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PLATO'S ASTRONOMY

In one of the most disputed passages of Greek literature Plato in the *Republic*, 7. 528e–530c prescribes astronomy as the fourth study in the education of the Guardians. But what sort of astronomy? According to one school of thought it is a purely speculative study of bodies in motion having no relation to the celestial objects that we see. While this interpretation has rejoiced the hearts of Plato's detractors, who regard him as an obstacle to the progress of science, it has dismayed his admirers. Another school of thought holds that what Plato meant was that astronomers must get to know the real motions of the heavenly bodies as opposed to their apparent motions as seen by us on earth. The opposed interpretations may be set out in the following representative citations from Sir Thomas Heath and John Burnet.

We have here, expressed in his own words, Plato's point of view, and it is sufficiently remarkable, not to say startling. We follow him easily in his account of arithmetic and geometry as abstract sciences concerned, not with material things, but with mathematical numbers, mathematical points, lines, triangles, squares, &c., as objects of pure thought... But surely, one would say, the case would be different with astronomy, a science dealing with the movements of the heavenly bodies which we see. Not at all, says Plato with a fine audacity, we do not attain to the real science of astronomy until we have 'dispensed with the starry heavens', i.e., eliminated the visible appearances altogether.

(Sir Thomas Heath, *Aristarchus of Samos* [1913], pp. 137–8)

This sentence is easily misunderstood and requires elucidation. In the first place, the visible motions of the heavenly bodies are what we call their apparent motions, which are of great complexity and at first sight seem quite irregular. The planets move at one time from east to west among the stars, at another from west to east, and sometimes they are stationary altogether. That is the 'problem' we have to solve. The 'real velocity' (τὸ ὂν τάχος) is spoken of simply as opposed to the apparent velocity... What is meant, then, is simply that we must have a science which will exhibit the true motions of the heavenly bodies and not the motions they appear to have.

(John Burnet, *Greek Philosophy: Thales to Plato* [1914, reprinted 1968], pp. 184–5)

Among the many distinguished scholars who have supported the former interpretation (a purely speculative science) are James Adam, *The Republic of Plato* 2 (1902, 2nd edition 1963), p. 131 n., Otto Neugebauer, *The Exact Sciences in Antiquity* (1951, 2nd edition 1958), p. 152, and J. Mittelstrass, *Die Rettung der Phänomene* (1962), pp. 117, 122. Among those who believe Plato was exhorting astronomers to study the real as opposed to the apparent motions are Richard Lewis Nettleship, *Philosophical Lectures and Remains* 2 (1897), p. 275, Bernard Bosanquet, *A Companion to Plato's Republic* (1893), pp. 292–3, Paul Shorey, *Plato: The Republic, Vol. II* (1935), pp. 180–9, D. R. Dicks, *Early Greek Astronomy to Aristotle* (1970), pp. 103–6. A *via media* has recently been taken by Gregory Vlastos, 'The rôle of observation in Plato's conception of astronomy' in John P. Anton (ed.), *Science and the Sciences in Plato* (1981), pp. 1–31, who writes: 'I hope to show that this passage, properly understood, permits us to recognize the positive impetus Plato gave to mathematical astronomy without requiring us to whitewash the anti-empirical strain in his whole philosophy which shows up as strongly in this passage as anywhere in his work' (p. 1).

'Who am I', as the Oxford undergraduate replied when asked to distinguish between the major and the minor prophets, 'to choose between such great men?' In fact, it is not necessary to choose. There is a simple and convincing explanation of the passage, according with both the internal and the external evidence, though it does not appear to have occurred to any of the commentators.

The key words, as everyone agrees, are in 530b, τὰ δ' ἐν τῷ οὐρανῷ ἐάσομεν, 'We shall let the things in the heaven alone'. There is no serious disagreement about the translation, only about its meaning. And what is the meaning? Clearly τὰ δ' ἐν τῷ οὐρανῷ in 530b are synonymous with τὰ ἐν τῷ οὐρανῷ ποικίλματα in 529c. On this point, again, there is no disagreement. It is on the meaning of ποικίλματα that the translators and commentators have gone astray. Even Shorey, whose translation and notes are usually so reliable, and who sees clearly that Plato is not dismissing observational astronomy, errs at this point. He translates τὰ ἐν τῷ οὐρανῷ ποικίλματα as 'those sparks that paint the sky'. But ποίκιλμα does not mean 'spark', nor do the supporting quotations that Shorey gives (Plato, *Timaeus* 40a, Euripides, *Helena* 1096, Critias, *Sisyphus* apud Diels, *Vorsokratiker*) bear out this interpretation. Shorey should perhaps have realized that he was on the wrong tack when he lost the connection between ποικίλματα and πεποίκιλται only four words farther on.

