

Chapter 2

The Shape and Motion of the Heavens

Nothing which concerns the eternal can be a matter of chance or spontaneity.

— Aristotle

2.1 Introduction

At the outset of Book I of *On the Heavens*, Aristotle argued that the celestial bodies cannot be comprised of one of the four commonly known elements—earth, water, air and fire. This is because these four elements, when left to themselves, obviously exhibit a linear motion either upward or downward. Witness, for example, the natural motion of a dropped rock or the ascent of tongues of fire. By contrast, the heavenly bodies obviously exhibit a naturally circular motion. The sun, moon, planets and stars rise and set daily. This natural motion has persisted without alteration or decay throughout recorded history—indeed from eternity, he argues—a fact which proves that the celestial bodies are comprised of a fifth element, which Aristotle calls *æther*. This is where the previous reading selection left off—at the end of Chap. 3 of Book I. In the reading below, we will jump into Chap. 4 of Book II. But before doing so, what did we skip over?

As it turns out, quite a lot. At the outset of Chap. 4 of Book I, Aristotle asks whether the world (*i.e.* the universe) is finite or infinite in size. After exploring the difficulties that the rotational motion of an infinite body would entail, he concludes that “it is clear that the body of the universe is not infinite.” According to Aristotle, the world is bounded by the sphere of fixed stars which rotates once per day around the earth. At the beginning of Chap. 8, he then asks whether there might be not just one, but perhaps many universes. While this may seem absurd, Aristotle considers such questions to be “all-important” in his search for truth. Indeed, the idea that there are multiple universes is considered by some modern cosmologists to be a plausible, or even necessary, explanation of the *anthropic principle*—that the exquisite suitability of the universe in which we find ourselves can be best understood if ours is but one of many universes which exist, or have existed. As for Aristotle, he concludes that more than one universe is impossible, and moreover that the one in which we live is eternal. His adversaries, however, argued that the heavens are *not* eternal, that they had a beginning and may some day suffer destruction, and that their present motion is transient and thus unnatural. So at the outset of Book II, Aristotle turns

his attention to their arguments. In addressing them, Aristotle is led to consider the source, or origin, of movement itself. Perhaps surprisingly, in the first three chapters of Book II, Aristotle claims that the heavenly bodies are in some sense *animate*—that they possess a “principle of movement” similar to that which allows animals to move from place to place. In plants and animals, this principle of movement is linked not only to their possession of a soul, but also to a certain internal asymmetry which they possess. For example in plants, growth is upward, toward where their shoots aim; and in animals, locomotion is forward, toward where their senses are directed. Lacking any distinction of their parts, these would be incapable of initiating such movements. But what about the perfect spheres which comprise the heavens and on which the planets and stars ride? Lacking any distinction of parts, they would seem to be incapable of initiating movement. Their movement must be caused, then, by a *prime mover*—an immortal and divine celestial sphere which surrounds them, contains them, and generates (or perhaps inspires) their movement.

It is in Chap. 4 of Book II that we now pick up our reading once again. Herein, Aristotle examines how the motion of the heavens are related to, or perhaps even dictated by, their shape. He begins by ranking the planar and solid figures according to the number of edges and angles they have. How does this geometrical classification inform his opinion on the shape of the heavens? Are his arguments reasonable? Moreover, how is his theory of heavenly motion informed by his understanding of the growth and decay of animals? Perhaps most interesting are Aristotle’s views, expressed in Chap. 5, on *chance* and *spontaneity*. In particular, can chance be the *cause of the motion* of the heavens? Which (if any) of his arguments pertaining to the shape and motion of the heavens would suffer if he were to admit chance or spontaneity as valid modes of explanation?

2.2 Reading: Aristotle, *On the Heavens*

Aristotle, On the Heavens, in *Aristotle: I, Great Books of the Western World*, vol. 8, edited by Robert Maynard Hutchins, Encyclopedia Britannica, 1952. Book II.

2.2.1 Chapter 4

The shape of the heaven is of necessity spherical; for that is the shape most appropriate to its substance and also by nature primary.

First, let us consider generally which shape is primary among planes and solids alike. Every plane figure must be either rectilinear or curvilinear. Now the rectilinear is bounded by more than one line, the curvilinear by one only. But since in any kind the one is naturally prior to the many and the simple to the complex, the circle will

be the first of plane figures. Again, if by complete, as previously defined,¹ we mean a thing outside which no part of itself can be found, and if addition is always possible to the straight line but never to the circular, clearly the line which embraces the circle is complete. If then the complete is prior to the incomplete, it follows on this ground also that the circle is primary among figures. And the sphere holds the same position among solids. For it alone is embraced by a single surface, while rectilinear solids have several. The sphere is among solids what the circle is among plane figures. Further, those who divide bodies into planes and generate them out of planes seem to bear witness to the truth of this. Alone among solids they leave the sphere undivided, as not possessing more than one surface: for the division into surfaces is not just dividing a whole by cutting it into its parts, but division of another fashion into parts different in form. It is clear, then, that the sphere is first of solid figures.

