Plato as "Architect of Science"

LEONID ZHMUD

ABSTRACT
The figure of the cordial host of the Academy, who invited the most gifted mathematicians and cultivated pure research, whose keen intellect was able if not to solve the particular problem then at least to show the method for its solution: this figure is quite familiar to students of Greek science. But was the Academy as such a center of scientific research, and did Plato really set for mathematicians and astronomers the problems they should study and methods they should use? Our sources tell about Plato's friendship or at least acquaintance with many brilliant mathematicians of his day (Theodorus, Archytas, Theaetetus), but they were never his pupils, rather *vice versa* – he learned much from them and actively used this knowledge in developing his philosophy. There is no reliable evidence that Eudoxus, Menaechmus, Dinostratus, Theudius, and others, whom many scholars unite into the group of so-called "Academic mathematicians," ever were his pupils or close associates. Our analysis of the relevant passages (Eratosthenes' *Platonicus*, Sosigenes *ap.* Simplicius, Proclus' *Catalogue of geometers*, and Philodemus' *History of the Academy*, etc.) shows that the very tendency of portraying Plato as the architect of science goes back to the early Academy and is born out of interpretations of his dialogues.

I

Plato's relationship to the exact sciences used to be one of the traditional problems in the history of ancient Greek science and philosophy.[1] From the nineteenth century on it was examined in various aspects, the most significant of which were the historical, philosophical and methodological.

In the last century and at the beginning of this century attention was paid peredominantly, although not exclusively, to the first of these aspects, especially to the questions how great Plato's contribution to specific mathematical research really was, and how reliable our sources are in ascribing to him particular scientific discoveries. The studies focused first on the

Accepted September 1997

[1] This article was written during my fellowship at the Centre for Hellenic Studies (Washington, D.C.). An earlier version of it was given as a talk at the Department of Classical Studies, Yale University. I am very grateful to Heinrich von Staden for his kind invitation to Yale and to Charles Price for his generous help in preparing the final English version. In quoting Greek authors I have used standard English translations where available.

mathematical passages of Plato's dialogues and second on the evidence (usually late) about his mathematical discoveries, such as the golden section, the method of analysis, the method of founding the "Pythagorean triplets," etc. The general conclusion of these studies was that Plato himself was not an active scientist and that the scientific discoveries and hypotheses attributed to him in the ancient tradition do not really belong to him.[2] In the second half of the 20th century it seems there have been no serious attempts to debate this conclusion,[3] and the discussion has been concerned with the two other aspects – philosophical and methodological.

In the first case the main question usually focused on the extent to which Platonism stimulated the development of the exact sciences in antiquity and/or how much it hindered the formation of the applied sciences and empirically oriented research. I recently stated my position regarding this question,[4] the essence of which can be summed up as follows: there is no ground for believing that in ancient Greece mathematics was much more influenced by philosophy (including Plato's philosophy) than it has been in the modern period. Because of the fundamental epistemological heterogeneity of science and philosophy, they *had* to be developed in a different way from their very beginning, i.e. from the sixth century B.C. on, and all the evidence available to us shows that they *were* actually developed in a different way. In fact, the relationship between the *exact* sciences and philosophy was essentially the same in antiquity as it is in the modern period: it was mathematics that influenced philosophy and not vice versa. As W. Knorr, one of the leading experts in ancient mathematics, emphasizes:

> ... mathematical studies were autonomous, almoust completely so, while the philosophical debates ... frequently drew support and clarification from mathematical work.... My view conforms to what one may observe as the usual relation between mathematics and philosophy throughout history and especially recently.[5]

---

[2] See, for example C. Blass, *De Platone mathematico*, Bonn 1861; G.J. Allman, *Greek Geometry from Thales to Euclid*, Dublin 1889 (Repr. New York 1976); M. Simon, *Geschichte der Mathematik im Altertum*, Berlin 1909 (Repr. Amsterdam 1973), 183ff; T.L. Heath, *A History of Greek Mathematics*, V. I, Oxford 1921, 284ff.

[3] See, however Ch. Mugler, *Platon et la recherche mathématique de son époque*, Strasbourg 1948; cf. a long review of Mugler by H. Cherniss, "Plato as Mathematician," *Rev.Met.* 4 (1951), 395-425 (= *Selected Papers*, Ed. L. Tarán, Leiden 1977, 222-252).

[4] L. Zhmud, "Die Beziehungen zwischen Philosophie und Wissenschaft in der Antike," *Sudhoffs Archiv* 78 (1994), 1-13.

[5] W. Knorr, "The Interaction of Mathematics and Philosophy in Antiquity," in:

It is revealing that we can discern the obvious influence of the exact sciences on Plato's conviction that any firm knowledge of physical reality is impossible, or on his belief in the mathematical structure of the universe, but we can hardly prove that these ideas in turn had any *immediate* influence on those who carried out research in ancient Greece.

In the field of methodology the argument concerned not so much Platonism as the exact sciences in the Platonic school.[6] Many suggested that even if Plato did not achieve any success in the exact sciences, he did play a considerable role as an organiser of scientific research and as a methodologist, who defined the problems mathematicians and astronomers studied and the methods they used.[7] I quote only one typical opinion:

> Die traditionelle Platosauffassung, wie sie auch von den beteiligten Mathematikern im wesentlichen geteilt wird, besagt: Plato hat natürlich keine mathematische Entdeckungen gemacht; die Überlieferung, die ihm Dodekaeder zuschreibt, ist wegzulegen; *aber Plato hat der Mathematik die allgemeinen Direktiven gegeben, die axiomatische Struktur der Elemente, die Beschränkung auf Konstruktionen mit Zirkel und Lineal allein, die analytische Methode sind Platos Werk*; die großen Mathematiker seines Kreises, Theätet und Eudoxus, haben die sogenannte Euklidische Mathematik unter seinem Einfluß geschaffen.[8]

Despite the criticism of this position frequently expressed both by philologists and by historians of mathematics,[9] in the last decades it has

---

N. Kretzman (ed.), *Infinity and Continuity in Ancient and Medieval Thought*, Ithaca 1982, 112.

[6] See the review article by M. Isnardi Parente, "Carattere e struttura dell' Accademia antica," in: E. Zeller, R. Mondolfo, *La filosofia dei Greci nel suo sviluppo storico*, II,3, Firenze 1974, 867-877.

[7] H. Usener, "Organisation der wissenschaftlichen Arbeit" (1884), in: idem, *Vorträge und Aufsätze*, Leipzig 1907, 69-102; U. von Wilamowitz-Moellendorff, *Antigonos von Karistos*, Berlin 1889, 279ff; I.L. Heiberg, *Geschichte der Mathematik und Naturwissenschaft im Altertum*, Leipzig 1912, 9f.; P. Shorey, "Platonism and the Unity of Science" (1927), *Selected Papers*. (Ed. L. Tarán) New York 1980, 434ff; F. Solmsen, "Platons Einfluß auf die Bildung der mathematischen Methode," *Q&St*. Abt. B, 1 (1929), 93-107 (= K. Gaiser (ed.), *Das Platonbild*, Hildesheim 1969, 125-139); H. Herter, *Platons Akademie*, Bonn 1946; G. Hauser, *Geometrie der Griechen von Thales bis Euklid*, Luzern 1955, 127-138.

[8] O. Toeplitz, "Mathematik und Antike," *Die Antike* 1 (1925), 201 (italics are mine). It is worth pointing out that Toeplitz himself understood the vulnerability of this position.

[9] For example E. Howald, *Die platonische Akademie und die moderne universitas litterarum*, Bern 1921; E. Frank, "Die Begründung der mathematischen Wissenschaften durch Eudoxos" (1932), in: L. Edelstein (ed.), *Wissen, Wollen, Glauben*, Zürich 1955, 144f; A. Szabó, "Anfänge des Euklidischen Axiomensystem," *AHES* 1 (1960), 99ff (= O. Becker (ed.), *Zur Geschichte der griechischen Mathematik*, Darmstadt 1965,

been developed in many important studies.[10] While different in approach, these studies share the tendency to present the Academy as a kind of a research institution, where the best mathematicians and astronomers of the time worked under Plato's methodological supervision.[11]

In the following sections of my paper I will discuss various aspects of this issue. Sections II and III deal with two specific scientific problems, the duplication of the cube and the "saving of the appearances," where Plato is supposed to play the role of the scientific organiser and methodologist. Section IV considers a recently restored papyrus text of Philodemus that directly calls Plato an architect of the mathematical sciences. The focus of this section is the authorship of this particular passage and its similarity to the well-known *Catalogue of geometers* in Proclus' commentary to Euclid, which also emphasises Plato's importance for the development of geometry. Section V, which is a central part of the paper, analyses what exactly the *Catalogue* says about Plato's relationship to contemporary mathematicians, and what is known about this from the other sources. The next section, VI, discusses the place occupied by the exact sciences in the educational curriculum and scientific practice of the early Academy. Then, finally, section VII deals with some passages from Plato's dialogues, mainly from Books VI and VII of the *Republic*, which can shed light on the origin of the Academic legend about Plato

450ff); H. Cherniss, Rev. of H. Herter, *Platons Akademie*, *CQ* 43 (1948), 130-132 (= *Selected Papers*, 217-221); K. von Fritz, *Platon, Theaetet und die antike Mathematik* (1932), Darmstadt 1969 (especially Nachtrag); idem, *Grundprobleme der Geschichte der antiken Wissenschaft*, Berlin 1971, 250ff. O. Neugebauer expressed his opinion definitively: "I think that it is evident that Plato's role has been widely exaggerated. His own direct contribution to mathematic knowledge was obviously nil. That, for a short while, mathematicians of the rank of Eudoxus belonged to his circle is no proof of Plato's influence on mathematical research. The exceedingly elementary character of the examples of mathematical procedures quoted by Plato and Aristotle gives no support to the hypothesis that Theaetetus or Eudoxus had anything to learn from Plato. The often adopted notion that Plato 'directed' research fortunately is not born out of facts" (*The Exact Sciences in Antiquity*, 2nd ed. New York 1962, 152).

[10] K. Gaiser, *Platons ungeschriebene Lehre*, Stuttgart 1963, 293ff; F. Lasserre, *The Birth of Mathematics in the Age of Plato*, London 1964; idem. *De Léodamas de Thasos à Philippe d'Oponte*, Napoli 1987 (further quoted as Lasserre); D.H. Fowler, *The Mathematics of Plato's Academy. A New Reconstruction*, Oxford 1987; K. Gaiser, *Philodems Academica*, Stuttgart 1988, 342ff; V. Hösle, *I fondamenti dell' aritmetica e della geometria in Platone*, Milano 1994.

[11] I. Mueller is also ready to admit that Plato was a "general mathematical director, posing problems to the mathematicians" (Mathematical Method and Philosophical Truth, in: R. Kraut (ed.), *The Cambridge Companion to Plato*, Cambridge 1992, 175).

as an architect of the exact sciences. Thus, as I am convinced that it is a legend, I will try to trace its development, moving back from such late authors as Proclus and Simplicius to their classical and Hellenistic sources and then to the early Academy, and Plato himself, who after all was an originator of the idea that science needs an architect.

