Clever Machines and the Gods Who Make Them: The Antikythera Mechanism and the Ancient Imagination

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After sitting, cryptically, silently, in the Archaeological Museum in Athens for nearly a century, the Antikythera mechanism only really began to yield up its secrets in the latter part of the twentieth century.¹ To be sure, there had been some speculation that the thing was some kind of planetarium or orrery from within a few years of its discovery, but it was hard for most scholars to really believe this was possible in the cold light of day. Not until Derek de la Solla Price managed to obtain images of the thing using gamma rays in the 1970's did we finally realize the complexity of its internal gearing, and even then there were plenty of surprises in store for us as imaging technology improved over the next 30 years. Publishing in 1974, Price was now certain that the device was some kind of “calendrical Sun and Moon computing mechanism,” and he was quick to try and establish a line between the mechanism and several ancient reports of “planetarium devices” associated with Archimedes by Cicero and others. These reports, too, have had a curious history. In the wake of our newfound (and quite revolutionary) understanding of the inner workings of the mechanism in the last ten years, it is now very easy to see many of the ancient reports of wonderful planetary machines as fairly unambiguous references to complex geared Antikythera-type planetaria. But before the last generation or so, most professional historians of astronomy resisted committing themselves to such a conclusion, wondering whether the stories in Cicero and his contemporaries were fancified accounts of much simpler instruments such as armillary spheres or decorative globes or something similar. Non-historians-of-astronomy, editors and

¹ See, e.g., Freeth and Jones, 2012; Freeth, Jones, Steele, and Bitsakis, 2008; Wright, 2007; Freeth *et al.*, 2006; Price, 1974; See also Field and Wright, 1985.

translators of Cicero, for example, were happier to refer to such descriptions as referring to ‘planetaria’ and ‘orreries’ even if professionals were more sceptical that devices of such complexity could have existed as early as the first century BC. To put the complexity of the mechanism in context: no geared device of this sophistication appears in the European historical record prior to the *fourteenth century AD*, which is to say, until the late-medieval astronomical clocks of Giovanni de Dondi and Richard of Wallingford. And for their part, historians of horology had often remarked on how complex the de Dondi and Wallingford clocks seemed to be, given that there was no apparent prior tradition from which they may have developed.

1. WHAT DOES THE ANTIKYTHERA MECHANISM DO?

The mechanism, found by sponge divers excavating a Mediterranean shipwreck for treasure at the very beginning of the twentieth century, is badly decayed and missing much of its original material. Nevertheless, recent imaging work has revealed it to be a complex astronomical-calendrical computer that uses intricate gearing to turn inputted motion, in the form of a cranked handle, into sophisticated output using a number of pointers on several dials. Apart from being hand-driven, the mechanics of the mechanism are very much analogous to those of a modern clock, but with more faces, and much more complex motions on its dials. The device itself was originally housed in a wooden box, perhaps 30 cm high by 18 cm wide by 12 cm thick. Hinged doors covered each of the two display sides, opening up to reveal clock-like dials on both faces, two main dials on what we are now calling the rear face of the machine, and a single dial with multiple pointers and scales on the front. Rather than telling the time, as a modern clock does, the mechanism told the Egyptian-calendar date on the front dial, as well as the month in what we now believe to be

the calendar of Epirus (including intercalary information) on one of the rear dials.² It also had a pointer for cyclical games (Olympia, Isthmia, etc.) and dials for eclipse prediction on the rear face. The front face contained a dial for the motion of the moon through the zodiac (noted also for the sun), and a clever rotating ball mechanism showing the moon's phase. Most scholars now believe that the front face also originally had pointers for the motion of the planets through the zodiac—which is no mean feat.

2. REPUBLICS

Now that we know this thing exists, we can look to literary descriptions of *sphaerae* in ancient sources with more appreciation of detail than we had done previously, since we now have a better idea of what the possibilities were. The earliest such description and in many ways the archetype of all later ones comes from Cicero's *Republic*.

Although written in the late 50's BC, the dialogue of the *Republic* is set a couple of generations earlier, in the turbulent aftermath of Tiberius Gracchus' disastrous land-reform proposals, and specifically in the year in which Scipio Aemilianus—a prominent character in the *Republic*—would be found dead under what many took to be suspicious circumstances. Early in the dialogue, after a bit of give and take on the relative importance of then-recent reports that two suns had been seen simultaneously (an ominous sign for ominous times), the character Philus makes a plea for the importance of our knowledge of the cosmos to our understanding of the solutions to the ills of the Roman republic. This appeal is one of Cicero's most cherished philosophical ideas (shared with the Stoics, among others), that human justice, and ethics in general, is rooted in an understanding of nature. And so for Cicero, right reason is grounded in an understanding of the divine governance of the

² The identification of Epirus is suggested by Freeth, Jones, Steele, and Bitsakis, 2008.

cosmos. And this turning to nature to see how the gods govern the world has immediate political import for Cicero, since, as he says very early on in the *Republic*,

neque enim est ulla res, in qua propius ad deorum numen virtus accedat humana, quam civitatis aut condere novas aut conservare iam conditas.³

There is no other area in which human virtue comes closer to the majesty of the gods, than in building new states, or in maintaining existing ones.

Given the strife rocking the state when Cicero wrote the *Republic*, this is clearly an important claim. Furthermore, we see from a number of related passages that the cosmos as a divine artifact plays heavily into his account of how the best state should be constituted. He goes so far as to frame the entire *Republic*, at its beginning and end, with cosmological discussions, as well as to pepper cosmological terminology throughout his political passages.⁴

And it is in this context that Cicero invokes the earliest reference we have to an Antikythera-type mechanism. Having stepped back from his own day to 129 BC for the main body of the dialogue, Cicero now has his character Philus briefly step us back one more generation, to 166 BC, when a similar report of a double sun had been circulating. Philus was at that time, he tells us, visiting Marcus Marcellus, grandson to the Roman conqueror of Syracuse, in the company of the younger Marcellus' co-consul Gaius Sulpicius Gallus.

nam memoria teneo C. Sulpicium Gallum, doctissimum ut scitis hominem, cum idem hoc visum diceretur et esset casu apud M. Marcellum, qui cum eo consul fuerat, sphaeram quam M. Marcelli avus captis Syracusis ex urbe locupletissima atque ornatissima sustulisset, cum aliud nihil ex tanta praeda domum suam deportavisset, iussisse proferri; cuius ego sphaerae cum persaepe propter Archimedi gloriam nomen audissem, speciem ipsam non sum tanto opere admiratus; erat enim illa venustior et nobilior in volgus, quam ab eodem Archimede factam posuerat in templo Virtutis Marcellus idem. sed posteaquam coepit rationem huius operis scientissime Gallus exponere, plus in illo Siculo ingenii quam videretur natura humana ferre potuisse iudicabam fuisse. dicebat enim Gallus sphaerae illius alterius solidae atque plenae vetus esse inventum, et eam a Thalete Milesio primum esse tornatam, post autem ab Eudoxo Cnidio, discipulo ut ferebat Platonis,

³ Cicero, *Rep.* I.12.