What, then, does ποικίλματα mean? The basic word is the adjective ποικίλος, for which Liddell–Scott–Jones gives the primary sense 'many-coloured, spotted, pied, dappled', with the secondary meaning, '*wrought in various colours*, of woven or embroidered stuffs'. The same authority renders the verb ποικίλλω as '*work in various colours, work in embroidery*', and it gives the primary meaning of ποίκιλμα as '*broidered stuff, brocade*, 2. *embroidery*'.

It is clear that if we render the word in its normal sense in Greek authors τὰ ἐν τῷ οὐρανῷ ποικίλματα should be translated, 'the embroideries in the heavens', 'the patterns in the heavens'. And what can these patterns in the sky be but the fanciful grouping of stars into constellations which, as we shall see, was taking place at that time? Strong confirmation of this interpretation may be found in another work which is Platonic even if not from the hand of Plato himself – *Hippias Major*, 298a, where Socrates is made to say, οἵ τέ γέ που καλοὶ ἄνθρωποι, ὦ Ἱππία, καὶ τὰ ποικίλματα πάντα καὶ τὰ ζωγραφήματα καὶ τὰ πλάσματα τέρπει ἡμᾶς ὁρῶντας, ἃ ἂν καλὰ ᾖ, 'For surely handsome men, Hippias, and all embroideries and pictures and sculptures which are beautiful delight us when we look at them'. Here ποικίλματα are put on the same footing as ζωγραφήματα and πλάσματα.

Arthur Hugh Clough got Plato's meaning right when he wrote in *Uranus*:

> Then Plato in me said
> 'Tis but the figured ceiling overhead
> With cunning diagrams bestarred.

It has been said above that the fanciful grouping of stars into constellations was taking place in Plato's time. There can be little doubt that the earliest groupings of stars into constellations were made by shepherds and sailors, farmers and hunters, whose daily work made them frequent observers of the stars. This is a main argument in the posthumous work of E. J. Webb, *The Names of the Stars* (1952), and he proves it conclusively. Some of the names of these constellations, such as the Pleiades and the Hyades, the Bear or Plough and Orion, are very ancient, being used by Homer and Hesiod. But the groupings of these primitive stargazers did not exhaust the sky, and as time went on the heavens were peopled with mythological and historical characters, and learned men joined the shepherds and sailors in framing such groups. They had a scientific value in enabling the positions of stars to be identified before location by means of latitude and longitude, declination and right ascension had been fully developed. The process was well advanced when Aratus wrote his extant poem *Phaenomena*, ed. E. Maass (1893), in the first half of the third century B.C. But Aratus was a poet, not an astronomer, and the astronomical details in the poems are not original. What Aratus did – and this is the important point for our purpose – was to put into metre (at least from verses 19 to 732) a work of the same title by Eudoxus of Cnidus, *c.* 390–*c.* 340 B.C., the distinguished pupil of Plato. The work of Eudoxus has not survived, any more than his similar *Mirror* (of the heavens), but Hipparchus (second century B.C.) wrote an extant *Commentary on the Phaenomena of Aratus and Eudoxus*, ed. C. Manitius (1894), from which we know its character. It gave a description of the constellations along with notices of risings and settings for the purposes of the calendar; and it was the first work to provide such a systematic description.

This work, even if not actually going on in the Academy under the eyes of Plato, must have been well known to him. And when Glaucon is made to say (*Republic*, 529c), ἀλλὰ πῶς δὴ ἔλεγες δεῖν ἀστρονομίαν μανθάνειν παρὰ ἃ νῦν μανθάνουσιν, 'But how then did you say that it is necessary to study astronomy differently from the things they now study?', there is a high probability that it is this concentration on grouping stars into fanciful patterns that Plato has in mind. This we can certainly say was going on at the time, and there is nothing else distinctive in the teaching of astronomy at that time of which we are aware.

This grouping of stars into fanciful constellations did have a scientific value in those days as we have seen, and as Eudoxus would have recognized. But Plato may well be forgiven for thinking that astronomy studied in this way was a looking down rather than upwards, even though the student were to pursue it lying flat on his back; and we can well imagine his dismay when he found that his brilliant pupil, whose genius he could recognize even when he could not wholly follow it, should be giving his mind to such trivialities, as he would have thought, when it was capable of much greater things.