II

The idea of the Platonic school as a center of scientific research is a continuation of an ancient tradition, which begins in the early Academy itself. A classic example is the story about the solution to the well-known Delian problem of the duplication of the cube, preserved by Theon of Smyrna, Plutarch and several late commentators.[12] For Greek mathematics the Delian problem was not unlike Fermat's theorem for modern mathematics: there is hardly a single famous Greek mathematician from Hippocrates of Chios (c. 440 B.C.) to Pappus Alexandrinus (fourth century A.D.) who does not propose his own solution to this problem.[13] Thus, the tradition connecting it with Plato makes him seem like the originator of one of the central problems in Greek geometry.

Plutarch discussed the problem in several works, giving various interpretations;[14] his versions can be generally summed up in the following way. The people of Delos, tormented by a plague which Apollo had laid upon them, asked Plato to solve the problem of duplicating a cubic altar, posed by the Delphic oracle. Plato, having reprimanded the Greeks for their contempt of geometry, commissioned the famous "academic mathematicians" Archytas, Eudoxus and Menaechmus to find a solution to the problem. In their approach they employed mechanical devices, and Plato rebuked them, because by sinking to the level of crude mechanics they ruined the value of geometry.

According to general opinion Plutarch's source was Πλατωνικός, a dialogue by Eratosthenes, a scientist and poet of the third century B.C.[15] The

[12] See A.E. Riginos, *Platonica. The Anecdotes Concerning the Life and Writings of Plato*, Leiden 1976, 141ff (NN 99-100).

[13] Knorr came up with more than ten solutions: W. Knorr, *Textual Studies in Ancient and Medieval Geometry*, Boston 1989, 11ff. However, unlike Fermat's theorem, this one was already solved in the generation after Hippocrates.

[14] *De E ap. Delph.* 386 E; *De genio Socr.* 579 A-D; *Quest. conv.* 718 E-F; *Marc.* 14.9-11.

[15] Theon refers directly to this work (*Expos.*, p. 2.3-12 Hiller). See W. Knorr, *The Ancient Tradition of Geometric Problems*, Boston 1986, 17ff, 49ff.

plot of this dialogue is clearly literary fiction: the problem of the duplication of the cube arose in the middle of the fifth century, and was not set for Plato by the Delians (Eratosthenes, by the way, was well aware of this fact). Hippocrates of Chios had reduced it to the finding of two mean proportionals between two given lines, and a brilliant solution to this last problem was found by Archytas. Eudemus of Rhodes, a student of Aristotle and our most reliable source on pre-Euclidean geometry, goes into great detail about Archytas' solution,[16] but does not once mention Plato. To whom does the legend about three great mathematicians of three subsequent generations (Eudoxus was a pupil of Archytas, and Menaechmus a pupil of Eudoxus), all working under Plato's supervision, belong? Was Eratosthenes its author or does it date back to an earlier time?

The answer is made more complicated by the fact that Eratosthenes' letter to king Ptolemy, preserved by the later commentator Eutocius of Ascalon (sixth century A.D.), gives an entirely different ending to the story (Eutoc. *In Archim. De sphaera*, p. 90.4f Heiberg = 47 A 15). It states that Archytas, Eudoxus and Menaechmus proposed their solutions to the problem, but they were all too *abstract* and therefore did not deal with the problem in a practical and useful way, with the exception of Menaechmus' (though even he met this practical criterion only to a very small degree and with difficulty). Knorr, who analysed this text in great detail, convincingly showed that the letter is not a later forgery (as Wilamowitz thought),[17] and that it belongs to Eratosthenes.[18] Eratosthenes also studied the problem of duplicating the cube, and it is noteworthy that his own solution was mechanical. He manufactured a device for drawing lines, the so-called "mesolabe," and dedicated a bronze model of it to king Ptolemy, accompanied by a letter and an epigram. Eratosthenes' solution correlates much better with the "mechanical" ending of the story than with the "anti-mechanical" one presented by Plutarch, all the more so because the epigram which is widely recognised as authentic also says that Archytas' solution was badly adapted for practice (δυσμήχανα ἔργα). Hence Knorr concludes that Eratosthenes had two versions: one more historically accurate, in the letter to Ptolemy, and another more literary version, recorded

[16] Eud. fr. 141 Wehrli = 47 A 14. It is probably from Eudemus that the evidence on Eudoxus' and Menaechmus' solutions derives, as well as the mention of Hippocrates (cf. fr. 139-140 Wehrli).

[17] U. von Wilamowitz-Moellendorff, "Ein Weihgeschenk des Eratosthenes" (1894), *Kleine Schriften*, Bd. 2., Berlin 1962, 48-70.

[18] Knorr, *Textual Studies*, 131ff.

in the *Platonicus* and carried down to us by Plutarch.[19] Knorr considers the story about the Delian problem to be a legend that arose in the middle of the fourth century in the Academy.[20]

III

A parallel tradition in the history of astronomy depicts Plato as being the first to put forward the principle of "saving the appearances" (σῴζειν τὰ φαινόμενα), explaining the apparently irregular movement of heavenly bodies by attributing uniform circular movement to them. Having formulated the problem in this way Plato posed it to the scientists who then studied it using their own methods; the first to achieve success was Eudoxus. It is easy to see that the roles in this story are distributed in exactly the same way as in the legend about the Delian problem: Plato's powerful intellect uncovers the essence of the problem and formulates it for the professional scientists; they then compete among themselves and in the end come up with an answer (either one or several in succesion). It is very revealing that this story occupies a central place in the arguments of those who seek to present Plato as a forerunner, and nearly as one of the founders, of European science. Unlike the Delian problem, which despite all of its importance cannot be related to the foundations of ancient mathematics, the principle of "saving the appearances" is a cornerstone of Greek astronomy.[21] If it could be successfully shown that Plato really did have a connection with the formulation of this scientific principle, then this fact alone would be sufficient justification for calling him an "architect of science."

If, however, we turn to the only ancient evidence on this story, the bright colours of this picture immediately begin to fade. Simplicius says the following:

> Eudoxus of Cnidus, as Eudemus reports in the second book of his *History of astronomy* and as Sosigenes repeats on the authority of Eudemus, is said to have been the first of the Greeks to deal with this type of hypothesis. For Plato, Sosigenes says, set this problem for students of astronomy: "By the assumption of what circular and ordered motions can the apparent motions of the planets be accounted for?" (*In Arist. De caelo*, p. 488.18f Heiberg = Eud. fr. 148 Wehrli).

---

[19] It is very likely, however, that the "anti-mechanical" ending of this story belongs to Plutarch himself, and not to Eratosthenes (Riginos, *op. cit.*, 145).

[20] Knorr, *Tradition*, 22, 24. Wehrli also noted this (Eud. fr. 141, comm. ad loc.).

[21] See G.E.R. Lloyd, "Saving the Appearances," *CQ* 28 (1978), 202-222.

Mittelstraß, who analysed this passage in great detail came to a very grounded conclusion: the mention of Plato belongs not to Eudemus, but to Sosigenes, a commentator of the late second century A.D.[22] Actually, with his characteristic pedantry, Simplicius notes that Eudoxus was mentioned by both Eudemus and Sosigenes (who relied on Eudemus), whereas the words concerning Plato belong to Sosigenes only. Thus Simplicius, to whom Eudemus' *History of astronomy* was still available, could not find in it anything relating to Plato.[23] It should also be noted that if Eudemus really did mention Plato in the context of posing such an important problem, we would surely know about it not only from Sosigenes. As for the latter, he was probably aware of the story connecting Plato with the Delian problem: both Plutarch and Theon of Smyrna, who lived in the same century wrote about it.[24] This tradition presenting Plato as a methodologist of τῶν μαθημάτων very likely encouraged Sosigenes to ascribe to him the most important principle of Greek astronomy.[25] However, Sosigenes could rely on much earlier sources.

---

[22] J. Mittelstraß, *Die Rettung der Phänomene*, Berlin 1963, 149ff. See also Fr. Krafft, "Der Mathematikos und der Physikos. Bemerkungen zu der angeblichen Platonischen Aufgabe, die Phänomene zu retten," *Beiträge zur Geschichte der Wissenschaft und Technik* 5 (1965), 5-24; W.R. Knorr, "Plato and Eudoxus on the Planetary Motions," *JHA* 21 (1990), 313-329.

[23] Von Fritz (*Grundprobleme*, 179 n. 375), commenting on this passage, points out that the repetition of Sosigenes' name might mean either that: 1) the words about Plato do not belong to Eudemus; or 2) that Simplicius knew about Eudemus' opinion only through Sosigenes, and was not sure exactly where the quotation from Eudemus ends. Since von Fritz did not see any evidence that Eudemus' *History of astronomy* was available to Simplicius he was inclined towards the second alternative. Yet such evidence does exist: 1) Simplicius gives a long wordy quotation from Eudemus' *History of geometry* (ἐκθήσομαι δὲ τὰ ὑπὸ τοῦ Εὐδήμου κατὰ λέξιν λεγόμενα, *In Arist. Phys.*, p. 60 Diels = Eud. fr. 140 Wehrli) and quotes more than a hundred times from his *Physics*; this makes it very likely that he did have access to Eudemus' *History of astronomy*; 2) three of the seven quotations preserved from the *History of astronomy* are quoted by Simplicius; 3) in quoting Eudemus, Simplicius makes it clear that he is dealing with his book: Εὔδημος δέ συντόμως ἱστόρησε . . . συντόμως καὶ σαφῶς ὁ Εὔδημος ἱστόρησεν (*In De caelo*, p. 497 Heiberg = Eud. fr. 149 Wehrli). I cannot see any reason why Simplicius should have praised the laconic and clear style of Eudemus' work if he did not have access to it. Therefore everything speaks for the first alternative mentioned by von Fritz. Krafft, on the other hand, believes that Simplicius knew this book only through Sosigenes, but that the latter made it clear that the reference to Plato belonged to himself (*Op. cit.*, 16). Cf. Knorr, "Plato and Eudoxus," 319f.

[24] They both also discussed the principle of "saving the appearances": Plut. *De facie* 923 A; Theon. *Expos.*, p. 180 Hiller.

[25] Before Sosigenes this principle was not connected with Plato. This is clear from

IV

Recent publications devoted to the *History of the Academy* by Philodemus (first century B.C.), formerly known as the *Index academicorum*, support the opinion that Plato's image as "architect of science" goes back to the early Academy. In column Y of the Herculanum papyrus 1021, which contains a part of Philodemus' book, we read the following:

> At this time the mathematical sciences (τὰ μαθήματα) were also greatly advanced, with Plato being the architect of this development; he set problems for the mathematicians, who in turn eagerly studied them. In this way, μετρολογία (the theory of proportions?) and research on definitions reached their peak, as Eudoxus of Cnidus and his students completely revised the old theory of Hippocrates of Chios. Especially great progress was made in geometry, as the methods of analysis and of diorismos (τὸ περὶ διορισμοὺς λῆμμα) were discovered. Optics and mechanics also were not (left in contempt) . . .[26]

The similarity of this passage (ἀρχιτεκτονοῦντος μὲν καὶ προβλήματα διδόντος τοῦ Πλάτωνος, ζητούντων δὲ μετὰ σπουδῆς αὐτὰ τῶν μαθηματικῶν) to the quotation from Sosigenes (πρῶτος τῶν Ἑλλήνων Εὔδοξος, . . . ἅψασθαι λέγεται τῶν τοιούτων ὑποθέσεων, Πλάτωνος, ὥς φησι Σωσιγένης, πρόβλημα τοῦτο ποιησαμένου τοῖς περὶ ταῦτα ἐσπουδακόσι), even if it does not allow us to speak for certain about a direct connection between the two texts, at least shows that Sosigenes was following an already long established pattern. His remark only relating to astronomy, seems to be a natural development of Philodemus' text, where *all* the mathematical sciences including mechanics and optics are mentioned. The occurrence of mechanics in this early text seriously undermines the historicity of the alleged "anti-mechanical" attitude of Plato, ascribed to him by Plutarch.