⁴ See Gallagher, 2001.

eandem illam astris quae caelo inhaerent esse descriptam; cuius omnem ornatum et descriptionem sumptam ab Eudoxo multis annis post non astrologiae scientia sed poetica quadam facultate versibus Aratum extulisse. hoc autem sphaerae genus, in quo solis et lunae motus inessent et earum quinque stellarum quae errantes et quasi vagae nominarentur, in illa sphaera solida non potuisse finiri, atque in eo admirandum esse inventum Archimedi, quod excogitasset quem ad modum in dissimillimis motibus inaequabiles et varios cursus servaret una conversio. hanc sphaeram Gallus cum moveret, fiebat ut soli luna totidem conversionibus in aere illo quot diebus in ipso caelo succederet, ex quo et in caelo <et in> sphaera solis fieret eadem illa defectio, et incideret luna tum in eam metam quae esset umbra terrae, cum sol e regione ... <lacuna> ...⁵

I am reminded of C. Sulpicius Gallus, a most learned man, as you know. At a time when a similar phenomenon was reported and he happened to be at the house of Marcus Marcellus, his colleague in the consulship, he ordered the sphere to be brought out which the grandfather of Marcellus had carried off from Syracuse when that very rich and beautiful city was taken (though he took home with him nothing else out of the great store of booty that was captured). Though I had heard this sphere mentioned quite frequently on account of the fame of Archimedes, when I actually saw it I did not particularly admire it; for that other one, also constructed by Archimedes, which the same Marcellus placed in the temple of Virtue, is more beautiful as well as more renowned among the people. But when Gallus began to give a very learned explanation of the device, I concluded that the famous Sicilian had been endowed with greater genius than one would imagine it possible for a human being to possess. For Gallus told us that the other kind of sphere, which was solid and full, was an old invention, the first one of that kind having been lathe-turned (*tornatam*) by Thales of Miletus, and later marked with the constellations which are fixed in the sky by Eudoxus of Cnidus (a disciple of Plato, it was claimed). He also said that many years later, Aratus, borrowing this whole arrangement and plan from Eudoxus, had described it in verse, without any knowledge of astronomy but with considerable poetic talent. But this newer kind of sphere, he said, in which were delineated the motions of the sun and moon and of those five stars that are called planets, or as we might say, wanderers, contained more than could be shown on the solid globe, and the invention of Archimedes deserved special admiration because he had thought out a way that a single turn saved the anomalous and changing courses in [their] completely different movements.⁶ And when Gallus moved the sphere, it happened that the moon advanced on the sun by as many turns in the bronze as it did by days in the sky itself. Thus the same eclipse of the sun happened in both the sphere and the heavens, and the moon came to the cone where the shadow of the earth would have been, at the very time when the sun ... from the region ...

⁵ Cicero, *Rep.* 1.21-22. Translation modified from Keyes.

⁶ I thank Michael Wright for suggestions on the translation.

The text unfortunately breaks up here and we have a lacuna of (probably) a few pages in the original before the dialogue picks up again with the character Scipio recounting a story about the time that Gallus talked his troops down from panic at the sight of a lunar eclipse by explaining the physics of the earth's shadow to them.⁷

In examining Cicero's account of this 'Archimedean sphere' I do not wish to worry overmuch about the plausibility of the device's survival (or its functionality) from the siege of Syracuse in 212, to the date of Philus' purported encounter with the device in 166–46 years is a long time in the life of a delicate and difficult-to-clean bronze instrument. Nor am I particularly committed to the idea that Archimedes himself built such a sphere. We do not need to take any of these claims as historical just so long as Cicero can be expected to be describing a *class* of device that really existed in his day, and that he did not think would be wholly unfamiliar to his readers.

As for the sphere itself, Cicero says that it modeled all five planets plus the sun and moon, and he seems to indicate that the geometry of it had the sun and moon pointers configured in such a way that one could talk of knowing where the shadow of the earth (presumably represented at the centre of the dials) would be: *et incideret luna tum in eam metam quae esset umbra terrae*, "the moon [pointer] came to the cone where the shadow of the earth would have been.". The use of the odd verb just before this, *seruo*, for the relationship between the display and the heavens—the device is said to have "saved the anomalous and changing courses"—seems to have been an attempt to translate the sense of the Greek σώζει τὰ φαινόμενα, "save the phenomena," meaning that it modeled the phenomena precisely. The phrase *in dissimillimis motibus*, "in [their] completely different movements," with its superlative of *dissimilis*, is a favourite of Cicero's for describing planetary motion (and it turns up, so far

⁷ On this story, see Bowen, 2002.

as I can find, rarely outside of Cicero).⁸ I take it here to be describing the surprisingly complex independent motions of the various pointers, one of the most striking features of the working Antikythera mechanism.

There are several features of Cicero's account that we will see prominently recurring in later references to mechanized *sphaerae*. First is the association with Archimedes, which, although not universally accepted by modern scholars, nevertheless proved to be a long-lasting ancient tradition. Second, we see Archimedes, insofar as he is the purported inventor of this astounding device, being lauded as having a transcendent, almost super-human intelligence for having come up with the thing: "I concluded that the famous Sicilian had been endowed with greater genius than one would imagine it possible for a human being to possess." Indeed, the standard invocation of the mechanized sphere sees it as the very pinnacle of human ingenuity, instantiated usually in the person of Archimedes. Although he is not quite called "divine" here, the impressiveness, complexity, and sheer cleverness of the device is such that it is scarce believable that it could have been the product of human hands. Indeed, this is still a common reaction to reconstructions of the Antikythera mechanism: *How*, everyone seems to ask, was it possible for the ancients to do that, way back then?

The other important theme is less marked here than it will be in later sources, but we will see that it will come to be central to later accounts as it gets more fully elaborated. This is the idea that the machine somehow instantiates the heavens themselves in miniature. We have already seen his use of the verb *servo*, which may be taken as a reference to modeling rather than instantiating, but the issue becomes more complex when Philus comes to describe his amazement at the combined motions of the sun and moon. Here the wording is interesting: the sun and moon make the "same" motions in the device as they make in the

⁸ Compare *ND* II.119 where the planets themselves are said to show that *tantus est concentus ex dissimillimis motibus*. He uses the superlative again in *Tusc.* I.63 to describe the motions in a *sphaera*.

heavens: *et in caelo <et in> sphaera solis fieret eadem illa defectio*, the very same eclipse happens in both the sphere and the heavens.⁹

This doubling is a curious feature of the entire passage, recurring in multiple, layered ways. The story is set in the past within a dialogue set in the past; it is reported by the character Philus, who is himself reporting an experience of a second person, Gallus. The mechanized sphere is second to the more famous Archimedean sphere in the temple of Virtue. The *sphaera* invented by Thales was later marked with constellations *described by* Eudoxus, presumably in his book called the *Phaenomena*, which prose version was itself copied into verse by Aratus, as Cicero has Philus tell us here.

