THE LUMINOUSNESS OF THE QUINTESSENCE

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I

IT WOULD BE CHURLISH INDEED to open fire on the many inconsistencies in Aristotle's cosmology, and foolish to try to eliminate them. There is quite enough evidence that Aristotle saw much of his cosmological speculation as essay, as trial, and that he advanced it tentatively;[1] on the whole the *De caelo* and the *Meteorologica* should be read as the deployment of unfinished doctrine. The explanatory enterprise of these books is so large that their theories must be unrefined; a degree of inconsistency is rather to be expected than not, and we should acquiesce in it.

But at least one set of problems cannot easily be passed over, namely the apparent impossibility of Aristotle's account of how the heavenly bodies—moon, sun, planets, stars—give heat and light. His proposal seems to be that these bodies are not themselves hot, but that as they orbit round the earth they chafe on the air beneath them, and the air, as a result of this friction, becomes hot and catches fire, and so emits light and heat. The principal locus for this proposal is *De caelo* B. 7:

ἡ δὲ θερμότης ἀπ' αὐτῶν καὶ τὸ φῶς γίνεται παρεκτριβομένου τοῦ ἀέρος ὑπὸ τῆς ἐκείνων φορᾶς. πέφυκε γὰρ ἡ κίνησις ἐκπυροῦν καὶ ξύλα καὶ λίθους καὶ σίδηρον· εὐλογώτερον οὖν τὸ ἐγγύτερον τοῦ πυρὸς, ἐγγύτερον δὲ ὁ ἀὴρ· οἷον καὶ ἐπὶ τῶν φερομένων βελῶν· ταῦτα γάρ αὐτὰ ἐκπυροῦται οὕτως ὥστε τήκεσθαι τὰς μολοβδίδας, καὶ ἐπείπερ αὐτὰ ἐκπυροῦται, ἀνάγκη καὶ τὸν κύκλῳ αὐτῶν ἀέρα τὸ αὐτὸ τοῦτο πάσχειν. ταῦτα μὲν οὖν αὐτὰ ἐκθερμαίνεται διὰ τὸ ἐν ἀέρι φέρεσθαι, ὃς διὰ τὴν πληγὴν τῇ κινήσει γίγνεται πῦρ· τῶν δὲ ἄνω ἕκαστον ἐν τῇ σφαίρᾳ φέρεται, ὥστε αὐτὰ μὲν μὴ ἐκπυροῦσθαι, τοῦ δ' ἀέρος ὑπὸ τὴν τοῦ κυκλικοῦ σώματος σφαῖραν ὄντος ἀνάγκη φερομένης ἐκείνης ἐκθερμαίνεσθαι, καὶ ταύτῃ μάλιστα ᾗ ὁ ἥλιος τετύχηκεν ἐνδεδεμένος. διὸ δὴ πλησιάζοντός τε αὐτοῦ καὶ ἀνίσχοντος καὶ ὑπὲρ ἡμῶν ὄντος γίγνεται ἡ θερμότης. ὅτι μὲν οὖν οὔτε πύρινά ἐστιν οὔτ' ἐν πυρὶ φέρεται, ταῦθ' ἡμῖν εἰρήσθω περὶ αὐτῶν (289a 19–35).

An earlier draft of this paper was read to the Canadian Philosophical Association in June 1978. I wish to thank Michel Roussel for first putting me onto this problem, and Andrew Lugg for subsequent encouragement. Unless otherwise noted, translations of passages in the *De caelo* are from the translation by J. L. Stocks in *The Works of Aristotle Translated into English*, ed. W. D. Ross, 2 (Oxford 1930), and passages in the *Meteorologica* are from the translation by H. D. P. Lee in the Loeb Classical Library (London 1952). As texts throughout I have used the OCT, except for the *Meteorologica* where I have used Bekker.

[1] E.g., *De caelo* 270b3, 283b31, 286a3 ff., *Meteorologica* 339a3, as well as the notorious instability of his views about the number of unmoved movers or about the besouledness of the stars.

The warmth and light which proceed from them are caused by the friction set up in the air by their motion. Movement tends to create fire in wood, stone, and iron; and with even more reason should it have that effect on air, a substance which is closer to fire than these. An example is that of missiles, which as they move are themselves fired so strongly that leaden balls are melted; and if they are fired the surrounding air must be similarly affected. Now while the missiles are heated by reason of their motion in air, which is turned into fire by the agitation produced by their movement, the upper bodies are carried on a moving sphere, so that, though they are not themselves fired, yet the air underneath the sphere of the revolving body is necessarily heated by its motion, and particularly in that part where the sun is attached to it. Hence warmth increases as the sun gets nearer or higher or overhead. Of the fact, then, that the stars are neither fiery nor move in fire, enough has been said.

When this idea is placed alongside the broad and stable features of Aristotle's cosmology, problems appear.

In addition to the traditional four elements of Greek science—earth, water, air, and fire—Aristotle postulated a fifth (*De caelo* A. 2), which he called variously the upper body (e.g., *De anima* 418b9), or the first element (e.g., *Meteorologica* 340b12), or the revolving body (e.g., *De caelo* 289a30) and which later thinkers called the fifth substance or quintessence. The spherical earth (*De caelo* 297a9) is at the centre of the world (296b8); around it and concentric with it is the sphere of water, around that the sphere of air, and around that the sphere of fire (*Meteorologica* A. 2). Under constraint these elements will intermingle to some extent, but they are always seeking to regain their proper spheres (*De caelo* Δ. 3). Their natural motion is thus vertical, or more accurately, radial. Around the sphere of fire is the sphere of fifth element; its natural motion is not radial but circular (*De caelo* A. 2), without beginning or end (A. 12), eternal (270b1), perfect (269a20), divine (286a10) (Figure 1). The heavenly bodies are made of fifth element, and they are set in the sphere of fifth element, and carried about with it as it revolves (B. 8).

Aristotle often speaks as though there is just one sphere of quintessence, but in working out the details of his astronomy he of course has to postulate a number of them, one containing the moon, one for the sun, one for each of the five planets,[2] and the outermost one for the fixed stars, all revolving on different axes at different speeds. But since the poles of each sphere are conceived as fixed to the wall of the sphere outside it, the motions become complicated. In order to build up the right, observed, motion for each of the heavenly bodies, Aristotle has to postulate some other spheres, not containing bodies, between those which do. The result of all this is that there are, in the end, fifty-six revolving spheres of quintessence nested one inside the other (*Metaphysica* Λ. 8).

Beyond the outermost sphere there is nothing, not even empty space (*De caelo* A. 9).

[2]Mercury, Venus, Mars, Jupiter, Saturn. See D. R. Dicks, *Early Greek Astronomy to Aristotle* (London 1970) 201.

