# WHY STARS HAVE NO FEET: EXPLANATION AND TELEOLOGY IN ARISTOTLE'S COSMOLOGY

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## 1. *Introduction: The scarcity of teleological explanations in the* De caelo

The most central feature of Aristotle's conception of natural science is his theory of natural teleology: everything that exists or comes to be "by nature" comes to be or changes, unless prevented, for a purpose and towards an end, and is present for the sake of that purpose or end. In the *De caelo*, which contains in the first two books Aristotle's problem-oriented exposition of his cosmology, traces of this teleological worldview are abundant. The nature of the elements is claimed to be such that it provides them with an immanent capacity to exercise their specific motions to reach their natural places. Left to their own devices, the four sublunary elements would naturally move to their natural places and thus constitute four separate, concentrically arranged spheres.[1] Teleology also permeates the heavenly domain of the stars and planets, as all celestial motions are said to be trying to reach "the most divine principle" as a final cause (*De caelo* 2.12, 292b20–25).

Although teleology as a natural tendency is thus without doubt an important part of the makeup of Aristotle's cosmology and celestial physics, his general reliance on teleology to *explain* the different motions and features of the heavenly bodies seems to be limited in comparison with the other physical treatises. For the whole of the *De caelo* contains only seven instances of explicit teleological explanations of cosmological phenomena, six of which are in the second book (there is only one

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[1] Bodnár and Pellegrin (2006) 282. For the teleological motion of the element earth and for the notion of natural place as end, see the contribution by Matthen (2009) in this volume (especially sections 2 and 5); for Aristotle's account of the elements in *De caelo* 2.1 and 4, see Gill (2009), especially section XX on elemental natural motion.

instance of teleological explanation in book one, there are none in books three and four).[2] Moreover, with one exception (*De caelo* 2.3, 286a8–9), none of these explanations refer directly to final causes. Instead, they all proceed through the supposition of teleological principles, such as "nature does nothing in vain," which in biology are only applied in very specific explanatory contexts, namely, in those cases where the discovery of final causes is relatively difficult.[3] This suggests that teleology is not readily discernible in the case of the heavens. Aristotle's use of teleological principles is all the more remarkable, because the teleological explanations are the only fully-fledged physical explanations that Aristotle offers in this treatise. By this I mean that the teleological explanations are the only explanations in *De caelo* 1–2 that address the nature and causes of the various features and motions of the heavens and that build upon some evidence from observation. Aristotle's cosmological treatise consists for the most part of statements of fact and of arguments building upon mathematical or numerical principles, which mainly address the number, shape, and possible motions of the heavenly bodies.[4]

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[2] For the teleological explanations and the principles used, see (a) *De caelo* 1.4, 271a22–33: Why is there no motion contrary to that in a circle? (*teleological principle*: nature does nothing in vain); (b) 2.3, 286a7–9: Why is there a plurality of motions of the heavens? (*teleological principle*: everything that has a function is for the sake of that function); (c) 2.5, 288a2–12: Why do the heavens move in the direction they do? (*teleological principle*: nature always does what is best among the possibilities); (d) 2.8, 290a29–35: Why do stars not move on their own or why have stars no organs for motion? (*teleological principle*: nature does nothing in vain); (e) 2.9, 291a23–25: Why do stars not move on their own or why is there no harmony of the spheres? (*teleological principle*: nature does nothing in vain); (f) 2.11, 291b10–15: Why do stars not move on their own or why stars do not have a shape fit for locomotion? (*teleological principle*: nature does nothing in vain); (g) 2.12, 292a15–b25: Why is there a difference in the complexity of the motions of the different heavenly bodies? (*teleological principle*: actions are for the sake of something and the analogy with motions of sublunary beings).

[3] Teleological principles in Aristotle's biology are generalizations pertaining to the "observed" actions of actual and particular formal natures of living beings, indicating what "nature" always or never does in generation. It is my contention that propositional principles of explanation, such as Aristotle's teleological principles, function as the framework within which the explanation needs to take place (they both limit the amount and kinds of explanations possible, and license the explanations actually given) and are only used where references to final causes are not immediately possible. Outside the framework set up by such principles, explanations lose their explanatory force and fail to make sense altogether.

[4] Bolton (2009) calls this second type of arguments *dialectical*; see in particular sections 1 and 2.1 of Bolton's contribution to this volume. According to Bolton, the dialectical arguments in the *De caelo* rely on mathematical, numerological, or even mythological starting points rather than on perceptual phenomena, and they establish only what is reasonable (εὐλόγως) rather than what is necessary and true. While I agree

The purpose of the present paper is to shed light on the specific nature of the teleological explanations in Aristotle's cosmology and on the problems related to their application within this particular branch of the science of nature.[5] In particular, I shall argue that the way in which Aristotle uses teleological principles to explain heavenly phenomena builds upon their very successful usage in biology,[6] and is thus consistent with his treatment of cosmology as a natural science. In section 2, I shall say more about the scientific status of cosmology. Next, in sections 3 and 4, I shall discuss two representative examples of teleological explanations from the second book of the *De caelo*.

## 2. *Cosmology as science of nature*

The approach to the study of the heavens taken by Aristotle's predecessors and contemporaries had predominantly been mathematical in nature. (In the *De caelo*, Aristotle refers to them as "mathematicians concerned with

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with Bolton's analysis of the nature of the bulk of the arguments used in the *De caelo*, I do not believe that *all* arguments in it are dialectical. I submit that a minority of the arguments, i.e., the teleological ones, are not dialectical, but *scientific* in nature. The teleological arguments lay out explanations that are proper to the natural sciences and make use of principles that are firmly grounded in the empirical evidence of the sublunary domain. The fact that the heavenly domain is empirically underdetermined limits the explanatory force of these explanations (hence Aristotle's "warning" that the explanations which he will offer are at most reasonable), but this does not mean that the explanations themselves are not scientific (φυσικῶς): rather, they generate the best causal accounts of the features and motions of the heavenly bodies that Aristotle can offer.

[5] The issues that I should like to discuss in this paper have received relatively little attention in the scholarly literature on Aristotle. Scholars who have studied teleology in Aristotle's cosmology have focused almost exclusively on the role of the Prime Mover as a final cause in Aristotle's *Physica* and *Metaphysica*. See, in particular, Kahn (1985). Other studies on cosmology have either left out the question of teleology completely (Falcon 2005), or have subsumed it under the "normal" use of teleology (Johnson 2005). On the other hand, Leggatt, in his commentary on *De caelo*, claims that Aristotle consciously played down the role of teleology in his cosmological treatise, because of his alleged dissatisfaction with the type of intentional and psychological teleological explanations deployed by Plato in the *Timaeus*: see Leggatt (1995) 18, 36–37, 207. Hence, Leggatt offers little analysis of the teleological explanations actually provided in this treatise, because he believes them to be of little importance.