It will be worth spending a moment on the—for our purposes—second sphere in this account. The fixed kind, turned on a lathe, we are (plausibly) told is the older. Marcellus is said to have taken as booty for himself only the mechanical sphere from Syracuse, but he did also, on this story, donate a fixed *sphaera* of Archimedes in the temple of Virtue at Rome. Scholars have often suspected that this is in fact a reliable account of a real sphere, and perhaps even the same sphere mentioned by Ovid as hanging in the temple of Vesta. As Ovid describes it, there is an image of the earth “suspended by Syracusan art” and apparently still extant in his day, hung up in the temple of Vesta at Rome:

terra pilae similis nullo fulcimine nixa,
 aere subiecto tam grave pendet onus.
 ipsa volubilitas libratum sustinet orbem,
 quique premat partes, angulus omnis abest
 cumque sit in media rerum regione locata
 et tangat nullum plusve minusve latus,
 ni convexa foret, parti vicinior esset,
 nec medium terram mundus haberet onus.
 arte Syracosia suspensus in aere clauso
 stat globus, immensi parva figura poli,
 et quantum a summis, tantum secessit ab imis

⁹ The addition of *et in* here follows Dobree. Ziegler prefers to excise *caelo* instead, leaving the comparator only implied.

terra; quod ut fiat, forma rotunda facit.¹⁰

The earth is like a ball, supported by no pillar; so heavy a burden weighs on the air beneath. This roundness¹¹ sustains the orb, balanced. It has no angle to press on any part. It is always situated in the middle of everything, and touches no side more and on no side less; were it not round, it would be closer in one part and the world would not have the earth as central mass. There stands a globe, suspended in enclosed air by Syracusan art, a tiny form of immense heaven, and the earth stands distant by the same amount from the top as from the bottom, caused as it is by the round shape.

Clearly this is no mechanical *sphaera*, as it shows only the position of the earth in the cosmos and Ovid makes no mention of the planets or of moving parts. In fact, it sounds very much like a device described in Hero of Alexandria (*Pneum.* 2.7) which has often puzzled modern commentators (it is perhaps the least complex or interesting of the devices in Hero's *pneumatica*, and its purpose or significance remains entirely unclear). If so, one wonders why the Archimedean globe attracted any renown at all. Cicero calls it *venusta*, charming, and *nobilis*, renowned, and Ovid's account seems to point toward a degree of subtlety in its design when he says that it is "suspended in enclosed air by Syracusan art." It is hard to imagine why, but it would seem that there must have been some kind of clever suspension system keeping the earth balanced in the middle, or some kind of *trompe l'oeil* effect hiding the strings, as it were, to make it worthy of the literary attention it gets.

3. JUST LIKE GOD DID

Now, if mechanized planetaria—made by clever craftsmen—can be seen as modeling or even in a sense bringing the cosmos into the hands and homes of people on earth, the

¹⁰ Ovid, *Fasti* 6.269-280.

¹¹ One often sees *volubilitas* translated as "rotation" or some such, but this is anachronistic. Ovid means nothing more than roundness, and this for two reasons: (a) *very* few ancients ever even floated the idea that the earth could be rotating, and (b) the physics he is appealing to here, going back to something like Anaximander's principle of indifference, requires roundness, not motion, as Ovid himself points out repeatedly in the subsequent lines. Furthermore, I know of no ancient physical theory that claims that rotation could keep something in equilibrium.

metaphor of the cosmos itself as a product of craftsmanship cannot be far off, putting the human craftsman into a direct conversation with the cosmic creator.¹² Indeed, even the simpler type of globe mentioned by Ovid and Cicero could be used to draw larger analogies about the construction of the whole cosmos. This becomes clear in a curious little passage from a little-known work attributed (albeit insecurely) to Apuleius (2nd c. AD). Apuleius is now perhaps most famous as the author of the celebrated novel *The Golden Ass*. He also, if the present work is in fact his, took enough of an interest in cosmology to translate into Latin the short Pseudo-Aristotelian text called *De mundo*. This translation shows some interesting departures from the original. One passage concerns the shape of the world, where Pseudo-Aristotle highlights the simple fact that, because the cosmos is a rotating sphere, it must have two unmoving poles around which it is turning:

τοῦ δὲ σύμπαντος οὐρανοῦ τε καὶ κόσμου σφαιροειδοῦς ὄντος καὶ κινουμένου, καθάπερ εἶπον, ἐνδελεχῶς, δύο ἐξ ἀνάγκης ἀκίνητά ἐστι σημεῖα, καταντικρὺ ἀλλήλων, καθάπερ τῆς ἐν τόρῳ κυκλοφορουμένης σφαίρας, στερεὰ μένοντα καὶ συνέχοντα τὴν σφαῖραν, περὶ ἃ ὁ πᾶς ὄγκος κύκλῳ στρέφεται· καλοῦνται δὲ οὗτοι πόλοι.¹³

The whole heaven and cosmos being spherical and moving, as I said, perpetually, there are two necessarily unmoving points opposite to each other, just as on a ball being turned on a lathe, that remain still and contain the sphere, around which the whole body of the circle rotates. These are called poles.

But if we turn to the Latin of (Pseudo?) Apuleius, we find that the lathe analogy has been expanded in an interesting way. The Latin no longer talks of a ball simply ‘being turned’ in the passive voice. Instead, it inverts the grammar to more clearly focus on the craftsman who is doing the turning (the craftsman was not even mentioned in the original), and indeed, adds a craftsman to the manufacture of the world itself:

¹² I thank Eduardo Escobar for this suggestion.

¹³ Ps-Aristotle, *De mundo*, 391b19-392a2. Latin translation in Apul. *De Mundo* 1.290.

sed cum omne caelum ita revolvatur ut sphaera, eam tamen radicibus oportet teneri, quas divina machinatio verticibus adfixit, ut in tornando artifex solet forcipe materiam comprehensam reciproco volumine rotundare: eos polos dicimus.

Because the whole heaven is turned as a sphere, nevertheless it is necessary that it remain still at the extremities, which divine artifice has fixed at the points, just as in lathe-turning the craftsman rotates the wood held by pincers in a repeating rotation. These we call poles.

That is, the two fixed points of the cosmos have been established (*adfixit*) by divine ‘artifice’ or ‘machinery’ (*machinatio*). The lathe comparison then comes in not just as a simple, passing observation (“just like something you have seen”), as it did in the Greek, but as a direct comparison to how god built the universe.

God as lathe operator can also be found in the fourth-century Christian writer Diodorus of Tarsus. In his commentary on verse 3 of Psalm 8, ὅτι ὄψομαι τοὺς οὐρανούς, ἔργα τῶν δακτύλων σου (“Because I shall see the heavens, the works of your fingers”), he says:

ἀλλ’ οὐδέν, φησί, θαυμαστόν εἰ τῆς σῆς τέχνης ἔργα ἦν ταῦτα, τό τε ἀνοιγῆναι νηπίων στόματα καὶ τὸ καταλυθῆναι τοσούτων ἐχθρῶν εἰρωνείαν. ἐκεῖνοι γὰρ ταῦτα ἐνήργουν, φησὶν, οἱ δάκτυλοι, οἱ καὶ τὸν οὐρανὸν παρὰ τὴν ἀρχὴν εὐρύθμως ἀποτορνεύσαντες.