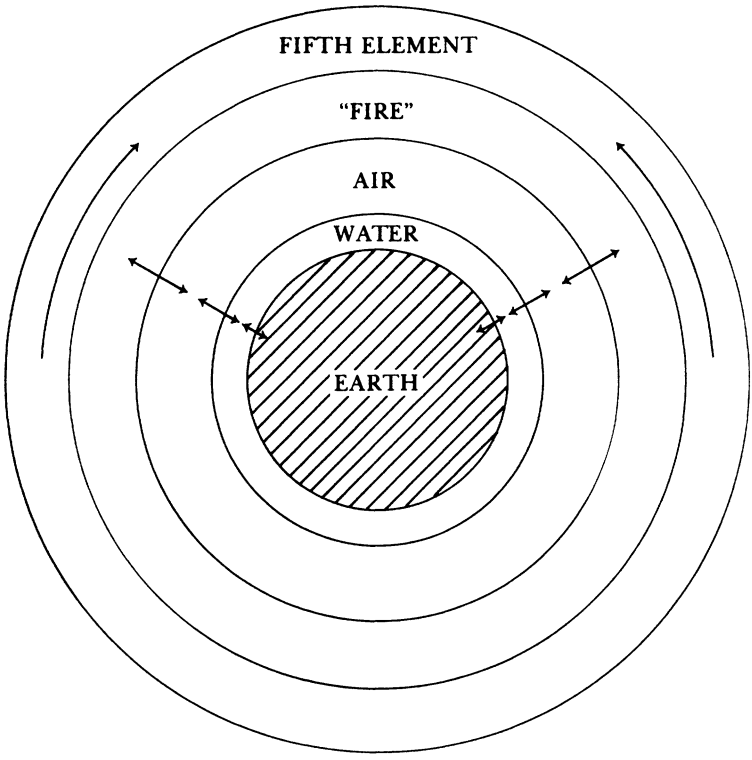

FIGURE 1.

II

THREE PROBLEMS

With this brief résumé of Aristotle's cosmology before us we can see the difficulties of his proposal concerning the light and heat from the heavenly bodies.

a) *Air and Fire.* The next-to-outermost layer of the world, in Aristotle's view, is not air but fire. If the bodies in the outer sphere, the quintessence, are to chafe upon anything, it can only be upon fire that they chafe. Fire is even more flammable than air (*Meteorologica* 341b20), so it is odd that Aristotle should be so definite that it is air that is ignited.

b) *Localized Chafing.* If a heavenly body is embedded in the wall of the sphere which carries it in rotation, it is hard to see why the chafing should be greater at that point on the inner wall of the sphere behind which the body lies than at any other place on the inner wall of the sphere (Figure 2). The image is like that of a hollow glass globe inside whose wall a grain of sand is embedded. Set the ball rotating. Why should there be any more friction with the air just where the grain of sand is than elsewhere?

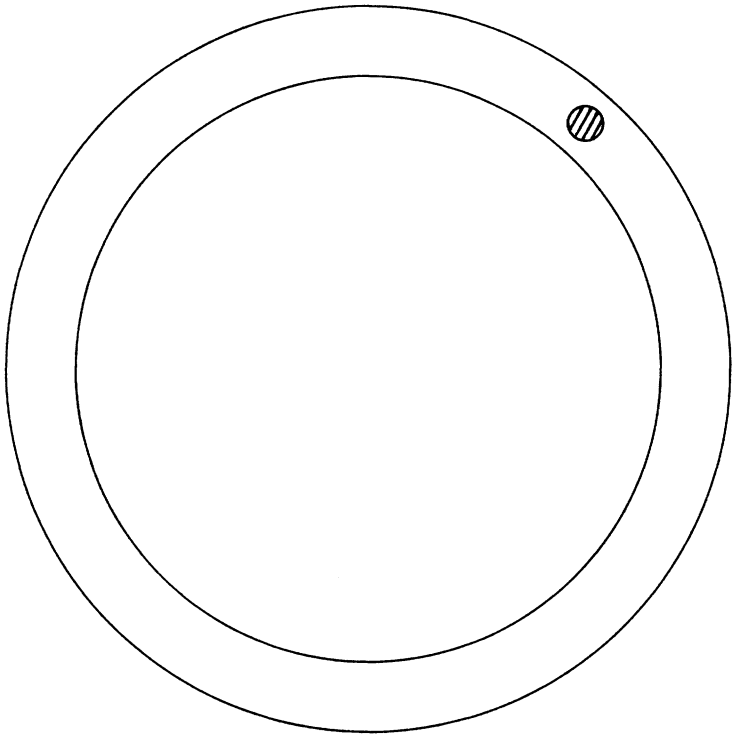

FIGURE 2.

c) *The Remote Bodies.* One could solve the second problem by supposing that the heavenly body protrudes inward from the sphere which carries it—rather as the nipple of a balloon protrudes but in the opposite direction (Figure 3). But this would work only for the innermost of the celestial spheres, that of the moon, and there would remain the problem of how the more remote bodies rub on air. (For it is clear that for Aristotle those bodies are both remote and very large: in *Meteorologica* 339b30 he ridicules as childish those who infer from the apparent smallness of the stars that they are really small.) If the remote bodies are to rub on air they would have to do so through an immensely thick blanket of fifth element, like a sort of celestial Princess and the Pea.

The ancient commentators struggled to overcome these problems: Alexander worked out a theory of bewildering subtlety to do so, requiring the postulation of corporeal but immaterial rays;[3] Simplicius found this theory inadequate to the text, struggled a little on his own, and then abandoned the problem.[4] The modern commentators have either merely

[3]Simplicius, *In Aristotelis de Caelo Commentaria*, ed. I. L. Heiberg (Berlin 1894) 194b40 ff.

[4]*Ibid.* 199b1 ff.

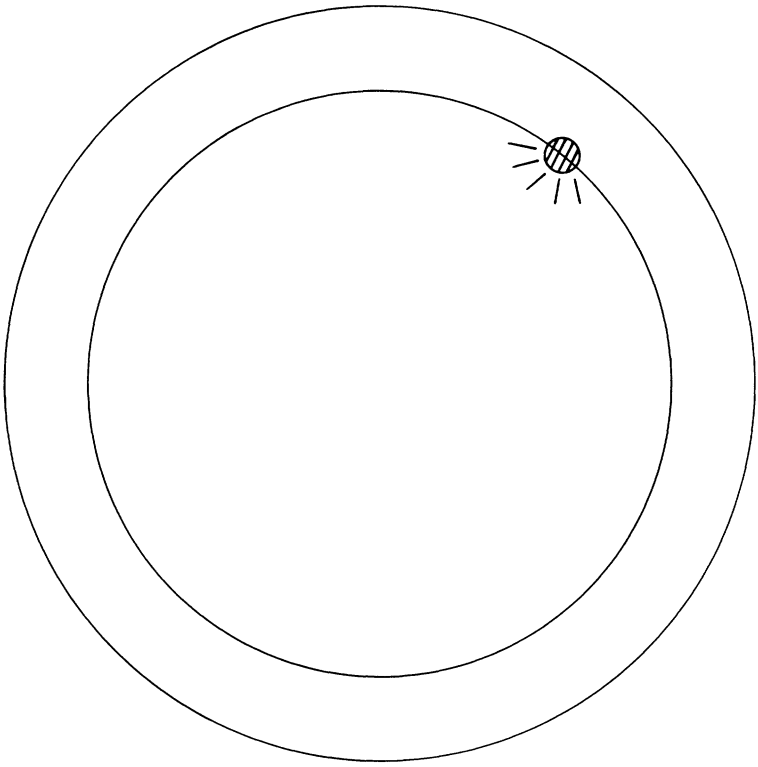

FIGURE 3.