The name of the author of this passage, taken by Philodemus from some early source, is omitted in the papyrus, and several theories have been proposed about his identity. Lasserre suggested that the passage comes ultimately from Plato's secretary Philip of Opus; he believed, moreover,

---

the fact that Theon does not mention it in his special work on Plato's mathematics, and that Geminus (first century B.C.) in his *Introduction to the phenomena* says that the Pythagoreans were the first to introduce the principle of uniform circular movement of heavenly bodies (*Eisag*. I, 19). To be sure, unlike Eudoxus the Pythagoreans did not make *conscious efforts* to reduce the visibly irregular movement of the planets to combinations of the circular movements. They neither explained nor even noticed the deviations of the planets from their circular orbits (retrograde movements, turnings, etc.). See L. Zhmud, *Wissenschaft, Philosophie und Religion im frühen Pythagoreismus*, Berlin 1997, 215ff; Knorr, "Plato and Eudoxus," 235.

[26] Gaiser, *Academica*, 152; T. Dorandi, *Filodemo, Storia dei filosofi. Platone e l'Accademia*, Napoli 1991, 126f.

that Proclus' *Catalogue of geometers*, which is very close to this passage, also derives from Philip.[27] Gaiser argued at length in favour of Peripatetic Dicaearchus as the author of the passage.[28] In his edition of Philodemus' book, Dorandi was careful enough to support neither theory explicitly;[29] but after recent publications on the subject by W. Burkert,[30] Dorandi accepted Philip's authorship.[31] Without going into details of the papyrological problems discussed by Gaiser and Dorandi, one must admit that Lasserre's suggestion is much more plausible than Gaiser's. It would be quite unnatural if Dicaearchus, a partisan of βίος πρακτικός, and having never been seriously interested in mathematics, had so enthusiastically praised Plato's leading role in the development of this science.[32]

As for Philip, according to the *Catalogue of geometers* (Procl. *In Eucl.*, p. 67.23ff Heiberg), he was precisely one of those "academic mathematicians" who studied mathematics under Plato's methodological direction:

> Philip of Mende, a pupil whom Plato had encouraged to study mathematics also carried on his investigations according to Plato's instructions and set himself to study all the problems that he thought would contribute to Plato's philosophy.

This extract from the *Catalogue* is in its own way an illustration of the papyrus passage, yet in the context of the *Catalogue*, which lists particular achievements of the Greek geometers, it looks rather odd: Philip's foremost merit in mathematics is that he studied problems connected *as he thought* with Platonic philosophy! Although this phrase does not necessarily come from Philip, it is possible to expect such self-appraisal from a devoted pupil and secretary of Plato who published the *Laws* and added to this the *Epinomis*, – if, of course, he did not have any other achievements in the field of τὰ μαθήματα that he might be proud of.[33] But if one agrees with Lasserre that both of the passages quoted above are to be

---

[27] Lasserre, 20 F 15a-15b, 611ff.

[28] Gaiser, *Academica*, 76f, 97f, 342ff.

[29] Dorandi, *op. cit.*, 207f.

[30] W. Burkert, "Philodems Arbeitstext zur Geschichte der Akademie," *ZPE* 97 (1993), 87-94; idem, *Platon in Nachaufnahme – Ein Buch aus Herculaneum*, Leipzig 1993, 26f.

[31] T. Dorandi, "La tradizione papirologica da Dicearco a Demetrio del Falero," in: W.W. Fortenbaugh (ed.), *Rutgers University Series in the Classical Humanities*, New Brunswick 1998 (*in press*).

[32] To judge from the preserved fragments of Dicaearchus (fr. 42, 43, 44, 71 Wehrli), he had a critical if not hostile opinion of Plato.

[33] Evaluating the little that is known about Philip's scientific work, one comes to the conclusion that this was in fact the case. See below, p. 238.

traced back to Philip's book Περὶ Πλάτωνος,[34] then the following very important question arises: does it follow, as Lasserre thought, that we should attribute to Philip not only the concluding phrase of the *Catalogue*, which concerns him, but the whole of the *Catalogue*?

It is customary to think of the information in the *Catalogue* as going back, albeit through intermediaries, to Eudemus' *History of geometry* (fr. 133 Wehrli, comm. ad loc.). Although Proclus does not mention his name in connection with the *Catalogue*, he refers to "those who wrote the history of geometry" before Euclid; besides, fragments of Eudemus, including those quoted by Proclus himself, coincide thematically with the *Catalogue* (fr. 134-141 Wehrli). On the other hand, the passage from Philodemus closely matches the description of Plato given in the *Catalogue* (*In Eucl.*, p. 66.8ff):

> Plato greatly advanced mathematics in general and geometry in particular because of his zeal for these studies. It is well known that his writings are thickly sprinkled with mathematical terms and that he everywhere tries to arouse admiration for mathematics among students of philosophy.

These words used to be regarded as a later insertion by either Proclus or one of his Neoplatonic predecessors.[35] Is it possible now to connect them with the papyrus passage, and so with its putative author, Philip? This seems not unlikely, since further on in the *Catalogue* Eudoxus is mentioned as the one who "applied the method of analysis to the theory of the section, which originated with Plato,"[36] as well as another geometer, Leon, who discovered the method of *diorismos* (used to determine whether the problem posed is capable of solution or not). Although the mathematical terminology of the two passages does not coincide word for word,[37] the similarity between them is entirely sufficient to make us take seriously the arguments in favour of Philip's being the author of at least the second part of the *Catalogue*, which begins with Plato and ends with Philip himself.

---

[34] Lasserre, 611ff.

[35] See, for instance, B.L. van der Waerden, *Science Awakening*, New York 1961, 91.

[36] In another chapter of his commentary Proclus remarks: "Plato, they say, told Leodamas of Phasos about a method of analysis, which helped the latter make many new discoveries in the field of geometry" (*In Eucl.*, p. 211.18f). Earlier, Diogenes Laertius (III, 24) had mentioned this, referring to Favorinus.

[37] The papyrus passage uses rather vague terms: τὰ περὶ μετρολογίαν (?), τὰ περὶ τοὺς ὁρισμοὺς προβλήματα, τὰ περὶ διορισμοὺς λῆμμα, τὰ περὶ τὴν γεωμετρίαν. Philodemus was not a specialist in mathematics, but he has hardly made any significant change in this passage.

Still, such a solution is by no means obvious. 1) There are no convincing arguments either that Philip was the author of the papyrus passage or that it was taken from his book Περὶ Πλάτωνος. Hermodorus of Syracuse, another student of Plato, may well have been its author: besides Plato's biography he wrote a historical (?) work Περὶ μαθημάτων (D.L. I, 2 and 8 = fr. 6 Isnardi Parente).[38] Philodemus mentions Hermodorus' book on Plato (col. 6), so it is likely to have been available to him.

2) By its form the *Catalogue* belongs rather to the history of science than to the biographical genre. It contains too much detailed information that has no connection with Plato, especially in its first part, which narrates the development of geometry from Thales to Hippocrates of Chios. Unlike Eudemus, Philip did not write a history of geometry, but an intellectual biography of Plato and he was scarcely interested in such half-forgotten figures from the sixth and fifth centuries as Mamerkus or Oenopides (Eud. fr. 133 Wehrli).[39]

3) It is unlikely that the *Catalogue*, in the form known to us, was available to Philodemus. In a list of Plato's students compiled by him (col. 6) only two of the twelve mathematicians from the second part of the *Catalogue* are mentioned: Amyclas (who however occurs here under the name Amyntas) and Archytas. Both of these names occur also in Diogenes Laertius' list (III, 46) and can be thus traced back to a common tradition that has no connection with the *Catalogue*.

4) We know that Proclus received the *Catalogue* through intermediary sources, the main one of whom is thought to be Geminus, the author of a mathematical encyclopaedia.[40] However, none of what we know about Geminus and his work Μαθημάτων θεωρία (Procl. *In Eucl.*, p. 38.4-42.8) is consistent with either Neoplatonic influence in the *Catalogue* or with its special interest in those predecessors of Euclid, who compiled the *Elements*.[41] I believe that the Neoplatonist Porphyry, who wrote a com-

---

[38] Lasserre (433f) considered Hermodorus as only an intermediary figure between Philodemus and Philip.

[39] There are too many coincidences between the *Catalogue* and Eudemus' fragments to deny his authorship, as Lasserre (599ff, 611ff) and C. Eggers Lan ("Eudemo y el 'catálogo de geómetras' de Proclo," *Emerita* 53 [1985], 127-204) do. See on this my forthcoming paper "Eudemus' History of Mathematics," in: W.W. Fortenbaugh & I. Bodnar (ed.), *Rutgers University Series in the Classical Humanities*, Vol. XI, New Brunswick 1999.

[40] P. Tannery, *La géométrie grecque*, Paris 1887, 71ff; B.L. van der Waerden, *Die Pythagoreer*, Zürich 1979, 38.

[41] Heath, *Elements*, 37; Eggers Lan, *op. cit.* 140f.

mentary on Euclid, is a much more appropriate candidate for the role of editor of the *Catalogue* and an intermediary between Eudemus and Proclus.[42] Thus the passages about Plato and Philip, which could scarcely belong to Eudemus, might have been inserted into the *Catalogue* by Porphyry or have been written by himself.

Discarding, for the time being, the intermediate variants, one arrives at the following alternatives: either the *Catalogue* was taken from a book by one of Plato's students (Philip or Hermodorus) and does not have any connection with Eudemus, or it was compiled on the basis of Eudemus' writing and its Platonic features are explained by later Neoplatonic editing. The second alternative seems to me preferable, since the traces of such editing are discernible also in the first part of the *Catalogue*, for example in the section where a discovery of five cosmic bodies is ascribed to Pythagoras, and typically Neoplatonic terms are used (*In Eucl.*, p. 65.15f). The reference to the late pseudo-Platonic dialogue *Anterastai* (p. 66.3) also can belong neither to Philip, nor to Eudemus. But we will delay our conclusion about the origin of the *Catalogue* until we have completed a more detailed analysis of what exactly it says about mathematicians of Plato's time.