It is no surprise, he says, if this was the work of your *techné*, the mouths of infants being opened and the false modesty of your enemies being destroyed. For those fingers, he says, that did these things also lathe-turned the heavens in beautiful proportion in the beginning.

God as craftsman: employing *techné*, and in particular the lathe, to fashion the world.

One is immediately reminded in these two passages of Plato’s *Timaeus*, where the demiurge is explicitly said to “turn” the heavens as on a lathe: κυκλοτερές αὐτὸ ἐτορνεύσατο.¹⁴ And the god of the *Timaeus* finds himself in fullest play in yet another passage from Cicero, this time from his *Tusculan Disputations*, where he invokes the full complexity of an

¹⁴ *Tim.* 33B.

Antikythera-like mechanism as an analogy for how the whole cosmos was put together by the demiurge in the beginning. As in his earlier *Republic*, when Cicero again mentions Archimedes in the *Tusculan Disputations*, we see the praise of his near-superhuman genius at the forefront, but this time Cicero takes it much further, using that genius as the keystone to an argument about the very immortality of the human soul. This is a long way from just invoking lathes and spheres as analogies.

The *Tusculan Disputations*, written in 45 BC, opens with a discussion of death and what happens to the soul afterwards. Harkening back to the *Dream of Scipio*, the character “M.” (Marcus himself)¹⁵ wonders at one point what the view will be like when, after death, the soul will be able to rise up to the heavens and look down on the whole earth. The conversation then moves on to how memory might work in the soul, and, ultimately for our purposes, to that other great ability of the soul: invention. A list of great inventions follows, starting with the most important crafts, music and astronomy:

nam et auribus oblectatio magna parta est inventa et temperata varietate et natura sonorum, et astra suspeximus cum ea quae sunt infixae certis locis, tum illa non re sed vocabulo errantia, quorum conversiones omnesque motus qui vidit, is docuit similem animum suum eius esse, qui ea fabricatus esset in caelo. nam cum Archimedes lunae, solis, quinque errantium motus in sphaeram illigavit, effecit idem quod ille, qui in Timaeo mundum aedificavit, Platonis deus, ut tarditate et celeritate dissimillimos motus una regeret conversio. quod si in hoc mundo fieri sine deo non potest, ne in sphaera quidem eosdem motus Archimedes sine divino ingenio potuisset imitari.¹⁶

For through them our ears have gained keen delight from the discovery of the due combinations of musical sounds of diverse quality, and we have looked up at the stars, both those that are fixed in certain spots and those that by name are “wandering” (though they are not really so), and he who has seen their revolutions and all their movements has taught that his soul resembles his who had fashioned them in the heavens. For when Archimedes fastened the movements of the moon, the sun, and the five planets on a sphere, just like Plato’s god who built the world in the in the *Timaens*, he

¹⁵ It has also been suggested that the M may be for *Magister*, but I think the internal cross-references to Cicero’s other works as his own suggest Marcus very strongly.

¹⁶ Cicero, *Tusc.* 1.62-3. Translation modified from King.

made one revolution of the sphere control several movements completely different in slowness and speed. Now if in this world of ours phenomena cannot take place without the act of god, neither could Archimedes have imitated the same movements upon a sphere without divine genius.

Reflecting upon this genius of discovery, the puzzles of how memory might work, and some quiet amazement even at simple perception, Cicero goes on to offer us a strikingly novel account of the soul. Virtually all Greek and Roman philosophers, so far as I am aware, thought the soul to be a physical entity, made up of the same stuff as the rest of the cosmos, whatever that may have been taken to be. Cicero tells us that he had realized, while grieving for his recently deceased daughter Tullia, that the elements of which the earth and cosmos are made could *in no way* be responsible for memory, thought, deliberation, or perception—earth, air, water, and fire simply do not have properties that could produce reason and consciousness. “Whatever it is,” he says, quoting his now-lost *Consolatio*, “that perceives, that is wise, that lives, that flourishes, must be heavenly and divine and for that reason eternal.”¹⁷ Cicero now moves us up from the divinity of the human mind to the divine governance of the universe as a whole, in a version of the same argument from design that we will see again shortly in the *De natura deorum*. In one extremely long, breathlessly flourishing sentence of 260-odd words, he takes us from our observation of the brilliance and wonder of the sky to the necessity of a divine creator or governor. Harking back to the *Dream of Scipio*, he says that the sun is (astrologically) called the *temperatio* and *moderator* of the planets. Picking up on Stoic themes from the *De natura deorum*, the natural order sees animals near-miraculously well suited to our every need (they serve as food and as draft animals, for example), and in the

¹⁷ *ita quidquid est illud, quod sentit, quod sapit, quod vivit, quod viget, caeleste et divinum ob eamque rem aeternum sit necesse est. Tusc.* I.66.

capstone statement of these dual themes, humans exist specifically *quasi contemplatorem caeli ac terrarum cultorem*, “to contemplate the heavens, as it were, and to till the earth.”¹⁸

Where Cicero had held back from calling Archimedes “divine” in the *Republic*, here he shows no such reticence, and in fact the marvel of the sphere itself is central to the whole claim: “if in this world of ours phenomena cannot take place without the act of god, neither could Archimedes have imitated the same movements upon a sphere without divine genius.” Archimedes’s genius is divine, and it is identified with the divine soul of the creator of the cosmos. But—and this is curious—the analogy runs unexpectedly backwards to the expected argument from design: it is not that the cosmos must have a creator and operator since it is like the sphere, which clearly has a creator and operator. It is instead that since the cosmos has a creator and operator who is divine, the imitation must also have a creator and operator, Archimedes, who is likewise divine. On the face of it perhaps not a very compelling argument, until we supply the intermediary assumption that this divinity is implied in both cases by the difficulty and cleverness of the created artifact. The marvel is so wondrous in both cases, that it could only have been devised by *divinum ingenium*, “divine genius.” Furthermore, the identity of the two makers is further reinforced when Cicero says that Archimedes “fastened” the parts of the mechanism together, where the verb for to fasten, *illigo*, is the same word used by Cicero in his translation of Plato’s *Timaeus* to describe how the gods fixed soul and body together to form living things, and, in case we might miss this subtle cross-reference, he then explicitly tells us that Archimedes’ construction is “just like Plato’s god who built the world in the *Timaeus*.”

¹⁸ *Tusc.* 1.69.