noted the inconsistency,[5] or offered but the ghost of a suggestion how to resolve it.[6]

Several considerations argue that there *is* a solution to it, that this is not just another case of one bit of unfinished doctrine not sitting quite happily with another bit. For one thing, the incompatibility between the two is gross and obvious. For another, Aristotle must have had a reasonably clear mental picture of the circular motion of the quintessence: he was very proud of the idea, and very frequently mentions it, even in quite unexpected places.[7] That he should have made such a grotesque mistake over a central and familiar doctrine seems incredible. For another, Theophrastus, writing soon after Aristotle, finds a good deal to complain of in his predecessor's cosmology, but he makes no mention of

[5]Sir Thomas Heath, *Aristarchus of Samos* (Oxford 1966) 242; J. L. Stocks *ad* 289a34.

[6]W. K. R. Guthrie, tr., *On the Heavens* (London 1953) 179, Leo Elders, *Aristotle's Cosmology* (Assen 1966) 215–216, and Paul Moraux, tr., *Du ciel* (Paris 1965) cii-civ.

[7]E.g., *Physica* Δ. 14; Θ. 8,9; *de Generatione et Corruptione* B.10; *Metaphysica* Λ.7.

this striking problem.[8] This is far from conclusive proof, of course, but it does at least suggest that the problem may be ours rather than Aristotle's.

III

AIR AND FIRE

The first problem, then, is how Aristotle can say that the heavenly bodies chafe on air, when it is not air but fire that is the outermost sublunary layer of the world. Alexander took "air" here to mean *ὑπέκκαυμα* or "fuel of fire;"[9] Simplicius declines to accept this baldly, but interprets the line of thought in this way: the revolving spheres of quintessence communicate their motion first to the *ὑπέκκαυμα* or fiery layer, and then to the layer inside that.[10] In the end, then, the air is indeed set in motion by the revolution of the heavenly bodies. Guthrie follows Simplicius here and offers the view that the fiery substance (*ὑπέκκαυμα*) is ignited by the celestial rotation, and air is ignited in turn by fire.[11] This seems unsatisfactory. Why would it not be enough to have the *ὑπέκκαυμα* ignited? And how would the pointlike nature of the ignition from the stars be preserved through such a large layer of *ὑπέκκαυμα*?

A much simpler solution is available. There is a passage in the *Meteorologica* which echoes the thought of our troublesome text from the *De caelo*:

φερομένου δὲ τοῦ πρώτου στοιχείου κύκλῳ καὶ τῶν ἐν αὐτῷ σωμάτων, τὸ προσεχὲς ἀεὶ τοῦ κάτω κόσμου καὶ σώματος τῇ κινήσει διακρινόμενον ἐκπυροῦται καὶ ποιεῖ τὴν θερμότητα (340b 11–14).

Now this primary substance and the bodies set in it as they move in a circle set on fire and dissolve by their motion that part of the lower region which is closest to them and generates heat therein.

Interestingly, this passage does not say that it is air that is made to catch fire by the celestial rotation; it says that the nearest part of the lower region is made to catch fire. A few lines further on Aristotle is more specific about this nearest part of the lower region, and solves our problem:

περὶ δὲ ταῦτα καὶ τὰ ἐχόμενα τούτων, ἀήρ τε καὶ ὃ διὰ συνήθειαν καλοῦμεν πῦρ, οὐκ ἔστι δὲ πῦρ· ὑπερβολὴ γὰρ θερμοῦ καὶ οἷον ζέσις ἐστὶ τὸ πῦρ. ἀλλὰ δεῖ νοῆσαι τοῦ λεγομένου ὑφ' ἡμῶν ἀέρος τὸ μὲν περὶ τὴν γῆν οἷον ὑγρὸν καὶ θερμὸν εἶναι διὰ τὸ ἀτμίζειν τε καὶ ἀναθυμίασιν ἔχειν γῆς, τὸ δ' ὑπὲρ τοῦτο θερμὸν ἤδη καὶ ξηρόν (340b 21–27).

Immediately round them (sc. earth and water) are air and what we are accustomed to call fire, though it is not really fire: for fire is an excess of heat and a sort of boiling. But we must understand that of what we call air the part which immediately surrounds the earth is moist and hot because it is vaporous and contains exhalations from the earth, but the part above this is hot and dry.

[8]Theophrastus *Metaphysics*, tr. W. D. Ross and F. H. Fobes (Hildesheim 1967) chapter 3.

[9]Simplicius (above, n.3) 198a11.

[10]*Ibid.* 198a28–31.

[11]Guthrie (above, n.6) 178.

The problem seems clearly to be one of ambiguity between common language and technical language. In normal speech we call all the sublunary atmosphere air; but for scientific purposes we must distinguish two layers of air. For the lower one, which is moist, we are to keep the word "air;" for the upper, which is dry, we are to appropriate the largely inappropriate term "fire." The first problem of the *De caelo* text dissolves when we see that Aristotle is there using the word "air" not in its technical but in its common sense; in its common sense it includes what is technically called "fire"—and the heavenly bodies have at least a chance of chafing on fire, where they had none at all of chafing on air in the strict sense.[12]

It is also clear from this passage, and from others in the *Meteorologica* (e.g., 341b15, 345b32), that Aristotle is not entirely happy with "fire" as a name for what lies immediately below the quintessence. In fact, most of the scientific explanation that he undertakes in this book is offered not in terms of air and fire, but in terms of the moist or vaporous exhalation (*ἀτμιδώδης ἀναθυμίασις*, or just *ἀτμίς*) and the dry or fiery or smoky exhalation (*πυρώδη, καπνώδη ἀναθυμίασις*—or just *ἀναθυμίασις*). He does not often use "fire" to mean the dry exhalation, and he does not often use "air" to mean the vaporous exhalation. It is as though he introduces these familiar philosophers' terms to keep continuity with his tradition, but prefers more accurate ones when the real theoretical work is to be done. All the more reason, then, why he should easily slip into calling the whole atmosphere air: it isn't a violation of *his* technical language.