V

Plato occupies a central place in the second part of the *Catalogue* and such a perspective, of course, brings it closer to the papyrus passage. But even then, only *one* mathematician whose name occurs here is directly named as a pupil of Plato, and nothing is said about the posing of problems. What is said about his contribution to the development of mathematics is supported with a reference to his dialogues but not to his role as an architect of τὰ μαθήματα. The author (or editor?) of the *Catalogue* uses more subtle means to express what is directly said in Philodemus: all the mathematicians of Plato's time worked under his methodological supervision. This effect is achieved mainly by situating all these mathematicians in the text between Plato and Philip, the latter being described as a devoted student working in accordance with Plato's instructions. Because of this arrangement, Plato's figure, as it were, casts a shadow on all his contemporaries. This impression is reinforced by the constant emphasis on temporal proximity and personal relationship: some "lived at the time of

[42] For a detailed argumentation see my "Eudemus' History of Mathematics."

Plato," others "were associated with him," and others "were friends of his students," etc.

Although Plato could not have been a reference point in Eudemus' history of fourth century geometry, he could play such a role both for the early Academicians and for the Neoplatonists. To be sure, for our present analysis it is not very important whether this perspective derives from the early or from the later Platonists. I would propose the following approach to the second part of the *Catalogue*: if, in spite of its clear bias, it does not specifically mention that someone was a pupil of Plato or that he worked at the Academy, it means that this was not known in the last part of the fourth century. It seems very unlikely that later authors would omit such a fact, if they found it either in Eudemus or in Philip (Hermodorus).

The first three mathematicians of Plato's time mentioned here are Leodamas of Thasos, Archytas and Theaetetus. Nothing is said about their connection with the Academy or about their personal relationships with Plato. Since the chronology in this part of the *Catalogue* is very accurate, one can suggest that Leodamas was the oldest of the three, or at least that he was not younger than Archytas. It is with him that Lasserre begins his collection of sources concerning the "Academic mathematicians," although there is absolutely no evidence about Leodamas' working at the Academy.[43] The only things linking him with Plato are Favorinus' statement (D.L. III, 24), repeated with some hesitation by Proclus (*In Eucl.*, p. 211.18f), that Plato taught him a method of analysis, and the pseudo-Platonic Letter XI addressed to a certain Leodamas. But then why should not Archytas be included in Lasserre's collection as well? After all, there is much more evidence concerning him: first, we have Eratosthenes' *Platonicus*, second, the authentic Letter VII that mentions the help he gave to Plato, and third, the fact that Archytas (but not Leodamas!) occurs in several lists of Plato's students. However, it is not so easy to make an Academic mathematician of Archytas, since unlike Leodamas, he was a famous and independent scientist, one moreover of a Pythagorean bent. But even if Leodamas was the same age as Archytas (born c. 435/430),[44] then at the time the *Meno* was written (c. 385/380), the first dialogue in which Plato shows an interest in mathematics and gives, in particular, a

---

[43] L. Tarán, "Proclus on the Old Academy," in: J. Pepin, H.D. Saffrey (eds.), *Proclus – Lecteur et interprète des Anciens*, Paris 1987, 273. Lasserre (24, 445) himself acknowledges this. See also K. von Fritz, "Leodamas," *RE Suppl.* VII (1940) 371-372.

[44] B. Mathieu, "Archytas de Tarent pythagoricien et ami de Platon," *BAGB* (1987), 239-255; L. Zhmud, *Wissenschaft*, 73.

description of the method ἐξ ὑποθέσεως (one of the forms of analysis), Leodamas must have been 45-55 years old. If he was only five years older than Archytas (what logically follows from arrangement of names in the *Catalogue*) then accordingly, he must be 50-60. Is this not too late for learning analysis, even from Plato?

The improbability of such an apprenticeship is strengthened by the following: 1) the statement relating to analysis can probably be traced back to early Platonic sources, but Proclus repeats it elsewhere, and not in the context of the *Catalogue*, where analysis is linked with Eudoxus, although the latter is not named as its discoverer; 2) Plato himself, describing the method ἐξ ὑποθέσεως in the *Meno* says that it was already in use by geometers (ὥσπερ οἱ γεωμέτραι πολλάκις σκοποῦνται); the method described by him is identical to the method of reduction (ἀπαγωγή), which Hippocrates used in trying to solve the problem of the duplication of the cube;[45] 3) to study analysis on the basis of the *Meno* (or of Plato in general) would not only be embarrassing for the not very young Leodamas, but impossible: despite endless interpretations of this passage, a clear understanding of what Plato had in mind has not been achieved to this day.[46]

Despite the mention of Archytas in the Academic legend about the duplication of the cube, there is no information whatsoever about whether he ever went to Athens.[47] Sources talk about his friendship with Plato, who visited him several times in Tarentum, but he was never Plato's pupil – rather: Plato studied with him and actively used what he learnt. The influence of Archytas on Plato has been repeatedly noted,[48] but no one has

---

[45] Knorr, *Problems*, 71f. ἀπαγωγή was one of the earliest forms of analysis. Proclus defined it as "the reduction of a problem or theorem to another one, which either being known, or already solved, makes the original proposition evident" and identifies it with the method that Hippocrates used for solving the problem of the duplication of the cube (*In Eucl.*, p. 212.24f). About the application of analysis in the fifth century see Allman, *op. cit.*, 41 n. 62, 97f; Heath, *History*, 291; Cherniss, *op. cit.*, 418f.

[46] R.S. Bluck, *Plato's Meno*, Cambridge 1964, 322f, 441ff. See also J. Klein, *A Commentary on Plato's Menon*, Chapel Hill 1965, 205ff; J.E. Thomas, *Musings on the Meno; A New Translation with Commentary*, The Hague 1980, 165f; Lasserre, 451f; Knorr, *Problems*, 71f. Lasserre (457f) eventually comes to the conclusion that it was Leodamas who influenced Plato rather than vice versa.

[47] Lasserre, 434; Tarán, "Proclus," 273; Gaiser, *Academica*, 448.

[48] Fr. Krafft, *Dynamische und statische Betrachtungsweise in der antiken Mechanik*, Wiesbaden 1970, 143ff; Mathieu, *op. cit.*, 251f; G.E.R. Lloyd, "Plato and Archytas in the Seventh Letter," *Phronesis* 35 (1990), 159-173. If the *Seventh Letter* emphasises Plato's independence from Archytas, it only means that Plato was unwilling to acknowledge this dependency. This tendency coincides with the scarcity of mentions of the Pythagoreans in the dialogues, and with Plato's total silence about Archytas.

yet succeeded in tracing the opposite influence. Where it is possible to find comparable material, the position of Archytas has either differed from Plato's position or been directly opposed to it.[49]

According to the *Catalogue*, Theaetetus was of Leodamas' and Archytas' generation, so there was not much difference in age between him and Plato. Theaetetus does not occur in any list of the Academics, and only the *Suda* calls him a student of Plato, although Plato himself describes him as a student of the Pythagorean Theodorus of Cyrene (*Tht.* 145c). Theaetetus' basic achievements in mathematics were the development of the theory of the five regular solids and the general theory of irrationals. Both of these theories suggest his Pythagorean predecessors (Hippasus)[50] and teachers (Theodorus), which makes the influence of Plato entirely redundant. On the basis of a commonly accepted chronology of Theaetetus (c. 415-369), he *might have been* one of the older associates of Plato working at the Academy. However, the absence of any evidence about his activity there on the one hand, and his studies with Theodorus (c. 475/70-400) on the other, make this suggestion very unlikely.[51]

Nothing is known about Neokleides, who follows Theaetetus in the *Catalogue*, and he is not mentioned anywhere else. His student Leon is

---

[49] See 47 A 23-25. Cf. also 47 B 1 and *Res.* 531c, 47 B 3 and *Res.* 525c-d.

[50] W.C. Waterhaus, "The Discovery of the Regular Solids," *AHES* 9 (1972), 212ff; E. Neuenschwander, "Die stereometrische Bücher der Elemente Euklids," *AHES* 14 (1974), 104; L. Zhmud, *Wissenschaft*, 171f.

[51] Tarán, "Proclus," 273, cf. Lasserre, 463. The biography of Theaetetus (Lasserre, 3 T 1-3) remains extremely confused. Eusebius places his acme in 438/5, and it is the conversion of this acme into his date of birth which would explain his synchronisation with Leodamas and Archytas. In the *Suda* there are two Theaetetuses, one a student of Socrates who lived at the time of the Peloponnesian war, and the other – a student of Plato. E. Sachs' suggestion that his dates were 415/412-369 (E. Sachs, *De Theaeteto Atheniensi mathematico*, Berlin 1914, 13ff) relies mainly on the fact that in the *Theaetetus*, whose dramatic date is 399, he is depicted as an adolescent; but she failed to explain either the confusion in Eusebius or the appearance of the two articles in the *Suda* (Lasserre, 461). Recently H. Thesleff proposed returning to the old date for his death, i.e., about 390 ("Theodoros and Theaetetus," *Arctos* 24 (1991), 147-159), without changing the date for his birth, about 415. This revision would make sense, if we prefer the dating of the *Catalogue*, which implies that Theaetetus belonged to the generation of Archytas and Plato; this makes his date of birth 435/425. Lasserre (461f) also proceeds from the dates of the *Catalogue*, but he places Archytas' acme in 368/7, which gives his date of birth impossibly as 408/407, and correspondingly understates Theaetetus' date of birth. Archytas' acme was clearly taken from Eratosthenes' *Platonicus* (dramatic date 368/7). Eudoxus was also given this acme, but in this case Lasserre reasonably refused to accept Eratosthenes' evidence.

named as the author of *Elements* and the discovery of the method of *diorismos* is attributed to him, something which, as we remember, has a parallel in the papyrus passage, although that passage does not mention Leon. Unless we want to regard Plato as responsible for this discovery – and there is not a slightest reason for doing so[52] – then no connection between him and Leon can definitely be established.[53]

Eudoxus is a key figure for understanding the nature of the real relationship between the Academy and mathematicians of the time, because in this case it is possible to make comparisons with an independent tradition. In the *Catalogue* Eudoxus is carefully named as ἑταῖρος τῶν περὶ Πλάτωνα γενόμενος, and nothing is said here about his being at the Academy, so Lasserre rightly does not include him in his list of "Academic mathematicians."[54] Let us turn first to Eudoxus' chronology. His traditional dates (408-355), which still appear in some works, relied firstly on his acme as given by Apollodorus (D.L. VIII, 90), i.e. 103 Ol. (368/5), and secondly on Diogenes Laertius VIII, 90, which says that Eudoxus lived to the age of 53. Apollodorus connects the acme with the most important event in Eudoxus' life, the discovery of curved lines (κάμπυλαι γράμμαι), and this unmistakably indicates his source: Eratosthenes' dialogue the *Platonicus*, where Eudoxus finds the solution to the Delian problem διὰ τῶν καμπύλων γραμμῶν. The dramatic date of the dialogue is 368/7 – an attempt to synchronize Archytas, Plato and Eudoxus.

[52] Actually, the method of *diorismos* was used even before Leon (Heath, *History*, 319f; Lasserre, 516f).