If, again, one orders figures according to their numbers, it is most natural to arrange them in this way. The circle corresponds to the number one, the triangle, being the sum of two right angles, to the number two. But if one is assigned to the triangle, the circle will not be a figure at all.

Now the first figure belongs to the first body, and the first body is that at the farthest circumference. It follows that the body which revolves with a circular movement must be spherical. The same then will be true of the body continuous with it: for that which is continuous with the spherical is spherical. The same again holds of the bodies between those and the centre. Bodies which are bounded by the spherical and in contact with it must be, as wholes, spherical; and the bodies below the sphere of the planets are contiguous with the sphere above them. The sphere then will be spherical throughout; for every body within it is contiguous and continuous with spheres.

Again, since the whole revolves, palpably and by assumption, in a circle, and since it has been shown that outside the farthest circumference there is neither void nor place, from these grounds also it will follow necessarily that the heaven is spherical. For if it is to be rectilinear in shape, it will follow that there is place and body and void without it. For a rectilinear figure as it revolves never continues in the same room, but where formerly was body, is now none, and where now is none, body will be in a moment because of the projection at the corners. Similarly, if the world had some other figure with unequal radii, if, for instance, it were lentiform, or oviform, in every case we should have to admit space and void outside the moving body, because the whole body would not always occupy the same room.

Again, if the motion of the heaven is the measure of all movements whatever in virtue of being alone continuous and regular and eternal, and if, in each kind, the measure is the minimum, and the minimum movement is the swiftest, then, clearly, the movement of the heaven must be the swiftest of all movements. Now of lines which return upon themselves the line which bounds the circle is the shortest; and that movement is the swiftest which follows the shortest line. Therefore, if the heaven

¹ Aristotle's *Physics*, III. 207^a 8.

moves in a circle and moves more swiftly than anything else, it must necessarily be spherical.

Corroborative evidence may be drawn from the bodies whose position is about the centre. If earth is enclosed by water, water by air, air by fire, and these similarly by the upper bodies—which while not continuous are yet contiguous with them—and if the surface of water is spherical, and that which is continuous with or embraces the spherical must itself be spherical, then on these grounds also it is clear that the heavens are spherical. But the surface of water is seen to be spherical if we take as our starting-point the fact that water naturally tends to collect in a hollow place—‘hollow’ meaning ‘nearer the centre’. Draw from the centre the lines AB , AC , and let their extremities be joined by the straight line BC . The line AD , drawn to the base of the triangle, will be shorter than either of the radii. Therefore the place in which it terminates will be a hollow place. The water then will collect there until equality is established, that is until the line AE is equal to the two radii. Thus water forces its way to the ends of the radii, and there only will it rest: but the line which connects the extremities of the radii is circular: therefore the surface of the water BEC is spherical.

It is plain from the foregoing that the universe is spherical. It is plain, further, that it is turned (so to speak) with a finish which no manufactured thing nor anything else within the range of our observation can even approach. For the matter of which these are composed does not admit of anything like the same regularity and finish as the substance of the enveloping body; since with each step away from earth the matter manifestly becomes finer in the same proportion as water is finer than earth.

2.2.2 Chapter 5

Now there are two ways of moving along a circle, from A to B or from A to C , and we have already explained² that these movements are not contrary to one another. But nothing which concerns the eternal can be a matter of chance or spontaneity, and the heaven and its circular motion are eternal. We must therefore ask why this motion takes one direction and not the other. Either this is itself an ultimate fact or there is an ultimate fact behind it. It may seem evidence of excessive folly or excessive zeal to try to provide an explanation of some things, or of everything, admitting no exception. The criticism, however, is not always just: one should first consider what reason there is for speaking, and also what kind of certainty is looked for, whether human merely or of a more cogent kind. When any one shall succeed in finding proofs of greater precision, gratitude will be due to him for the discovery, but at present we must be content with a probable solution. If nature always follows the best course possible, and, just as upward movement is the superior form of rectilinear movement, since the upper region is more divine than the lower, so forward movement is superior to

² Aristotle's *On the Heavens*, Book I. 4.

backward, then front and back exhibits, like right and left, as we said before and as the difficulty just stated itself suggests, the distinction of prior and posterior, which provides a reason and so solves our difficulty. Supposing that nature is ordered in the best way possible, this may stand as the reason of the fact mentioned. For it is best to move with a movement simple and unceasing, and, further, in the superior of two possible directions.