In any case there are other passages in the *Meteorologica* where Aristotle seems clearly to be using "air" to designate the whole atmosphere. At 342b1 he speaks of *ὁ ἄνω ἀήρ*, and clearly means means the dry exhalation. At 345b33 he writes that "the outer part of what is called air has the properties of fire." Again at 360a21: "air, then, as we have said before, is made up of these two components, vapour which is moist and cold . . . and smoke which is hot and dry."

Furthermore, as one reads on into the *Meteorologica* and gets a better sense of Aristotle's theory of the dry and vaporous exhalations by seeing them put to work, it becomes clear that at least these two elements intermingle very extensively. Indeed virtually all the phenomena he explains in this book—from comets to earthquakes to the saltness of the sea—are caused by different forms and degrees of intermingling of the dry and the moist exhalations.[13] This fact gives Aristotle a good reason

[12]E. W. Webster's rendition in the Oxford Translation is misleading. *ὃ διὰ συνήθειαν καλοῦμεν πῦρ* should not be rendered "what we commonly call fire," for that suggests that we call it so in everyday speech; but in everyday speech we call the whole lot air. The phrase would be better translated "what is conventionally called fire."

[13]I.e., in *Meteorologica* A, B, Γ. Book Δ is more terrestrial in its concerns.

not to drop altogether the use of a term meaning the whole atmosphere: any bit of atmosphere one may encounter is likely to be neither entirely vaporous exhalation nor entirely fiery exhalation, but a mixture of both.

Altogether, then, it is not only possible, but unsurprising and natural that Aristotle should refer to the whole intermingled atmosphere as air, and when "air" is understood in that sense the first problem of the *De caelo* text disappears. The nearest thing for the heavenly bodies to rub against is, precisely, air—the mingled vaporous and dry exhalations.

IV

LOCALIZED CHAFING

The second problem was that of explaining how it is, since the whole shell of the quintessence revolves, that the chafing occurs only at the places where the heavenly bodies—moon, sun, planets, stars—are fixed. Aristotle nowhere suggests that they protrude from the shell which carries them, and yet, unless they do, how can they be in friction with the air?

The first part of the answer is that the chafing is *not* altogether localized. At least the text of the *Meteorologica* just cited suggests that it is not: "this primary substance and the bodies set in it, as they move in a circle set on fire and dissolve by their motion that part of the lower region which is closest to them and generate heat therein" (340b11–14). Now this chapter is concerned solely with the phenomenon of heavenly heat, not with heavenly light. The picture which begins to emerge is that, whereas heat is generated by the general friction all along the surface where the celestial and terrestrial spheres meet, the greater friction that is required to produce light occurs only at the places where the heavenly bodies are set.

But this point, though it refines the statement of our problem, does not advance its solution. For now we must explain why the friction is greatest at those parts of the sphere behind which lie heavenly bodies.

It might help if we had a clearer idea of the relationship between a heavenly body and the sphere which carries it. We know that both are made of fifth element (289a18), and it seems clearly implied by a text of the *Meteorologica* that the heavenly bodies are solid (341a28); but are the spheres which carry them solid, liquid, or gas? I can find no text which raises this question. Later tradition knew the spheres as crystalline, but there is no hint of this notion in Aristotle. We are told in *De caelo* A. 3 that the upper body can possess neither heaviness nor lightness (270a6), that is, neither a tendency to move downwards nor a tendency to move upwards (269b23); and that neither naturally nor unnaturally can it move with any motion other than its own (270a10).

This last point might suggest that the spheres are rigid and so prevented from downward or upward motion. But if they are rigid they are

solid, and how then would the bodies which they carry differ from them? Simply by being more dense? This seems bizarre. But in any case it doesn't do justice to the special nature of Aristotle's fifth element. The rigidity of a sphere would stop its radial collapse, but a rigid sphere would still have the tendency to collapse. Aristotle's fifth element, however, lacks even the tendency to collapse.

It might seem that we can solve our problem about localized chafing if we assume that the sphere of fifth element is gaseous, whereas the heavenly bodies are solid. Gas is more pliant than a solid, and we might think that the rush of air created as the sphere revolves pushes back on the gas leaving the heavenly bodies protruding (Figure 4) to generate strong friction. But this idea is of no use either, for fifth element will not be moved in a radial direction by any force whatever (270a10).

No solution to the problem of localized chafing is emerging. Let us leave it aside for the moment and turn to the third problem, that of the chafing of remote bodies. These two problems are not independent; perhaps a solution to the third will carry with it a solution to the second.

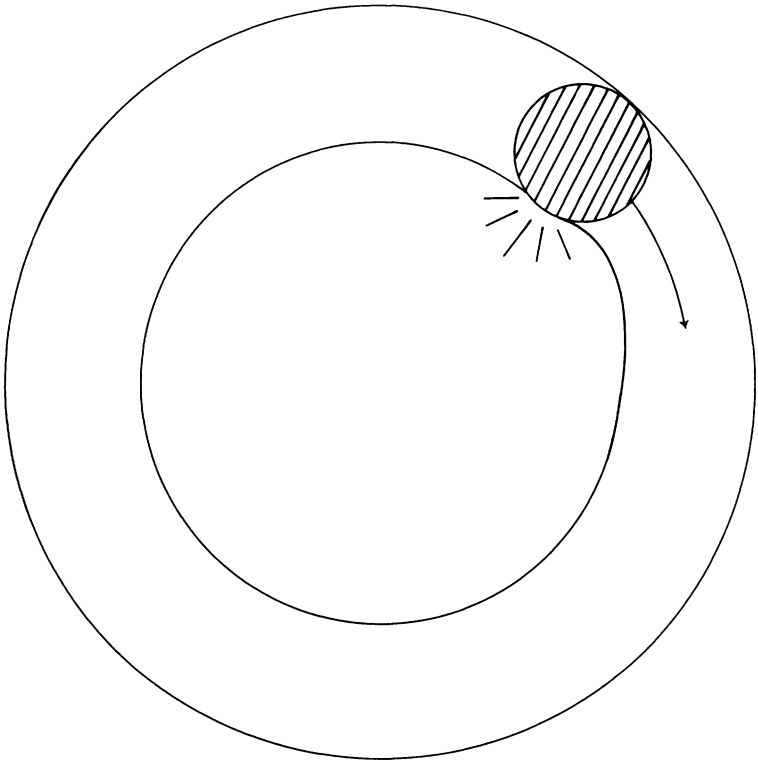

FIGURE 4.

V

THE REMOTE BODIES

Solution (a): The Princess and the Pea. I suggested earlier that, given the picture of the world that one naturally extracts from the *De caelo*, the only way for the remote bodies to chafe on air would be for them to chafe *through* the blanket of quintessence in which they are set, like a celestial Princess and the Pea. The presence of a solid body even far off in the quintessence would cause a protrusion in the inner surface (Figure 5), and that protrusion, moving as the remote body moves, would grate upon the air and inflame it. The idea is an elegant one, but it founders on several problems.