[53] Tarán, "Proclus," 273f. Although Tannery thought it impossible to make any reliable identification of the mathematician Leon, he gives the names of two "platoniciens" with the same name (*op. cit.*, 130). One of them was a sophist from Byzantium and possibly the author of the pseudo-Platonic dialogue *Alcyon*; the other was from Heraclea and took part in the assassination of the tyrant Clearchus, former student of Plato. According to Lasserre (513f) the author of the *Alcyon* is actually the mathematician Leon, and this serves as the main evidence that he belonged to the Academy. All this has absolutely no basis, since: 1) Leon of Byzantium, a historian of the fourth century B.C., has nothing in common with the alleged author of the *Alcyon*, which was written in the Hellenistic period; 2) the name of Clearchus' assassin was Leonides, which was corrupted into Leon in Tzetzes' transmission of Memnon's work; 3) these two contemporaries of Plato are "platoniciens" only in the sense that they have the same (or *almost* the same) name as the "platonicien" Leon, the alleged author of the *Alcyon*! 4) None of these three persons can be certainly identified with the mathematician Leon.

[54] "Sicher trat er nicht in die Akademie ein, 'dozierte' also nicht dort" (F. Lasserre, *Die Fragmente des Eudoxos von Knidos*, Berlin 1970, 141). Cf. H.J. Krämer, "Die ältere Akademie," in: H. Flashar (ed.), *Die Philosophie der* Antike, Bd. 3, Basel 1983, 73ff.

Eudoxus' traditional dating was criticised for a long time. Susemihl suggested 390-337, Gisinger – 395-342; both of them relied on the fact that Eudoxus mentioned the death of Plato (fr. 342 Lasserre) and could not therefore have died before 347.[55] Von Fritz proposed his "minimal" dates as being 400-347,[56] but in a special article about Eudoxus' chronology Santillana reasonably returned to 390-337.[57] The latter dates are accepted by Lasserre who gives a detailed proof of them in his edition of Eudoxus' fragments.[58] Since then, no one has seriously tried to defend the traditional chronology, though it has been tacitly used even since Lasserre's edition.[59]

Eudoxus' teacher in mathematics was Archytas (D.L. VIII, 86), and it is not by chance that Diogenes Laertius finishes the book about well-known Pythagoreans (VIII) with a biography of Eudoxus. He visited Athens twice (VIII, 86-88). The first time, when he was 23, i.e. in the year 367, he went there for two months. He attended the Sophists' lectures and possibly visited the Academy, but nothing is said about his acquaintance with Plato, since the latter was in Sicily.[60] The second time he was already a grown man and came to Athens "bringing with him a great number of pupils: according to some, this was for the purpose of annoying Plato who had originally passed him over."[61] According to Santillana and Lasserre Eudoxus

[55] F. Susemihl, "Die Lebenszeit des Eudoxos von Knidos," *RhM* 53 (1898), 626ff; F. Gisinger, *Die Erdbeschreibung des Eudoxos von Knidos*, Leipzig 1923, 5.

[56] K. von Fritz, "Die Lebenszeit des Eudoxos von Knidos," *Philologus* 39 (1930), 478-481.

→ G. de Santillana, "Eudoxus and Plato. A Study in Chronology," *Isis* 32 (1940), 248-282.

[58] Lasserre, *Eudoxos*, 137ff. See also H.-J. von Waschkies, *Von Eudoxos zu Aristoteles*, Amsterdam 1977, 34ff; K. Trampedach, *Platon, die Akademie und die zeitgenössische Politik*. Stuttgart 1994, 57ff.

[59] An attempt by Merlan to propose another dating (395-342) is unconvincing, since it depends, first, on the early dating of *Metaphysics* Λ 8, where Eudoxus and Callippus are mentioned, and second, on the highly unlikely proposition that at the age of 27 Eudoxus came to Athens with a group of his students and at 28 became a scholarch in the Academy (P. Merlan, *Studies in Epicurus and Aristotle*, Wiesbaden 1960, 98ff).

[60] It is to this visit that the well known statement from the late biography of Aristotle refers: 'Αριστοτέλης φ(οιτᾷ Πλάτωνι ἐπὶ Εὐδ)όξου (*Vita Marciana* 10). These words used to be taken as evidence that during Plato's absence Eudoxus played the role of scholarch. The impossibility of this reconstruction has been shown many times (Waschkies, *op. cit.*, 41f; Krämer, *op. cit.*, 74; Trampedach, *op. cit.*, 59). The point of the statement is probably that Aristotle, joining the Academy in 367, met Eudoxus there, which fully correlates with the chronologies of Santillana and Lasserre. Cf. Waschkies, *op. cit.*, 41f.

[61] The tradition about the personal hostility between Plato and Eudoxus has hardly

probably spent a few years in Athens, from about 350 to about 349, and then returned to his homeland in Cnidus, where he died in 337. It seems that one may relate his participation in academic discussions on the relationship between Forms and things and on what is the highest Good to Eudoxus' second visit to Athens. His answers to both problems were so un-Platonic in character[62] that it is totally inconceivable that he should have served his apprenticeship at the head of the Academy.

There seems to have been still less of Plato's influence in Eudoxus' famous work *On velocities*, in which he put forward his system of homocentric spheres. The impulse to create this system comes not from Plato's metaphysics, but from professional astronomy, where, in the middle of the fourth century, the problem of the anomalous movements of the planets and their varying brightness became very important.[63] The fact that both Plato and Eudoxus were adherents of the principle of uniform circular movement shows the common Pythagorean source of their astronomical ideas,[64] which was most likely Archytas. Although Archytas is practically unknown as an astronomer,[65] there are strong grounds for suggesting that it was exactly his mathematical and mechanical research that led Eudoxus to discover the *hyppopede* – the curve which is created by the rotation of several interconnected spheres and describes the visible looped motion of the planets.

Archytas' research in mechanics was as it were a mirror reflection of his mathematical research. On the one hand he introduced movement into geometry, while on the other he applied geometry to the movement of the mechanisms (D.L. VIII, 83). One of the few pieces of evidence pertaining to Archytas' *Mechanics* reports that natural movement "generates circles and circular forms" (47 A 23a). It is exactly on this principle that the Aristotelian treatise *Mechanical problems* is based, which, as Krafft showed, derives its main features from Archytas' *Mechanics*.[66]

---

any historical ground. The only time when Eudoxus mentions Plato it is with great respect (fr. 342 Lasserre).

[62] Arist. *Met.* A 9, M 5; *Nic. Eth.* I, 12; X, 2. See Krämer, *op. cit.*, 74f, 80f with suggestions on the preceding literature.

[63] Knorr, "Plato and Eudoxus", 323f.

[64] "The hypothesis underlying the whole astronomy is that the sun, the moon and the five planets circulate at uniform speeds in the direction opposite to that of the heavenly sphere. The Pythagoreans were the first to approach such questions, and they assumed that the motions of the sun, the moon and the five planets are circular and uniform" (Gemin. *Eisag.* I, 19). See above, n. 25.

[65] On the astronomical aspect of Archytas' work see Zhmud, *Wissenschaft*, 219ff.

[66] Krafft, *Mechanik*, 149ff.

Mechanical problems reduced all mechanisms described (the lever, the windlass, the pulley, the winch, etc.) to the principle of unequal concentric circles. Archytas established that the linear speeds of concentric circles, moving with equal angular speed, are different, and he gave a mathematical analysis of this movement. Eudoxus' treatise *On velocities* developed Archytas' investigations,[67] perceiving every planet as fixed to a rotating sphere, the axis of which, in turn, is linked with another sphere, etc. The curve resulting from the rotation of these spheres can be regarded as the intersection of the inner sphere with the cylinder. This construction is very similar to the one which helped Archytas to solve the problem of duplicating the cube. Here the necessary curve is made by the intersection of three rotating bodies – the cone, the torus and the cylinder (47 A 14).[68] Thus all the mathematical and astronomical elements necessary for the development of Eudoxus' theory were contained in the Pythagorean tradition.

Eudoxus' book *On velocities* was most likely written during the last period of his activity, when he was living in Cnidus, and it is only reasonable to suppose that Plato knew nothing about it. Theoretically, *he might have* learned about the basics of Eudoxus' astronomical system in 350 when the *Timaeus* was already written, and the *Laws* had not yet been finished. However, no one has succeeded in finding convincing evidence of his knowledge of the system of homocentric spheres in the *Laws*, so Eudoxus' influence on Plato remains as unproved[69] as Plato's influence on Eudoxus.

---

[67] Ibid., 145f; O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Part I-III, Berlin 1975, 678. Not accidentally, Archytas' definition of astronomy begins from περὶ τᾶς τῶν ἄστρων <u>ταχυτᾶτος</u> (cf. Pl. *Gorg*. 451c), and he ascribes to his Pythagorean predecessors a "clear knowledge" of this subject (47 B 1).

[68] Heath, *History*, 333f; Knorr, *Tradition*, 54f; R.C. Riddell, "Eudoxian Mathematics and Eudoxian Spheres," *AHES* 20 (1979) 1-19.

[69] Lasserre, *Eudoxos*, 181f; L. Tarán, *Academica: Plato, Philip of Opus and the Pseudo-Platonic Epinomis*, Philadelphia 1975, 107. Mittelstraß (*op. cit.*, 133ff), although a keen adherent of the idea of such an influence (relying on the old chronology for Eudoxus), nevertheless admitted that Plato did not change his former astronomical system, as proposed in the *Republic* and *Timaeus*, and that only from some occasional hints in the *Laws* can we conclude that Plato was acquainted with Eudoxus' theory. To unravel Platonic hints is not a very rewarding task, so I propose a few more obvious arguments. 1) The most important elements of Eudoxus' theory are missing from the *Laws*, primarily the idea that all planets are attached to spheres by which they rotate. How is it possible to be under the influence of Eudoxus' theory and not mention spheres at all? 2) There are no traces of Eudoxus' conception even in the *Epinomis* written by Philip after Plato's death (Tarán, *Academica*, 110; Knorr, "Plato

Let us return to the point where Diogenes Laertius talks about Eudoxus' second visit to Athens from Cyzicus, where he had his own school with a large number of pupils (VIII, 87). I believe it was this group of Eudoxus' students that formed the main body of "Academic mathematicians" of the younger generation. In the *Catalogue*, after Eudoxus there are six mathematicians mentioned (after whom follows Philip): Amyclas of Heraclea, Menaechmus, Dinostratus, Theudius of Magnesia and Athenaeus of Cyzicus. They are said to have had spent their time together in the Academy and collaborated in their research; separate from this group follows Hermotimus of Colophon. The *Catalogue* names Menaechmus and his brother Dinostratus as Eudoxus' students, and to them two mathematicians from Cyzicus must be added: Athenaeus and Helicon (who was mentioned by Plutarch)[70] and perhaps Hermotimus who "continued the work that has been done by Eudoxus and Theaetetus" (*In Eucl.*, p. 67.20f). Theudius' origin (whichever of the two Magnesia's he was born in) may also indicate that he studied with Eudoxus in Cyzicus and travelled with him to Athens. Although the last possibility remains unproved, it is revealing that almost all Eudoxus' young contemporaries came from Asia Minor.[71] From this group, only one mathematician, Amyclas, is *directly* named εἷς τῶν Πλάτωνος ἑταίρων (*In Eucl.*, p. 67.9). Meanwhile Amyclas, an acquaintance of Plato, is presented by Aristoxenus as a Pythagorean (fr. 131 Wehrli)![72] In any case, we do not know anything about Amyclas' mathematical research.