[6] The possible relative chronology of Aristotle's works (according to which the *De caelo* is an early work and the biological works are late) does not affect my claim: since none of these treatises were published during Aristotle's life time, he may well have adjusted and revised them continuously in the light of new discoveries or conceptual distinctions made. For a defense of this view (based on a pedagogical interpretation of the cross-references in Aristotle), see Burnyeat (2004) 21–22.

ἀστρολογία"—where ἀστρολογία is best rendered by "astronomy"—or simply as "mathematicians".)[7] The theory reportedly put forward by Eudoxus and revised by Callippus represented the apparent motions of the stars and planets as outcomes of systems of concentric rotating spheres. This theory as reported did not explain the physical mechanics and causes underlying those motions, perhaps because neither Eudoxus nor Callippus was concerned with those issues. In *Phys.* 2.2, 193b22–194a12, Aristotle distinguishes this theoretical manner of studying the heavens (ἀστρολογία) from the proper study of nature by pointing out that astronomers—like mathematicians—do not study the properties of bodies *qua* properties of those bodies, but *qua* separable from them.[8]

For Aristotle, however, just as for Plato, the study of the heavens is part of the investigation of nature,[9] and thus the heavenly bodies and their features will have to be studied in a manner that takes their natures fully into account—nature both in the sense of form and of matter. This physical approach to the study of the heavens is evidenced, for instance, in Aristotle's claim that each of the spheres in his system is corporeal, and thus not simply a mathematical construct (*De caelo* 2.12, 293a7–8):

> ἑκάστη δὲ σφαῖρα σῶμά τι τυγχάνει ὄν.
>
> For each sphere is some kind of body.

Therefore, if for Aristotle cosmology is part of the science of nature, and if scientific knowledge involves the knowledge of all four causes,[10] a merely mathematical approach (such as favored by the astronomers and by Aristotle himself in many of the arguments in the *De caelo*) will not be sufficient to generate complete knowledge concerning the heavens, for the following reasons. By its very nature, mathematical reasoning cannot yield understanding of final causes (there are no final causes

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[7] See *De caelo* 2.14, 297a2–4 (Μαρτυρεῖ δὲ τούτοις καὶ τὰ παρὰ τῶν μαθηματικῶν λεγόμενα περὶ τὴν ἀστρολογίαν; "what the mathematicians say in *astrologia* also testifies to this"), 2.10, 291a29–b9; 2.14, 298a15.

[8] Cf. *Meta.* 1.8, 989b33–990a15; 3.2, 997b16–998a1 and 13.2, 1076b39–1077a4 where Aristotle describes ἀστρολογία as not dealing with perceptible magnitudes or with the heavens above. Cf. Simplicius *In phys.* 293.7–10, 290.20–24 (on the Greek conception of ἀστρολογία as being part of mathematics, not physics); Mueller (2006) 179–181.

[9] Aristotle emphatically introduces his study of the heavens as a part of the study of nature: see for instance *De caelo* 1.1, 268a1 (Ἡ περὶ φύσεως ἐπιστήμη), 3.1, 298b2–3 (τῆς περὶ φύσεως ἱστορίας), and *Meteor.* 1.1, 338a20–25.

[10] See e.g. *Phys.* 1.1, 194a10–16, 194b17–23; *An. post.* 1.2, 71b9–13 and 2.11, 94a20–27: cf. also Falcon (2005) 15.

in mathematics, because there is no change or good in that domain).[11] Hence, astronomy only yields understanding of the shape and size of the heavenly bodies, and of their distances from each other and from the earth. This gives important information about the quantitative properties of the heavenly bodies and their motions, especially if combined with arguments drawing from principles of physics. However, as a natural philosopher, Aristotle is also interested in the nature of the heavenly bodies, in their material composition, and in the causes of their motions (i.e., in their material, formal, efficient, and final causes). The opening words of the *De caelo* are significant:

> Ἡ περὶ φύσεως ἐπιστήμη σχεδὸν ἡ πλείστη φαίνεται περί τε σώματα καὶ μεγέθη καὶ τὰ τούτων οὖσα πάθη καὶ τὰς κινήσεις, ἔτι δὲ περὶ τὰς ἀρχάς, ὅσαι τῆς τοιαύτης οὐσίας εἰσίν·
>
> The science of nature is patently concerned for the most part with bodies and magnitudes, the affections and motions of these, and further, with all the principles that belong to this kind of substance. (1.1, 268a1–4)

Because the natural sciences are concerned with all four types of causes, and especially since the understanding of final causes is crucial (because the natural sciences are concerned with things that undergo change), Aristotle needs an additional strategy to extend scientific knowledge as he understands it to the domain of the heavens. This strategy involves the application of teleological principles of the sort he employs in his biology precisely as a heuristic for finding final causes where they are not immediately observable. In short, Aristotle uses teleological principles to discover purposes and functions among the heavenly phenomena, and thereby tries to turn his study of the heavens into a proper natural science.[12]

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[11] *Meta*. 2.2, 996a21–b1.

[12] Aristotle's treatment of cosmology as part of the study of nature also explains why the teleological explanations are mainly found in the second book of the *De caelo*. For it is this book that deals most specifically with the heavenly bodies *qua* subjects of motion, that is, with the plurality, direction, and complexity of their motions, the physical mechanisms underlying those motions, and the shape of the heavenly bodies required to perform those motions. On the other hand, we find no teleological accounts regarding Aristotle's views on the nature of the heavens as a whole (for instance, for such features as the heavens' size, uniqueness, or eternity—topics that are dealt with primarily in book I), or regarding the motions and features of the four terrestrial elements (dealt with in books 3–4), which are not part of cosmology properly speaking. Aristotle's use of causal language in the *De caelo* also reveals that the second book is more concerned with Aristotle's *own* attempts to provide physical explanations than any of the other books: of the 28 occurrences of the term *αἴτιον* in the whole of the *De caelo*, 10 can

For Aristotle, scientific research comprises two stages of enquiry: the first stage consists in the systematic collection of observations of the phenomena, and the second one in the attempt to detect correlations and to give causal explanations of the phenomena. However, as Aristotle makes clear several times in the *De caelo* (see his introductions to teleological explanations discussed below in section 3), it is not at all an easy undertaking to give physical explanations of cosmological phenomena. The central problem is the limitedness—or even lack—of empirical evidence: the observations of the heavens we have are too few, and the objects of observation are too far away to offer any certain evidence.[13] The only observation that seems to be rock solid is that of the rotation of the heavens (*De caelo* 1.5, 272a5–6 τὸν δ' οὐρανὸν ὁρῶμεν κύκλῳ στρεφόμενον: "we see the heavens turning about in a circle"). Notwithstanding the many methodological caveats we find in *De caelo* (I shall discuss them in section 3 below), Aristotle remains confident that it is still possible to give explanations of cosmological phenomena that go beyond the mere fact that heavens rotate, and also beyond the conclusions (mathematical or numerical) that reasoning yields about numbers, sizes, shapes, and distances, for instance.

