of the moon's own light is described by Plutarch, *De facie in orbe lunae*, 934B1-2 in terms close to those used by Philoponus ('that smouldering and glowing colour of the moon', *to gar anthrakôdes ekeino kai diakaes khrôma tês selenês*).

299. 106,15. This is Alexander's interpretation 38,32-39,6.

300. 106,21-8. (i)-(iii) formalise Aristotle's argument at 345b12-22, cf. also Alexander 39,7-19.

301. 106,28-32. Cf. Alexander, 39,19-24. The principle is strictly true only for plane mirrors. Alexander has also another explanation (39,24-34) incorporated in Philoponus' (ii).

302. 106,33. With relation to the distant objects of sight in heaven, because the real size of the earth is negligible compared to the distances in question. See next note.

303. 106,34. Philoponus may be referring to Ptolemy, *Almagest* 1.6 (but the assumption that the size of the earth is negligible with respect to the size of the universe goes back at least to the time of Eudoxus).

304. 107,8. See Textual Questions 2.

305. 107,15-16. 'Faster than the rest (*tôn allôn*)', presumably, faster than the fixed stars. The tropical year is a little (about 20 minutes) shorter than the sidereal year because of the precession of equinoxes which was both known and recognised in the Alexandrian school (cf. also Philoponus *Contra Aristotelem*, fr. 7, 15 Wildberg; Olympiodorus 76,19-21; on Ammonius, Simplicius *in Cael.* 462,12-31), even if they may not always fully understand it (see n. 307 ad 107,27-8 below).

306. 107,23. Delphinus, a constellation in Northern hemisphere, close to the Milky Way (constellation XVII in Ptolemy's *Almagest* 7.5).

307. 107,27-8. Notably, Aristotle at this point does not speak of the speed of the fixed stars vs the sun, but only of the changing position of the sun with respect to the fixed stars. The precession of equinoxes was discovered by Hipparchus in the second century BC (although there are reports that Aristarchus of Samos, third century BC, may have had the values for the sidereal and tropical year) and first extensively discussed by Ptolemy on whose work Philoponus and Olympiodorus ultimately rely. Aristotle did not know it; and more importantly, it cannot be proved by the example discussed by Aristotle. All this example shows is that the sun as it moves along the ecliptic circle changes its position with respect to constellations.

308. 107,36-108,2. In order to make this point, Philoponus would not need to invoke speed at all (just as Aristotle makes no use of it).

309. 108,10-13. Olympiodorus at this point registers disagreement between Alexander and Ammonius with regard to the possibility of multiple reflections. On his presentation, Alexander thinks that multiple reflections are impossible (69,15-17), while Ammonius points out that they are possible as such, as the case of multiple mirror reflections shows. 'But Philosopher Ammonius says that it is not absurd that two reflections arise. For the mirror specialists (*enoptrikoi*) say that there can be two, three, and more. For if, he says, one were to place two mirrors, one in front and another in the back, he would see his own back. But this would not happen unless the sight stream underwent bending in each of the mirrors. If so, why does Aristotle call this absurd?' (69,17-22) The answer Ammonius gives is 'because of the distance'. But in fact Alexander (40,15-22) also points out that multiple reflections are impossible because of the distance, so there is full consensus of all the four commentators in this matter.

310. 108,13-15. See the discussion of Hippocrates' theory of comets in 1.6 above and Fig. 2.

311. 108,21. Perhaps read 'let us start' instead of 'we start' printed by Hayduck (see Textual Questions 1).

312. 108,27-8. 'Under' translates *hupo* which could be understood in a strong causal sense, 'by', 'because of'. As is clear from the commentary, Philoponus prefers the causal sense, but at this point the importance of the local rather than the causal sense is also clear. Lee and Thillet translate in the causal sense, 'by one of the stars', or even 'sous l'effet'; but this seems too strong (perhaps influenced by the commentators).

313. 109,7-12. On the formation of the two types of comets, see *Meteor*. 1.7, 344a33ff. and Philoponus at 94,31-95,34 above.

314. 109,21. 'As we have proven' refers both to the refutation of the third assumption above (105,25-108,21) and the proof of the reality of the comets in 1.7 above, since comets and the Milky Way have the same nature.

315. 109,28. On the simultaneous motion of halo, see 95,20-34 above.

316. 109,31-2. Ptolemy uses the theory of epicycles to describe the motion of the planets. The fixed stars, according to him, keep the same relative positions with respect to each other, but he adopts and develops further the theory of precession, slow eastward movement of the 'fixed' sphere around the poles of the ecliptic (see n. 308 above and the Introduction).

317. 109,34-7. Aristotle, *De Caelo* 2.7, 289b30.

318. 109,34-7. *Cael*. 2.7, 289b30. Philoponus takes 'bound' (*endedemenai*) as equivalent to 'fixed (*aplaneis*) and on this basis criticises Aristotle for drawing a distinction in this passage between the fixed stars and the planets which could be misleading because it suggests that planets on Aristotle's view are somehow not bound. The concentric theory which attaches each 'star' to its own carrying sphere is developed by Aristotle only for planets (with each planet having several concentric spheres), whereas all the fixed stars are located in the same sphere.

319. 110,11. Alex. *in Meteor*. 41,17-22. For a similar disagreement with Alexander, see Philoponus *in GC* 291,18 (cf. Kupreeva 2005, 85 nn. 326-7).

320. 110,14. 'As Ptolemy thinks'. See Introduction, pp. 3-4 and n. 24. Philoponus makes the same attribution of nine spheres to Ptolemy in *De opif. mundi* 3.3 and 1.7; cf. also Scholten 1996, most recently Sorabji 2007, 587-8, who suggests that this attribution may be based on Ptolemy's *Planetary Hypotheses* 2.11, 2.123.8, and 2.125.23 (Heiberg).

321. 110,20. *Polit*. 269D.

322. 110,21-2. Alexander in the beginning of his lost commentary on *On the Heavens* (fr. 1) discusses the three meanings of the word *ouranos* used in the title: (a) the sphere of fixed stars only; (b) the divine element of which the heavenly spheres and stars are made; (c) the whole world, including the sublunary region. (Incidentally, in that case, unlike in this passage, his preferred meaning is (c), since it alone can adequately represent Aristotle's discussion of the four elements in books 3 and 4.) Philoponus in his enumeration here apparently replaces the 'fifth element', which he denies, with the heavenly spheres without reference to their material.

323. 110,24-31. Cf. the first argument cited by Olympiodorus 74,26-75,2 and Introduction, p. 17.

324. 110,34. Philoponus' use of the word *tekmêrion* translated here as 'probative sign' seems to correspond to Olympiodorus' *epikheirêma* for 'argument' in marking the structure of Aristotle's hypothesis as presented by Ammonius (see Introduction, p. 17).

325. 110,34-111,5. Cf. with the second argument (*epikheirêma*) cited by Olympiodorus (75,19-23).

326. 111,11-13. 246a6-8 and 110,24-31 above.

327. 111,11-23. Cf. the third argument cited by Olympiodorus (75,14-19) and Introduction, p. 17.

328. 111,31-2. 'Why it is formed in this one', i.e. in the circle of celestial equator.

329. 111,32. 'The greatest circle' (*ho megistos*) is the one that is concentric with the cosmos and has the same radius. 'Cutting the sphere in two' (*dikhotomôn*), viz. equal parts. Cf. next note.

330. 112,6-7. Geminus, *Introd.* 5.70 lists seven types of greatest circle: the equator, the meridian, the circles through the poles, the zodiac, the horizon at each place, and the Milky Way. Cf. previous note.

331. 112,16-18. Aratus, *Phaenomena* 225-7, tr. D. Kidd. The Ram, Aries, is the sign on celestial equator (greatest circle), Bear Cynosura is Ursa Minor, which is close to the Arctic circle (smaller circle).

332. 112,26-8. i.e. not along the ecliptic, but along the celestial equator (around the cosmic poles).

333. 111,31-112,32. Cf. the second argument cited by Olympiodorus 75, 2-14 and Introduction, p. 17.

334. 112,37-9. Aratus, *Phaenomena*, 389-91, tr. D. Kidd. Water-pourer – Aquarius, Monster – Cetus, Fish – Pisces. Note the same lines quoted in Olympiodorus 77,21-5, see Introduction, p. 17.