In the first place, the stars appear to be points of light. Now the normal effect of blanketing an object is to enlarge and diffuse its apparent shape. Even if the fifth element made a perfect blanket, through which the shape and size of the body protruded unaltered, the stars ought each to appear to be as large and as bright, roughly, as the sun. And Aristotle explicitly says that the stars are very large, but very

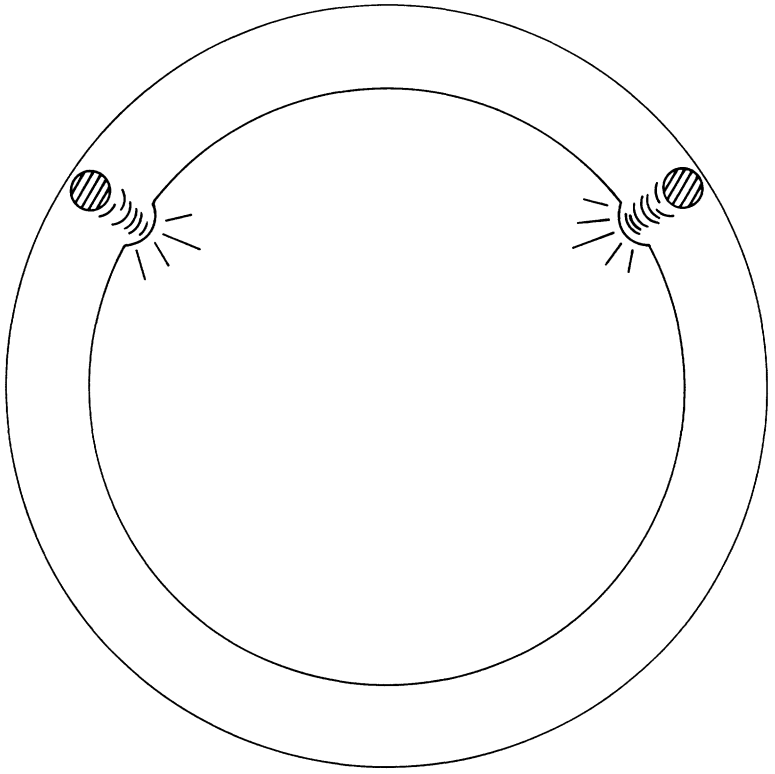

FIGURE 5.

distant (339b8, 34; 355a20). If the fifth element makes an imperfect blanket, then the stars ought to appear much larger and dimmer than the sun. The phenomena will not be saved by this theory.

Secondly, eclipses of the sun could not be produced. The effect of the passage of the moon before the sun would be to *increase* the protrusion into the air, so that an eclipsed sun should be brighter and hotter than an ordinary one.

A third objection is definitive. We remember that there are fifty-six spheres of quintessence nested together and revolving on different axes and at different speeds. Protrusions, therefore, into the air from the remotest stars, the fixed stars, would have to work through fifty-five moving blankets. Consider how this would work. Assuming that the spheres are flush with each other—and if they are not the protrusion will be lost in the intervening space—the spheres will have to be elastic, each bit of a sphere being displaced inwards as it passes over a lump, and moving back into place when the lump has gone by. The image requires something that Aristotle does not allow: radial motion in the fifth element. For as a bit of quintessence gives way to the lump and then falls back it is moving radially, first down and then up again. But the quintessence has neither a tendency to move downwards nor a tendency to move upwards, and "it cannot move locally by being violently forced either up or down, for it is impossible for it to move, either naturally or unnaturally, with any other motion but its own, either itself as a whole or any of its parts" (270a10 ff.). These lines could almost have been written expressly to rule out the Princess and the Pea hypothesis.

Solution (*b*): Alexander's subtle solution to these problems begins with the observation that quite often one thing can affect another through a medium without similarly affecting the medium itself. He gives the example of the sun, which can ignite dry wood without igniting the intervening air; or again, a torpedo can numb a man through a fishing net without numbing the net as well.[14] Alexander proposes that in a like way the heavenly bodies produce a chafing on the air without chafing the fifth element. Simplicius offers a version of the mechanism of this: the heavenly bodies emit corporeal but immaterial rays which pass unhindered through the immaterial quintessence. When they reach the material air, however, their progress is impeded and they cause a disturbance, thus heating the air.[15]

Now the rays in question must be rays of light, since the Greeks knew of no other sort; so this explanation does not do justice to the *De caelo* text, which was clearly meant to explain not only celestial heat but also celestial light: "the warmth and light which proceed from them. . . ."

[14]Simplicius (above, n.3) 198b20 ff.

[15]*Ibid.* 198b40 ff.

Alexander, however, is assuming that the heavenly bodies just *are* luminous, and he uses this assumption to explain their heat. Simplicius refers to a passage in *De anima* B. 7 (at which we shall be looking) to justify the view that the stars just are luminous;[16] but that, of course, does not lessen the difficulty that Aristotle explicitly says, in a text that shows no sign of corruption, that his friction theory explains heat *and light* from the stars. Alexander's interpretation cannot be correct, for it assumes and uses as *explanans* part of what Aristotle wanted to explain.

Solution (c): Impurity of the Quintessence. A third line of solution to these difficulties, to which several commentators have adverted, relies on a text in the *Meteorologica* in which Aristotle asserts that the quintessence is impure:

τὸ μὲν γὰρ ἄνω καὶ μέχρι σελήνης ἕτερον εἶναι σῶμά φαμεν πυρός τε καὶ ἀέρος, οὐ μὴν ἀλλ' ἐν αὐτῷ γε τὸ μὲν καθαρώτερον εἶναι τὸ δ' ἧττον εἰλικρινές, καὶ διαφορὰς ἔχειν, καὶ μάλιστα ᾗ καταλήγει πρὸς τὸν ἀέρα καὶ πρὸς τὸν περὶ τὴν γῆν κόσμον (340b 6 ff.).

The celestial region as far down as the moon is occupied by a body that is different from air and from fire, but which varies in purity and freedom from admixture, and is not uniform in quality, especially when it borders on the air and the terrestrial region.

The picture this gives is that the fifth element is not unalloyed nearest to the earth and only gradually becomes so out towards the fixed stars. It seems reasonable to suppose that the adulterant is air, the mixture of moist and dry exhalations. That is, lower down air is actually mixed in with the fifth element.

The two commentators who have adopted this solution, Elders and Moraux, take from it a seven-layer-cake view of the outer world, in which spheres of air alternate with spheres of quintessence.[17] That, together with the assumption that the heavenly bodies protrude from the matrix of fifth element which carries them, will give rise to the friction between heavenly bodies and air which the *De caelo* text seems to require.