My contention is that Aristotle's use of teleological principles, by analogy with their use in the biological domain,[14] forms an important part of his strategy to increase the possibility of gaining scientific knowledge of the heavens. Thus, when Aristotle does proceed to give "physical" or "scientific" explanations, he is unremittingly teleological in his approach. The explanations thus presented will not qualify as demonstrations in a strict sense (i.e., not as demonstrations as described in *Analytica posteriora* or *De partibus animalium*),[15] because they do not set out to demonstrate the truth but merely the reasonableness of certain causal scenarios. However, they go a long way in taking away some of the puzzlement

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be found in book 2 (as opposed to 4 in book 1, 3 in book 2, and 11 in book 4), and of the 28 occurrences of the term *αἰτία*, 21 can be found in the second book (as opposed to none in the first and the third book, and 7 in the fourth), while the references to causes and explanations in the fourth book are often (i.e., in 4.1, 308a25; 4.2, 309a5, 309a10, 309a28 and 310a2; 4.6, 313a22)—although not exclusively—used in descriptions of views entertained by Aristotle's predecessors.

[13] Cf. *Meteor.* 1.7 and *An. pr.* 1.30.

[14] *Pace* Falcon (2005) 101, who argues that "Aristotle is reluctant to extend the results achieved in the study of plants and animals to the imperishable creatures populating the celestial world."

[15] Cf. Lloyd (1996) 182.

pertaining to the heavenly realm and thus in making sense of the heavenly phenomena. And as Aristotle has indicated elsewhere,[16] "making sense" in such difficult circumstances entails giving an account of the heavens that is free of impossibilities.

Let us finally turn to some examples of the actual teleological explanations Aristotle provides in the *De caelo*. Broadly speaking, Aristotle gives two kinds of teleological explanations. The first kind consists of explanations that stand on their own (that is, they do not form part of an interrelated sequence of arguments), and set out to explain the *presence* of certain features and motions of the heavens.[17] In these cases (i.e., 2.3, 286a7–9; 2.5, 288a2–12 and 2.12, 292a15–b25), Aristotle explains the presence of some observed fact by reference to the good it serves within the heavens as a whole. The basic teleological idea is that whatever can be seen to be present, must be there to serve some good.

The second kind consists of those teleological explanations that explain the *absence* of heavenly features (this kind is used in 1.4, 271a22–33; 2.8, 290a29–35; 2.9, 291a23–25 and 2.11, 291b10–15). They usually follow after a series of mathematical or numerical arguments following the style of the astronomers. While the latter point out that it is, for instance, mathematically impossible for some motion or feature to be present, the teleological explanation is set up to provide a counterfactual argument claiming that those motions or features in reality could not exist in the heavenly realm, because if they did, they would be in vain. The teleological principle invoked in all of these cases is that nature does nothing in vain.

In the next two sections, I shall discuss an example from each group.

## 3. *Explaining why there is a plurality of motions of the heavens (Example 1)*

The first example of a teleological explanation that I should like to discuss pertains to the plurality of the heavenly motions: different heavenly bodies are observed to move in different directions—why is it that they do

[16] *Meteor*. 1.7, 344a5–7: "We consider a satisfactory explanation of phenomena inaccessible to observation to have been given when we reduce them to what is possible."

[17] Evidently there are no teleological explanations of the generation of the heavenly bodies as they are eternal and not generated. Cosmological teleological explanations are thus naturally restricted to the explanation of the features and motions belonging (or not belonging) to the eternal heavenly bodies.

not all move in the same direction? Aristotle introduces his explanation as follows (*De caelo* 2.3, 286a3–7):

> Ἐπεὶ δ' οὐκ ἔστιν ἐναντία κίνησις ἡ κύκλῳ τῇ κύκλῳ, σκεπτέον διὰ τί πλείους εἰσὶ φοραί, καίπερ πόρρωθεν πειρωμένοις ποιεῖσθαι τὴν ζήτησιν, πόρρω δ' οὐχ οὕτω τῷ τόπῳ, πολὺ δὲ μᾶλλον τῷ τῶν συμβεβηκότων αὐτοῖς περὶ πάμπαν ὀλίγων ἔχειν αἴσθησιν. ὅμως δὲ λέγωμεν. ἡ δ' αἰτία περὶ αὐτῶν ἐνθένδε ληπτέα.
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> Since there is no motion in a circle contrary to motion in a circle, we must examine why there are several locomotions, though we must try to conduct the inquiry from far off—far off not so much in their location, but rather by virtue of the fact that we have perception of very few of the attributes that belong to them [i.e., the motions]. Nonetheless, let us speak of the matter. The explanation concerning these things must be grasped from the following [considerations].

This text shows that Aristotle is very well aware of the fact that it is problematic and difficult to offer explanations of what is present in the heavens, given the lack of empirical evidence: we are simply too far removed from the objects of inquiry in distance.[18]

It is significant that Aristotle is nevertheless confident that there is a way of answering this particular question, and that this answer follows from a *teleological* consideration. As we will see shortly, the considerations "from which the explanation must be grasped" is the supposition of the teleological principle that everything that has a function must exist for the sake of that function. By positing a teleological principle and, hence, by setting a framework within which one can search for the possible functions of those very features that have been

[18] Cf. Burnyeat (2004) 15–16, who observes that "*De caelo* 1 contains an unusually high number of occurrences of words like εἰκοτῶς and εὔλογον which express epistemic modesty: this or that is a *reasonable* thing to believe." I should like to add to this observation that words of "epistemic modesty" are even more abundant in book 2 where the explanation of the presence and absence of heavenly features properly speaking is at stake (I counted only two occurrences of the word εὔλογον and none of the word εἰκοτῶς in *De caelo* 1; in *De caelo* 2, I counted 15 occurrences of the word εὔλογον and two of the word εἰκοτῶς). On the significance of words like εἰκοτῶς and cognates, see also the contribution by Bolton (2009) in this volume. Note also that Bolton reads "disclaimers" like the one quoted above as marking the inferior dialectical arguments Aristotle provides throughout *De caelo* (see in particular section 2.1). In my reading, these introductions indicate that Aristotle, after having offered dialectical or astronomy-style arguments earlier, now intends to offer genuine physical or scientific explanations, but that they will necessarily be of a weaker kind and, hence, only amount to what is reasonable.

observed, one might be able to find the explanation of why those features are present. On the other hand, the implication also seems to be that this kind of knowledge cannot be gained by other means: observation is certainly ruled out (observation in this case will only yield knowledge of the fact that there are several motions, not of the reason why), but also mathematical arguments are not what is called for in these situations, again because they cannot yield the reason why there are several motions.