335. 113,1. 'This is also made into a sign' , a pun: the word *sêmeion* (sign) is used for the zodiacal signs, but also in philosophy, for a kind of proof (see Aristotle, *An. Pr*. 1.27, 70a6ff.).

336. 112,32-113,9. Cf. the fourth argument cited by Olympiodorus (75,19-23) and Introduction, p. 17.

337. 113,12. 'On the sphere', Lee ad loc.: 'suggests that [Aristotle's lecture room] also contained a celestial sphere'. Thillet notes that 'diagram' must refer to the diagram accompanying the text in the manuscript, similar to some drawings preserved by the MS tradition such as the rose of winds in *Meteor*. 2.6.

338. 113,35-114,7. This corresponds to Ammonius' first objection 'from the unchanged' (Olympiodorus 75,26-9 and Introduction, p. 17). The argument is similar to the one Aristotle himself used against the theory of the Milky Way as reflection of our sight-streams 345b13-25.

339. 114,17-30. This is the objection to the argument 'from the fixed stars', not found in Olympiodorus in this precise form.

340. 114,30. 'Proof', *deiknuein*, cf. Ammonius' 'demonstrations', *apodeixeis* (Introduction, p. 17).

341. 114,30-115,16. This section contains the objections which correspond to Ammonius' 'demonstrations' (2)-(4) listed by Olympiodorus (see Introduction, p. 17). The difference of Philoponus' presentation from that of Olympiodorus is that he shows the logical connexion between these demonstrations which Olympiodorus lists as separate points. Philoponus shows that Ammonius' (2), 'from the universal', provides ground for the arguments of (3) and (4).

342. 114,33. 'Settings and risings', *krupseis kai parallaxeis*. *parallaxeis*, seems to be referring to the rising due to the deviation of the star from the accompanying effect of the Milky Way (if the latter is construed as a condition of the air, as Aristotle suggests).

343. 114,39: 'In front of them' (*hous hupotrekhei nephos*), literally, 'running beneath them', which is ambiguous, because the position of a cloud beneath the sun or the moon is conceivable within the visual field of the observer. Translating 'in front' is supposed to point to the position of the cloud with respect to the observer, closing his view of the heavenly bodies.

344. 115,5. 'Middle', reading *mesa* following Hayduck's suggestion in the apparatus (see Textual Questions 1).

345. 115,12. Cf. Olympiodorus 75,36-76,2 (= Ammonius' (4)).

346. 115,14. Cf. Olympiodorus 76,2-4.

347. 115,16. 'It is reasonable that each of the stars constitutive of that circle has some such condition' filling a lacuna in the text, see Textual Questions 1.

348. 115,16-17. 'We think that <this account is a> the myth <similar> to the one that says that this circle was formed of Hera's milk'. Filling the end of the lacuna indicated in previous note. The preceding discussion must be introducing the theme of the Milky Way as either a path of the souls ascending to the heaven or the heavenly abode of the ascended souls (this is indicated by the parallel with the myth of Hera's milk at 115,21-4 and once again by the connection between the two drawn at 117,15-18). For suggested Greek text, see Textual Questions 1. The text of the initial sentence was something like the following: *ton logon touton homoion einai hêgoumetha ton muthon tôi ek tou galaktos tês Hêras phaskonti* etc.

349. 115,16-21. cf. Achill. Tat. *Isag*. 24,1-5; see 117,13-19 below.

350. 115,24-36. In this argument against Aristotle's theory of Milky Way Philoponus seems to be deepening Ammonius' first objection, 'from sameness', using ad hominem tactics. Aristotle himself admits that the Milky Way is a permanent condition in the sky, not having any visible change. But everything in the sublunary world is subject to change. So he must either admit a theoretical contradiction or else, if he allows for some sort of change in the Milky Way, he must explain why this changing condition does not produce any appearance of change: that again would involve a methodological problem for Aristotle.

351. 115,36-8. cf. Aristotle, *Top*. 105b10-11.

352. 115,39-116,1. It is not clear whether Aristotle is committed to the view that the Milky Way will never change; it is more likely an assumption of Ammonius and others who believe that the Galaxy is a part of the heavenly rather than sublunary cosmic order.

353. 116,10. 'Eastwards', *epi ta hepomena*; 'westwards' *epi ta hêgoumena*. For this meaning, cf. Geminus *Elem*. 1.4, Theo Sm. 147 H. It is not entirely clear which spheres Philoponus is talking about. Ceteris paribus, it would be quite natural to think of the planetary spheres of Aristotle and Callippus (*Metaph*. 12.8); although it is technically possible also that these are Ptolemy's planetary spheres with epicycles.

354. 116,11-12. 'That being' (*ekeinês tês ousias*), heavens; 'as its attribute *per se*' (*sumbebêke kath'hauto*), i.e. as a non-accidental property (Philoponus is probably thinking of Aristotle's discussion of *per se* (*kath'hauto*) attributes in *An. Post.* 1.4. Philoponus must be thinking of Aristotle's second type of *per se* attribute; Milky Way belongs per se to heavenly substance, and heavenly substance belongs to the definition of the Milky Way).

355. 116,18. 'Cannot be expressed in theoretical terms' (*oude logôi rhêtê*). It is not clear whether Philoponus is aware of Ptolemy's calculation of the distance from earth to the fixed stars as 20,000 earth radii using the system of 'nested' planetary spheres in *Planetary Hypotheses* 1.

356. 116,18-23. Philoponus elaborates on two main objections. (i) The stars are too far to produce the effect described by Aristotle in his theory of the Milky Way as consisting of the 'tinder' of dry exhalation. In fact, Aristotle seems to contradict himself, since earlier in *Meteor.* 1.3 he argued that it is the motion of the sun only that heats the atmosphere. (ii) But if we grant that the motion of the stars has a heating effect strong enough to produce the Milky Way by friction, then the Milky Way should not differ from other processes in the atmosphere, which are subject to change. Because it has the same material and efficient cause as things perishable, it cannot be permanent and indestructible.

357. 116,33. In the commentary on *Meteor.* 1.3, see vol. 1, pp. 75-6, 84.

358. 116,32-5. Philoponus seems to be thinking of a possible reply by the Aristotelians, pointing out that the heating action of the stars differs from that of the sun. His answer is that in that case we would be attributing some of that action not just to friction produced by motion as in the case of the sun, but to the *quality* of the stars which determines the special type of heating. But if that is the case, the Aristotelians are in effect admitting that the cause of heating is quality, and so Platonists are on better ground again, since they believe that the stars are made of fire, while Aristotle's theory of the fifth substance makes it difficult for him to say which of its qualities is conducive to heating. It is not at all clear that Philoponus would be happy with such a theory of the Milky Way: again, the ultimate force of the argument is *ad hominem*.

359. 116,36-8. Philoponus is drawing on a lost work by Damascius, see Introduction, pp. 2-3.

360. 116,38-117,4. The argument 'from the unchanged' of the Milky Way, similar to the one used by Ammonius in the first demonstration (Ol. 75,26-9), and going back to Aristotle, see 113,35-114,7 and n. 338 above.

361. 117,4-8. Damascius seems to be using the word aether (*aithêr*) not in the Aristotelian meaning, referring to the indestructible element of which the heavenly bodies are made, but in the sense in which it is used by Plato in *Tim.* 58D1-2 (cf. *Epin.* 984B6-E3), referring to the second elemental layer after the fire, which consists of bright and pure air. The pure fire in this system is the proper element of the heavens.

362. 117,8-10. Empedotimus is the character in the dialogue *On Soul* (?) by Heraclides of Pontus. This passage is fr. 52 in Schütrumpf 2008, see also Gottschalk 1980, Kupreeva 2009, esp. 108-16. The force of 'well' in 'well appropriates' is not prima facie clear since Philoponus is severely critical of Damascius' use of the myth. It is probably an ironic reference to the affinity between Damascius' own theory and Empedotimus' story. It is possible that the first 'fairy tale' view condemned in the lacuna at 115,16 belongs to Damascius (see nn. 347-8 above).

363. 117,13. 'Heavenly becoming' (*tês en ouranôi geneseôs*): probably refers to the soul's being in the heaven (where the word 'being' is not appropriate because of the nature of the souls).