2.2.3 Chapter 6

We have next to show that the movement of the heaven is regular and not irregular. This applies only to the first heaven and the first movement; for the lower spheres exhibit a composition of several movements into one. If the movement is uneven, clearly there will be acceleration, maximum speed, and retardation, since these appear in all irregular motions. The maximum may occur either at the starting-point or at the goal or between the two; and we expect natural motion to reach its maximum at the goal, unnatural motion at the starting-point, and missiles midway between the two. But circular movement, having no beginning or limit or middle in the direct sense of the words, has neither whence nor whither nor middle: for in time it is eternal, and in length it returns upon itself without a break. If then its movement has no maximum, it can have no irregularity, since irregularity is produced by retardation and acceleration. Further, since everything that is moved is moved by something, the cause of the irregularity of movement must lie either in the mover or in the moved or both. For if the mover moved not always with the same force, or if the moved were altered and did not remain the same, or if both were to change, the result might well be an irregular movement in the moved. But none of these possibilities can be conceived as actual in the case of the heavens. As to that which is moved, we have shown that it is primary and simple and ungenerated and indestructible and generally unchanging; and the mover has an even better right to these attributes. It is the primary that moves the primary, the simple the simple, the indestructible and ungenerated that which is indestructible and ungenerated. Since then that which is moved, being a body, is nevertheless unchanging, how should the mover, which is incorporeal, be changed?

It follows then, further, that the motion cannot be irregular. For if irregularity occurs, there must be change either in the movement as a whole, from fast to slow and slow to fast, or in its parts. That there is no irregularity in the parts is obvious, since, if there were, some divergence of the stars would have taken place before now in the infinity of time, as one moved slower and another faster: but no alteration of their intervals is ever observed. Nor again is a change in the movement as a whole admissible. Retardation is always due to incapacity, and incapacity is unnatural. The incapacities of animals, age, decay, and the like, are all unnatural, due, it seems, to the fact that the whole animal complex is made up of materials which differ in respect of their proper places, and no single part occupies its own place. If therefore that which is primary contains nothing unnatural, being simple and unmixed and in its proper

place and having no contrary, then it has no place for incapacity, nor, consequently, for retardation or (since acceleration involves retardation) for acceleration. Again, it is inconceivable that the mover should first show incapacity for an infinite time, and capacity afterwards for another infinity. For clearly nothing which, like incapacity, is unnatural ever continues for an infinity of time; nor does the unnatural endure as long as the natural, or any form of incapacity as long as the capacity. But if the movement is retarded it must necessarily be retarded for an infinite time. Equally impossible is perpetual acceleration or perpetual retardation. For such movement would be infinite and indefinite, but every movement, in our view, proceeds from one point to another and is definite in character. Again, suppose one assumes a minimum time in less than which the heaven could not complete its movement. For, as a given walk or a given exercise on the harp cannot take any and every time, but every performance has its definite minimum time which is unsurpassable, so, one might suppose, the movement of the heaven could not be completed in any and every time. But in that case perpetual acceleration is impossible (and, equally, perpetual retardation: for the argument holds of both and each), if we may take acceleration to proceed by identical or increasing additions of speed and for an infinite time. The remaining alternative is to say that the movement exhibits an alternation of slower and faster: but this is a mere fiction and quite inconceivable. Further, irregularity of this kind would be particularly unlikely to pass unobserved, since contrast makes observation easy.

That there is one heaven, then, only, and that it is ungenerated and eternal, and further that its movement is regular, has now been sufficiently explained.

2.3 Study Questions

QUES. 2.1 What is the shape of the heavens?

- a) How does Aristotle classify plane figures? What shape does he rank as the first, or of the highest priority? And how do the notions of completeness, divisibility and number figure into his ranking?
- b) What does all this have to do with the shape of the heavens? Is Aristotle justified in relating figures and bodies in this way?
- c) What does the circular motion of the heavens imply about its shape? In particular, why does he say the heavens cannot be egg-shaped or lens-shaped? Does he consider the heavens to be a body, or a void? And what conceptual difficulty is he encountering here?
- d) What does the speed of the heavens imply about its shape? Is his argument convincing? What corroborating evidence does he cite pertaining to the shape of the heavens?

QUES. 2.2 What is the motion of the heavens?

- a) Is Aristotle correct that “nothing which concerns the eternal can be a matter of chance or spontaneity?” How does this fit into his argument?
- b) Are the motions of the heavens *regular* or *irregular*? What does this mean?

- c) What evidence does he provide that the heavens are *unchangeable*? And why, according to Aristotle, do animals decay, but the heavens do not?

2.4 Exercises

EX. 2.1 (CAUSALITY AND CHANCE). Is *chance* a valid mode of explanation for observed phenomena? Consider: do we learn anything from positing chance as the *cause* of some thing? What does your answer to this question imply?

2.5 Vocabulary

- | | |
|------------------|------------------|
| 1. Rectilinear | 9. Posterior |
| 2. Curvilinear | 10. Acceleration |
| 3. Contiguous | 11. Incorporeal |
| 4. Palpably | 12. Divergence |
| 5. Void | 13. Admissible |
| 6. Corroborative | 14. Perpetual |
| 7. Folly | 15. Fiction |
| 8. Cogent | |

A Student's Guide Through the Great Physics Texts

Volume I: The Heavens and The Earth

Kuehn, K.

2015, XXVII, 396 p. 79 illus., 11 illus. in color., Hardcover

ISBN: 978-1-4939-1359-6