

Theokritos Kouremenos

Heavenly Stuff

The constitution of the celestial objects and the theory of homocentric spheres in Aristotle's cosmology

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To my brother

Nikos

and to my sister

Chrissie

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PREFACE

As described by modern cosmology, the true composition of the universe bears no resemblance to our composition and to that of our surroundings, or to that of anything we can observe far beyond them. We, everything around us and all we can see consist of baryonic matter, but a not yet detected nor well understood "cold dark matter" dominates on the scales of galaxies and cluster of galaxies; over truly cosmological scales, dominant is a completely mysterious "dark energy", the most abundant content of the universe. The idea that the cosmos, for the most part, contains something very different from what constitutes us, our local environment and its furniture can be traced back to Aristotle, though his conception of the cosmos is a very distant ancestor of ours: the stars of our galaxy, which are visible with the naked eye, arranged spherically around the Earth–that is, the celestial sphere, or the sphere of the fixed stars, physically conceived–with the five planets of our solar system known in antiquity–Saturn, Jupiter, Mars, Venus and Mercury–and the Sun and the Moon in between. Aristotle believed that all celestial objects consist of the same substance that pervades the heavens, which are almost the whole of the cosmos. This stuff is unlike those found near the center of the cosmos which compose us and everything immediately around us, the famous four elements introduced by Empedocles of Acragas in the fifth century BC. Within Aristotle's physics, it is as puzzling as dark energy is today within our physics. It is commonly known as ether, and its distant descendant, "the luminiferous ether", played a role in the development of Einstein's special theory of relativity, and thus of his general theory, too, a pillar of modern physics and cosmology.

I argue in this monograph that Aristotle did not introduce this heavenly stuff at one go, but originally as matter only of the remotest celestial objects from the Earth–the stars–and as filler of the spherical shell they are fixed in–the crust, or nutshell, of the cosmos. I also argue that at no point in the development of his cosmological thought did Aristotle hold that the theory of homocentric spheres of Eudoxus of Cnidus, who seems to have aimed at modeling geometrically some aspects of the observed motions of the planets, the Sun and Moon, mirrors the structure of the heavens.

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1. ARISTOTLE'S COSMOLOGY

1.1. PLANTS AND ANIMALS VS. CELESTIAL OBJECTS

In *Cael.* B 5 Aristotle sets out to answer the surprising question why the direction of the diurnal rotation is from east to west, not the other way around.[1] Since he believes that, in contrast to what is the case with plants and animals, substances coming into being and passing away, nothing occurs randomly in the eternal realm of celestial objects, there cannot but be some reason why the diurnal rotation is from east to west (287b24–28). His brief explanation is prefaced by some words of caution, betokening understandable distress at his raising and trying to settle, albeit tentatively, the issue at hand.

To try to pronounce an opinion on intractable matters, such as the one Aristotle himself is looking into here, and the unwillingness to circumvent any subject might be considered a symptom of excessive eagerness to investigate or, worse, simple-mindedness. However, it is unfair, Aristotle continues, to chastise indiscriminately all those who dare tackle some very difficult problems without first taking into account their reason for so doing, and without considering whether the confidence, with which they put forward their proposed solutions, is commensurate with human cognitive limitations or not. He concludes by saying that, in explaining why the diurnal rotation is from east to west, he will say just what seems to him to be the case, and that we ought to be grateful to future thinkers who might be successful in coming up with adequate explanations of necessarily compelling nature (287b28–288a2).[2]

Similar sentiments are expressed in *Cael.* B 12. Aristotle opens this chapter with the remark that he must attempt to state what seems to him to be the case as regards two baffling problems, whose difficulty anyone would acknowledge, concerning the celestial objects and their motions.[3] His eagerness to attack such impenetrable questions is a sign of humility, not impetuousness, stemming from the willingness, due to a desire for knowledge, to be satisfied with making even very small steps towards an understanding of those things which we are most puzzled about (291b24–28). Before going on to put forward what by his lights is just a plausible solution to the problems at issue, Aristotle notes that it is good to try to expand our understanding of the celestial objects, though our starting points are necessarily scanty, for enormous distances separate us from the celestial phenomena (292a14–17).[4] But his deep conviction that the study of these phenomena is an intrinsically worthy enterprise motivates him to forge stubbornly ahead.

1 For the diurnal rotation, and the associated concept of the celestial sphere, see 1.3.3.

2 What Aristotle contrasts at the end of this passage are τὸ φαινόμενον and αἱ ἀκριβέστεραι ἀνάγκαι, however the latter might be understood.