364. 117,13-19, cf. 115,16-21 above. In Damascius' account the role of Hera's myth is different from the one described in the myth above: the milk constitutes the whole cosmos (both fixed and wandering stars), while the Milky Way is the trace of the souls which sucked in Hera's milk before the ascent. For the use of the myth of Hera's milk by late Platonists, see Kupreeva 2009, 110.

365. 117,19-20. The wording is similar to the doxographical reports of Democritus, cf. 'Aët.' 3.1.6, which do not coincide with Aristotle's report in this chapter (cf. Mansfeld 2002, 33-4).

366. 117,21-6. On the soul-vehicles, see Kupreeva 2009, 111-14.

367. 117,36. 'You yourself', Damascius.

368. 118,1. Plato, *Crat.* 404B9-C5.

369. 118,9-10. Cf. 117,19-20 and n. 365 above.

370. 118,12. 'The shape of those stars would not have escaped us', i.e. we could see the constellations.

371. 118,14-15. Damascius' objection 'from brightness' is not effective because the proponents of the souls theory of Milky Way may (and do in fact) claim that the souls are made of the (heavenly) aether, i.e. they are made of the same stuff as gods and demons.

372. 118,19-20. 'Why they should stick to that beaten road' seems to be Philoponus' own, stronger, objection to the souls theory: if these are individual souls there is no clear explanation for the location of the Milky Way within the limits of physical theory. Évrard 1953 argues that Philoponus' criticisms of Damascius reflect his Christian stance, but it is not easy to see this from this bit of the discussion which seems to rely on the authority of Aristotle and the naturalistic reading of Plato (see Introduction, p. 18).

373. 118,22-4. 'Is a sign that you speak knowing none of these things, but only appear not to be ignorant of what presents itself to your imagination' (*tou mêden toutôn eidota legein, alla monon to hupopipton têi phantasiâi tou mê dokein agnoein*). Philoponus says this because Damascius criticises the theory of soul-vehicles.

374. 118,25. *Meteor.* 1.1, 339a2.

375. 118,25-6. Philoponus adopts chapter division different from the editions of Aristotle and from that used by two other commentators, Alexander and Olympiodorus, closing the chapter on Milky Way, and with it the whole discussion of the smoky exhalation, approximately one paragraph earlier (excluding the 346b10-15, which opens the next section, see Textual Questions 2). Notably, again, as at the end of commentary on chapter 3, he marks the end of a self-contained discussion covering thematically close subjects (cf. vol. 1, p. 84 n. 240 and Introduction, p. 1).

376. 118,27-8. 'In the part of the world around the earth, which is continuous with the [heavenly] motions' (*en tôi peri tên gên kosmôi tôi sunekhei tais phorais*). This is the meaning suggested by all modern translations as well as by Alexander who spells out the meaning of 'continuous' (*sunekhei*) as 'being in contact' (*to gar haptomenon sunekhes eipen*) (43,32). Philoponus in the commentary below (119,11-15, n. 379) rather oddly explains that 'continuous' (*sunekhes*) here refers nicely to the continuous and uninterrupted motion of bodies moving in a circle. He seems to understand *tais phorais* as the dative of mode rather than comitativus.

377. 118,32-119,7. See Introduction, pp. 4-5.

378. 118,6. 'Is also moderately hot'. This is Philoponus' reading of Aristotle *Meteor*. 1.3, 340b27-9, where most modern editors adopt the reading 'cold' in the description of the moist exhalation. Philoponus seems to be following the tradition of the ancient commentators (Alexander of Aphrodisias and Olympiodorus also have 'hot').

379. 119,11-15. Philoponus understands the construction 'continuous with motions' as referring to the own motions of the part of the sublunary cosmos that is carried along with the heavens. This differs from the much more common reading of this passage which takes 'motions' to refer simply to heavenly motions, and 'continuous' to the continuity existing between the heavens and the upper layer of fire. It is hard to say why Philoponus prefers this unnatural reading. He may believe that Aristotle would not want to make the heavenly region strictly continuous with the sublunary.

380. 119,15. 'Proper place', *idion topon*, a reference to Aristotle's theory of natural place from *Cael*. 4.5.

381. 119,17-18. 'Torches' and 'goats', see *Meteor*. 1.4 and Philoponus' commentary above.

382. 119,19. On shapes, see 59,30-60,12 and nn. 37, 38, 40 above.

383. 119,23 (= 346b19) Philoponus (below) understands *autou* as referring to *air*. Cf. Lee's note: '*autou* l.19 must refer to water: so O.T. and Ideler I p. 423.' Alexander takes the reference to be to *both* air *and* water (44,4-6). Olympiodorus reads *autôn* (82,26-9).

384. 119,32. 'About which he now explains', *peri hôn nun edidaxe*, aorist of aspect rather than tense (but cf. 119,6-8)

385. 120,7. 'Solids', *xêra*, the same word as for 'dry', an elemental quality, hence the contrast with the liquids.

386. 120,4-8. In *GC* 2.2 Aristotle defines the function of the heat as 'combining things that are of the same kind' (329b26-9), pointing out that its function of separation is secondary.

387. 120,8-9. In *GC* 2.2, the function of the cold is defined as combining homogeneous and heterogeneous things (329b29-30).

388. 120,11. 'Proximate and secondary cause'. In his commentary on *GC* 2.9, Philoponus illustrates the distinction between the primary and proximate efficient cause saying that 'father is the proximate efficient cause and the heavenly bodies the remote and first cause' (295,23-4). The first cause is more remote, and the proximate causes are closer to the thing that is being generated.

389. 120,17. 'Co-cause', *sunaitía*. cf. Aristotle, *De Anima* 2.4, 416a14, where fire is said to be co-cause (*sunaition*) with the vegetative soul in the process of nutrition. Fire, i.e. 'heat', as a material property, constitutes the body of a living being, where it can also act as a subordinate efficient cause, co-cause with the main efficient cause, which is a full-fledged cause. Cf. Olympiodorus ad loc. who says that the sun is the remote and secondary efficient cause of the processes in question, while cooling is the proximate and first efficient cause (*in Meteor*. 79,30-2; 83,4-11).

390. 120,35-7. The first reason why the sun, by approaching, causes coming to be, is stated in terms of formal and final cause (maturation of an individual living being and propagation of the species). Cf. Philoponus *in GC* 2.10 (289,27-290,7).

391. 120,37-9. The second reason (not incompatible with the first) is stated in terms of the material and efficient cause (generation of fruits provides nutrition, while the seed is conducive to new generation).

392. 120,41-121,3. Cf Aristotle, *De Caelo* 4.3, 310b7-23. It is remarkable that Philoponus describes this answer as the 'more universal and uncontroversial.'

393. 121,4-5. Cf. Aristotle *De Caelo* 4.3, 312a12-21.

394. 121,24-5. Aristotle, *Meteor*. 1.4, 341b6-12.

395. 121,27-9. 'As referring to the totality', i.e. to all the earth (and water) in the universe, of which there is always the same mass; this is clearly beyond the point of Aristotle's discussion.

396. 121,32-3. 'Theoretically or hypothetically', *hoionei logôi kai en hupothesei*, i.e. assuming this is the case, for the sake of explaining the origin of the moist exhalation. In reality, it is impossible to isolate the process of dry exhalation from that of moist exhalation. Since the construction Aristotle uses at 346b23 allows for conditional reading, Philoponus' puzzlement may have pedagogical aims (cf. the same explanation in Olympiodorus 83,28-84,3).

397. 122,4: 'Shiny', *steatinos*, lit. of hard fat, lard, so perhaps 'oily'.

398. 121,35-122,4. This is the explanation of the 'secondary' heating of the air around the earth by the sunrays reflected from earth. Aristotle gives it in *Meteor*. 1.3, 340a24-33, explaining why the clouds are not formed in the regions close to the earth (the reason is that reflected heat vaporises the mist). Philoponus discusses this explanation and seems to be supplying his own examples of burning mirrors, see *in Meteor*. 31,21. Alexander (ad 346b24-6) speaks of 'the heat coming from the sun and the other [heat] coming from above' (44,19-21). According to Olympiodorus (84,1-5), 'the other heat' refers to the smoky exhalation.

399. 122,11. Plato, *Tim*. 63B.