I find this picture somewhat implausible. It does not easily fit the text, since it would be very unnatural to use the language of impurity and admixture to describe a system of alternating layers. Furthermore, it is so precise an image that it is odd that Aristotle would *not* describe it in some detail if it were what he had in mind.

Another picture can be more readily extracted from this text: simply that the air which adulterates the quintessence is mixed up with it more or less thoroughly, like oil and vinegar in a salad dressing. Lower down the proportion of air mixed in is much greater than it is further out.

[16] *Ibid.* 199a9.

[17] Elders (above, n.6) 216; Moraux (above, n.6) cii-ciii.

We can see how this picture might account for the required friction. The natural movement of air is radial, though it can be made to deviate; the natural movement of the quintessence is circular. Where the two are mixed their tendencies will always be at odds. The quintessence, being divine, will always win, but not without a heat-releasing struggle. We might further suggest that, whatever the material state of the quintessence in the spheres, it is quite rare or porous, so that air can move through it without much friction; the quintessence in the heavenly bodies, on the other hand, might be thought to be densely packed, so that when air gets into *its* way there is much more friction, giving off heat and light. This solution would also explain the dimness of the stars: that far out the quintessence is fairly pure, so there are not many particles of air for them to collide with. Further, when Aristotle writes in the *De caelo* that the air is fired by the revolving sphere "especially in that part where the sun is fixed" (289a32), he might mean that in the lower region of the quintessence, where the sun is, the proportion of air is great, and so there is more friction and more heat.[18]

[18]This solution seems simple and obvious, and in retrospect it is astonishing that one should not have hit upon it at once. All the other elements intermingle extensively in in Aristotle's cosmology; why, then, did we so readily assume that the fifth element is pure? (We are not the only ones to have done so. The critical tradition which follows this line of solution goes back, as far as I can see, only to Guthrie's Loeb translation of 1939.) Aristotle nowhere claims that the quintessence is pure, only that it is eternal, perfect, divine, and revolving. Somehow we have unconsciously inferred that the quintessence must be pure as well. Why?

The only justification for such an inference would be the metaphysical principle that "relations are internal," that a thing's relational properties are part of the constitution of that thing. According to this principle, if A is related to B, a change in A *itself* constitutes a real change in B. For example, Mr Roberts is related to me in that he is my landlord; if Mr Roberts takes off his red socks and puts on his yellow socks one day, a change in me has occurred. I have shed the property of having a landlord in red socks, and replaced it with the property of having a landlord in yellow socks. The claim is not that this change in my landlord's dress induces some further change in me (a change in my knowledge, for example), but that it by itself constitutes a change in me, a change in one of my relational properties.

Now Aristotle held that the quintessence is eternal, and he usually regards what is eternal as immutable. Quintessence, that is, is not subject to change. Normally one would have thought that this is easy to secure: the quintessence can surely itself be unchanging even if it is studded with pockets of changeable air. The quintessence can be impassive as the air smoulders or ignites or cools down. But if relations are internal this is not so. The change in temperature of a pocket of air would, given that principle, itself constitute a change in the tract of quintessence next to it. That tract of quintessence alters from the state of being beside a pocket of cool air to the state of being beside a pocket of hot air. This may well produce no change in the temperature of the quintessence, but it would still *be* a change in the quintessence—a change in its properties, albeit its relational properties. Thus, if relations are internal, the quintessence can be immutable only if it is free from all relation with the changeable substance—only if it is pure.

To this solution, however, there are two objections, one definitive:

(i) If we account for the heat and light from the stars by taking the quintessence to be impure, we must suppose that the friction takes place at various places all through the quintessence: that seems to be the only way for it to occur at all in the case of the remote bodies. But one of the two *De caelo* texts on the subject seems definitely to say "the air underneath the sphere of the revolving body is fired. . . . :" *τοῦ δ' ἀέρος ὑπὸ τὴν τοῦ κυκλικοῦ σώματος σφαῖραν ὄντος ἀνάγκη . . . ἐκθερμαίνεσθαι* (289a29). It is not the air that is dissipated throughout the sphere that is fired, but the air that is *underneath* it. It is hard to see how this text can be squared with the picture we have been elaborating. One possibility is that this part of this passage, like the whole parallel passage in the *Meteorologica*, is only about heat, not about light. The extended analogy which precedes this sentence suggests that such may well be the case: *it* is all about heat and there is no mention of light. And of course heat *is* produced by the rubbing of the quintessential sphere against the sphere of air. But it would be preferable to find some way in which *ὑπό* here could mean "dissipated throughout."

(ii) A second problem is more serious. Two chapters after this passage of the *De caelo* comes Aristotle's famous rejection of the Pythagorean doctrine of the harmony of the spheres. In the course of that rejection Aristotle denies both that "the stars move in a quantity either of air or of fire diffused throughout the whole" (291a19), and also that the heavenly bodies are in friction with their surroundings: he likens them to a ship which moves downriver with the current and is stationary in regard to it (291a10). That is, not only does the impurity of the quintessence seem to be denied, but also the basic notion that the stars are somehow in friction. Guthrie remarks, "the inconsistency with ch. vii, in which friction with the air is adduced to account for the brightness of the stars, seems glaring and indefensible,"[19] and the other commentators join chorus with this.[20]

Of these two difficulties the first can be overcome fairly straightforwardly. Aristotle need not be denying that there is *any* air and fire diffused through the upper region, but only that there is a mass of it,

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This doctrine exercised a powerful hold over Alexander and Simplicius, who as a result made heavy going of the fact that Aristotle wants the quintessence sometimes to rub on air and sometimes not ([above, n.3] 196a19 ff.); it may have been the grip of the same doctrine which led Elders and Moraux to their seven-layer-cake model: in that model the quintessence is pure at least within each layer, if not overall. But the doctrine is not characteristic of Aristotle, and if we dismiss it we dismiss some problems in reading him—in particular a barrier to construing the *Meteorologica* text in the more natural way that I suggest.

[19]Guthrie (above, n.6) 196.

[20]E.g., Moraux (above, n.6) ciii.

enough to count as the medium through which the bodies move. The whole emphasis of the argument in this chapter is that the heavenly bodies are carried in a moving medium, not moving through a stationary one. For "what makes noise is that which is moving in a stationary medium" (291a16), and noise is precisely what Aristotle seeks to preclude. A whole mass of air or fire would be stationary with respect to the bodies; Aristotle is concerned to deny that *that* is the arrangement. The spheres of quintessence he postulates are a moving medium, and it makes no difference to his point if this moving medium is somewhat adulterated with air or fire.

But the second difficulty remains. On the one hand Aristotle postulates friction to explain heat and light; on the other he denies friction in order that there shoud be no sound.

Nor can we regard the chapter on the harmony of the spheres as a momentary aberration. For it is supported by another troubling doctrine mentioned at various places in the *Meteorologica*, namely that the whole mass of the air about the world moves in a circle around it, carried by the motion of the heavens (340b34 ff., 344a11 ff.). If the air moves *with* the quintessence, how can any bit of quintessence chafe upon it? Friction requires that things move against each other, not with each other. The incoherence here seems to run distressingly deep.