---

and Eudoxus," 323); 3) Aristotle, in all probability, learned about Eudoxus' system after 330, already in a form modified by Callippus (Simpl. *In Arist. De Caelo*, p. 493 Heiberg; Tarán, *Academica*, 107 n. 484).

[70] Lasserre, *Eudoxos*, 141. Two other students of Eudoxus, Callippus and Polemarchus, also were from Cyzicus (Simpl. *In Arist. De Caelo*, p. 504-505 Heiberg).

[71] The origin of Menaechmus and Dinostratus is unknown. The identification of the mathematician Menaechmus with a certain Menaechmus of Alopecae or Proconnesus who is mentioned in the *Suda* is unconvincing. The *Suda* says: φιλόσοφος Πλατωνικός. ἔγραψε φιλόσοφα καὶ εἰς τὰς Πλάτωνος Πολιτείας βιβλία γ' (Lasserre, 12 T 2), which refers certainly to a later writer, and not to a contemporary of Plato, otherwise he would be called his "student" and not just "a Platonic philosopher." When this Menaechmus was alive is not clear (in Proclus' commentary on the *Republic* he is not mentioned), but it is well known that with the first generation of Academics there were no *special* commentaries on the Platonic dialogues. Proclus (*In Tim.*, p. 76.1-2 Diehl) names Crantor (340/35-275), a student of Xenocrates as the first interpreter of Plato. See Krämer, *op. cit.*, 161f; Tarán, "Proclus," 270f.

[72] Aristoxenus tells us that Plato wanted to collect all Democritus' books and burn them, but the Pythagoreans Amyclas and Cleinias persuaded him not to do this, explaining that too many people had copies of them. Cleinias (DK 54), unlike Amyclas

It seems very likely that after Eudoxus' return to Cnidus (before 348 according to Lasserre) his students remained for some time in Athens and worked at the Academy. How long they stayed there is unknown, as is the nature of their relationship with Plato, who was nearly eighty. As has been already noted above, in the earliest known list of his students, preserved by Philodemus,[73] the names of five of these mathematicians are missing; only Amyclas is named, and he is the only one of this group who appears in Diogenes Laertius' list of Academics (III, 46). The other five are not on any list of early Academics and practically nothing is known about their connection with the Academy.[74] This could mean either that their stay at the Academy was very short and did not leave any traces outside the *Catalogue*, or that they worked there only after Plato's death. Whichever of these versions we favour, none of them support the Academic legend of Plato as the architect of mathematical science.

Let us now return to the authorship of the *Catalogue*. Despite its undoubted proximity to the papyrus passage, there are a number of features which prevent suggesting a common origin of these two texts. Apart from the lack of connection of the first part of the *Catalogue* with Plato, the perspective of the second part is much wider than in Philodemus' text, which concludes with a polemic against certain unnamed students of Plato who used the "fruits of knowledge" for their own benefit.[75] If the quotation from Philodemus goes back to the *Catalogue*, why in his own list of

---

occurs in a catalogue of Pythagoreans, compiled by Aristoxenus (Zhmud, *Wissenschaft*, 67f). *Pace* Lasserre, who considered the evidence of Aristoxenus doubtful (7 T 6), the latter did not say that Amyclas was born in Italy or that he was an opponent of Plato; therefore I do not see any problems in identifying Amyclas of Heraclea with the hero of this anecdote. It should be also pointed out that the Pythagoreans from Italy were Plato's friends.

[73] Gaiser, *Academica*, 110ff, 443ff.

[74] Menaechmus occurs in Eratosthenes' *Platonicus* as one of the "Academic mathematicians," but here even Archytas is present, despite the following: 1) he never went to the Academy; 2) when Eudoxus went to Athens in 350 Archytas was probably already dead. It is evident that Archytas and Menaechmus were included in the *Platonicus* because they were, respectively, a teacher and a student of Eudoxus' and proposed their solutions to the problem of the duplication of the cube, and not because of their association with Plato. Menaechmus' peculiar description in the *Catalogue*, Μέναιχμος ἀκροατὴς ὢν Εὐδόξου καὶ Πλάτωνι δὲ συγγεγονώς (*In Eucl.*, p. 67.10), very likely goes back to the *Platonicus*. On the alleged argument between Menaechmus and Speusippus (Procl. *In Eucl.* p. 77.7-79.2 = Lasserre 12 F 4-5) see A.C. Bowen, "Menaechmus versus the Platonists: Two Theories of Science in the Early Academy," *AncPhil* 3 (1983), 13-29; cf. Tarán, "Proclus," 237 n. 36f.

[75] This part of the papyrus is in a very damaged state.

Plato's students is the overwhelming majority of the names mentioned in the *Catalogue* missing? Further, the information about most of the mathematicians of the fourth century named in the *Catalogue*, such as Leodamas, Neokleides, Leon, Theudius, Athenaeus, Menaechmus, Dinostratus and Hermotimus presumes an acquaintance with their writings rather than personal acquaintance at the Academy. We know almost nothing about them, except for the fact that they did make some mathematical discoveries. All this speaks rather in favour of Eudemus' *History of geometry* than of Philip's biography of Plato.

We know that Eudemus wrote about Archytas and Theaetetus (fr. 141-141.I Wehrli); the information about Eudoxus' and Menaechmus' solutions to the problem of duplicating the cube very likely also goes back to Eudemus,[76] as does the evidence about Dinostratus (Papp. *Coll. math.* IV.30 = Lasserre 13 D 1); in the *History of astronomy* he mentions Eudoxus and his student Callippus (fr. 148-149 Wehrli). So, one can hardly exclude Eudemus from the list of possible sources of Proclus' *Catalogue*, where those who wrote the history of mathematics before Euclid are explicitly mentioned (οἱ τὰς ἱστορίας ἀναγράψαντες, *In Eucl.*, p. 68.4). Was Philip (Hermodorus) among them as well? There is nothing inconceivable in the suggestion that Eudemus used the writings of the Academics, but it is hard to agree that he simply transferred from them the descriptions of Plato and Philip.

When analysing the *Catalogue* many have overlooked the fact that the Platonizing tendency in this text does not finish with Philip, but includes Euclid as well. Proclus, once again uniting all previous mathematicians around Plato, says:

> Euclid was younger than τῶν περὶ Πλάτωνα . . ., but belonged to his school and had an excellent knowledge of his philosophy, and he even set the final goal of the *Elements* as the construction of the five Platonic bodies (*In Eucl.*, p. 68.20f).

This description could not come either from Eudemus or from Philip (Hermodorus), which means it was *after* the fourth century that the whole historical digression of Proclus' *Introduction II* was subjected to Platonizing editing. All this leads us to the conclusion that the Platonic features in the *Catalogue* must be attributed rather to Porphyry, who reworked Eudemus' *History of geometry*, than to the early Academicians. Although Porphyry *might* have used some Academic writings, it is revealing that the description of Philip in the *Catalogue* seems to be written in the same

[76] Fr. 141 Wehrli, comm. ad loc.; Knorr, *Problems*, 21.

vein and by the same hand as that of Euclid:[77] both Philip and Euclid worked under Plato's guidance (even though in Euclid's case it was not direct guidance), and their final goal in mathematics was Plato's philosophy. This makes it more likely that it is Porphyry, and not Philip (as Lasserre thought) who stands behind the Platonizing tendency of the second part of the *Catalogue*.

VI

The *Catalogue* names four predecessors of Euclid who had written the *Elements*: Hippocrates, Leon, Theudius, and Hermotimus. The first of these is well known and the last three are not mentioned at all outside the *Catalogue*. But whoever followed in the tradition of writing the *Elements*, it is obvious that its originator was Hippocrates[78] – as in the case of the other two famous problems: the duplication of the cube and the quadrature of the circle. It is very likely that there were attempts to systematise geometrical knowledge before Hippocrates,[79] but his achievement was greater and served as an example to later generations. Is there anything especially significant in the fact that all the authors of the *Elements* were contemporaries of Plato – one older than him and the three others younger? The "Plato-centric" view of ancient philosophy is honoured because of its antiquity (it comes from the Neoplatonic school) and because of the number of people who shared it; however the majority of experts for a long time now has not shared this view, and it has brought nothing except misunderstanding to the history of Greek science. What is behind it except the natural desire to see genius in everything? Primarily, the obvious fact that from the pre-Euclidean period not a single mathematical writing is

[77] Notice a similar structure of these two phrases and the closeness of their wording:

Φίλιππος . . . καὶ τὰς ζητήσεις ἐποιεῖτο κατὰ τὰς Πλάτωνος ὑφηγήσεις καὶ ταῦτα προύβαλλεν ἑαυτῷ, ὅσα ᾤετο τῇ Πλάτωνος φιλοσοφίᾳ συντελεῖν (p. 67.23f).	Εὐκλείδης . . . καὶ τῇ προαιρέσει δὲ Πλατωνικός ἐστι καὶ τῇ φιλοσοφίᾳ ταύτῃ οἰκεῖος, ὅθεν δὴ καὶ τῆς συμπάσης στοιχειώσεως τέλος προεστήσατο τὴν τῶν καλουμένων Πλατωνικῶν σχημάτων σύστασις (p. 68.20f).

[78] W. Burkert, "ΣΤΟΙΧΕΙΟΝ. Eine semasiologische Studie," *Philologus* 103 (1959), 167-197.

[79] B.L. van der Waerden convincingly reconstructs a Pythagorean compendium, preceding Hippocrates and containing the basis of the first four books of Euclid: "Die Postulate und Konstruktionen in der frühgriechischen Geometrie," *AHES* 18 (1978), 343-357.

preserved, whereas the *Corpus Platonicum* was handed down through the generations in its entirety. Certainly, Plato knew and valued mathematics and often used mathematical examples in his reasoning.[80] But was this love mutual? To judge from the *Elements* of Euclid, whom Proclus or his source enlisted as a Platonist, this was not the case.[81] One can only guess about the contents and nature of the books of Euclid's predecessors, but it is more reasonable to base these guesses on the natural tendency of all the sciences of that time to systematise accumulated knowledge rather than on Plato's demand for the axiomatization of geometry[82] or on his more prosaic demand of text books for the Academy.

On what does the current general opinion that geometry and possibly other mathematical sciences were *taught* at the Academy rest? There is no reliable historical evidence on this subject,[83] and we actually know very little about what exactly was taught at the Academy. Most reconstructions rely on the Platonic dialogues, and in particular on book VII of the *Republic*, where a solid program of mathematical education is put forward (for those between the age of 20 and 30). Nevertheless, an expert such as Krämer notes: "We have no knowledge of a stable program of education at the Academy like the one described in the *Republic* and in the *Laws*. The sort of education known from these dialogues could not be directly transferred to the reality of the Academy."[84]

To judge from Plato's dialogues, the mathematical element in his work increases towards the end of his life. Hence one might conclude that during the last decade of his life mathematics was especially intensively taught at the Academy. However, almost none of the younger Academics

[80] The mathematical passages from the dialogues are collected in: R.S. Brumbaugh, *Plato's Mathematical Imagination*, Bloomington 1954; A. Frajese, *Platone e la matematica nel mondo antico*, Roma 1963.