400. 122,11-14. Philoponus uses this opportunity to criticise once again Aristotle's theory of 'primary' heating of the sublunary air by the sun by friction. An extensive discussion of Aristotle's argument is to be found in his commentary on *Meteor*. 1.3; see vol. 1, pp. 70-84.

401. 122,18. 'To its own totality', see n. 395 above and the Introduction.

402. 122,19. 'Lacking tension', *atonos*, lacking strength necessary to continue the upward motion (Philoponus uses a Stoic term, cf. 84,13).

403. 122,21-4. Invoking Aristotle's theory of 'secondary' heating by reflected rays, which requires a high density of rays, such as is available at the earth's surface, in order that the air could be heated by the heat of reflected sunrays (*Meteor*. 1.3, 340a30-3 and n. 398 above).

404. 123,5-6. Reference to the mechanism of *antiperistasis* described in more detail in the beginning of the following chapter (12).

405. 122,31-123,17. Olympiodorus (84,17-26) gives the same explanation in both cases, more concisely stated, but perhaps responding to the same difficulty. He also uses a similar example of white and black. There is no similar discussion in Alexander; it is possible to think of a common source for both Alexandrian commentators.

406. 123,17. A major lacuna in all received manuscripts.

407. 123,18. Preceded by a lacuna in all the MSS that corresponds to the commentary on about one Bekker page of Aristotle text (347b34-348a20). Aristotle's chapter opens with two problems with regard to hail: (1) Hail is ice; water freezes in the winter: why do hailstorms always happen in spring or autumn, i.e. when it is not very cold? (2) How does water get frozen in the upper region, where it should evaporate? According to the view of Anaxagoras (348a15-20), the answer to question (2) is that water freezes in the upper region since it is colder there because the reflection of the sun rays from the earth does not reach it. And the same principle underlies the answer to question (1):

hailstorms happen in the warmer season (in summer and in warmer regions) because the heat forces the clouds further from the earth. The extant lemma opens the series of Aristotle's objections to this theory.

408. 124,13. No appeal is made to the sight-streams theory of vision; instead Philoponus uses Aristotle's 'canonical' theory of the transparent as the medium of vision familiar from *De anima* 2.7.

409. 124,14-18. Correct observation concerning the irregular shapes of hailstones, but incorrect explanation: the shape has to do with the way crystallisation is organised.

410. 124,22. 'A round boulder', *oloiotrokhos*, *Il*. 13.137 (cf. LSJ s.v.)

411. 125,1. 'Mutual replacement', *antiperistasis,* see Lee's note ad loc. and Furley 1989, 140-5.

412. 125,6. 348b8. 'And sometimes hail' (*hote de khalazan*). These words are missing in all Aristotle manuscripts except one and in other commentators (see Textual Questions 2).

413. 125,19-21. Apollonius of Rhodes, *Argonautica* III.225-7.

414. 125,32-126,1. Cf. Theophrastus *De Igne* 13, Philoponus *in GC* 2.10, 292,31-2.

415. 126,1-2. That Northern people have larger and stronger bodies seems to be a commonplace. Galen, *De Temperamentis* I 627, 8-16 K. says that Northern people have their innate heat inside the bodily organs and that their skin is cold and moist.

416. 126,11. 'About those who have not acquired a good end: "He got the Goth's end"', *epi ouk agathon ktêsamenôn to peras: ta pros eskhatên Gotthou pepoiêke* (see Textual Questions 1). Presumably, somebody who did not get a good end is said to have ended up like a Goth. This proverb does not occur in any known literary sources.

417. 126,18-23. Philoponus warns against a simplified picture of the hot and cold as entities exchanging places due to the season and says that in order to understand how *antiperistasis* works we need to consider more precise causal mechanisms that bring about the changes in question.

418. 126,27-8. 'In winter, when the outside air and the surface of the earth become dense': the earth freezes and the air gets condensed.

419. 127,15-26. cf. n. 417 above.

420. 128,21-2. 'In the way in which dew is the analogue of rain and rime is the analogue of snow'. Aristotle discusses these relations in *Meteor*. 1.11, 347b16-26, where our text of Philoponus' commentary has a lacuna.

421. 128,29. So it must be when still inside the cloud.

422. 128,34. 'Without depth', *abathês*, a geometrical term referring to two-dimensional figures (e.g. used of a surface by Sextus, *PH* 3.43).

423. 128,35. 'Thunders break out': thunders (discussed in *Meteor*. 2.9) are produced when bits of smoky exhalation blocked inside the cloud by cold air are squeezed out, like fruitstones from the fingers (369a22-3, on the role of the density of a cloud, 369a33-b4).

424. 129,2-3. 'Because of the short distance', i.e. the distance to the earth which frozen water traverses.

425. 129,6-8. Philoponus is probably thinking about snow and ice in the mountains where on this theory they 'associate with the hottest air'.

426. 129,20-1. 'Those waters that are pre-heated are particularly easy to chill', see 131,5-11 below.

427. 131,11. This is the end of Philoponus' text in all the extant Greek manuscripts. There are about a dozen lines till the end of Aristotle's chapter.

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English-Greek Glossary

able, be *exiskhuein*
absorb *analuein*
absurd *apoklêrôtikos*, *atopos*
absurdity *atopia*
accompany *parakolouthein*
account *logos*, *hupothesis*
act, act upon *poiein*
activity *energeia*
add a difficulty *prosaporein*
addition *epidosis*, *prosthêkê*
adjacent *sunekhês*
adjacent, be *plêsiazein, geitniazein*
adjudicate *epikrinein*
advance *proüpantân*
Aegospotami *Aigos potamoi*
aether *aithêr*
affection *pathos*
aggregation *sustasis*
agree *sumphônein*
air *aêr*
allegory *allêgoria*
along a straight line *ep'eutheias*
also refute *sunelenkhein*
alteration *alloiôsis*
always *pantote*
analogue *to analogoun*
analogue, be an *analogein*
analogous *analogos*
angle *gônia*
animal *zôion*
annular shape *krikoeidês*
ant *murmêx*
apparent *phainomenos*
apparition *phasma*
appear *phainesthai*
appear milky *galaktizein*
appear through *diaphainesthai*
appearance *emphasis, phainomenon, phantasia*
appellation *prosêgoria*
append *parartân*
apprehend *antilambanesthai*
apprehension *antilêpsis*
approach *plêsiasmos*
approach (v.) *plêsiazein*
appropriate *oikeiousthai*
Aquarius *hudrokhoos*
arbitrariness *apoklêrôsis*
arbitrary *apoklêrôtikos*
argue *elenkhein*, *pistousthai*
argument *epikheirêma, logos, pistis*
Aries *krios*
arise *sunistanai*
arrange *kosmein, diakosmein*
arrangement *diakosmêsis*
arrive *anagein hupo*
article *arthron*
artificial *tekhnêtos*
artist *zôgraphos*, *grapheus*
ascend *anatrekhein*, *epanabainein*
ascent (of the souls) *anagôgê (tôn psukhôn)*
assign the cause *aitiasthai*
associate *homilein*
assume *hupokeisthai*
assumption *hupothesis*
astronomer *astronomos*
astronomical *astrologikos, astronomikos*
at once *euthus*
at the same speed *isotakhôs*
atmosphere *to periekhon*
attending to a difference *diakrisis*
autumn *metopôron*
axiom *axiôma*
axis *axon*

backwater *palirroia*
balanced *summetros*
bath *balaneion*
beam *dokias*
Bear *arktos*
'bearded' star *pôgônias*
beat *thrauein*
beat around *perithrauein*
beat off *perithrauein*

beginning *arkhê*
belt *zônê*
bending back *antanaklasis*
bind *endein*
black *melas*
black, be clad in *melaneimonein*
blend *krasis*
blood-red *haimatôdês*
blow *ephodos*
blow (v.) *pnein, pneein*
blunt *amblunein*
body *sôma*
boiling *zesis*
book *logos*
breadth *platos*
break *thrauein, diaspan*
breast *mazos*
breath *pneuma*
breath-like *pneumatôdês*
brickstone *plinthos*
bright *lampros*, *leukos*
bright, be *eklampein*
brightness *to lampron*
bring to *anagein hupo*
bring to conclusion *sumperainein*
bring together *sunagein*
broad *eurus*
bubble *pompholux*
budding *blastê*
burn *ekkaiein*
burn out *kataphlegein*
burn through *diakaiein*
burn up *ekdapanân*
burning *ekkausis*