VI
FRICTION AND MOTION

But in fact there is no incoherence here at all. It is we who are projecting a bit of our own science onto Aristotle. A careful look at the various statements about the firing of air shows that it is not *friction against* the air which causes it to fire, but *movement of* the air. We possess a unified science of thermo-kinetics; when a missile is in motion we say that it is in friction with air, and so both the missile and the air heat up. For us the motion is the remote cause, and the friction the immediate cause, of heat. The Greeks, I believe, saw friction and motion as alternative immediate causes of heat.[21] For them, that is, a missile moving without friction would heat up just by its motion. Moreover, I doubt that they would think that there is any very significant amount of friction between air and a missile which cleaves it. When a missile moves in air the heat comes almost entirely from motion, not from friction.

This vital point is borne out by a careful reading of the *De caelo* passage. There it is *movement* which is said, by nature, to cause heat in

[21]For non-Aristotelian evidence see Plato *Theaetetus* 153a7–10. The language here—especially the dual τούτω—strongly suggests that φορά and τρίψις are distinct causes of heat.

wood, stone, and iron (*πέφυκε γὰρ ἡ κίνησις ἐκπυροῦν*), and since air is closer in nature than these to fire, movement will heat up air all the more readily. This part of the argument makes no sense unless Aristotle means that *movement* makes air fiery. Notice too the progression of thought in the analogy of missiles: the missile is heated by its movement, and consequently the surrounding air is also heated. How does this happen? Not just by heat transfer; rather, the surrounding air *διὰ τὴν πληγὴν τῇ κινήσει γίγνεται πῦρ*. The Oxford Translation renders this as "turned into fire by the agitation produced by (sc. the missiles') movement." But that requires that a dative of means modify *πληγή*—a highly unnatural construction. It would be more natural to take the dative to belong to *γίγνεται*: the air, as a result of the blow (from the missile), is fired by means of motion. This reading accords with the view that it is movement, not friction, that is here the immediate cause of heat. The blow is a remote cause of heat, for it sets the air in motion, and the motion of the air is the immediate cause of its heat.

δεῖ δὲ νοῆσαι οἷον ὑπέκκαυμα τοῦτο ὃ νῦν εἴπομεν πῦρ περιτετάσθαι τῆς περὶ τὴν γῆν σφαίρας ἔσχατον, ὥστε μικρᾶς κινήσεως τυχὸν ἐκκάεσθαι πολλάκις ὥσπερ τὸν καπνόν (341b 19).

Now we must think of the substance we have just called fire as extending round the outside of the terrestrial sphere like a kind of inflammable material, which often needs only a little motion to make it burst into flames, like smoke.

Here there is no mention of friction at all: the dry exhalation is fired just by being in motion. Other evidence along the same lines is to be found, e.g., at 344a14 and 345b34.

Unfortunately, however, the *De caelo* text does seem unambiguously to speak of friction: *παρεκτριβομένου τοῦ ἀέρος ὑπὸ τῆς ἐκείνων φορᾶς*. This, though, seems to be the only occurrence of *παρεκτρίβω*, and so its exact meaning must be taken from a reading of this passage. Now *παρεκ-* in compounds has a number of different forces; one of them is the notion of deviation from a norm, as in *παρεκδέχομαι*, misconstrue; *παρεκβαίνω*, transgress; or *παρεκτελέω*, accomplish against one's wish. And although *τρίβω* primarily conjures up an image of rubbing, it can also signify a notion which is less directly frictive, namely the inflicting of blows. In the *Knights* (5) Aristophanes speaks of *προστρίβεσθαι πληγάς*, meaning beating with stripes. In the present chapter of the *De caelo* as well as in B. 9, *πληγή* is Aristotle's word for the impact of a moving body on its medium: I suggest that we find in *παρεκτριβομένου* not the notion of being rubbed, but rather that of suffering a series of impacts, being buffeted. The air is buffeted along by the quintessence and is thus made to diverge (*παρεκ-*) from its normal radial motion to a circular one. The pockets

of air in the quintessence are jostled along in a circular path, and this motion makes them ignite.

There is no significant rubbing, then, between air and quintessence, but the air both in and beneath the quintessence is buffeted along in a circular path. Although there is πληγή of the quintessence upon the air, no sound is made by this, for the air is carried along with the quintessence. In the same way a river which carries a ship downstream makes πληγάς on the hull of the ship,[22] but since the ship moves with the river, no sound is made. "Bodies which are attached or fixed to a moving body . . . do not make sound" (291a10).

This subtle but important revision in the theory about how the stars give heat and light removes the glaring incompatibility between this chapter and the chapter denying the harmony of the spheres. The heavenly bodies are not in friction with the air, for the air is carried along by them. (Indeed this last point is made explicitly in the *Meteorologica* at 340b34 ff. and at 344a11 ff.) What produces heat and light is the *motion* of the air as it is buffeted along by the gyrating quintessence.

VII
"BENEATH THE SPHERE"

One problem in the *De caelo* text remains unsolved, namely the meaning of ὑπό in τοῦ δ' ἀέρος ὑπὸ τὴν τοῦ κυκλικοῦ σώματος σφαῖραν ὄντος. If it means "underneath," then it refers only to the sublunary air, and not at all to the pockets of air that are caught up *in* the quintessence. Now it is true that this sublunary air is in motion, and thus true that it heats up (*Meteorologica* 340b11–14); but if this is the only air that is so affected then the problem of the luminousness of the remote bodies arises all over again. We must either admit that Aristotle is here explaining only a small part of the phenomena he is concerned with, or else we must read ὑπό in such a way that it includes the air in the remoter regions of the quintessence. Clearly the latter is the preferable alternative.

The standard phrase in Aristotle for "under the ground" is ὑπὸ γῆν; this does not mean under the whole sphere of the earth, but *in* the sphere of earth, *under* its crust. I suggest that we construe ὑπὸ τὴν σφαῖραν in an analogous way: underneath the crust of the quintessence, underneath the roof of the world. At first glance this is an unnatural way to speak, for it implies that one is standing outside the globe of quintessence, as in the other case one is standing outside the globe of earth. But it becomes more natural if we suppose that Aristotle had in the room a globe representing the world, or perhaps a diagram of the world, and referred

[22] I infer this from the fact that Aristotle lacked the concept of inertia, and tie that to his theory of movement in a medium, expressed, e.g., at *Physica* 215a15.

to it as he spoke. Pointing to such an object, it would be natural to speak in a way which suggests that we stand outside the world.