This elevation of Archimedes to divine status gets further developed and brought almost full circle in a charming short poem by Claudian (4th century), *On the Sphere of Archimedes*, where Jupiter himself marvels at the cleverness of the inventor:

Iuppiter in parvo cum cerneret aethera vitro
 risit et ad superos talia dicta dedit:
 hucine mortalis progressa potentia curae?
 iam meus in fragili luditur orbe labor?
 iura poli rerumque fidem legesque deorum
 ecce Syracusius transtulit arte senex.
 inclusus variis famulatur spiritus astris
 et vivum certis motibus urget opus.
 percurrit proprium mentitus Signifer annum,
 et simulata novo Cynthia mense redit,
 iamque suum volvens audax industria mundum
 gaudet et humana sidera mente regit.
 quid falso insontem tonitru Salmonea miror?
 aemula naturae parva reperta manus.¹⁹

When Jupiter saw the firmament in tiny glass, he laughed and put these words to the gods: “Has the power of mortal thought come so far? Is my work mimicked in a fragile globe? Behold! An old Syracusan has by handicraft translated the ordinances of the heavens, the truth of things, and the laws of the gods. An enclosed soul is servant to the various stars and drives the living work in precise motions. A counterfeit zodiac traverses its year, and an imitation moon returns at the beginning of the month. Now daring diligence rejoices at moving its own world, and conducting the stars by human mind. Why am I surprised at guiltless Salmoneus with his pretend thunder? His tiny hand is shown to be the rival of nature.”

One of the more curious features of this poem is Claudian’s use of “soul” as a description for the inner mechanism of the device. He is being very subtle here, simultaneously drawing the reader’s eye away from the messy gearwork inside the device while at the same time elevating its mystery by identifying it with the invisible and ineffable *spiritus* that drives the heavens.²⁰ The machine thus transcends itself and becomes a living thing, and this at the hand of a *human* creator. But Jupiter is not jealous, he is amused. Nevertheless, Claudian

¹⁹ Claudian, *Shorter poems* LI.

²⁰ On Claudian’s fascination with hidden causes, see also his poems on the electric eel and the magnet, respectively.

reminds the reader of how close a call this all was for Archimedes when he compares the “old Syracusan” to Salmoneus, the mythological king of Elis, who had demanded that he be called *Zeus* by his subjects and then went so far as to outfit his chariot with special effects so that it made the sound of thunder while it rode and shot out lit torches to imitate lightning.²¹ Zeus accordingly struck him down with (what else?) a thunderbolt. Here Claudian may also be making a subtle reference to Manilius, who in his great astrological poem describes Salmoneus as *qui caelum imitatus in orbe*, one who imitated the heavens *in orbe*, or on a globe (one presumes Manilius means “on earth,” although Claudian’s playful reference reimagines the passage completely).²² That Jupiter could have seen Archimedes, with his “tiny hand,” as overstepping human bounds is reinforced repeatedly throughout the poem: the heavens were “mimicked,” *luditur*, by Archimedes, which word (in Latin as in English) can refer to mockery as well as to sport; Archimedes is the rival of nature, where the semantic overlap between neutral emulation and outright hostility in *aemulus* (rivalling, imitating) plays out; the pejorative sense of *mentitus Signifer*, “counterfeit zodiac,” is hard to miss. Nevertheless, Archimedes is said to be “blameless,” and Jupiter to be highly amused. Perhaps the threatening talk was just the god’s jest.

It is interesting, too, that Archimedes does not in the first instance *copy* the heavens, but instead “translates” them. And here legal metaphors abound: what Archimedes has translated are the judgments or laws of the cosmos, the laws of the gods, and the *fidem rerum*, literally the promise or binding trust of things.

4. JUST LIKE ARCHIMEDES DID

²¹ See e.g., Vergil, *Aen.* 6.585 f.

²² See also Manilius 4.267-8: *sidereas caelumque novum versabit in orbem*.

The trope of Archimedes imitating or emulating the gods in his sphere gets turned entirely on its head by the 5th century writer Martianus Capella. His encyclopedic *Marriage of Philology and Mercury* is a survey of the seven liberal arts, in the elaborate conceit of a wedding feast, where each branch of learning is introduced as a goddess, coming as a bridesmaid to the wedding of Philology and Mercury, and giving an account of her branch of learning. It is a difficult and often unnerving text, a mixture of florid prose and highly allegorical poetry. C. S. Lewis once famously said of it “this universe, which has produced the bee-orchid and the giraffe, has produced nothing stranger than Martianus Capella.”²³

In the *Marriage*, two of the characters are Geometry and Astronomy, Geometry entering after Grammar, Dialectic, and Rhetoric. She is followed by Arithmetic and then Astronomy. Harmony comes last to close the book. In these proceedings, we find another reference to mechanized sphere, again associated with Archimedes, but it is surprisingly not in the hands of Astronomy. Instead it is Geometry who comes in bearing it. What is even more surprising about the sphere Geometry holds, perhaps, is that it turns our whole previous narrative on its head, with the goddess now bearing what must be a divinely made sphere that imitates the one Archimedes is supposed to have made in imitation of the heavens.

When she makes her appearance, the character of Geometry enters only after two of her attendants had preceded her. They were bearing that most basic tool of geometry, an *abacus*, that is, an erasable mathematical drawing-tablet, on which, we are told, the shapes of lines, the curves of circles, or the angles of triangles may be etched.²⁴ Note here the slightly curious wording. We are not drawing mathematical objects—lines, circles, triangles—in the first instance. We are drawing, to use Martianus’ wording “linear shapes” (*lineares ductus*),

²³ Lewis, 1936, p. 78.

²⁴ 6.579.

“circular curves” (*circulares flexus*), and “triangular bends” (*triangulares anfractus*). He continues by telling us that the abacus can show the *facies*, the image, of the cosmos as a whole—and note here the idea of representation starting to creep in, and the perhaps surprising appearance of the cosmos as the ultimate object of Geometry’s drawing. That we are dealing with a high degree of abstraction is emphasized by Martianus’ summation of the *abacus* as a tool for depicting (*videbis istic depingi*) “whatever cannot be explained in words” (*quicquid verbis non valeas explicare*). That imitation is one of Geometry’s paramount skills gets further emphasized when Martianus next compares her to three, and only three, legendary figures, saying that her skill surpasses them all. These are Apelles, the painter, Polyclitus, the sculptor, and Daedalus, who was famous in fable for having made statues that could move about on their own.

A further peculiarity of Geometry, especially considering that the character of Astronomy is waiting in the wings for her own grand appearance just two books away, is that she is so thoroughly adorned with astronomical imagery. Indeed, apart from the mention of circles and lines and triangles in connection with the abacus, nearly all of Geometry’s attributes in these early passages are astronomical. She comes in bearing the *sphaera* and wearing a mantle adorned with images of celestial magnitudes, planetary bodies and their orbits, as well as a picture of the earth’s shadow and of a gnomon. If we contrast this to Astronomy’s later entrance (book 8), we see again an emphasis on Geometry as modeler. Where Geometry comes in with a material sphere in hand, Astronomy simply materializes out of a magically appearing ball of what sounds like actual aether:

et ecce globus quidam lucis aetheriae et concava perspicui ignis aggestio, ut
apparebat intra se quandam virginem claudens, miti vertigine sensim volutus
inlabitur. quo candore luminis propinquantis plures irradiati refulsere divi,

fatalesque maxime, quorum etiam habitus motusque et quicquid in his
ignotum credebatur emicuit.²⁵

And behold: there appeared a sphere of aetherial light, a concave filled with transparent fire, enclosing within it a maiden, and turning with the slightest perceptible motion. A number of gods, especially the ones who determine fates, were bathed to the point of reflecting the brightness of the outpouring light, their habits and motions and other such things that had been concealed, shone forth.