calculate *logizesthai*
calm weather *nênemia*
Cancer *karkinos*
Canis Maior *kuôn*
Capricorn *Aigokerôs*
carry about with *sumperiagein*
carry along around sth *sumperiagein*
carry around with *sumperipherein*
carry down along with *sunkatapherein*
catch fire at the side *parekpurousthai*
catch light *ekkaiein*
cauldron *lebês*
cause *aitia*, *aition*
cause (v.) *poiein*
cause to rise *anagein*
cave *antron*, *spêlaion*
cavity *koilôma*
celebrate *diaboan*
centre *kentron*
Cetus *kêtos*
chaff *akhuron*
change *metabolê*, *kinêsis*
change (v.) *metaballein*
chaos *khaos*
characterise *kharaktêrizein*
chasm *khasma*
cheat *phenakizein*
child, of a *paidikos*
chill *katapsukhein*
circle *kuklos*
circular *kuklikos*, *enkuklios*
circular motion *kuklophoria*
circular motion, be in *kuklophoreisthai*
circumference *periphereia*
clear *katharos*, *enargês*
clear night, weather *aithria*
clearing *dialeimma*
clearly *enargôs*
clearly seen *diaphanês*
close *engus*, *puknos*
close, be *plêsiazein*
close packing *puknotês*
close-pressed *nastos*
close spacing *puknotês*
close to, being *plêsiotês*
close to earth *perigeios*
cloud *nephos*
co-cause *sunaition*
cold *psukhros*
cold, become *katapsukheisthai*
coldness *psuxis*, *psukhrotês*
collect *athroizein, sunistanai*
colour *khrôma*
colour (v.) *khrômatizein*
combine *sunkrinein*, *sunagein*
come about *sunistanai*
come to rest *êremein*
come together *sunerkhesthai, sunistanai*
come under *hupopiptein*
comet *komêtês*
coming to be *genesis*
coming together (of the stars or planets) *sunodos* (*asterôn*)

commensurate *summetros*
comment *exêgeisthai*
comparison *sunkrisis*
complete *dianuein*
complete, be *pimplanai*
completely *dia telous*
composed, be *sunistanai*
compress *sunôthein, pilein, sunthlibein*
compression *sunôsis, pilêsis*
concave *koilos*
concentrated *athroos*
conclude *sumperainein*, *sunagein*
concoct *pettein*
concoction *pepsis*
concurrent *isodromos*, *sundromos*
condensation *sunkrisis*, *sustasis, puknôsis*
condense *puknoun*, *sunistanai*, *sunkrinein, pakhunein*
condition *pathos*
conducting sound *diêkhês*
cone *kônos*
conflagration *purôsis*, *ekpurôsis*
conflict, be in *antikeisthai*
conform in shape *suskhêmatizein*
conic shape, of *kônoeidês*
conically *kônoeidôs*
conjecture *tekmairesthai*
conjoined be *sunerkhesthai*
conjunction (gramm.) *sundesmos*
conjunction (of the stars) *sumphasis*, *sunodos*
conjunction, be in/be brought to *sunerkhesthai*
consider *theôrein*
constitution *sustasis*
consume *ekdapanân*
consume by flame *kataphlegein*
contact *haptein*
contain *sunekhein*, *periekhein*
continuity *sunekheia*, *to sunekhes*
continuous *sunekhês*
continuously *sunekhôs*
contract *sunkrinein, sunerkhesthai*
contrary *antikeimenon*, *enantios*
contrary to nature *para phusin*
contrast *antidiastellein*
convoluted, be *anadiploun*
convolution *anadiplôsis*
cool *katapsukhein*
cooling *psuxis*
co-operant cause *sunaition*
cork *phellos*
correct, be *alêtheuein*
cosmos *kosmos*
count *aparithmein*
count along with *sunarithmein*
count in *sunarithmein*
counter-objection *antiparastasis*
counteract *antibainein*
cover *epiprosthein, sumperilambanein*
create *poiein*
crimson *phoinikios*, *phoinikous*
crop *karpos*
cross *parallassein* (*parallattein*)
cross-section *diametros*
crosswise *plagios*
current of air *pneuma*
cut in two *dikhotomein*

dark blue *kuanous*
deduce *sullogizesthai*
deep *bathus*
Delphinus *Delphis*
delude *pseudein*
demonstration *apodeixis*
dense *pakhus*, *puknos*
dense texture *puknotês*
density *pakhutês*, *puknotês, puknôsis*
depict *hupographein*
depth *bathos, to bathu*
desert *apolimpanein*
determine *diastellein*
deviate *parallassein* (*parallattein*)
deviation *parallaxis*
dew *drosos*
diagonal *diagônios (grammê)*
diagram *diagramma*
diameter *diametros*
differ *diapherein*
difference *diaphora, to diaphoron*
different *diaphoros*
differentiate *diakrinein*
differentiated, be *diapherein*
differentiating characteristic *diaphora*
difficult to discern *dusdiakritos*
difficult to kindle *dusexaptos*
difficulty *aporia*
dim *amudros*

dimension *diastolê*
diminish *meioun*
diminution *meiôsis*
din *ktupos*
disappear *aphanizein*
disapprove *katagignôskein*
discernment *krisis*
discourse about gods *theologein*
discussion *didaskalia, logos*
disjunctive *diazeuktikos*
disordered *ataktos*
disorderly *ataktos*
disperse *diaphorein*
disposition *diathesis*
dissolution *analusis, dialusis, lusis*
dissolve *analuein, diakrinein, dialuein*, *ekhein dialusin*
dissolving *diakritikos*
distance *apostasis, diastasis*
distinct, be *diakrinesthai*
distinguish *diastellein*
distinguishing *diakrisis*
distribution *diadosis*
divine discourse *theologia*
do *poiein*
document *anagraphein*
Dog Star (Syrius) *kuôn*
door *thura*
double *epanadiploun*
doubling *diploê*
drag *sunephelkein*
drag along *sunôthein*, *huposurein*
draw *sunelkein*
draw conclusion *sunagein*
draw in the contrary way *anthelkein*
draw near *plêsiazein*
draw up *sunelkein*
drawing *graphê*
drive *elaunein*
drive a chariot *diphrêlatein*
drop *psekas*
drought *aukhmos*
dry *xêros*, *aukhmêros*
dry up *katadapanan*, *kataxêrainein*

earthquake *seismos*
easily affected *eupathês*
easily dissolved *eudialutos*
east *anatolê, to anatolikon*
east (adj.) *anatolikos*
easy to chill *eupsuktos*
easy to move *eukinêtos*
ebony *ebenos*
eclipse *ekleipsis*
eclipse (v.) *ekleipein*
effect *pathos*
efficient cause *poiêtikê aitia, aition poiêtikon*
effluence *ekkrisis*
eject *ekkrinein*
ejection *ekkrisis*
element *stoikheion*
elemental *stoikheiôdês*
elevation *hupsos*
embrace *periekhein*
emit (of sight-streams) *ekballein*
emit sparks *apospinthêrizein*
emit vapour *atmizein*
enclose *enapoklein, enapolambanein*
enclose with *sunapolambanein*
end *peras*, *telos*
endurance *epimonê*
enough *autarkôs*
entire *holoklêros*
entrance *parodos*
equal in powers, be *isodunamein*
equator *isêmerinos kuklos, hô isêmerinos, kuklos megistos*
err *planân*
eruption of fire *ekpurôsis*
establish *sunistanai*
evaporate *anathumian*, *exatmizein, atmidoun*
evenly *homalôs*
evidence *ta phainomena*
examination *exetasis*
example *hupodeigma*
exceed *parallassein* (*parallattein*), *huperballein*
excess *akron, huperbolê*
exchange places *antiperiistasthai, parameibein*
excrement *diakhôrêma*
exhalation *anathumiasis*
exhale *anathumian*
exhausted, be *exasthenein*
existence, *huparxis, hupostasis*
expand *pleonazein*
expel *ekkrinein*
experience *peira*