Interestingly, the other two teleological explanations that stand on their own and explain the presence of heavenly phenomena are also immediately preceded by a discussion of the methodological problems related to this very enterprise of providing explanations in the strong sense for phenomena at such a remove (see *De caelo* 2.5, 287b29–288a2; 2.12, 291b24–28 and 292a14–18). In all these methodological introductions, Aristotle expresses his conviction that, even though the empirical evidence is scanty, it is still possible to state the phenomena; and that given all the limitations, the explanations offered are the best ones possible.[19] The explanations that follow these introductions are all teleological in nature, which shows that Aristotle has strong confidence in the explanatory force of teleology also in these difficult cases.[20]

Returning to our example from *De caelo* 2.3, the teleological principle from which "the explanation of why there are several locomotions of the heavens must be grasped", is the following (*De caelo* 2.3, 286a8):

> Ἕκαστόν ἐστιν, ὧν ἐστιν ἔργον, ἕνεκα τοῦ ἔργου.
>
> Each thing that has a function is for the sake of that function.

[19] *Pace* Guthrie (1939) 165.

[20] This point is also made by Lloyd (1996) 171, with regard to the explanations in *De caelo* 2.5 and 2.12: "Thus it is surely significant that both on the problem of why the heavens revolve in one direction rather than in the other—in 2.5—and on the difficulty of the complexities of the motions of the non-fixed stars—in 2.12—his positive speculations invoke teleology." I disagree, however, with Lloyd's interpretation of the significance of this connection between Aristotle's methodological disclaimers on the one hand and his use of teleology on the other. According to Lloyd (1996) 161, 173, 175, 180, Aristotle's main interest in cosmology follows from his concern to establish his teleology, and especially the orderliness of the heavens. However, I do not believe that Aristotle's epistemological hesitations are not genuine here, or that Aristotle's concern for the establishment of teleology is all that prominent in the *De caelo*. On the contrary, I believe that Aristotle uses his teleology, already firmly established on the basis of the abundance of empirical evidence discussed in his biological works, to extend—where possible—his knowledge of the heavens.

This is a common principle in Aristotle's biology (see, e.g., *De part. an.* 1.5, 645b15–18), where it is claimed that each part of the body is for the sake of the performance of some function. By stating it here, Aristotle makes explicit that in his view, teleology extends to the heavenly domain and, hence, that some of the puzzling cosmological phenomena can be explained by reference to teleology. Aristotle also *must* refer to teleology here, since material causes alone cannot account for the differences in locomotions in the heavens (for all spheres are made from the same material, which is aether).[21] The assumption that everything that has a function is present for the sake of that function allows a series of inferences that ultimately yield the explanation of why there are several motions of the heavens: if this principle applies, then each of the motions must serve its own function.

Aristotle continues his explanation by identifying the function of the first motion, in the following way (*De caelo* 2.3, 286a8–11):

> Θεοῦ δ' ἐνέργεια ἀθανασία· τοῦτο δ' ἐστὶ ζωὴ ἀΐδιος. ὥστ' ἀνάγκη τῷ θειῷ[22] κίνησιν ἀΐδιον ὑπάρχειν. Ἐπεὶ δ' ὁ οὐρανὸς τοιοῦτος (σῶμα γάρ τι θεῖον), διὰ τοῦτο ἔχει τὸ ἐγκύκλιον σῶμα, ὃ φύσει κινεῖται κύκλῳ ἀεί.
>
> The activity of god is immortality, and that is everlasting life. In consequence, it is necessary that eternal motion belongs to the divine. Since the heavens are of this sort (for this body is a divine thing), for that reason the heavens have a circular body that moves naturally in a circle forever.

The reasoning is that, if the function of the divine is immortality, and if the heavens are divine, then the function of heaven is immortality. Furthermore, if being immortal is the defining function of heaven, then it is a necessary prerequisite for it to possess an eternal motion. That is, for heaven as a whole to be able to perform its defining function or its activity of being immortal, it has to perform at least one kind of eternal motion. And the only kind of motion capable of uniform eternal continuity is motion in a circle.

This explanation, curious as it may sound, resembles a particular type of explanation that Aristotle frequently offers in his biological works.

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[21] Cf. Simplicius (quoting Alexander), *In de caelo* 396.6–9: "it is not possible to make either natural or material necessity responsible for these things, since both spheres have the same matter, but it is necessary to give an account of the difference in terms of some divine governance or ordering." For an analysis and defense of Aristotle's arguments for the existence of aether, see Hankinson (2009) in this volume.

[22] Here I follow Leggatt in reading θειῷ instead of θεῷ with most manuscripts: see Leggatt (1995) 227. I believe Aristotle's argument to be that the celestial sphere is *like* a divine being in the sense that both partake in eternal motion, not that it itself is a god.

Consider the following example taken from *De partibus animalibus*, where Aristotle provides an explanation of why birds have wings (4.12, 693b6–14):[23]

> τῶν γὰρ ἐναίμων ἡ τοῦ ὄρνιθος οὐσία, ἅμα δὲ καὶ πτερυγωτός. … τῷ δ' ὄρνιθι ἐν τῇ οὐσίᾳ τὸ πτητικόν ἐστιν.
>
> For the substantial being of the bird is that of the blooded animals, but at the same time it is also a winged animal, … and the ability to fly is in the substantial being of the bird.

Aristotle takes the essence, or the substantial being of the animal, as a starting point, and derives from this essence the necessary prerequisites of something being what it is. Just as birds must have wings because they are essentially flyers (and the only way for birds to perform their defining function is by using their wings), so too the heavens must have a spherical body and move eternally in a circle because they are essentially immortal. According to this argumentation, eternal motion in a circle is the proper attribute of an immortal body such as the heavens.

