**Greek Astronomy**

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One may suspect that this is a treatise on Greek Astronomy giving a historical and explanatory account of the subject. Far from it, it is an anthology of ancient Greek writings on astronomy from Thales to Plutarch, but without any running commentary, and hence somewhat of a disappointment. You read those extracts without getting any wiser. True, the real part of the book is to be found in the lengthy introduction, providing a birds eye view of the matter, and one surmises that the bulk of the book should be thought of as a stimulation for the reader to work out his own understanding. But it does not work that way really. The reader finds himself left in the lurch, after all you read a book for guidance, otherwise you write it yourself.

Anyway the long introduction gives at least some guidance, on which we can comment. First Greek Astronomy had precedents, the two most relevant being the traditions of Egypt and Babylonia (there were also at the time Chinese ones, but Chinese culture was isolated far away in the East). Both of them had long documentary data from which they had determined the length of the year (365.25 days), noticed the irregular movements of the planets, and been able to determine some cycles, which with luck could be used to predict eclipses[1]. What is striking about the ancient tradition is the meticulous accumulation of empirical data with no attempts to understand them. Of course this is the popular conception of science, championed by Bacon, namely extolling the unprejudiced observation of nature and letting yourself be instructed by it. But you cannot read nature you have to put questions to it, and the ancient Egyptians and Babylonians did not do that. What is needed is an initial speculation to be tested and modified.

The first scientist, (in the modern sense), on the scene is Thales, who according to legend fell into a well while walking staring at the stars in the sky. Thales earned a certain celebrity through successfully predicting an eclipse using the old method of regular periods. As noted above this is a matter of luck. What the cycles predict will be an eclipse somewhere on the Earth, or at least reasonably close to it, not where it happens to occur. Although some credit can be accorded him as a mathematician stressing the deductive approach, and also as a scientist, in taking exception to dogmas and encouraging his disciples to criticize his thoughts, as an astronomer, or rather as a cosmologist, his contributions are modest and do not really go beyond that of the traditional creation myths. With Anaximander, some more daring speculations enter the stage. He postulated that the Earth was suspended in space without any mechanical support, as there were no preferred directions along which it could fall (as opposed to the case on the Earth). This is of course not an empirical observation but a purely cerebral speculation of great

[1] What we need is a length of time being an integral multiple of years as well as months, the latter being the so called sidereal periods of the Moon, i.e. the interval between two full moons. However, the latter varies due to the ellipticity of the orbit of the Moon.

elegance and persuasive power[2]. And indeed it does speak directly to our intellect, and not to our senses, as the notion of the superfluity of external mechanical support goes against our quotidian intuition, and it is only when we go beyond that we enter the realm of true scientific thinking. He also postulated an infinite number of different worlds in different stages of development. Thus the modern fashionable idea among cosmologists with a large popular following, has a long historical tradition. Anaximander was indeed a remarkable man, who also drew a map of the entire world, which of course necessitated going beyond the petty constraints of empirical thinking, and he also had the germ of the idea of evolution. Another Greek man of speculation was Anaximenes who claimed that the earth was flat(as was the sun) and rested on air, and provided some thoughts on the nature of matter, making air and water being the primordial components. What he is remembered for is his idea that there is in the stellar region earthy bodies. What is remarkable is that the Greeks thought of space as being an extension of the space we know. They made a distinction between Euclidean Geometry, which governs our local world and spherical geometry which describes the celestial vault. It does not seem as if they made a distinction between them, because after all the stars could be infinitely far away, and their realm would have no connection to our own earthen space. Our own space is accessible not only by sight, but also by mechanical movement, while that of the celestial objects is only known to us by sight. Astronomy started to make progress when people started to take seriously the notion that the Moon and the Sun had distances to us, which we could in principle measure once we extended our geometrical considerations to their full logical applicability. Pythagoras is probably the first who proposed that the Earth is spherical in shape. To prove this empirically was beyond the technical means of the Greek[3], so once again we have the case of daring speculation based on rather abstract principles. But he still believed that the Earth was immobile and in the center of the universe (whatever that really means). Te contributions of Xenophanes and Heraclites are, according to the author, measly and we can safely forget about them. More interesting is Parmenides. He continued the Pythagorean belief in the Earth and the Universe as a whole being spherical. But if so, what was beyond the spherical shell of the stars? Parmenides famously claimed the non-existence of the void, and of course what was beyond the universe must be void[4].Thus the universe was finite, according to Parmenides. More substantially he claimed that the Moon was illuminated by the Sun, which would explain the succession of phases. However, the author remains skeptical, the evidence for such insights does not go beyond some obscure lines in his poetry. The first indisputable source for such an insight is due to Anaxagoras explaining the phases of the Moon as well as eclipses, something which we find obvious. It goes to show that a clear idea of the spatial relations between celestial bodies are far

[2] This does away with the tower of turtles. If the Earth rests on a turtle, what does the turtle rest on? Another turtle, and if so will there be turtles all the way, but hen what do they rest on?