explain *aitiologein,* the meaning *hermêneuein*
explanation *didaskalia*
expose *elenkhein*
expound *gumnazein*,
extend (the discussion) *sumperainein*
extend beyond *huperballein huperekpiptein*
extraction *ekkrisis*
extraordinary *exaisios*
extreme *akron*
extremely *akrôs*

fabulous *muthôdês*
face to face *antiprosôpos*
facing *antiprosôpos*
faintness *amudrotês*
fairy tale *muthôdês*
fall behind *hupoleipesthai*
fall under *hupopiptein*
false *pseudês*
fast *takhus*
fast-moving *takhukinêtos*
faster *thatton*
feebleness *astheneia*
fibre *inarion*
fiction *plasma*
fiery *purios, purôdes*
fine *leptos*
fine-structured *leptos*
fine texture *leptomereia*
fine-textured *leptos*, *leptomerês*
finger *daktulos*
finish *peras*
finish (v.) *sumperainein*
fire *pur*, *purôsis*
first recount *proïstorein*
fixed *aplanês*, *endedemenos*
flame *phlox*
flame, become *ekzein*
flame kindled at the side *parekpurôsis*
float on *epipolazein*
flock of wool *mallos*
flood *epiklusmos*
follow *parakolouthein*
following *akolouthos*
food *trophê*
force *bia*
force, by *biaiôs*
force together *sunôthein*
forced *biaios*
forcibly *biaiôs*
form *eidos*
form (v.) *poiein*, intr. *sunistanai*
form an impression *dokein*
form in(to) image *eidôlopoiein*
formation *sunkrisis*, *sustasis*
formed, be *sunistanai*
formula *logos*
fragment *thrausma*
freeze *pêgnunai*
freezing *pêxis*
friction *paratripsis*
frighten beyond measure *ekdeimatoun*
frost *pagos*
frosty weather *pagos*
fruit *karpos*
full of light *phôteinos*
fumigate *thumian*
fumigations *thumiômena*

gathered, be *sunerkhesthai*
Gemini *didumoi*
generation *genesis*
gentle *blêkhros, êremaios*
gentleness *to blekhron*
get inflamed *phlegmainein*
give a systematic treatment *tekhnologein*
give place in turn *antiparakhôrein*
give preliminary explanation *prodidaskein*
glass *huelos*
go/move beyond *parallassein* (*parallattein*)
goal (of the work) *skopos* (*tês pragmateias*)
goat *aix*
golden *khrusoeidês*
good for kindling *euexaptos*
good order *eutaxia*
grey *phaios*
gulf *kolpos*

habit *sunêtheia*
habit, in accordance with *sunêthôs*
hail *khalaza*
halo *halôs*
hang down *apaiôrein*
hard *duskherês*

hard to discern, *dusdiakritos*
hard to work on *duskatergastos*
have formation *sunistanai*
have inclination *rhepein*
have periods of rest *stasei dialambanein*
head towards *rhepein*
heap *thêmôn*
heat *thermasia, to thermon, thermotês*
heat (v.) *thermainein*
heaven *ouranos*
heavenly *ouranios*
heaviness *baros*
heavy *barus*
height *hupsos*
hemisphere *hêmisphairion*
hide *aphanizein*
high *hupsêlos*
high above *en hupsei*, *meteôros*
hint *ainittesthai*
hold along with *sunapolambanein*
hold together *sunekhein*
hollow *koilos*
hollowness *koilotês*
hope *elpis*
horizon *horizôn (kuklos)*
hot *thermos*
hurl forth *exakontizein*
hurling *rhipsis*
hunt down *thêreuein*
hypothesis *hupothesis*
hypothetically *hupothesei*

ice *krustallos*
idea *dianoia*
ignite *ekphlogoun, ekkaiein*
ignition *ekpurôsis*
ignorance *agnoia*
illuminate *phôtizein, kataugazein*
illusion *dokêsis,* of sight *planê tês opseôs*
image *eidolon, phantasma, phantasia*
image-making *eidôlopoiia*
imagination *phantasia*
imagine *phantazesthai*

immediately *euthus*
immutable *aparabatos*
impart *metadidonai*
impassive *apathês*, *duspathês*
imperishable *aphthartos*
implicate *sumplekein*
impossible *adunatos*
impression *phantasia*
imprint *apotupoun*
in a way that suits *prosphorôs*
in accordance *sumphônos*, *sumphônôs*
in accordance with nature *kata phusin*
in agreement with *sumphônos*
in conflict with *asumphônos*
in general *hapaxaplôs*
in proportionate amount *summetrôs*
in the air *to meteôron*
in the beginning *ex arkhês*
in the right measure *summetros*
incense *thumiama*
incipient fire *arkhê puros, arkhê purôdês*
incline *rhepein*, *loxoun*, *neuein*
incommensurability *ametria*
incompetent *anennoêtos*
incongruity *atopon*
incongruous *atopos*
incredible *apithanos*
indicate *sêmainein, episêmainesthai, episêmeiousthai*
indication *sêmeion, endeixis*
indivisible *adiairetos*
ineffable *aphatos*
infer *sunagein*, *tekmairesthai*
inflammation *ekpurôsis*
initial *ex arkhês*
initially *ex arkhês*
innate *emphutos*
innate weight *emphuton baros*
inquire *zêtein*
inquiry *zêtêma*, *zêtêsis*
inseparable *akhôristos*
intensification *epitasis*
intensify *epiteinein*
intercept *mesolabein*
interpret *exêgeisthai*
interpretation exegesis
interrupt *dialeipein*
intertwine *sumplekein*
interval *dialeimma*, *diastêma*
intervene *dialeipein*
introduction *prooimion, ta prooimia*,
investigate natural causes of *phusiologein*

investigation of natural causes
phusiologia
invisible *aphanês*
irrational *alogos, arrhêtos*
irregular *anômalos*
irregular, be *anômalian ekhein*
irregularity *anômalia*
ivory *elephas*

jar-shaped comet *pithias*
javelin *akontios*
judge *kuroun*
jump *halma*
jump over *huperallesthai*

keep *stegein*
kindle *haptein, exaptein,*
ekphlogoun, ekkaiein
kindle above measure *huperexaptein*
kindling *exapsis, ekkausis*

laborious *ergôdês*
lack *endeia*
lack (v.) *ekleipein*
lacking tension *atonos*
lag behind *hupoleipesthai*
lamp *lampas*, *lukhnos*
lamp light *lukhniaion phôs*
last *teleios*
last (v.) *diarkein*
late summer *opôra*
later, be *husterizein*
leap over the *huperallesthai*
leave out *ekleipein*, (of account)
hupostellein (*tou logou*)
leek-green *prasinos*
left behind/over, be *hupoleipesthai*
legendary *legomenos*
length *mêkos,* of time *hôra*
Leo (constellation) *leôn*
lie over against *antikeisthai*
lie round *perikeisthai*
life *zôê*
light *phôs*
light (adj.) *kouphos*
lightness *kouphotês*
lightning *astrapê*
liken *apeikazein*
limit *peras*
line *grammê*
local *topikos*
local motion *topikê kinêsis*
long-lasting *polukhronios*
look *apoblepein*
look at *theôrein*
look for *zêtein*
look hard *atenizein*
loose texture *manotês*
loose-textured *araios*
lunar *selêniakos*
lune *mêniskos*

make *poiein*
make a casual remark *prosrhiptein*
make a full revolution
apokathistasthai
make fine-textured *leptopoiein*
make over *metapoiein*
make up *anaplassein*
map *katagraphê*
marsh *helos*
material *hulikos*
material cause *hulikê aitia, aitia hôs*
hulê, *aition hulikon*
mathematician *mathêmatikos*
matter *hulê*
meaning *dianoia*
meaningless *asêmos*
melt *têkein*
meteorite *lithos meteôristheis*
method *methodos*
midnight *mesonuktion*
mid-way *metaikhmios*
mid-way point *to metaikhmion*
mild *malakos*
milk *gala*
Milky Way *gala, galaxias*, *ho tou*
galaktos kuklos
mirror *katoptron*, *esoptron, enoptron*
mist *akhlus, homikhlê*
misty *akhluôdês, homiklôdês*
mock sun *parêlion*
moment *kairos*
momentum, downward *rhopê*
moon *selênê*
moon, of the *selêniakos*
more quickly *thatton*
mortal *thnêtos*
motion *kinêsis, metabasis, phora*
motley *poikilos*
mountain *oros*
mouth *stoma*