However, Aristotle has not yet explained why there are *several* motions of the heavenly bodies. The second part of the explanation of why there are several motions consists of a complicated chain of arguments, based on a total of six assumptions. The starting point of this chain is the conclusion of the first part of the explanation, which is the necessity of there being an eternal motion of the outer sphere in order for the heaven to be immortal. The reasoning Aristotle employs is deductive, but the type of necessity to which Aristotle refers is sometimes that of a necessary consequence, while at other times it is the necessity of something having to be present first if something else is to be present (the latter is what Aristotle calls conditional necessity).[24] Let me give a summary of the chain of arguments (*De caelo* 2.3, 286a13–286b2):

(a) If there is to be a body that moves in a circle eternally, it must have a center that remains at rest.
(b) For there to be a fixed center, the existence of the element earth is a necessary condition (i.e., since whatever is made of aether cannot

[23] Cf. *De part. an.* 4.13, 697b1–13 and 3.6, 669b8–12. For my analysis of the structure of this type of teleological explanation, see Leunissen (2007) 170–171.

[24] The formula "ἀνάγκη … εἶναι" is repeated six times: in *De caelo* 2.3, 286a13; 286a20, and 286b2 (see (a), (b), and (f) above), the necessity is conditional; in 286a22, 286a28, and 286a32 (see (c), (d), and (e) above), the necessity indicates a necessary consequence.

remain at rest, there must be a second element next to aether, the natural motion of which is to move towards the center and then to remain at rest in the centre).

(c) If there is to be earth, then it is a necessary consequence that there is also fire (for earth and fire are contraries, and if the one exists, so does the other).

(d) If there is to be fire and earth, then it is a necessary consequence that the two other elements exist (for water and air are in a relation of contrariety to each of the other two elements).

(e) From the existence of the four elements, it necessarily follows that there must be generation (for none of the four sublunary elements can be everlasting).

(f) If there must be generation, then it is necessary that there exists some other motion.

According to this account, generation is a necessary consequence of there being sublunary elements, whose existence is a necessary condition for there to be an eternal, cyclical motion of the outermost sphere of the heavens carrying the fixed stars. However, having established that it is necessary for there to be generation (as a consequence of there being the four sublunary elements), Aristotle turns the argument around, and reasons that if there is to be generation, then it is conditionally necessary for there to be other motions, because the motions of the outermost sphere alone cannot cause generation. Accordingly, generation is that for the sake of which all the other motions (namely, the motions of the planets) take place. This is how Aristotle summarizes his explanation (*De caelo* 2.3, 286b6–9):

> Νῦν δὲ τοσοῦτόν ἐστι δῆλον, διὰ τίνα αἰτίαν πλείω τὰ ἐγκύκλιά ἐστι σώματα, ὅτι ἀνάγκη γένεσιν εἶναι, γένεσιν δ', εἴπερ καὶ πῦρ, τοῦτο δὲ καὶ τἆλλα, εἴπερ καὶ γῆν· ταύτην δ' ὅτι ἀνάγκη μένειν τι ἀεί, εἴπερ καὶ κινεῖσθαί τι ἀεί.
>
> For the moment so much is clear, for what reason there are several bodies moving in circles, namely, because it is necessary that there is generation; and (because) generation (is necessary) if there also has to be fire; and (because) that one and the others (are necessary) if there also has to be earth; and (because) that one because it is necessary that something always remains at rest, if there has to be something that is for ever in motion.

The complete explanation of why there are several motions of the heavens is thus that there are several functions for the sake of which these motions are present. There is one eternal motion in a circle (performed

by the outer sphere carrying the fixed stars) for the sake of realizing the immortality of the heavens, and there are other motions (performed by the inner spheres carrying the planets) for the sake of generation.

Here, the use of the teleological principle allows Aristotle to draw an organic picture of the cosmological system in which all the observed motions can be explained by the purpose they serve. Arguably, this picture and the type of reasoning behind it are not without problems,[25] but at least Aristotle is able to give some rationale for some phenomena the astronomers did not explain. The plurality of the motions of the heavenly bodies makes sense in the light of the need for the heaven as a whole to perform an eternal motion, if it is to be truly immortal, and as a corollary—of the need for there to be generation, if this eternal motion is to be at all. In sum, the lack of empirical evidence makes it hard to provide fully-fledged physical explanations in cases like these, but through the use of teleological principles that are well established in his biology Aristotle at least succeeds in mitigating some of the perplexities pertaining to some heavenly phenomena.

### 4. *Explaining why stars have no feet (Example 2)*

I shall now turn to an example of the second type of teleological explanations, where Aristotle uses some form of the teleological principle that nature does nothing in vain in order to explain the *absence* of heavenly features, usually after a series of mathematical arguments or discussions of the available empirical evidence.

The *explanandum* to be discussed concerns the question whether or not the stars and planets possess a motion independently of the motion of the spheres. One explanation is given in chapter 2.8. Ultimately, the purpose of the chapter is to show that the heavenly bodies (most likely) do not possess a motion of their own, but are carried around fixed in concentric spheres.[26] First, Aristotle sketches three possible scenarios concerning the motions of the heavenly bodies and their spheres (*De caelo* 2.8, 289b1–3). As both are observed to move as a whole, it is

[25] For instance, it does not establish an explanation for *each* of the individual motions of the planets, or for the need for there to be generation. This latter point is well brought out (along with others worth noting) by Hankinson (2002–2003) 31–32.

[26] The basic idea is that if the stars possessed their own motion, they would be self-movers; and this would make them in principle able to stop their motions, which would threaten the eternity of the heavens and life as we know it.

necessary that the change of position takes place with both the heavens and the stars being at rest, or with both moving, or with the one moving and the other at rest. Aristotle then refers to empirical evidence (*De caelo* 2.8, 289b5 οὐ γὰρ ἂν ἐγίγνετο τὰ φαινόμενα, 289b10 φαίνεται) and gives mathematical arguments (2.8, 289b27–28 τὰ αὐτὰ καὶ ὁμοίως ἔσται ἄλογα) in order to show that the scenario in which the spheres move while the heavenly bodies are at rest is "the least absurd" (2.8, 289b34–35 μόνως γὰρ οὕτως οὐθὲν ἄλογον συμβαίνει). In addition to this, Aristotle offers a final teleological argument in favor of this theory, arguing for the unlikelihood of the stars and planets possessing a motion on their own. The argument runs as follows (*De caelo* 2.8, 290a29–35):

> Πρὸς δὲ τούτοις ἄλογον τὸ μηθὲν ὄργανον αὐτοῖς ἀποδοῦναι τὴν φύσιν πρὸς τὴν κίνησιν (οὐθὲν γὰρ ὡς ἔτυχε ποιεῖ ἡ φύσις), οὐδὲ τῶν μὲν ζῴων φροντίσαι, τῶν δ' οὕτω τιμίων ὑπεριδεῖν, ἀλλ' ἔοικεν ὥσπερ ἐπίτηδες ἀφελεῖν πάντα δι' ὧν ἐνεδέχετο προϊέναι καθ' αὑτά, καὶ ὅτι πλεῖστον ἀποστῆσαι τῶν ἐχόντων ὄργανα πρὸς κίνησιν.
>
> In addition to these arguments, it would be absurd that nature gave them no organ for motion (since nature does nothing as a matter of chance), and that she should care for animals, but disregard such honorable beings; rather, it seems that nature, as though deliberately, has taken away everything by means of which they might possibly in themselves have effected forward motion, and that she set them at the greatest distance from those things that possess organs for motion.