Moreover, if it was a diagram that he had, since the world chart is geometrically very simple (Figure 1), Aristotle may well have slipped into mathematical language in describing it. Now in Euclid ὑπό with the genitive regularly means "enclosed by"[23]—the rectangle enclosed by AB & BC, the angle enclosed by ABC—and ὑπό with the accusative means "subtending,"[24] the side subtending an angle. Much later, in Pappus, the phrase ὑπὸ τὴν σφαῖραν means "inscribed in the sphere."[25] It appears, then, that ὑπό with the genitive signifies exhaustion (the angle enclosed by ABC takes up the whole of ABC) but ὑπό with the accusative does not signify exhaustion (the side which subtends ABC does not fill up the whole space described by ABC). Similarly in Pappus, the cube inscribed in the sphere does not fill up the whole sphere. If, therefore, Aristotle is looking at a diagram as he speaks, since the air in question does not fill the whole of the sphere but is only scattered in pockets here and there, ὑπό with the accusative is the appropriate mathematical jargon to use. And when referring to a two-dimensional drawing it is natural to take "sphere" to mean just the circumference of the drawn circle. τοῦ δ' ἀέρος ὑπὸ τὴν τοῦ κυκλικοῦ σώματος σφαῖραν ὄντος may thus be read "the air which subtends the sphere of quintessence."

VIII

LIGHT AND SHINING

Abstractly, then, our problems are solved. But when we try to picture how the system works an old difficulty recurs. What explains the *localized* brilliance of the heavenly bodies? On a friction model localized chafing was possible, but we have given up friction and substituted motion. But *all* the air that is caught up in the quintessence is in motion, so why is there not general brilliance? Is it that little pockets of air close to, and just the same size as, the heavenly bodies are in more rapid motion than the rest? This seems unlikely. Or should we say that each heavenly body is attended by a pocket of air of just the right consistency to burn at the speed of motion of the body, though the rest of the air (at night) is not of the right consistency? This seems somewhat intricate and arbitrary.

Here again the problem is that we are in the grip of our own scientific doctrines. Aristotle did not rejoice, as we do, in a comprehensive and settled theory of light, and partly because of this he did not mean quite what we mean by "light." His theory is set forth in *De anima* B. 7. Light

[23]Euclid, *Elementa*, edd. J. L. Heiberg and H. Menge (Leipzig 1883) 2.4.
[24]*Ibid.* 6.4,5,6.
[25]Ed. F. Hultsch (Berlin 1876–1878) 440.5

is there defined as the actualized transparency of a medium, and by a transparent medium he seems to mean one which, so to speak, looks bright: "light is, as it were, the proper colour of what is transparent" (418b12). Light, however, is not necessary to vision, for some things can be seen in darkness, for example fungi and fish scales and eyes. (Presumably the fungi in question are phosphorescent, and perhaps the fish are, or perhaps they are just good reflectors, as we should say, catching and reflecting the otherwise invisible ambient light.) That is, Aristotle does not use his concept of light to cover—as we would do—these dimly luminous phenomena. The point emerges quite starkly in a parallel passage of the *De sensu*: "things which are smooth have the natural property of shining in darkness, without, however, producing light" (437a33).

Shining, therefore, is not necessarily light; and shining in darkness is definitely not light. Now the stars and planets certainly, and the moon perhaps, shine in darkness. That shining does not, on Aristotle's view of light, count as light. So the *De caelo* passage is not seeking to explain the punctiform shining of the stars, but something else. Our exegetical problems have stemmed not so much from our not understanding Aristotle's explanation of the phenomenon, as from not understanding what phenomenon it was that he sought to explain.

What, then, is the phenomenon that Aristotle here calls "light" ("the heat and the light from them. . . .")? Light is the property, not of an object, but of a medium: it is the colour of a transparent medium. What Aristotle calls light is what we would call a lit up region. Now we can be aware of such regions in two ways, by being in one ourselves and by seeing one from afar. The former is the normal case of the daylit world; the latter is rarer and more interesting. If we look at a village from a distance at night we see just points of light, but no lit up region. If, however, we look at a floodlit stadium from a distance, we are aware of not only the bright points of the floodlights, but also of the lightedness of the whole region of the stadium—a sort of cloud of light. We can see such a cloud of light from afar without ourselves being (noticeably) lit by it. *That* is the phenomenon that Aristotle means by light, not a luminous object but an illuminated space, a cloud of light.[26]

Which, then, are the astral phenomena that Aristotle is attempting to

[26]If we accept this general claim then we must rescind our earlier rejection of Alexander's solution to these problems: we rejected it on the grounds that he assumed that the stars just were luminous, whereas Aristotle wanted to explain their luminousness. We see now that Aristotle did indeed think that stars just were luminous and that he did not, therefore, want to explain their luminousness. On the other hand, Alexander's approach still will not answer, for he must make all ignition occur below the moon; we have seen that Aristotle wants also to explain ignition above the moon.

explain by his account of heavenly light? Strictly, there are, I believe, only three. The first is daylight, the case where we ourselves are in the lit-up region. The other two phenomena are cases where we see the light from afar. The first of these is the tails of comets, which Aristotle sees not as a mass of luminous objects but as an illuminated space. He distinguishes two types of comets, those which occur below the moon and those which occur above it, and strictly he can have only the latter in mind here.[27] His explanation, using the theory of the enforced motion of air, is that a patch of dry exhalation becomes juxtaposed to a star and then fired by the motion; the result is a region of actualized transparency, a cloud of light, surrounding the star, or rather dragging after it. The last phenomenon is the Milky Way, which Aristotle of course saw not as a cluster of stars, but rather as a cloud of light, and which he explains as air fired by being involved in the motion of the fixed stars. The many other luminous phenomena with which Aristotle is concerned in the *Meteorologica*—"goats," "torches," northern lights, etc.—are all sublunary, and so not light "from the stars."

IX

I think we now have a coherent and clear picture of what Aristotle was proposing in the troubling chapter in the *De caelo*. He sought to explain heat from, and illuminated regions in, the heavens: these need explaining because the heavens are not themselves fire or fiery. He did so by supposing that the quintessence is impure, and contains pockets of air of various sizes and consistencies. Now air is rarefied by motion, and when sufficiently rarefied it becomes hot and eventually fiery. The revolving quintessence keeps the air in motion, both the air that is mixed up with it and the air that is below it. By this motion that air is heated, and so there is warmth on earth. Occasionally pockets of rarefied air form about stars; the star moves the air and it becomes fiery, and so we have comets and their tails. The Milky Way is a sort of communal tail of the fixed stars, for up there a mass of rarefied air is constantly gathering. For reasons that remain obscure,[28] a large mass of rarefied air also gathers about the sun, and being fired by the motion that is imparted to it by the sun's revolution, it gives us daylight and the day's heat. There is no friction to speak of in all this, and so no heavenly harmony: the air which becomes fiery does so not by being chafed, but by being moved.

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[27] *Meteorologica*, A7.
[28] *Ibid.* A.8, 345b31 ff.