3 Here, too, "what seems to be the case" translates τὸ φαινόμενον (cf. previous note).

4 Cf. *Cael.* B 3, 286a3–7.

Aristotle stresses how difficult it is to study the celestial objects also in the preface to *PA* (A 5), where he adds that the difficulty is more than adequately made up by how much excitement even a small progress in this area can generate. Contrasting the study of the eternal and divine celestial objects with the inquiry into transient plants and animals, he notes that the former is much worthier, for it deals with an eternal and divine, hence more valuable, subject-matter, but is unfortunately hampered by the fact that very few starting points are available to our senses, from which we can theorize about the celestial objects and those phenomena they exhibit that we desire most to understand. To obtain knowledge of perishable plants and animals is easier, because they live with us, here on Earth. As a consequence, we can learn much about each kind of plant and animal if we are willing to undertake sufficient efforts. If we manage to advance even a little our understanding of the heavens, however, this knowledge is so valuable that to possess it is more pleasurable than to have grasped all things that are close to us, just as to have been granted a mere glimpse of those we are in love with is more gratifying than the detailed inspection of many and much larger, or much more important, things (644b22–35).[5]

The beautiful *PA* passage might have influenced a section in Cicero's *Lucullus*, 127–128, where Cicero himself explains an Academic skeptic's cognitive attitude towards the study of celestial objects. In Cicero's view, the study of nature in general is a kind of natural food for thought. By inquiring into the highest reaches of the cosmos we are uplifted, and led to look down upon our totally insignificant affairs. He admits that these are matters as extremely inscrutable as they are supreme in importance, and adds that if we chance upon some ideas about the heavens that appear to have a likeness to what is true, our mind is filled with the kind of pleasure most appropriate to human beings. The Stoics, Cicero says, study the phenomena of the sky in order to affirm the truth of whatever conclusions they might be led to, but the Academic skeptics, wary of holding rash opinions, engage in the same branch of intellectual endeavor ready to be content with what seems to bear a likeness to the truth.

Aristotle does not think that the celestial objects are different from plants and animals only insofar as our epistemic access to them is concerned. It is generally agreed that, within the framework of his physics, at least after an initial phase of its evolution, for which we have very little, if any, evidence, the celestial objects are assumed to be made out of a kind of matter totally different in nature from those kinds of matter that are thought to make up all plants and animals.[6] The second

5 On the passages discussed so far see Falcon (2005) 85ff.

6 An initial phase in the evolution of Aristotle's physics, when he did not posit the existence of a special celestial matter, has been detected in the fragments of his early dialogue *On Philosophy*. See Solmsen (1960) 287, with n. 1, and Hahm (1982) 60, with n. 2. Hahm denies that in his lost work Aristotle introduced this novel kind of matter. Freudenthal (1995) 101–105 argues that is was introduced some time after the composition of the dialogue *On Philosophy*, as direct development of the physics Aristotle elaborated therein. Modern developmental accounts of Aristotle's physics usually focus on the evolution of his views about the ultimate sources of all motion and change in the cosmos. Surveys in Graham (1996) 171–172 and Graham (1999) xiii–xiv.

chapter of this study is an attempt at elucidating the stages at which Aristotle introduced this celestial matter.

1.2. THE FOUR TRADITIONAL SIMPLE BODIES

1.2.1. Fire, air, water and earth, and their qualities

Everything within the scope of our immediate experience is, according to Aristotle, ultimately made up of four kinds of elementary body, matter continuous in all three dimensions, or of four simple bodies.[7] These simple bodies are the "traditional" elements Empedocles of Acragas introduced into physics in the fifth century BC: fire, air, water and earth. Their simplicity lies in their unanalyzability into other bodies.[8] Aristotle thinks of them as combinations of qualities, which form two pairs of contraries. Earth is dry and cold, water is cold and wet, air is wet and hot, fire is hot and dry (*GC* B 3, 331a3–6);[9] as he explains in *Mete*. A 3, what is habitually called "fire" is the simple body of the same name when undergoing combustion (340b19–23). On what can be appropriately called "the cosmological scale" in this context, these four simple bodies are sorted out concentrically. The simple body earth is clumped around the center of the cosmos into a globe–the Earth; the simple body water is concentrated on the surface of this globe within a spherical shell of air, around which there is a spherical shell of fire.[10] All things in our close surroundings are ultimately constituted by all of these four simple bodies, bound together in insignificant amounts by comparison to how much of each exists in the cosmos (*GC* B 8, 334b30–335a9).[11]

This makes clear that, although the four traditional simple bodies are always neatly stratified on the cosmological scale, on much smaller scales they are not separated at any given time. They cannot be completely sorted out, Aristotle explains in *GC* B 10, 337a7–15, because, on scales much smaller than the cosmological scale, they constantly transform into one another, and, as a result, the concentration of each on the cosmological scale contains bits of all others, an exception, as Aristotle seems to suggest in *Mete*. A 3, being the outermost part of the

7 For the three-dimensional continuity of bodies see *Cael*. A 1, 268a1–10, an introductory characterization of what is studied in physics.