[81] W. Knorr, "On the Early History of Axiomatics: A Reply on Some Criticism," in: J. Hintikka *et al.* (eds), *Theory Change, Ancient Axiomatics and Galileo Methodology*, Dordrecht 1981, 194ff; idem, "What Euclid Meant: On the Use of Evidence in Studying Ancient Mathematics," in: A.C. Bowen (ed.), *Science and Philosophy in Classical Greece*, New York, 1991, 141ff; I. Mueller, "On the Notion of Mathematical Starting Point in Plato, Aristotle and Euclid," ibid., 59-97.

[82] In practice this demand meant the construction of the "philosophical base" for mathematical definitions: C.C.W. Taylor, "Plato and the Mathematicians," *PhilosQ* 17 (1968), 193-203.

[83] The famous inscription ἀγεωμέτρητος μηδεὶς εἰσίτω is a later literary fiction (the fourth century A.D.). See H.D. Saffrey "ΑΓΕΩΜΕΤΡΗΤΟΣ ΜΗΔΕΙΣ ΕΙΣΙΤΩ: Une inscription légendaire," *REG* 81 (1968), 67-87.

[84] Krämer, *op. cit.*, 5.

show any special interest in geometry.[85] As for the older Academics, at the time of Plato's death Speusippus was about 62, Xenocrates about 48, Heraclides about 42, Aristotle and Philip about 37. At this age they were more suited to teaching than to learning mathematics. Their writings imply that they received some mathematical training, but did this take place in the Academy? It is difficult to imagine Plato himself teaching mathematics, but if he did not, then who did, and what kind of mathematics? (Although Eudemus was the major authority on the exact sciences and Aristoxenus on musical theory, no one has yet come to the conclusion that Aristotle himself taught these sciences at the Lyceum.) Cherniss developed his idea about the teaching of mathematics at the Academy only because it was necessary to support his thesis that Platonic metaphysics was *not* taught there.[86] What then was taught at the Academy if not mathematics? The easiest answer to this is dialectic; the most honest answer is that we do not know.

Even if one agrees that Plato was not only a propagandist but also a practitioner of mathematical education, the role of founder of mathematical education still does not belong to him. The four sciences which make up the quadrivium (arithmetic, geometry, astronomy and harmonics) were taught at the Pythagorean school at least a hundred years before the Academy was founded.[87] There is no doubt that Philolaus, Theodorus of Cyrene and Archytas (see 47 B 1) received this kind of Pythagorean education. From the generation of the sophists, Hippias of Elis was especially known for his teaching of the four μαθήματα (Pl. *Prot.* 318e). Whether Plato adopted this educational program from the Pythagoreans or the sophists is not so important; the significant point is that his predecessors realised it in practical teaching and produced generations of brilliant mathematicians such as Theodorus, Hippocrates, Archytas, Theaetetus, Eudoxus and his pupils. With Plato we come across this program only in the dialogues, and even there only as a preparation for the study of dialectic, which was for him far more important than any other science.

He handed this attitude down to his students. Aristotle wrote about his colleagues at the Academy: "Philosophy has become mathematics for modern thinkers, although they profess that mathematics is only to be studied as a means to some other end" (*Met.* 992 a 31). His commentator,

---

[85] List of Academics see Lasserre, I T 2-9; Gaiser, *Academica*, 444. The only exception is Amyclas who is discussed above.

[86] H. Cherniss, *The Riddle of the Early Academy*, Berkeley 1945, 60ff.

[87] On the Pythagorean origin of the quadrivium see Zhmud, *Wissenschaft*, 169ff.

Alexander of Aphrodisias, quoting what is probably one of Aristotle's lost treatises,[88] explains:

> Because of their (*sc.* the Platonists) eagerness to study τὰ μαθήματα and their conviction that philosophy is reasoning about these things, they spent all their time in the study of mathematical science... They philosophised only about mathematical objects and dealt only with them... (*In Met. comm.*, p. 121.25ff Diels).

Isocrates remarked that it is worth studying mathematics at a young age, but that those who "have become so thoroughly versed in these studies as to instruct others in them" do not become wiser in the other things (*Panath.* 27-28). Since this speech was written soon after the death of Plato, in about 340, it is very likely that Isocrates had in mind Speusippus, Xenocrates, and several other Academics who often wrote on mathematical themes. Speusippus wrote a Μαθηματικός, and Περὶ τῶν Πυθαγορείων ἀριθμῶν, Hermodorus Περὶ μαθημάτων, Xenocrates Περὶ τῶν μαθημάτων in six books, Περὶ γεωμετρῶν in five books, Περὶ ἀριθμῶν, an 'Αριθμῶν θεωρία, a Περὶ ἀστρολογίας in six books and a Περὶ γεωμετρίας in two books (D.L. IV, 13-14). But despite all their fertility in the field of the philosophy (and possibly the history) of mathematics, none of them left any mark in the exact sciences. To judge from fragments of their work, for instance the large fragment from Speusippus' book *On Pythagorean numbers* (fr. 28 Tarán), the material they were interested in was very far from the real problems of the contemporary mathematics and their approach could in no way be described as professional. The reason for this is very simple: they studied mathematics *for the sake of philosophy* rather than for its own sake.

One can of course object that the fragments that remain may not be very representative. But also in the case of Hippocrates, Archytas and Eudoxus we have only a few fragments at our disposal; this evidence, however, seems completely different. Speusippus, Xenocrates and Hermodorus are no exceptions. Strictly speaking, none of Plato's immediate students achieved anything remarkable in mathematics. If we look at the sciences as a whole, then it is only Aristotle who achieves any real success; and significantly, that success was primarily in biology, i.e., in an area that was *not* studied at the Academy. The nature of the mathematical examples Aristotle uses in his writings shows the rather modest level of his mathematical knowledge,[89] and his interest in actual mathematical problems is even less.

[88] Ibid., 323ff.

[89] T.L. Heath, *Mathematics in Aristotle*, Oxford 1949.

Philip was known as an astronomer; the *Suda* attributes to him a number of mathematical and astronomical writings, which we know practically only by their titles.[90] It is hardly possible to prove whether Philip really was the author of all these books; Neugebauer expressed serious doubts about the authenticity of the majority of the astronomical treatises.[91] Tarán and Lasserre have succeeded only in some cases in linking the flimsy surviving evidence with titles known only from the *Suda*.[92] Paradoxically, most of the astronomical material connected with Philip's name relates to the so-called παραπήγματα, i.e., to observational astronomy and meteorology, which his teacher, Plato, held in very low opinion (*Res*. 529a-530c) and could hardly have encouraged Philip to study them. What is significant, however, is that we do not know about any personal discoveries made by Philip in astronomy.[93] And still more important is the fact that in the *Epinomis*, written in all probability by Philip, there are no astronomical ideas which cannot be found in the *Timaeus* or the *Republic*.[94] If Philip really was converted by Plato to study the exact sciences and worked under his guidance, then the results of this work seem rather poor.

With another Academic, Heraclides Ponticus, tradition connects two interesting astronomical hypotheses (fr. 104-110 Wehrli). One of these, about the rotation of Venus and Mercury around the Sun which in turn rotates around the Earth, rests, as Evans and Neugebauer showed, on an incorrect interpretation of the sources.[95] The other hypothesis about the rotation of the Earth around its own axis has nothing in common with Platonic

---

[90] IV, 733.24-34 Adler. Mathematics: Ἀριθμητικά, Μεσότητες, Περὶ πολυγόνων ἀριθμῶν; astronomy: Περὶ πλανητῶν, Περὶ μεγέθους ἡλίου καὶ σελήνης καὶ γῆς α΄, Περὶ ἐκλείψεως σελήνης, Περὶ τῆς ἀποστάσεως ἡλίου καὶ σελήνης; meteorology: Περὶ ἀστραπῶν, Περὶ ἀνέμων; optics: Ὀπτικῶν β΄, Ἐνοπτ⟨ρ⟩ικῶν β΄.

[91] Neugebauer, *History*, 574.

[92] Tarán, *Academica*, 115ff, 135f; Lasserre, 596ff. Relatively successful attempts were made to identify the book on lunar eclipses and the meteorological writings.

[93] In the second half of the fourth century a demonstration of the sphericity of the moon, which Tarán refers to (*Academica*, 136), cannot be regarded as a discovery. Even in the field of παραπήγματα Philip was not independent (Neugebauer, *History*, 740 n. 12).

[94] Tarán, *Academica*, 98-114.

[95] P. Evans, "The Astronomy of Heraclides Ponticus," *CQ* 20 (1970), 102-111; O. Neugebauer, "On the Alleged Heliocentric Theory of Venus by Heraclides Ponticus," *AJP* 93 (1972), 600-601. Gottschalk's arguments in favour of Heraclides' epicyclical model do not seem convincing (H.B. Gottschalk, *Heraclides of Pontus*, Oxford 1980, 69ff). Our main source, Chalcidius, was by no means an expert in astronomy (*In Tim.*, p. 176 Wrobel = fr. 109 Wehrli), and the fact that he attributes the same epicyclical model to Plato makes his evidence about Heraclides especially suspicious.

astronomy;[96] in all probability it was borrowed by Heraclides from the Pythagorean Ecphantus,[97] who continued the line of Philolaus. According to Diogenes Laertius, Heraclides studied with the Pythagoreans and wrote a special book about them (V, 86); his ideas have a whole series of other similarities with Pythagorean astronomy (fr. 104, 113 Wehrli).

Is it really necessary to go on insisting that the Academy in all the time of its existence never produced even one significant mathematician or astronomer? It does seem necessary, especially when one takes into account the exaggerated significance usually given to the program of mathematical education described in the Platonic dialogues. The *Republic*, *Theaetetus* and *Laws* probably persuaded not a few talented youths to take up mathematics, but having begun the study of it, they inevitably had to comply with the demands worked out by the professional mathematicians. If they still considered Plato more worthwhile than mathematical truth, then they developed a mathematical theology in the spirit of Anatolius or Iamblichus, or compiled a commentary on the mathematical passages in the Platonic dialogues, or in the best case, they wrote a philosophical commentary on Euclid, as Proclus did.[98]

VII

It is evident that tracing back all the stories about Plato as an organiser of the exact sciences (the duplication of the cube, the "saving of the appearances," the discovery of analysis and general progress in mathematics) to their Academic sources does not prove their reliability. That these stories are not supported by sources outside the Academy, especially Peripatetic, is not decisive in itself, since one can always object that, if the Academics exaggerated the role of their teacher, then the Peripatetics were themselves less than objective in their assessment of him as well.[99] However,

[96] Heraclides (fr. 106 Wehrli) interpreted a controversial passage in *Timaeus* (40b) in this sense; it turned out to be a point of much debate between the Academics (cf. Arist. *De caelo* 293 b 30f). See Tarán, "Proclus," 263f. It is interesting that Proclus, seeing such a divergence between Plato and Heraclides, refused to consider him a student of Plato.