Astronomy is carrying a book in one hand, and in the other, a *cubitalem fulgentemque mensuram*, “a shining cubit-measure” (probably something like a dioptra).²⁶ She proceeds to describe, and indeed to verbally construct before the audience, the various circles in the heavens. Here she nods to Geometry several times, but in contrast to the account given by Geometry, for Astronomy all the constructions are presented as taking place in the real world: circles, that is, are drawn in the heavens and not on models. She then offers us a detailed list of paranatellonta and rising-times for the zodiacal constellations, and an account of the eccentricity of the sun and the motions of the planets and moon.

Turning back to Geometry’s entrance, we note that in the description offered of the Archimedean sphere she carries, there is the familiar note of human genius emulating that of the gods:

ipsa etiam laeva sphaera fulgebat honora,
assimilis mundo sideribusque fuit;
nam globus et circi zonaeque ac fulgida signa
nexa recurrebant arte locata pari.
tellus, quae rapidum consistens suscipit orbem,
puncti instar medio haeserat ima loco.
hanc tener et vitreis circumvolitabilis auris
aer complectens imbrificabat aquis.
quae tamen immenso, quo cingitur illa, profundo
interrivata marmore tellus erat.
texerat exterior qui fulget circulus orbis
aetheris astrifico lumina multa peplo.
hinc nitidus rutilum Titan succenderat orbem,

²⁵ Martianus Capella, *De nuptiis*, 8.810.

²⁶ Martianus Capella, *De nuptiis*, 8.811.

moxque imitata pium lactea Luna diem.
 sic igitur furvae oculos splendescere noctis
 cernas ex auro ut sacra flamma micat.
 sic Cypris Oceani perfuso sidere lymphis
 Lucifero annuerat lumina tota suo.
 omnia compar habet paribus sub legibus ordo,
 nec minus haec mira est quam domus alta deum.
 hanc mundo assimilem stupuit Trinacria tellus
 Archimedeae astrificante manu.
 o felix cura, et mentis prudentia maior,
 corpore sub nostro aequiperasse Iovem.²⁷

The glorious sphere shone at her left hand; it was very like the world and the stars. And the sphere and the circles and the zones and the shining fixed stars orbited, put skillfully in place. The earth, which, unmoving, holds up the fast orb, hangs in the middle, the lowest place, like a point. A soft atmosphere holding it in, blowing round in gentle breezes, waters it with rains. The earth was riven by an immense and deep sea which belted it. The outer circle was covered by a very bright mantle that shone with aetherial stars. Next the gleaming sun kindled his golden orb, and then the milky moon imitating true daylight. Thus you could see these sights shining in the dark of night, as a sacred flame flashes from gold. So Venus gave her morning star full light when it was still immersed in the waters of the ocean. A similar order maintains all under equal laws, and this (sphere) is no less astonishing than the lofty home of the gods. Sicily was amazed by this copy of the cosmos made by an Archimedean star-making hand. What fruitful skill, and great intelligence of mind to make oneself equal to Jupiter with subterranean matter.

Notice that this is an entirely fictional globe, invented by Martianus for the story. It has properties no earthly model could possess: the winds and rain, the glowing of the sun. So, too, it is envisaged as an actual sphere in shape, entirely unlike the Antikythera box. It is self-lit, and is somehow shrouded in an outer shell of fixed stars that nevertheless is transparent enough to see through.

As in our earlier discussions of mechanized spheres, we see here the amazement at the mechanism: “this sphere is no less astonishing than the lofty home of the gods.” And note again the ubiquitous reference to Archimedes. Martianus credits Archimedes with manufacturing “this copy of the cosmos” but surely he is speaking loosely or at best

²⁷ Martianus Capella, *De nuptiis*, 6.583-5.

allegorically, given the impossibility of the many features already mentioned. Finally, Archimedes transcends mortality in the machine, making himself equal to Jupiter.

5. DIVINE WATCHMAKER

We have seen mechanized sphaera used as proofs of the divinity of Archimedes' genius, as well as its deployment in Cicero's proof of the immortality of the soul. Sphaera have been the go-to example in our authors of the intellectual heights attainable by human beings—look what we can do!—one that impresses even the gods themselves. It also gets invoked in another context, one hinted at already but so far not fully developed. This is in a version of what theologians know as the “divine watchmaker” argument, usually attributed to the English philosopher and theologian William Paley (1743-1805).²⁸ On Paley's formulation, the finding of a rock lying unattended upon a heath should occasion no surprise and no pressing question of how it came to be—one could easily suppose it had simply always been there. The finding of a working watch, on the other hand, would not lead to the supposition that it had always been there. Instead, given its complexity, utility, and obvious signs of deliberate design, one would suppose that it had in the first instance been manufactured by an intelligent being for some purpose. Paley then argues for an analogous complexity and purposiveness to the world as a whole, and draws the conclusion that the world must therefore have had a designer just as surely as the watch did, one as far above the human watchmaker as the world is above the watch in majesty.

But the argument is a very old one, and we find several versions of it in antiquity, only, instead of a watch as the exemplar of complex, deliberate design, it is a mechanized sphere. The earliest of these arguments appears, once again, in Cicero.

²⁸ See for example, Shapiro, 2015.

In the *De natura deorum*, Cicero has his Stoic character, Balbus, argue at length for the rationality and divinity of the cosmos as a whole. In the course of laying out the case for the governance of the world by divine reason, Balbus argues that the perfect regularity shown by the motions of the planets shows not only that their motions are not due to chance, but further, that their motions are due to deliberate, divine design:

quodsi in Scythiam aut in Britanniam sphaeram aliquis tulerit hanc quam nuper familiaris noster effecit Posidonius, cuius singulae conversiones idem efficiunt in sole et in luna et in quinque stellis errantibus quod efficitur in caelo singulis diebus et noctibus, quis in illa barbaria dubitet quin ea sphaera sit perfecta ratione? hi autem dubitant de mundo ex quo et oriuntur et fiunt omnia, casune ipse sit effectus aut necessitate aliqua an ratione ac mente divina, et Archimedes arbitratur plus valuisse in imitandis sphaerae conversionibus quam naturam in efficiendis, praesertim cum multis partibus sint illa perfecta quam haec simulata sollertius.²⁹

Suppose someone had brought the sphere that our friend Posidonius recently made into Scythia or Britain, on which the individual motions pertaining to the sun and the moon and the five wandering stars are effected just as it happens in the sky on specific days and nights. Who in that foreign land would doubt that the sphere was completed by reason? But these [opponents of mine] waver on the subject of the world, from which everything arises and is made, whether it happens by chance, or whether by necessity, or by divine reason and will. They judge Archimedes to have been better for imitating the motions of the sphere than nature for causing them, even though nature's construction is many times more skillful than the imitation.