8 See the definition of "element" in *Cael*. Γ 3, 302a15–25.

9 The qualities constituting each and every portion of one of these four simple bodies can be paralleled to the so-called tropes, or abstract particulars, of modern metaphysics. Brief introductory account in Mellor & Oliver (1999) 17–20; fuller discussion in Williams (1999), Campbell (1999). Cf., though, Gill (1991a) 77–78.

10 Aristotle demonstrates in *Cael*. B 4 that the cosmos is stratified into spherical shells, with the Earth as the central sphere. Some of his arguments are discussed below, in 2.3.

11 Aristotle's explanation of why the constitution of any medium-sized object must include air and fire, too, is problematic. See Williams (1982) 178–179. Presupposed might conceivably be the assumption that all of the four traditional simple bodies are present near the surface of the Earth, where medium-sized objects exist, and the application of the principle that everything is made out of the body, or bodies, in which it is situated; see below, 1.3.1.

shell of fire (340b6–10; see Appendix 2), and perhaps the depths of the Earth (this seems to be implied by *GC* B 3, 330b33–331a1).[12] As we will see next, such impurities must exist in the first place if the four Empedoclean simple bodies are to be transmuted into one another.

1.2.2. The change of one simple body into another

We will leave aside for the time being what powers this change and how, to discuss how the analysis of the four traditional simple bodies into qualities allows them to turn into one another within the framework of Aristotelian physics. Aristotle describes three transmuting processes in *GC* B 4. By the first of them, fire transforms into air, air into water, water into earth, and earth into fire; this cyclical change can occur in the other direction. By the second process, fire turns into water, air into earth, water into fire, and earth into air. By the third process, fire and water change jointly into earth or air, air and earth into fire or water.[13]

The three processes that transmute one or two traditional simple bodies into another involve physical contact and interaction between two simple bodies.[14] But the real agents are the contraries. Two traditional simple bodies act on each other in virtue of their contraries. The cold e.g. is potentially the hot, and the hot is potentially the cold, just as the dry is potentially the wet, and the wet is potentially the dry. If the simple bodies they characterize come into contact, each quality acts on its contrary. The cold tries to assimilate to itself the hot, and its action is being met by an opposite reaction: if one of the contraries is "overpowered", it assimilates itself to the other, which also suffers a reciprocal change, as result of the interaction (*GC* B 7, 334b20–29).[15] But if the cold of e.g. earth assimilates itself to

12 For fire inside the Earth see *Mete*. B 4, 360a5–6, B 8, 365b24–27. Probably the best explanation of its presence is the mixture of all four traditional simple bodies in the surface layers of the Earth. When Aristotle speaks in *GC* B 3, 330b33–331a1, of the two simple bodies earth and fire as the purest of the traditional simple bodies, for they are "extremes", whereas the other two are "intermediates", it is quite unlikely that he tacitly denies the existence of impurities in the surface layers of the Earth and in the lowest layers of the spherical layer of fire. On terrestrial fire see also Freudenthal (1995) 70–73.

13 For the three transmuting processes see the helpful account in Gill (1991a) 67–77.

14 For the requirement that there must be physical contact between an agent and what is being acted upon by the agent see Aristotle's description in *Ph*. Γ 2, 202a3–12, of how a change is brought about by an agent; cf. *GC* A 6, 322b22–25.

15 On Aristotle's "law of action and opposite reaction" see *GA* Δ 3, 768b15–25, and cf. Kouremenos (2002) 114–115. That something which is hot or cold in actuality is cold or hot in potentiality, and can thus, under the right conditions, become actually cold or hot is stated by Aristotle in *GC* B 7, 334b20–22; for the principle at work here see *GC* A 7, 323b18–324a9. The transformation of one, or two, of the four traditional bodies into another occurs, as explicitly said in *GC* B 7, 334b20–29, if two interacting contraries, each of which is in potentiality the other, are not equal, or, as Aristotle puts it in *GC* A 10, 328a23–31, when the quantity of one of the two interacting simple bodies does not match the amount of the other in power; what is called "power" here is the capacity of each mass to assimilate the other to itself, by acting on the antagonist in virtue of its having in actuality the quality the antagonist has only in potentiality. For how Aristotle supposes this power to be quantifiable in theory–nothing hints that he