How, then, did Plato wish astronomy to be studied? He has told us himself through the mouth of Socrates – ἃς τὸ ὂν τάχος καὶ ἡ οὖσα βραδυτὴς ἐν τῷ ἀληθινῷ ἀριθμῷ καὶ πᾶσι τοῖς ἀληθέσι σχήμασι φοράς τε πρὸς ἄλληλα φέρεται καὶ τὰ ἐνόντα φέρει, 'the motions with which the real speed and the real slowness move in relation to one another, carrying their contents with them, in the true numerical relation and in all the true forms'. These are matters that can be grasped only by reason and understanding, not by sight, λόγῳ μὲν καὶ διανοίᾳ ληπτά, ὄψει δ' οὔ (*Republic*, 529d).

This programme is remarkably similar to one that is attributed to Plato by Simplicius, and which is particularly mentioned in connection with Eudoxus. Simplicius, living in the sixth century A.D., would not by himself be the best authority for what Plato said in the fourth century B.C., but he claims Eudemus as his authority – though whether it is by direct knowledge or through citation by Sosigenes (the Peripatetic philosopher living in the second century A.D. and teacher of Alexander Aphrodisiensis, not Julius Caesar's astronomical advisor) is a matter of some uncertainty; and Eudemus of Rhodes, living in the same century as Plato, and the author of histories of geometry and astronomy (no longer, alas, extant) which are invaluable source books on many points through citation, is not likely to have erred. The references are in two passages, which have always been obstacles for those who attribute to Plato a purely speculative astronomy. They read:

καὶ πρῶτος τῶν Ἑλλήνων Εὔδοξος ὁ Κνίδιος, ὡς Εὔδημός τε ἐν τῷ δευτέρῳ τῆς Ἀστρολογικῆς ἱστορίας ἀπεμνημόνευσε καὶ Σωσιγένης παρὰ Εὐδήμου τοῦτο λαβών, ἅψασθαι λέγεται τῶν τοιούτων ὑποθέσεων Πλάτωνος, ὥς φησι Σωσιγένης, πρόβλημα τοῦτο ποιησαμένου τοῖς περὶ ταῦτα ἐσπουδακόσι, τίνων ὑποτεθεισῶν ὁμαλῶν καὶ τεταγμένων κινήσεων διασωθῇ τὰ περὶ τὰς κινήσεις τῶν πλανωμένων φαινόμενα. (Simplicius, *Aristotelis De Caelo Commentaria*, 2. 12, ed. Heiberg 488. 18–24)

And first of the Greeks Eudoxus of Cnidus – as Eudemus related in the second book of his *History of astronomy* and also Sosigenes, taking this from Eudemus – is said to have pursued such hypotheses, Plato, as Sosigenes says, having set as a problem for those seriously studying such questions, by what hypothetical uniform and ordered movements the appearances of the movements of the planets might be explained (literally, 'the phenomena might be saved').

καὶ εἴρηται καὶ πρότερον, ὅτι ὁ Πλάτων ταῖς οὐρανίαις κινήσεσι τὸ ἐγκύκλιον καὶ ὁμαλὲς καὶ τεταγμένον ἀνενδοιάστως ἀποδιδοὺς πρόβλημα τοῖς μαθηματικοῖς προὔτεινε, τίνων ὑποτεθέντων δι' ὁμαλῶν καὶ ἐγκυκλίων καὶ τεταγμένων κινήσεων δυνήσεται διασωθῆναι τὰ περὶ τοὺς πλανωμένους φαινόμενα, καὶ ὅτι πρῶτος Εὔδοξος ὁ Κνίδιος ἐπέβαλε ταῖς διὰ τῶν ἀνελιττουσῶν καλουμένων σφαιρῶν ὑποθέσεσι. (Ibid. 492. 31–493. 5).

It has been mentioned earlier that Plato, having unhesitatingly ascribed to the heavenly bodies circular and uniform and ordered motion, set this problem to the mathematicians, by what hypotheses of uniform and circular and ordered movements the phenomena concerning the planets can be saved, and that Eudoxus of Cnidus was the first to engage in such hypotheses by the so-called counteracting spheres.

In the former of these passages it is not made clear that the movements must be circular, but the context shows that this is implied, and it is explicitly stated in the latter. The former passage suggests that Simplicius did not find the problem set by Plato in Eudemus, but only in Sosigenes.