In a way, Aristotle's explanation here parallels that of Plato in the *Timaeus* (33d–34a). In this dialogue, Timaeus explains that the divine craftsman did not think it necessary to equip the heaven—self-sufficient and perfect as it is—with hands or feet for walking:

> ἡγήσατο γὰρ αὐτὸ ὁ συνθεὶς αὔταρκες ὂν ἄμεινον ἔσεσθαι μᾶλλον ἢ προσδεὲς ἄλλων. χειρῶν δέ, αἷς οὔτε λαβεῖν οὔτε αὖ τινα ἀμύνασθαι χρεία τις ἦν, μάτην οὐκ ᾠήθη δεῖν αὐτῷ προσάπτειν, οὐδὲ ποδῶν οὐδὲ ὅλως τῆς περὶ τὴν βάσιν ὑπηρεσίας. κίνησιν γὰρ ἀπένειμεν αὐτῷ τὴν τοῦ σώματος οἰκείαν, τῶν ἑπτὰ τὴν περὶ νοῦν καὶ φρόνησιν μάλιστα οὖσαν· διὸ δὴ κατὰ ταὐτὰ ἐν τῷ αὐτῷ καὶ ἐν ἑαυτῷ περιαγαγὼν αὐτὸ ἐποίησε κύκλῳ κινεῖσθαι στρεφόμενον, τὰς δὲ ἓξ ἁπάσας κινήσεις ἀφεῖλεν καὶ ἀπλανὲς ἀπηργάσατο ἐκείνων. ἐπὶ δὲ τὴν περίοδον ταύτην ἅτ' οὐδὲν ποδῶν δέον ἀσκελὲς καὶ ἄπουν αὐτὸ ἐγέννησεν.
>
> For he thought that a being which is self-sufficient would be much better than one which is in need of other things. And he did not think it was necessary to attach hands to it to no purpose—hands for which there would be no need either to grasp or to defend itself against anything; nor had it any need of feet, nor of the whole apparatus of walking. For he assigned to it the motion that is most suited to its body, [the motion] which, of the

> seven, is the most appropriate to mind and to thinking. And, therefore, he caused it to move in the same manner and on the same spot and revolving in a circle within its own limits. All other six [motions] he took away and it was made not to partake in their deviations. And as this circular motion required no feet, the universe was created without legs and without feet.

In this passage, Plato describes how the heaven was created and was given its circular motion, which is most appropriate for its spherical shape. The other types of motion—forwards/backwards, to the left/to the right, and up/down—were taken away from it (*Tim.* 34a5 ἀφεῖλεν). However, instead of this mythological account for why the stars have no feet, Aristotle opts for a naturalistic explanation.

The structure of Aristotle's argument is quite complex. In short, it consists of a *reductio ad absurdum* followed by an alternative account proclaiming the purposiveness or, perhaps even the providence, of nature. The first part of the argument builds upon the implicit counterfactual assumption that if the stars "were intended by nature" to be moving on their own, it would be absurd for nature not to have given them organs for motion, given the fact that nature did provide such organs to "lesser" beings. I take the expression that "nature does nothing as a matter of chance" to be equivalent to the principle that nature does nothing in vain: living beings always have the parts that they need, and if the heavenly bodies lack organs for motion, that lack must be for the sake of something; or, to put it the other way around, if the organs for motion are absent in heavenly bodies it must be because their presence would have been in vain (they would have had no function to fulfill in this particular kind of being). The reference to the honorable status of heavenly beings implies that Aristotle takes the teleology of nature to apply even *more* to them than to the sublunary beings.[27]

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[27] Aristotle repeatedly offers the *a fortiori* argument that if one agrees that animals and plants neither come to be nor exist by spontaneity (but for the sake of something), then the claim that spontaneity is the cause of the heavens—which is most divine and exhibits the greatest order—must be absurd, and that one has to conclude that final causality pertains to the heavenly realm as well. See *Phys.* 2.4, 196a24–b5; 2.6 198a1–13 and *De part. an.* 1.1, 641b10–23 and 641b16–23:

> This is why it is more likely that the heavens have been brought into being by such a cause—if it has come to be—and is due to such a cause, than that the mortal animals have been. Certainly the ordered and definite are far more apparent in the heavens than around us, while the fluctuating and random are more apparent in the mortal sphere. Yet some people say that each of the animals is and came to be by nature, while the heavens, in which there is not the slightest appearance of chance and disorder, were constituted in that way by chance and the spontaneous.

The *implicit* underlying teleological principle here is that each capacity (in this case the capacity to locomote) requires an organ[28] and that thus locomotion of the stars is possible if and only if they have organs for locomotion. The absurdity lies in the fact that nature *did* provide less honorable beings with organs for motion, and that we would have to conclude, were we to accept this account as true, that nature purposely neglected more honorable beings such as the stars. Since this account is of course unacceptable within Aristotle's view of the way nature operates, the opposite scenario, set out in the second part of the argument, must be the case: nature has *taken away* every means of locomotion, and thereby set a distance between the heavenly bodies and the sublunary beings equipped with organs for motion.[29] As Aristotle explains, spherical bodies are least fit to effect forward motion on their own, because they lack "points of motion" (*De caelo* 2.8, 290b5–8):

> πρὸς δὲ τὴν εἰς τὸ πρόσθεν ἀχρηστότατον· ἥκιστα γὰρ ὅμοιον τοῖς δι' αὑτῶν κινητικοῖς· οὐδὲν γὰρ ἀπηρτημένον ἔχει οὐδὲ προέχον, ὥσπερ τὸ εὐθύγραμμον, ἀλλὰ πλεῖστον ἀφέστηκε τῷ σχήματι τῶν πορευτικῶν σωμάτων.
>
> For forward motion it is least fit, since it is least like to those things that produce motion on their own; for it does not have any appendage or projection, as does a rectilinear figure, but stands most apart in shape from those bodies equipped for locomotion.