[97] Hippolitus attributes this theory to Ecphantus (51 A 1), whereas Aëtius mentions both Ecphantus and Heraclides (51 A 5).

[98] Cf. W. Burkert, "Konstruktion und Seinsstruktur: Praxis und Platonismus in der griechischen Mathematik," *Abh. d. Braunschweigischen Wiss. Gesell.* 34 (1982), 125-141.

[99] Aristoxenes gathered all the gossip about Plato (fr. 61-68, 131 Wehrli), Dicaearchus wrote that he raised and then destroyed philosophy (Philodemus, col. 2), Eudemus

it is also impossible to find support for the idea of the exact sciences flourishing under Plato's directorship even in Academic writings concerned with τὰ μαθήματα. The source of these legends was, therefore, not the real relationship between Plato and contemporary mathematicians, but his dialogues. It is here that we must look for, and can find, the basis for the idea of Plato as an architect of the sciences, which was then developed further by the Academics.

So far I have neglected the issue about the extent to which the efforts of the Academics to emphasise Plato's role in establishing the methodology of the exact sciences reflected his own position. Was the very idea of science depending on and patronised by philosophy born from Plato? He often criticised the scientific methodology of his contemporaries, especially in books VI-VII of the *Republic*, where he outlines a program of education for future guardians of the ideal polis. Let us compare, for example, Archytas' description of numerous acoustic experiments and observations (47 B 1) with Plato's remark that the true science of harmonics must be independent of all this, measuring mathematical and not audible consonances, which is something what even Pythagoreans fail to realise (531c). While Archytas sings the praises of the social and even moral consequences of practical arithmetic (47 B 3), Plato insists that arithmetic should be pursued for the sake of pure knowledge, not for any practical ends (525c-d). The geometers derive their propositions from several premises, which they consider to be self-evident and do not give them any further explanation (510c-e); solid geometry is in a very undeveloped state (528b-c). For Plato true astronomy is concerned not with the movement of the visible heavenly bodies, but with ideal kinematics of mathematical heavens (529a-530c).

These well-known passages have been discussed many times, now in support of Plato's anti-empiricism and of his hostility towards the real sciences of that time, and now as an example of his prescience of future mathematical astronomy.[100] I do not think it possible to add anything sig-

clearly preferred Archytas to him (fr. 60 Wehrli), and Aristotle himself was known for his inordinate criticism for his teacher.

[100] See for instance F.M. Cornford, "Mathematics and Dialectic in the *Republic* VI-VII" (1932), in: R.E. Allen (ed.), *Studies in Plato's Metaphysics*, London 1965, 61-95; R.M. Hare, "Plato and the Mathematicians," in: R. Bambrough (ed.), *New Essays on Plato and Aristotle*, London 1965, 21-38; Taylor, *op. c* → A. Barker, "Σύμφωνοι ἀριθμοί: A Note on *Republic* 531c1-4," *CPh* 73 (1978), 337-342; J.P. Anton (ed.), *Science and the Sciences in Plato*, New York 1980; A.P.D. Mourelatos, "Astronomy and Kinematics in Plato's Project of Rationalist Explanation," *SHPS* 12 (1981), 1-32;

nificantly new to what has already been said on this subject. If, however, one tries to concentrate on what is uncontroversial, or at least to avoid extreme points of view, then it must be said that the position of external and competent critic was only natural for Plato, as were his efforts to put the results and methods of the exact sciences to the use of his favourite science – dialectic. It is also obvious that the exact sciences at that time variously suited Plato's goal: some to a greater extent, some to a lesser. The controversy begins when, on the ground of Plato's often rather vague remarks, we try to understand what stands behind his criticism: is he proposing an alternative program for developing the exact sciences, anticipating the work of Euclid and Ptolemy, or is he simply worried about how to adapt the exact sciences for his own pedagogical purposes, how to make them a true preliminary for dialectic. I personally prefer the second answer,[101] but I am ready to admit that these passages *could* be interpreted as valuable methodological instructions on how to develop the exact sciences. I think they were understood in exactly this way in the early Academy.

The first indication here is the term πρόβλημα, which we came across in the quotations from Philodemus and Simplicius: Plato sets problems for the specialists.[102] This is the approach insistently put forward in the *Republic*. When discussing astronomy Socrates proposes: προβλήμασιν ἄρα χρώμενοι ὥσπερ γεωμετρίαν οὕτω καὶ ἀστρονομίαν μέτιμεν (530b6), and returns to this when discussing harmonics: ζητοῦσιν, ἀλλ' οὐκ εἰς προβλήματα ἀνίασιν ἐπισκοπεῖν, τίνες ξύμφωνοι ἀριθμοὶ καὶ τίνες οὔ (531c3). Whatever Plato meant by these appeals, the appeals themselves, urging the necessity to study the *real* problems of a *true* science, inevitably remain in the memories of readers of the *Republic*.

The resemblances become even greater if one compares Plato's reprimands for the contempt of geometry, known from the story about the

J. Annas, *An Introduction to Plato's Republic*, Oxford 1981, 27:→ I. Bulmer-Thomas, "Plato's Astronomy," *CQ* 34 (1984), 107-112; K. Gaiser, "Platons Zusammenschau der mathematischen Wissenschaften," *A&A* 32 (1986), 89-124; I. Robins, "Mathematics and the Conversion of the Mind," *Republic* vii 522c1-531e3, *AncPhil* 15 (1995), 359-39; A. Gregory, "Astronomy and Observation in Plato's *Republic*," *SHPS* 27 (1996), 451-471.

[101] G.E.R. Lloyd, "Plato on Mathematics and Nature, Myth and Science," in: idem, *Methods and Problems in Greek Science*, Cambridge 1991, 333-351; N.S. Hetherington, "Plato and Eudoxus: Instrumentalists, Realists, or Prisoners of Themata?," *SHPS* 27 (1996), 278.

[102] Plutarch (*Marc.* 14.9-11) also mentions the "problems," but here the term has a special mathematical meaning; Philodemus and Simplicius use it in a wider sense.

duplication of the cube, with Socrates' description of the situation in solid geometry (528b-c). His definition of solid geometry, ἔστι δέ που τοῦτο περὶ τὴν τῶν κύβων αὔξην καὶ τὸ βάθους μετέχον, contains, as was long ago noted, a clear reference to the problem of the duplication of the cube.[103] Glaucon agrees with this definition and remarks that this field is not yet properly investigated. Socrates gives two reasons for this situation: first, the state does not support these studies, and being very complex, they develop rather slowly,[104] and second (and this is my *Kronzeuge*) the investigators need a director, without whom they will hardly discover anything (ἐπιστάτου τε δέονται οἱ ζητοῦντες, ἄνευ οὗ οὐκ ἂν εὕροιεν). It is hard to find a more clear expression of the need for philosophical or even state-philosophical patronage of science. The passage from Philodemus (ἀρχιτεκτονοῦντος μὲν καὶ προβλήματα διδόντος τοῦ Πλάτωνος, ζητούντων δὲ μετὰ σπουδῆς αὐτὰ τῶν μαθηματικῶν) becomes thus an immediate reflection of Plato's words, the more so as both ἐπιστάτης and ἀρχιτέκτων come from the same technical field and mean in this context practically the same.

Shorey's suggestion that Plato designed the role of this ἐπιστάτης for himself[105] acquires substance from the following words of Socrates:

> It is not easy to find such a director, and then if he could be found, as things are now, investigators in this field would be too arrogant to submit to his guidance. But if the state as a whole join in superintending these studies and honour them, these specialists would accept advice and continuous and strenuous studies would bring out the truth (528b8-c4).

So long as this is not so, mathematicians are prompted exclusively by their intellectual interest to solve problems. Interpretations taking this "director" as some famous mathematician of that time, for example, Archytas or Eudoxus[106] seem naive, and to impute to Plato an unlikely generosity. Obviously what is meant here is not a specialist but a dialectical philosopher, one who would be obeyed only in the ideal state and only with the support of this state. Hippocrates, Archytas or Eudoxus did not need such a support and they definitely would react to the dialectician's advice with a μεγαλοφροσύνη, so characteristic to all specialists.

---

[103] J. Adam (ed.), *The Republic of Plato*, V. 2, Cambridge 1902, 122; Robins, *op. cit.*, 370.

[104] It is worth mentioning that according to Aristotle the situation was quite different: the exact sciences, being unsupported by society and the state, nevertheless develop faster than τέχναι, since they are superior by nature (fr. 53).

[105] P. Shorey (ed.), *Plato's Republic*, V. 2. Cambridge (Mass.) 1935, 177; Cornford, *op. cit.*, 78.

[106] See Adam, 123f; Heath, *History*, 12f.

Earlier, in the *Euthydemus* (290c), Plato did not yet lay claims to setting problems for the scientists, but only to a true interpretation of scientific achievements. Mathematicians and astronomers themselves do not know how to use their discoveries, so they have to "hand them over to the dialecticians to use properly, – those of them, at least, who are not utter blockheads" (μὴ παντάπασιν ἀνόητοι). How then were Archytas and Eudoxus supposed to respond to such advice?[107]

One more line which leads towards the *Republic* is the reference in the *Catalogue* to a certain section, which originates from Plato: Eudoxus augmented τὰ περὶ τὴν τομὴν ἀρχὴν λαβόντα παρὰ Πλάτωνος (*In Eucl.*, p. 67.6). The only place where Plato mentions geometrical section is the well-known passage about the division of a line into extreme and mean ratio (golden section): this proportion symbolises the relationship between the material world and the world of ideas (*Res.* 509d-e). Meanwhile, the golden section was already known to the Pythagoreans,[108] so only someone who was absolutely sure that everything Plato says about mathematics derives from himself could have regarded him as an author of this discovery. The author of the remark about the section was probably Proclus, but he was only following a tendency which came from the early Academy.

Can we conclude that the seventh book of the *Republic*, in which Plato gives valuable instructions on how to develop mathematical sciences in order to make them most useful for dialectic, or similar passages from other dialogues, were necessary and sufficient conditions for the creation of the academic legend about Plato as the architect of science? If we take into account the previous analysis showing an absence of any firm historic evidence that he really did play this role, such a conclusion seems to me very compelling. The legend about his Apollonian ancestry, mentioned by Speusippus (fr. 1 Tarán), serves here as an excellent parallel, since it was also born out of an interpretation of the Platonic dialogues, in this case the *Phaedo*.[109] The tendency to reconstruct or, rather, to construct a biography relying on the author's writing was widespread in antiquity. If the image of a Plato who gives the instructions to the scientists originated from the

[107] One has to put in much effort to dispel the associations evoked by these passages with a state science, guided by philosophers-dialecticians, which we know so well from the Soviet experience. I do not think these associations to be entirely inappropriate, but to develop them would take us too far from our central theme.

[108] Heath, *History*, 324f; Lasserre, *Eudoxos*, 176f.

[109] Riginos, *op. cit.*, 9ff, 30f.

image of Socrates, the hero of the dialogues, such a transformation would have been well justified in the eyes of the Platonists, since it corresponded to the basic intention of their teacher: to see further and to penetrate deeper than any of those whose knowledge he used.

Institute for the History of Science and Technology
St. Petersburg