Whether it was due to the prompting of Plato or not – and there is no reason to doubt what Simplicius says – Eudoxus carried out precisely what was enjoined. In a work entitled *Περὶ ταχῶν*, *On Speeds*, he devised an ingenious system of homocentric spheres carrying the sphere of the fixed stars, the sun, moon and planets to account for the apparent motions of the heavenly bodies, including the retrogradations and stationary points of the planets. The work has been lost, but a brief description by Aristotle, *Metaphysics Λ* 8 1073b17–1074a14 (with improvements suggested by Callippus and by himself) and a fuller account by Simplicius in his commentary on Aristotle, *De caelo*, Book 2, ed. Heiberg, pp. 488. 18–24 and 493. 4–506. 18 enable it to be reconstructed. This has been done most elaborately by G. V. Schiaparelli, 'Le sfere omocentriche di Eudosso, di Callippo e di Aristotele' in *Pubblicazioni del R. Osservatorio di Brera in Milano*, 9 (1875), and most recently by Erkka Maula, 'Studies in Eudoxus' Homocentric Spheres' in *Commentationes Humanarum Litterarum* 50 (1974). Modern critics have found flaws in the system and particularly in the observational data, e.g. G. J. Toomer, 'Eudoxus', in the *Oxford Classical Dictionary* (2nd edition, 1970), but these cannot outweigh the facts that it was the first attempt to give a mathematical theory of the celestial motions, that it did so correctly to a remarkable extent for a first venture, and that the method pursued – to find what combination of uniform circular motions would 'save the phenomena' – reached its culmination in Ptolemy's system of epicycles and eccentric circles, which *did* account for the phenomena to an astonishing extent and dominated the world until the sixteenth century A.D. If this interpretation is correct, Plato's influence on the development of astronomy, far from being negligible or baneful, was immense and beneficial. It is idle to say that his postulate of uniform circular motions set back a true explanation, for this is the natural first hypothesis, and until it had been fully worked out it is improbable that astronomers would have realized that the planetary orbits are ellipses in which the planets move with varying speeds according to their distance from the sun. And if Plato, through Eudoxus, did have this influence upon astronomy, the notion that he prescribed in the *Republic* a purely speculative study of bodies in motion must be rejected.

The subject of Plato's other astronomical references cannot be pursued here, but it is worth noting that in none of them – and they are both numerous and long – is there any suggestion that astronomy should be pursued as a theoretical study of bodies in motion having no relation with the actual heavens. These other passages are often fanciful, but the celestial bodies to which they refer are always the celestial bodies we see.

What has been said above about Plato's role accords with one of the earliest testimonies to his influence on the exact sciences, namely, that of Dicaearchus, a pupil of Aristotle, as cited by Philodemus in a papyrus roll found among the ruins of a villa at Herculaneum, P. Herc. 1021. It was edited in 1902 by S. Mekler in *Academicorum philosophorum index Herculanensis*, but Konrad Gaiser, who has recently drawn attention to its importance in an article in the *Neue Zürcher Zeitung* (7–8 November 1981), states that a new edition is planned and this will no doubt be more interpretive. In one of the passages cited Dicaearchus aptly compares Plato with an architect, who laid down tasks that the mathematicians zealously sought to fulfil.

An attempt has been made in this paper to show that the theory of a purely speculative astronomy has arisen through a misunderstanding of what Plato meant by saying that we must discard the things in the heavens. Two more questions need to be examined before we can leave it. Immediately before these disputed words in 530 b, Plato lays down that the Guardians must pursue astronomy as he had laid down that they must pursue geometry, by using problems – *προβλήμασιν ἄρα, ἦν δ' ἐγώ, χρώμενοι ὥσπερ γεωμετρίαν οὕτω καὶ ἀστρονομίαν μέτιμεν*. Some have taken this to mean that the heavenly bodies are only approximations to the true objects of astronomy, just as the line drawn on paper is only an approximation to the geometrical line existing in thought alone. Some have postulated astronomical intermediates between the objects of sense perception and the Forms, a belief that Aristotle, *Metaphysics* B 2, 997 b 12–18, indeed attributed to Plato, though it led, as he pointed out, to many difficulties. Neither of these interpretations seems to be required or justified by the Greek. The natural meaning of the words is that in astronomy we must use the same method of deductive reasoning that was already employed in geometry in Plato's day, was to reach perfection in Euclid's works shortly after his death and, if Árpád Szabó is to be believed (*The Beginnings of Greek Mathematics* [1978], pp. 250–3), had its origin with Parmenides and the Eleatic school.