move *kinein*
move along *sunkinein*
move at the same speed *isodromein*
move in a circle *kuklophoreisthai*
move together with *sunkinein*
move under *hupotrekhein*
movement *kinêsis*
mutual replacement *antimetastasis*, *antiperiistasthai*, *antiperistasis*
mutual transformation *antimetabolê*
mutually intensify *antepiteinein*
myth *muthos*
mythological account *muthologia*

naïve *euêthês, paidikos*
name *epônumia*
natural *phusikos*, *kata phusin, phusei*
naturally *phusikôs, kata phusin, phusei*
nature *phusis*
nature, by *tên phusin*, *phusei*
near the earth *perigeios*
night *nux, hespera*
noise *psophos*
north *to boreion*
north of *boreioteros*
north wind *boreas*
northern *boreios*
northern places *arktos*
northern tropics *therinoi kukloi*
northernmost *boreiotatos*
note *episêmeiousthai*
notion *katastêma*
nourishment *trophê*

oar *kôpê*
object *antipiptein*, *diastasiazein*
objection *antilogia*, *antipipton*, *to diastasiazomenon*, *enstasis*
oblique *loxos*
obliquely *loxôs*
oblong *epimêkês*
observe *theôrein*, *paratêrein*, *epitêrein*
occult *epiprosthein*
occur *sunistanai*
oil *elaion*
old age *gêras*
opinion *doxa*
opposite *antikeimenon*
optician *optikos*
order *taxis*
order (v.) *kosmein*
origin *arkhê*
overcome *nikân*
overcrowd *pleonazein*
overpower *epikratein*
overshadowed, be *skiazesthai*

paint *katakhriein*, *graphein*
paint in white *leukographein*
painting *graphê*
painting in white *leukographia*
palm-branch *klados phoinikos*
palm-tree *phoinix*
papyrus *papuros, khartês*
parallels (on the celestial sphere) *parallêloi (kukloi)*
partake *metalankhanein*
particle *epirrhêma*
pass *metakhôrein, metabainein*
pass by *parallassein* (*parallattein*)
pass on *metadidonai*
pass the mark of the prime *parakmazein*
pass through *diaporeuesthai*
pass under *hupotrekhein*
passage *hodos, metabasis, poros*
path *hodos*
peculiar *idikos*
peculiar nature *idiazousa phusis*
perceptible *aisthêtos*
perception *aisthêsis*, *antilêpsis*
periphery *periphereia*
perishing *phthora*
perpendicular *kathetos*
persuasive evidence *pistis*
petrify *apolithoun*
phantom *dokêsis*
phase *phasis*
phenomenon *phainomenon*
picture *graphê*
picture (v.) *phantazesthai*
pip *purên*
Pisces *ikhthus*, *hoi ikhthues*
place *topos*
planet *ho planômenos*, *planêtês* (*astêr*), *to planômenon, planêtes* (*astron*)
plausible *pithanos*, *eulogos*
plenty *dapsileia*

poetry *poiêsis*
point *sêmeion*
position *thesis*
position in relation *skhesis*
possible *dunatos*
pot *lekanê*
potentially *dunamei*
pour out *ekkhein*
power *dunamis*
precise *akribês*
pre-heat *prothermainein*
present itself *hupopiptein*
press out *ekthlibein*
prevail *epikratein, huperballein*
prime age *akmê hêlikias*
principle *arkhê*
probable reasoning, use *pithanologeisthai*
probative sign *tekmêrion*
produce *poiein,* (a refutation) *epipherein*
produced, be *sunistanai*
producing a flame *ekphlogôsis*
productive *poiêtikos*
productive cause *poiêtikon aition*, *poiêtikê aitia*
projecting *propetês*
proof *pistis*
propel *exakontizein*
proportion *summetria*, *logos*
proportionate *summetros*
proportionately *analogôs*
prove *pistousthai*
proverbial expression *paroimia*
provide *khorêgein*
providence *pronoia*
proximate *prosekhês*
proximity *engutês*, *geitniasis*
pull *sunelkein*, *sunephelkein*
pull along *sunelkein, sunephelkein*
punctuate with a comma *hupostizein*
pupil (of the eye) *korê*
pure *eilikrinês, katharos*
purify *kathairein*
purple *porphurous* (*porphureos*)
push *exakontizein*, *ôthein*
push along *sunelaunein*,
push each other *antôthein*
quadrangle *tetragônon*
quality *poiotês*
quick *takhus*
quicker *thatton*
quickly *takhu, takheôs*
quiet *hêsukhia*

radiant *augoeidês*
rain *huetos*
rainbow *iris*
raindrop *psekas*
raise a difficulty *aporein*
raise to a height *meteôrizein*
Ram (constellation) *krios*
rare *araios, manos*
rarefaction *manôsis*
rarefied *manos*
rarefy *araioun, manoun*
ray *aktis*, *augê*
reach out to *exikneisthai*
real *alêthês, ousiôdes*,
real effect *hupostasis*
reality (opp. mere impression) *huparxis*
reason *logos*
reasonable *eulogos*
receive along with *sunapolambanein*
record (v.) *historein*
recorded facts *historia*
records *historia*, *to historêsai*
red *eruthros*
reflect *anaklan*
reflecting surface *enoptron*
reflection *anaklasis*
refute *anairein, elenkhein*, *dielenkhein*
refutation *elenkhos*
region *topos*
regular *homalos*
reign *dunasteuein*
relate *historein*
relation *skhesis*, *logos*
relative position *skhesis*
relaxation *anesis*
release *diakrinein*
relocate *metakinein*
relocation *metabasis*
replaced in turns, be *antiperiistasthai*
representation *phantasia*
reproduce *zôiogonein*
reside in *empoliteuesthai*
resistance *to antibatikon*

resistent *antibatikos*
resolution *diakrisis*
resource *euporia*
rest *êremia, monê*
rest (v.) *êremein*
rest, be at *akinêtein, êremein*
restrain *kolazein*
return *apokathistasthai*
revolution *apokatastasis, periphora*
revolution with *sumperiagôgê*
revolve *kuklizein*
ridiculous *katagelastos*
right away *euthus*
right, be *alêtheuein*
rime *pakhnê*
rise *anatellein, epanatellein*
rise (n.) *anatolê*
rise next to *paranatellein*
rising *phasis*, *epanastasis, parallaxis, anatolê*
rising mountains *hê tôn orôn epanastasis*
road *hodos*
rotation *periphora*
round *strongulos*
round boulder *olooitrokhos*
round-shaped *strongulos*
row *kôpêlatein*
run *diathein*
run back *palindromein*
run in the opposite direction *palindromein*
run through *paratrekhein*
run under, beneath *hupotrekhein*,
'running' of a star *diadromê asteros*
'running' stars *diatheontes asteres*

Sagittarius *Toxotês*
same kind of matter, of the *homoülos*
say *legein*
say in a myth *mutheuein*
scatter *diaspan*, *diaphorein*
scattered *sporas*
Scorpio *skorpios*
school (of philosophy) *didaskaleion*
scorch *ekdapanân*
screen off *antiphrassein, epiprosthein*
screening *antiphraxis*
sea-purple *halourgos*
season *kairos, hôra*
section *diakrisis, tmêma*
seed *sperma*
seek *zêtein*
seem *phainesthai*
semi-circle *hêmikuklion*
send off sparks, *apospinthêrizein*
sending up, *anadosis*
sense perception *aisthêsis*
senses *coll. aisthêsis*
separate *ekkrinein*, *diakrinein*
separated by a huge distance, be *akhanês*, *eis akhanes diistasthai*
separation *diakrisis, ekkrisis*
serve *diakonein*
set apart *antidiastellein, parallassein* (*parallattein*)
set at the same time *sunkataduesthai*
set on fire *ekrhipizein*, *ekpuroun*
set simultaneously as *sunkataduesthai*
setting *dusis, dusmê*, *krupsis*
settle *katastêrizein*
sever *diakoptein, skhizein*
shade *skiasma*
shadow *skia*
shadow, be in *skiazesthai*
shape *skhêma*
shape (v.) *morphoun*
sheen *phengos*
shine *phainesthai*
shine through *dialampein*, *diaphainesthai*
shining *lampros*
shiny *steatinos, diaphanês*
shoot *thallos*
shoot (v.) *diaittein*
shoot out *exakontizein, ekthlibein*
'shooting stars' *diaittontes astêres*, *diaissontes*
short-lived *takhus*
show through *diaphainesthai*
side (of a rectangle) *pleura (tetragônou*)
sideways *epi ta plagia*, *eis to plagion*, *ek plagiou*, *ek plagiôn*
sign *tekmêrion*, *sêmeion*
sign of the zodiac *zôidion sêmeion*
sight *opsis*
sight-streams *opseis*
sky *to meteôron, ta meteôra*
slant *loxoun*
slight *leptos*