For the first time, we see the instantiation of a real sphere in the room, rather than a story about an offstage encounter. Moreover, the *sphaera* is one recently made by “our friend,” Posidonius. Where all of our Archimedian spheres have up to this point been essentially hearsay, I see no reason to doubt that Cicero has actually seen a Posidonian one.

Nevertheless, Archimedes is still not very far away: it is not Posidonius, this sphere's maker, who gets the final credit for his clever device, but the old Syracusan, presumably for designing the plans followed by Posidonius. (For what it is worth, we do know that

²⁹ Cicero, *ND* 2.88.

Archimedes is supposed to have written a book, now lost, on the art of *Sphaeropoia*, and the tenacity of the tradition associating him with Antikythera-type displays may be on the grounds of this book rather than on the preservation and display of any particular globe he may have made).

And notice here how Cicero turns the familiar idea of Archimedes' genius against his opponents: "they judge Archimedes to have been better for imitating the motions of the sphere than nature for causing them." For all that he has been quick to praise Archimedes in his other works, here he berates his interlocutors for failing to recognize how much better than Archimedes' little sphere the model from which it was copied really is.

Curiously, we find in the Christian author Lactantius, a direct attack on Balbus's larger position in the *De natura deorum*, but one that nevertheless seems to come to almost the same conclusion as Balbus had, with the exception that instead of the regularity of the motions of the stars proving their own divinity, it instead proves the divinity of the one who created the stars.

an Archimedes Siculus concavo aere similitudinem mundi ac figuram potuit machinari, in quo ita solem lunamque composuit, ut inaequales motus et caelestibus similes conversionibus singulis quasi diebus efficerent et non modo accessus solis ac recessus vel incrementa deminutionesque lunae, verum etiam stellarum vel inerrantium vel vagarum dispares cursus orbis ille dum vertitur exhiberet, deus ergo illa vera non potuit machinari et efficere quae potuit sollertia hominis imitatione simulare?³⁰

Could Archimedes of Sicily have devised in hollow bronze a model and figure of the world, in which he has arranged the sun and the moon such that they would effect unequal motions and similar ones to the celestial rotations almost day by day, and the sphere, when rotated, show not only the rising of the sun and its setting and the waxing and waning of the moon, but also the disparate courses of the stars, both fixed and wandering, and yet God himself could not devise and bring about what human ingenuity is able to copy by imitation?

³⁰ Lactantius, *Divinarum institutionum*, 2.5.

The argument in which this is embedded wanders considerably, and relies to an extent on a certain amount of sleight-of-hand on Lactantius's part, as indeed the key move in this passage relies on the reader's prior acceptance of the idea that anything Archimedes could do (the Christian) God could do better, but we get the idea: if a man could make something displaying complex regularity like the sphere does, so God could make the stars that move that way too.

Finally, the Pyrrhonian sceptical philosopher Sextus Empiricus had also earlier elaborated a version of the Stoic argument from design, one very similar to that in Cicero's *De natura deorum*. Sextus begins by noting that the cosmos moves with an order that precludes what Democritus had called necessity (ἀνάγκη) or accident, and requires (so the Stoics say) a divine mover. Sextus then compares the situation to that where someone looks at an Archimedian *sphaera*:

τά γε μὴν αὐτομάτως κινούμενα τῶν κατασκευασμάτων θαυμαστότερά ἐστι τῶν μὴ τοιούτων. τὴν γοῦν Ἀρχιμήδειον σφαῖραν σφόδρα θεωροῦντες ἐκπληττόμεθα, ἐν ᾗ ἥλιός τε καὶ σελήνη κινεῖται καὶ τὰ λοιπὰ τῶν ἀστέρων, οὐ μὰ Δία ἐπὶ τοῖς ξύλοις οὐδ' ἐπὶ τῇ κινήσει τούτων τεθηπότες, ἀλλ' ἐπὶ τῷ τεχνίτῃ καὶ ταῖς κινούσαις αἰτίαις.³¹

Devices that move by themselves are more marvellous than those that do not. Thus we are especially astounded on seeing an Archimedean sphere, in which the sun and the moon and the rest of the stars move—not, by Zeus, marveling at the materials or their motions, but at the artificer and at how the motions are brought about.

This he reports as proof for the Stoics that there must be a divine intelligence guiding the complex motions of the cosmos as a whole.

6. REALIST OBJECTIONS

³¹ Sextus, *Adv. math.* 9.115.

Notice in Sextus the implied reference to the inner workings of the machine: we are more impressed by *how the motions are brought about* than by the materials or the motions themselves. It is the gearing and the construction, opening the thing up and looking inside it that really get us excited, he says. And this is true. On seeing a modern reconstruction of an ancient *sphaera*, such as Michael Wright’s remarkable reconstruction of the Antikythera mechanism, the display is very impressive,³² but for most people that is nothing compared to seeing the elegance, complexity—and above all the non-obviousness—of the inner workings.

But we have one author, believe it or not, who was unimpressed. Or at least unhappy with how the motions were brought about. Claudius Ptolemy, the greatest astronomer and one of the greatest mathematicians of the whole ancient period: he thought he had a good idea of how the motions in the heavens were brought about, and in his mind, that didn’t look anything like the insides of an Archimedean sphere. Being a good scientific realist, this bothered Ptolemy.

Before turning to Ptolemy, though, let us briefly look back at something both Claudian and Martianus Capella said: “a similar order maintains all under equal laws, and this (sphere) is no less astonishing than the lofty home of the gods” (Martianus), and “an old Syracusan has translated the ordinances of the heavens, the truth of things, and the laws of the gods” (Claudian). Both of them seem to be saying that the Archimedean sphere follows the same laws as the cosmos, which may be to say that the sphere can tell us something about the mechanism of the heavens themselves. Ptolemy is having none of it:

ἐνταῦθα δὲ προήχθημεν αὐτὸ μόνον ἐκθέσθαι κεφαλαιωδῶς καὶ ὡς ἂν μάλιστα
προχειρότερον κατανοηθεῖεν ὑπὸ τε ἡμῶν αὐτῶν καὶ τῶν εἰς ὀργανοποιίαν
ἐκτάσσειν αὐτὰ προαιρουμένων, ἐάν τε γυμνότερον διὰ χειρὸς ἐκάστης τῶν
κινήσεων ἐπὶ τὰς οἰκείας ἐποχὰς ἀποκαθισταμένης τοῦτο δρῶσιν, ἐάν τε διὰ τῶν
μηχανικῶν ἐφόδων συνάπτωσιν αὐτὰς ἀλλήλαις τε καὶ τῇ τῶν ὅλων. οὐ μὴν ὄν
εἰώθασι τρόπον σφαιροποιεῖν· ὁ γὰρ τοιοῦτος καὶ χωρὶς τοῦ διημαρτῆσθαι τὰς

³² See, for example, Yirka, 2011.