The core of this teleological argument for why the heavenly bodies do not have a motion of their own and, hence, must be fixed in spheres, is thus the assumption (presented as a fact) that heavenly bodies do not have feet or any other organs for locomotion. For, if nature—for the most part—does nothing in vain and the heavenly bodies have no feet, then the conclusion is reasonable that nature must have "designed" the heavenly bodies not to be able to move on their own.

The teleological argument that Aristotle offers here is again in many ways similar to explanations we find in the biological works. In biology, Aristotle holds that all animals that are capable of locomotion must have organs for motion[30] and that animals without organs for motion are not

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[28] *De gen. an.* 1.2, 716a24–25.

[29] Aristotle considers it to be better for the superior to be separated from the inferior; cf. *De gen. an.* 2.1, 732a6–8, where Aristotle explains that it is better for the male and the female to be separated, for "it is better that the superior principle should be separated from the inferior."

[30] *De part. an.* 4.10, 686a35–b1: "all (animals) that walk must have two hind feet"; *De incessu* 3, 705a19–22: "That which moves always makes its change of place by the

capable of locomotion.[31] These two "laws" are exhaustive with regard to all blooded land walkers. The one and only exception to this rule is formed by the footless snake,[32] which obviously does not have organs specifically designed for locomotion, but moves forward by bending itself. Just as in our example concerning the heavenly bodies, Aristotle explains the absence of feet by invoking the principle that nature does nothing in vain (*De incessu* 8, 708a9–20):

> τοῖς δ' ὄφεσιν αἴτιον τῆς ἀποδίας τό τε τὴν φύσιν μηθὲν ποιεῖν μάτην, ἀλλὰ πάντα πρὸς τὸ ἄριστον ἀποβλέπουσαν ἑκάστῳ ⟨ἐκ⟩ τῶν ἐνδεχομένων, διασώζουσαν ἑκάστου τὴν ἰδίαν οὐσίαν καὶ τὸ τί ἦν αὐτῷ εἶναι· ἔτι δὲ καὶ τὸ πρότερον ἡμῖν εἰρημένον, τὸ τῶν ἐναίμων μηθὲν οἷόν τ' εἶναι πλείοσι κινεῖσθαι σημείοις ἢ τέτταρσιν. ἐκ τούτων γὰρ φανερὸν ὅτι τῶν ἐναίμων ὅσα κατὰ τὸ μῆκος ἀσύμμετρά ἐστι πρὸς τὴν ἄλλην τοῦ σώματος φύσιν, καθάπερ οἱ ὄφεις, οὐθὲν αὐτῶν οἷόν θ' ὑπόπουν εἶναι. πλείους μὲν γὰρ τεττάρων οὐχ οἷόν τε αὐτὰ πόδας ἔχειν (ἄναιμα γὰρ ἂν ἦν), ἔχοντα δὲ δύο πόδας ἢ τέτταρας σχεδὸν ἦν ἂν ἀκίνητα πάμπαν· οὕτω βραδεῖαν ἀναγκαῖον εἶναι καὶ ἀνωφελῆ τὴν κίνησιν.
>
> The reason why snakes are footless is both that nature does nothing in vain, but always, from among the possibilities, picks what is best for each thing, preserving the proper substantial being of each, and its essence; and further, and as we have stated previously, none of the blooded animals can move by means of more than four points. For from these [two premises] it is apparent that none of the blooded animals that are disproportionately long relative to the rest of their bodily nature, as are the snakes, can be footed. For, on the one hand, they cannot have more than four feet (since in that case they would be bloodless); and, on the other hand, having two or four feet they would be pretty much completely immobile—so equipped, their motion would necessarily be slow and useless.

In short, starting from this principle, Aristotle offers the counterfactual argument that if nature had equipped snakes with feet, snakes would move very badly and the feet would have been next to useless. Given the principle that nature does nothing in vain (*and* that nature cannot give snakes more than four feet, since, in that case, the snake would not be blooded), snakes do not have feet.[33]

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employment of at least two organic parts, one as it were compressing and the other being compressed."

[31] *De incessu* 3, 705a23–25: "And so nothing that is without parts can move in this manner; for it does not contain in itself the distinction between what is to be passive and what is to be active".

[32] *De part. an.* 4.11, 690b14–18; *De incessu* 4, 705b25–29.

[33] However, the fact that snakes do not have organs for motion does not mean that they do not locomote: they move forward by bending themselves (see *De incessu* 7, 707b6–

There is, however, an important difference between the explanatory force of the use of this principle in biology as opposed to its use in cosmology, and this difference derives directly from the lack of observational evidence in the latter domain. For, in the biological domain *observation* determines the possibilities of what nature does and does not produce.[34] In the case of the footless snake, observation shows that all other blooded animals that live on land have feet; blooded land dwellers share to a certain extent the same formal nature, which explains the occurrence of certain coextensive features like the possession of a maximum of four feet. The snake also possesses all the properties that belong to blooded land dwellers, except for one. It is therefore rational to ask why this particular property is absent in snakes. It is not rational to ask why snakes lack wings, telescopic eyes, or any other part that cannot be observed to belong to the wider class to which snakes belong. As there is a virtual infinity of properties that any animal does not have, it only makes sense for a natural scientist to explain the absence of those properties that belong to the "natural possibilities" of that animal; and what those natural possibilities are, can be established inductively, on the basis of observation and through comparison with related beings.

In the cosmological domain, on the contrary, the range of possible ways in which a certain feature or motion can be present is only partly determined by observation. What cannot be observed might still be present, and what can be observed might be the result of a visual illusion. Aristotle often struggles with this question of how much credence we must attribute to our observations of the heavens, and of which observations we should explain and which we should explain away. His general strategy is to explain the phenomena and hence to save them; but on occasion, especially when there are contradictory observations, the observations that conflict with the thesis that the stars move around fixed in concentric spheres are rather explained away. This is exactly what happens in the paragraphs leading up to the explanation of why stars have no feet in *De caelo* 2.8, 290a12–29. Before giving his teleological argu-

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131; 8, 709a25–b4; 10, 709b27–28.). This may point to a problem for Aristotle's argument concerning the heavenly bodies: for the absence of *organs* for locomotion as such does not provide conclusive evidence that the stars in fact do not locomote. Of course, as the remainder of *De caelo* 2.8 points out, Aristotle is actually committed to the stronger claim that spherical bodies do not only lack organs for motion, but also "points of motion", which (at least given Aristotle's laws of sublunary mechanics) rules out any possible way of locomotion.

[34] Lennox (2001) 214–215.

ment demonstrating the likelihood of the absence of feet in stars, Aristotle argued that if the heavenly bodies were to move on their own, they would either roll or rotate, but that neither of these motions is observed to take place. The impression that the Sun rotates in rising and setting[35] is then explained away: according to Aristotle, the rotation is merely a visual illusion, caused by the weakness and unsteadiness of our vision.