[3] That the height of a star above the horizon differs from one location to another is of course an empirical falsification of flatness

[4] The division of space into a finite, yet infinite in its potentiality Euclidean part, and an infinitely distant celestial part would solve this dilemma in an elegant way. Another way would claim that the universe is the 3-dimensional boundary of ball in 4-dimensional space. Finite but unlimited. But this would presuppose a mathematical sophistication not to be expected.

from being immediate to the mind. He is also credited with having proposed the nebular mechanism for the creation of the celestial bodies, which were later taken p by Kant and more or less conclusively by Laplace, who was the only one able to subject it to a hard mathematical analysis.

What Plato really thought about astronomy in general, and cosmology in particular, (and the latter has a powerful existential component that strikes at the heart of most curious people) is not too easy to infer, his dialogues being written tongue in cheek. However, he was the first to propose a real science project, namely to find a model for the erratic movements of the planets (to which the Sun and the Moon should count) to 'save the appearances'. To find a model was not the same thing as giving a real explanation of what was, but to provide a mechanism that allowed you to predict the future. Or as he put it, 'what are the uniform and ordered movements by the assumptions of which the motions of the planets can be accounted for'. This is of course very much in the platonic spirit, of finding simpler underlying explanations for phenomena that occur confusing in the world of the senses, and this has provided much of the inspiration for future scientific work, its success being most notable in physics.

It was Eudoxus, one of Plato's earnest students, who came up with an ingenious and sophisticated mathematical solution, involving systems of spheres rotating, four to each planet. It is pure geometry and has nothing mechanical about it really, and given the state of the art a striking testimony to the remarkable skill he displayed. His approach was developed further by his successors and was given its ultimate expression in the Ptolemaic system of epicycles, which can be seen as the crowning achievement of Greek, or rather Hellenic astronomy. The Ptolemaic system is often disparaged by the half-educated as crude and primitive, but it was in fact quite effective, and more to the point amenable to improvement. In fact modern science is very much conducted in the same spirit, giving models which are continually being fine-tuned, until there is a major paradigm shift of which there are actually few.

Aristotle did not contribute much to astronomy, his role was rather that of a critic and a commentator. He conceived of natural movements as moving along a straight line or in a circle, with the latter the most divine and hence particularly appropriate to the celestial world, and out of which every movement should be reduced. He also added a mechanical element to the purely geometrical constructions of Eudoxus, thus taking it literally. Those spheres actually existed and had to physically interact with each other. He also added to the models of Eudoxus adding many more spheres, and as the author notes, without improvement.

While some Greek philosophers had abandoned the idea that the Earth was resting immobile in the center of the universe, Aristarchus became retrospectively singled out as prescient by postulating a heliocentric theory, which may or may not have been encountered by Copernicus later. Certainly Archimedes was impressed by him, although he found few followers. He was also one of the first who took the spatial characteristics of the celestial regions seriously, by trying to compute the distances to the Moon and the Sun. The principles were good, after all he was a mathematician with a firm command of geometry, but at the time not practical. Similarly Eratosthenes, a contemporary of Archimedes, measured the size of the Earth using a simple geometrical principle. His estimate is surprisingly good, and he must have had some luck at being interpreted by posterity[5]. The hard part is practical, namely to accurate measure an angular distance on Earth which has nothing to do with the geometrical principles[6]. The refinement of the Eudoxus approach centered, as noted above, not on actual spheres but on epicycles and other tricks such as eccentric circles, showing great ingenuity in sidestepping the artificial constraints imposed by Aristotle and not shattered until the work of Kepler.

When it comes to real astronomy with definite concrete achievements, Hipparchus is considered the most distinguished astronomer. He employed trigonometry systematically, especially spherical, compiled numerical tables, improved instruments, and furnished catalogs of stars, thereby introducing spherical co-ordinates. In the eyes of posterity he is most admired for his discovery of the precession of the equinoxes, and thus to identify the relevant definition of the year as the so called tropical, which he determined with great accuracy. He also improved on the determination of astronomical distances done by Aristarchus, so indeed at the time of Ptolemy the distance to the Moon was known with some accuracy (the determination of the length of an astronomical unit (i.e. the distance to the Sun) was technically much more difficult and beyond the technical means of the Greeks).

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[5] The crucial thing is how to interpret the unit of length - a stade

[6] The same thing with the measuring of the meridian in the mid 18th century. The principle is very easy, but to put it into practice you needed to send two expeditions, one to the sub-arctic Lapland one to the equatorial tropics in South America, which cost a lot of lives.