ὑποθέσεις τὸ φαινόμενον παρίστησι μόνον καὶ οὐ τὸ ὑποκείμενον, ὥστε τῆς τέχνης καὶ μὴ τῶν ὑποθέσεων γίνεσθαι τὴν ἔνδειξιν.³³

In this book, we go on to set [these hypotheses] out in summary so that they can be most easily understood both by ourselves and by those proposing to arrange them for the purposes of instrument-making, whether they do this in the more stripped-down manner, returning each of the motions to its proper epoch by hand, or by a mechanical method, joining the motions to each other and to the motion of the whole. But this is not the usual way they do sphere-making, for there—apart from betraying the hypotheses, they represent the appearances only and not the cause (lit: “the underlying”), such that the show is about the craftsmanship, not about the hypotheses.

What Ptolemy is objecting to here is that the mechanical spheres made by the sphere-makers, although they model the phenomena, do not show the real workings of the cosmos. In a perfect world, he seems to be arguing, the sphere-makers would make their *sphaerae* with a mechanics identical to that set out in the *Planetary Hypotheses*: spheres turning within spheres within spheres. The mechanical sphere, then, would for once be a true model of the cosmos, mirroring not only the appearances of the planetary motions, but also demonstrating in their interlocking moving parts, the actual physical causes of those heavenly motions.

Turning it the other way around, Geminus of Rhodes, the first-century-BC author of an introductory textbook of astronomy, seems to think that in fact the *sphaerae* can tell us about how the universe is constructed. He goes so far as to tell us that the cosmos is itself a *sphaeropoia*. Evans and Berggren have found in this claim a strong realist stance on Geminus’ part (one with which I agree), and they cite three passages where Geminus describes the cosmos as a *sphaeropoia*, plus one where they take *sphaeropoia* to mean the spherical theory of the world more broadly.³⁴ I will focus on two of these passages, leaving aside the “spherical theory of the world” one, and one of their instances of *sphaeropoia* as the actual spherical construction of the world (at 12.23) because I think those instances may just possibly refer

³³ Ptolemy, *Plan. Hyp.* 1.70.11-23.

³⁴ Evans and Berggren, 2006, p. 52-3.

to *sphaera*-making in the more traditional sense.³⁵ At 14.9, Geminus is discussing stars that rise and set: some never rise or set, and some do one or the other but not both on any given night. He says:

διὰ δὲ τὴν τοιαύτην σφαιροποιίαν, οὐ πάντα τὰ ἄστροα ἀνατέλλει καὶ δύνει καθ’
ἐκάστην νύκτα, ἀλλὰ τινὰ μὲν ἀνατέλλει καὶ δύνει, τινὰ δὲ ἀνατέλλει μὲν, οὐ
δύνει δέ, ἃ δὲ οὔτε ἀνατέλλει οὔτε δύνει.

Because of this spherical construction [of the cosmos], not every star rises and sets every night. Instead, some rise and set, some rise but do not set, and some neither rise nor set.

Again, at 16.19, he wants to explain how he knows that there are southern inhabitable zones on the earth, where the antipodes live. He spells out that he has not had traveller’s reports from those regions. Instead, it is ἔνεκεν τῆς ὅλης σφαιροποιίας καὶ τοῦ σχήματος τῆς γῆς καὶ τῆς παρόδου τοῦ ἡλίου τῆς μεταξύ τῶν τροπικῶν γινομένης, “because of the spherical construction of the whole and the shape of the earth and the path the sun takes between the tropics” that we can know there to be an inhabitable temperate zone on the opposite side of the earth.

Here the cosmos itself has become the product of the sphere-making craft. Just as in the simpler lathe-turning analogies we saw much earlier, only this time with more explicit reference to those craftsmen who make astronomical *sphaerae* (whether mechanized or not, however, he does not say). The analogy now runs from the model to the original, and the manufacture of the original is somehow modeled on the model. Just as for Ptolemy, Geminus is here betraying a commitment to the idea that the models we make should really capture the structure of the world, and he believes this so immediately that he sees no need to even explain himself. He takes it for granted that he can just call the universe a manufactured *sphaera* and that his readers will accept the move unproblematically. The

³⁵ They may well mean what Evans and Berggren take them to mean, but they are just ambiguous enough (as I think Evans and Berggren also see) that I will stick to the two clear-cut instances.

implications of a divine creator, Geminus does not draw out (this would not be the place in any case), but if our previous authors are any indication, a heavenly creator cannot have been too far in the wings.

7. CONCLUSION

The ancients, just as we do now, marveled at the incredible ingenuity on display in their geared astronomical models. Indeed, in many contexts, such devices stood as the very embodiment of the pinnacle of human intelligence, and in many cases elevated human genius on a par—dare they say it?—with the divine. Fully conscious that such hyperbole may have been not entirely theologically sound, Cicero and Claudian gird themselves, Claudian by neutralizing it through playful storytelling, and Cicero by actually embracing the consequences and running them home, holding them up as the very proof of the immortality of the soul. Human creators are modeled on divine ones, just as the human-made mechanisms are modeled on the created cosmos, and the complexity of the task sometimes even has even the gods standing in admiration. So, too, the models could tell us something about the complexity and origin of the cosmos, and for the Stoics, and Cicero siding with them the mechanism's self-implied proof of design furnishes an argument for our earliest version of the theological argument from design.

But the very difficult question of the extent to which such mechanisms can really tell us something about the heavens was not lost either (and here the philosophical literature of modeling and metaphor becomes relevant). After all, if we are to use any model to think about the original thing that it models, we need to first know which features of the model are meant to be representative of the real thing, and which are compromises inherent in the

act of modeling.³⁶ Ptolemy, whose philosophical reflections on the methodology of science have been getting increasing attention in recent years, worried very clearly about which features of the model were, to use the modern parlance, positive analogies (which ones really copied the details of the original, and so could be used heuristically), and which were negative analogies (non-identical and therefore non-heuristic). For him, the negatives seem to have outweighed the positives, and he seems to have been wishing for a better type of mechanism.

But Ptolemy's higher-order question about the nature of the analogy between mechanism and sky seems to have been spoken in his voice alone. Across the board, from Christians to late pagans and all the way back, the idea of a craftsman building something so marvellous struck a chord in the ancient imagination, and told them, so they thought, some very important truths about themselves, the world they lived in, and their place in it.

³⁶ I am here thinking of what Weisberg, 2012 calls 'concrete' models, physical objects that are meant to model systems in the world. Such models are intended to capture as many features of the modelled system as possible, but without being exact copies (exact in scale, exact in material, exact in function). They inherently introduce what I am calling 'compromises,' where they model does things differently than the modelled system (it is smaller or larger, it is made of plastic or metal, it uses strings and rods instead of fundamental forces). This is not necessarily a problem so long as all interested parties are aware of what compromises are being made and which features of the model are meant to be taken as what we might call more literally representative, but it does introduce epistemic issues that are nontrivial. See recently, e.g., Weisberg, 2012; Suárez, 2009; Giere, 2004; Sismondo and Gissis, 1999; Morgan and Morrison, 1999.

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