After astronomy Plato posits harmonics as the next study in the education of the Guardians, and he censures those who measure audible concords and sounds against one another as labouring ineffectually like the astronomers who have just been rebuked – *τὰς γὰρ ἀκουομένας αὖ συμφωνίας καὶ φθόγγους ἀλλήλοις ἀναμετροῦντες, ὥσπερ οἱ ἀστρονόμοι, ἀνήνυτα ποιοῦσιν* (531 a 1–3). To those who believe that Plato advocated a speculative astronomy this has seemed strong confirmation of their views. Plato, they say, sought a purely *a priori* science of acoustics having no relation with practical music as, for example, W. Burkert, *Lore and Science in Ancient Pythagoreanism* (1972), p. 872. Certainly the two interpretations hang together, and those who would exculpate Plato from the charge of *a priori* astronomy must also look for a different interpretation of what he says about harmonics. It is not difficult to do so. We could, with Keats, *Ode on a Grecian Urn*, remind ourselves that

> Heard melodies are sweet, but those unheard
> Are sweeter,

that the composer must necessarily 'hear' the notes in his head before he commits them to paper, and that Beethoven still composed when he was deaf; but this is not what Plato has in mind. Gregory Vlastos, loc. cit. pp. 11, 17–18, usefully points to a passage in the *Phaedrus*, 268 d–e, where Socrates tells a practising musician that because he knows how to get varying notes from a string he must not think that he is a master of harmonics; he knows what it is necessary to know before harmonics but not harmonics itself – τὰ γὰρ πρὸ ἁρμονίας ἀναγκαῖα μαθήματα ἐπίστασαι ἀλλ' οὐ τὰ ἁρμονικά. And what then is this true science of harmonics? The answer lies in 531c1–4 – τοὺς γὰρ ἐν ταύταις ταῖς συμφωνίαις ταῖς ἀκουομέναις ἀριθμοὺς ζητοῦσιν, ἀλλ' οὐκ εἰς προβλήματα (that word again!) ἀνίασιν, ἐπισκοπεῖν τίνες σύμφωνοι ἀριθμοὶ καὶ τίνες οὔ, καὶ διὰ τί ἑκάτεροι, 'They seek the numbers in these heard concords, but do not apply themselves to problems, examining which numbers are concordant and which not, and for what reason in each case.' The Pythagoreans knew that the octave, fourth and fifth were concordant, but what Plato wants to know is *why* they are concordant. His requirement could hardly be met until the wave theory of sound was established. We now know that if a string is tuned to Middle C it vibrates at 256 cycles a second, and the ear hears not only the fundamental note but the harmonics or overtones at multiples of the frequency of the fundamental pitch. I am not aware that a scientific theory to account for concordance has ever been propounded, but I would guess that the explanation must lie in the number and nature of the waves reaching the eardrums when a string is struck or bowed or plucked, and in particular whether they reinforce or interfere with each other. In the case of the fifth, the ratio of the frequency of the fundamental notes is 1:1·5, and the second harmonic of the lower note vibrates at the same frequency as the first harmonic of the upper note. The kind of consideration that Plato had in mind is the kind of reasoning that led J. S. Bach to devise the equal-temperament scale, still in universal use, in which the ratio between adjacent semitones in the scale is constant (the twelfth root of 2). Plato can have had no inkling of what he was demanding, but it was a natural demand to make and entirely in line with the demand he made of astronomers. Those who pursue these sister sciences, as the Pythagoreans called them (530d3–4), must apply themselves to 'problems' and the deductive reasoning implied in that term.

The main object of this paper has been to argue that what Plato meant by 'leaving the things in the heaven alone' was to drop the grouping of stars into fanciful figures and to concentrate on a mathematical explanation of celestial motions. This suggestion was first made in the brief final paragraph of a review of John P. Anton (ed.), *Science and the Sciences in Plato*, in *CR* n.s. 32 (1982), 197. But as the suggestion is novel it seems desirable to elaborate it. This paper retracts what I wrote in *Selections Illustrating the History of Greek Mathematics* i (1939), p. 14n. It was the editing of E. J. Webb, *The Names of the Stars* (1952) that set me on the right track, as I now believe, and I would end by expressing my belief that the question how the stars and constellations received their names has not received from classical scholars nearly as much attention as it deserves.

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Note: Since the proofs of this article were passed I have learnt that a theory of concordance was propounded by the great German physicist, Hermann von Helmholtz, in his *Tonempfindungen* (1862), of which the English translation by A. J. Ellis *On the Sensations of Tone* has been reprinted in the Dover series (1954); see pp. 192–3. I see also that the theory was propounded earlier still in a lecture he gave at Bonn in 1857, 'On the physiological causes of harmony in music', included in his *Populäre Vorträge*, translated as *Popular Lectures on Scientific Subjects*, First Series (1873, 2nd edition 1881); see especially pp. 88–9. He finds the essential character of dissonance to lie in a 'roughness of tone' explained much as I guessed in the penultimate paragraph above. This strengthens my belief that I have correctly interpreted Plato's meaning.