What this makes clear is, first of all, that while in biology observations clearly show that snakes lack feet, observational evidence of the heavens gives much less certainty about the absence of feet in the heavenly bodies. For all we can tell, the heavenly bodies might be too far away for us to see their organs of motion. Secondly, observations of the heavens will not tell us whether there are any *natural* limitations to the possible ways in which nature could have "crafted" stars in order to make them able to move on their own. The absence of feet in the heavenly bodies in itself seems hardly enough to establish the reasonableness of the alternative theory that they do not effect any forward motion at all.

This difference between the reliability and applicability of observational evidence in biology and cosmology is important, because Aristotle's explanation in the case of the heavenly bodies is not *prompted* by the observation that they do not have organs for motion, as it is in the case of snakes.[36] There are no observations of the heavens that would reasonably lead to the expectation of heavenly bodies having feet in the first place. (One might object, however, that in this case the philosophical tradition within which Aristotle is working prompts this question).[37] Rather, Aristotle works the other way around: because he wants to make the theory that the stars do not move on their own as reasonable as possible, he uses the teleological principle that nature does

[35] Xenophanes might have observed the same phenomenon, and gives it a similar explanation: see Diels and Kranz (1951) 21A41a δοκεῖν δὲ κυκλεῖσθαι διὰ τὴν ἀπόστασιν; "[the Sun] seems to turn in a circle due to its distance."

[36] In *De part. an.*, the principle is commonly used in the context of a discussion of why animals have certain parts, where it is "discovered" that a certain kind of animal lacks that part while other members of its larger family or otherwise related animals have it. The question thus arises through comparative and empirical research. For examples, see *De part. an.* 4.12, 694a13–20 and 694a16–18; 4.13, 696a10–15 and 696a12.

[37] On this tradition, see Cornford (1937) 55–56; besides Plato, Empedocles also seems to have argued for the footlessness of the celestial sphere (Diels and Kranz, 1951) 31B29: τὴν Φιλίαν διὰ τῆς ἑνώσεως τὸν Σφαῖρον ποιοῦσαν, ὃν καὶ θεὸν ὀνομάζει, καὶ οὐδετέρως ποτὲ καλεῖ '*σφαῖρον ἦην*'. οὐ γὰρ ἀπὸ νώτοιο δύο κλάδοι ἀίσσονται, οὐ πόδες, οὐ θοὰ γοῦν(α), οὐ μήδεα γεννήεντα, ἀλλὰ σφαῖρος ἦην καὶ ⟨πάντοθεν⟩ ἶσος ἑαυτῶι).

non-matching parenthesis

nothing in vain to argue for the likelihood of the absence of the organs of motion in the heavenly bodies.[38]

In sum, it seems that in this example Aristotle goes out of his way to establish the reasonableness of the assumption that the heavenly bodies do not have a motion of their own and, hence, must be carried around while being fixed in concentric spheres. In the biological realm, the observation of what happens always or for the most part in nature is what allows us to draw inferences about cases in which the goal-directedness is less evident. In a domain such as cosmology, which is empirically underdetermined, such inferences are necessarily of a conjectural nature. However, if teleology extends to the heavenly realm, and Aristotle assumes that it does, then the use of teleological principles allows Aristotle to make the most sense of the phenomena, and to provide explanations appropriate to the science of nature, rather than merely astronomical or mathematical ones.

## 5. *Conclusion*

To a modern audience, Aristotle's teleological explanations of heavenly phenomena may sound rather unusual, but what I hope to have made clear in this chapter is that they make perfect sense within Aristotle's conception of natural science. If the heavens are part of nature, then we need at least to attempt to state all four causes for every heavenly phenomenon, even if the investigation has been made difficult because of the scarcity of empirical data. Aristotle's use of teleological principles thus follows from his treatment of the study of the heavens as part of the study of nature; and we have seen that this approach is especially prominent in the second book of the *De caelo*, where Aristotle searches for explanations of the features and motions of the heavens as a whole and of the heavenly bodies. The scientific investigation of an empirically undetermined domain such as the heavens is difficult, as his methodological reflections show, Aristotle is mostly well aware of all the problems involved. However, if one wants to gain knowledge of the heavens and its bodies, one has to try to give explanations that at least make the phenomena—both in terms of what can and of what cannot be observed—seem as reasonable as possible.[39]

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[38] Aristotle repeats this argument in a reversed form in *De caelo* 2.11, 291b11–17.

[39] Cf. Irwin (1988) 34.

The strategy that Aristotle employs to give plausible accounts is to posit teleological principles as a way of finding final causes in difficult cases. The principles used are not *a priori* axioms, but suppositions derived from empirical evidence. They are generalizations over the actions of the formal nature of beings, based on numerous observations made in the biological domain. Just as the use of these principles helped Aristotle to find final causes in cases where these were not immediately observable in biology, in the same way Aristotle hopes to find explanations for natural phenomena in the cosmological realm. This gives a very central role to Aristotle's scientific practice in biology: one could say that where Aristotle's philosophy of science as described in the *Analytica posteriora* offers the student of nature his scientific toolbox, the accessible and rich domain of biology is the student's main workplace. The experience and knowledge acquired in studying biological phenomena may then—of course with suitable adaptations and refinements—be applied to other, less accessible domains of nature, such as that of the heavens.

The application of teleological principles to the cosmological domain is itself based on the assumption that the heavens are no less teleological —and, perhaps even more teleological—than the sublunary realm is. However, as I have pointed out, the lack of empirical evidence in the cosmological realm also weakens to some extent the inferences that Aristotle draws within this teleological framework:[40] the explanations are plausible, but not as "conclusive" as the ones we can find in the biological works.

For the *De caelo* this means that Aristotle argues as much from as towards teleology: starting from the assumption that the heavens as a whole are goal-directed, Aristotle tries to give a coherent, plausible, and reasonable picture of the heavens in which things are present or absent for a reason. This is Aristotle's main goal in the *De caelo*: even if it is not possible to give deductions that demonstrate why the heavens and the heavenly bodies have the features they have, one can still offer plausible physical accounts or inferences to the best explanation that take away some of the puzzlement concerning the heavens.

[40] Cf. Falcon (2005) ix: "there are features of the celestial world that outrun the explanatory resources developed by Aristotle for the study of the sublunary world."

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Simplicius, *In Aristotelis de caelo commentaria*. See Heiberg 1894.

———, *In Aristotelis physica commentaria*. See Diels 1882–1885.

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