slip away *parallassein* (*parallattein*)
slowness of motion *bradukinêsia*
smoke *kapnos*
smoke (v.) *kapnizein*
smoky *kapnôdês, kaumatôdês*
smouldering *anthrakoeidês*
snow *khiôn*
so called *legomenos*
soft *malakos*
solid *stereos*
solidify *pêgnunai*
solstice *tropai*
solution (of a difficulty) *lusis*
soon *takhu*
soul *psukhê*
soul-vehicle *okhêma psukhês*
sound *psophos* source *arkhê*
south *notios*
south (n.) *notos*
southern tropic *kh. tropikos*
space *topos*
spark *spinthêr*
special *idikos*
special, be *idiazein*
special matter *idiazousa hulê*
special property *idiotês*
species *eidos*
specific *eidikos*
speed *takhos, takhutês*
sphere *sphaira*
spherical, become *sphairoun*
spherical in shape *sphairoeidês*
spread *ekkhein*
spread around *periteinein*
spread over *epinemesthai, metadidonai*
spring *ear*
squeeze out *ekpurênizein*
squeezing out *ekpurênisis, ekthlipsis*
squaring (of a circle) *tetragônismos (ho tou kuklou)*
sponge *spongos*
spot *sêmeion*
stagnant, be/become *limnazein*
stagnate *limnazein*
stand close *plêsiazein*
star *astêr*, *astron*
star-gaze *epitêrein*
star-like *asteroeidês*, *astroeidês*
starry *astrôios*
start *arkhê*
starting point *arkhê*
state *legein*
stationary be *êremein*
steam *atmos*
stick out *exô neuein*
stone *lithos*
stop *pnigein*
straight *euthus* (also as adv.)
strange phenomenon *phasma*
stream *aktis*
strength *dunamis*
stretch under *hupotrekhein*
strong *biaios*
strong enough, be *exiskhuein*
structure *sustasis*
stubble *kalamê*
study *theôria*
sublunary *hupo selênên*
subsequently *akolouthôs*
substance *sustasis*, *ousia*
substantial *ousiôdês*
substrate *hupokeimenon*
succession *diadokhê*
such as to draw (the sight streams) together *sunkritikos* (*opseôn*)
suck *ekmuzein*
sufficient, be *diarkein*
suitable disposition *euphuia*
suitably mixed *eukratos*
summer *theros*
summer (adj.) *therinos*
summer solstice *therinai tropai*
sun *hêlios*
sun, of the *hêliakos*
sunlight *to hêliakon phôs*
sunrise *anatolê*
sunset *hê tou hêliou krupsis*
superfluous, be *pleonazein*
superlative degree *huperthesis*
supernatural *huper phusin*
superposition *epiprosthêsis*
supply *khorêgia*
supposition *huponoia*
surface *epipedon, epiphaneia*
surpass *parallassein* (*parallattein*)
surround *periekhein*, *perikeisthai*
surrounding the earth *perigeios*
susceptible to affection *eupathês*
suspect *hupotopein*
suspended *ekkremês*
swift *takhus*
systematic *tekhnikôs*

tail *komê*
take a side look *parablepein*
take on (affection) *antilambanesthai*
take shape *sunistanai*
take the upper hand *epikratein*
Taurus *Tauros*
teacher *didaskalos*
temperature *thermasia*
tension *epitasis*
tepid *khliaros*
text *lexis*
theorem *theôrêma*
theoretically *logôi*
theory *hupothesis*
thick *puknos*, *pakhus*
thick smoke *lignus*
thicken *puknoun*
thickening *puknôsis*
thickness *pakhutês, puknôsis*
thigh *iskhion*
thin *leptunein*
thin texture *manotês*
things in the sky *ta meteôra*
throw *rhiptein*
throwing *rhipsis*
tidal wave *kuma*
time *khronos, kairos*
tinder *hupekkauma*
top *koruphê*
torch *dalos*
torrid zone *hê diakekaumenê*
totality *holotês*
touch, *haptein*
tow *stupeion*
transform *metaballein*
transformation *metabolê*
transformed into each other, be *antimetaballein*
transparent *diaphanês*
transparent medium *diaphaneia*
transparency *diaphaneia*, *diaphasis*
transpire up *diaphainesthai*
transverse *loxos*
traverse *parallassein* (*parallattein*), *diodeuein*
treat of *dialambanein*
treat systematically *tekhnologein*
'trench' *bothunos*
triangular, be *trigônizein*
tropic *tropikos* (*kuklos*)
true *alêthês*
true, be *alêtheuein*
trust *pisteuein*
truth *alêtheia*
turn aside *hupoklinein, loxoun*
turn into air *exaeroun*
turn into vapour *exatmizein*
turn (the eyes) obliquely *hupoloxoun* (*tas opseis*)

unaffected *apathês*
unalterable *analloiôtos*
unchangeable *ametablêtos, aparallaktos*
unclear *asaphês*
uncontroversial *anendoiastos*
undergo mutual replacement *antiperiistasthai*
underlie *hupokeisthai*
undershrub *phruganôdês*
understand *anagignôskein*
uneven *anômalos*
unfold (a myth) *anaptussein*
uniform *homalês*
unify *henoun*
uninhabited *aoikêtos*
uninterrupted *adiakopos, sunekhês*
universal *katholikos*
unlikely *apithanôs*
unmoved *akinêtos*
unreasonable *alogos*
unstable *astatos*
unsuitable *anepitêdeios*
up in the sky *meteôros*
upward-moving *anôphoros*
Ursa Minor *kunosoura*
usage *sunêtheia*
use up *dapanan, ekdapanân*
usual *sunêthês*

vaporise *atmidoun*, *anathumian*
vaporous *atmidôdês*
vapour *atmis, atmos*
variation *diaphora*
variety *diaphora*
various *diaphoros*, *poikilos*
varying *diaphoros*
vertical *kathetos*
vertically towards something *kata katheton tini*
very dry *kataxêros*

very far apart, be *akhanês*, *eis akhanes diistasthai*
vigorous *akmaios*
vine-branch *klêmatis*
violent *labros*, *rhagdaios*
Virgo *parthenos*
visible *diaphanês*
vision *opsis*
visual illusion *planê tês opseôs*
void *kenos*

wander *planân*
wandering star *see* 'planet'
warm *aleeinos*
warmth *alea*
water *hudôr*
water cistern *dexamenê*
watery *hudatôdês*
wave *kuma*
way *hodos*
weak, be *atonein*
weakened, be *asthenein*
weather *aithria*
well *phrear*
well advised *eulogos*
west *dusis, dusmai, dusmai hai isêmerinai, to dutikon*
western *dutikos (meros gês)*
whip *himasthlê*
white *leukos*
white, be dressed in *leukheimonein*
wick *thruallis*
widen *eurunein*
wind *anemos, pneuma*
windy *pneumatôdês*
winter *kheimôn*
winter (adj.) *kheimerinos*
winter solstice *kheimerinai tropai*

winter tropics *kheimerinoi kukloi*
with equal force *isosthenês*
with equal strength *isosthenês*
within the same time *isokhronôs*
without a beginning *anarkhos*
without an end *ateleutêtos*
without depth *abathês*
without dismantling *athraustos*
without impediment *akôlutôs*
wood *hulê, drus*
words *lexis*
work hard *prosphiloponein*
world *kosmos*
write *graphein*
writing *sungramma*
writing in letters of gold *khrusographia*

year *eniautos*, *etos*
yellow *xanthos*

zodiac circle *zôidiakos* (*kuklos*), *kuklos tôn zôidiôn*
zone *zônê*
zenith *mesouranêma*
zenith, be in *mesouranein*

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