# 12 Compromise, Negotiation and Political Tactics - Tycho Brahe and Copernican Theory

We are now returning from our trip into scientific methodology in Section 3. We are returning to the historical story, or I should say, an historical story, because there are others, obviously, about this subject matter. We are going to look at one of the social phenomena of science that historians and sociologists of science find very important to study. This is the reception, the interpretation, of a new theory when it is put forward -- the process of professional negotiation that finally accepts or rejects the new theory -- as well as ongoiningly reinterprets its content and character. Because, after all, a theory is not just what its inventor says it is, a theory is what the other members of a profession say it is, as debate and negotiation unfold about the acceptability of the new claim. You cannot impose your will upon an entire profession. It's up to your colleagues to judge and interpret your theory.

This Chapter concerns the response to Copernicus' theory in the first fifty years after his death in 1543. It deals mainly with the work of Tycho Brahe (1547-1601) whose theory, rather than those of Copernicus or Aristotle/Ptolemy, was the most successful in the period 1600-1630. Old fashioned, Whiggish historians of science find this outburst of Tycho's theory uncomfortable and embarrassing, because they of course want a story of a bad old theory, Ptolemy-Aristotle, being replaced by the good, true, new theory of Copernicus. They want to ignore the business of this fellow Tycho, whose theory actually was the dominant one in the intervening period. To old fashioned historians of science this is an uncomfortable fact, but one which teaches us a lot about the nature of scientific change in general.

The main general point I am aiming at in this Chapter is as follows: scientific change, the transformation of theories, does not occur simply as the result of great individual 'heroes' proposing some obviously more true theory than the old one. Change in science occurs within and is a phenomenon of the scientific community, the community of relevant experts. When anyone proposes a change, large or small, in an existing theory, that proposal circulates in the relevant community, and each expert or group of experts must interpret and judge the bid which has been made. Since there is no simple method or way of determining the 'truth' of a claim, the claim must be judged on criteria, which are variable, and can differ in weighting from expert to expert. (We have already tried to weigh up Copernicus' theory in terms of contemporary criteria of the 1500s.) What we then get is a process of negotiation and jockeying for position, as experts size up their attitude to a new claim-- do they accept it as a whole, in part, not at all, with re-interpretation etc.

So, what we're going to learn here is a very good example of historical, sociological and political points about science, that are basic to our field. The situation I am trying to describe is not all that different from what happens today in science.

Again, the situation is that any time a scientist proposes a new theory to his colleagues in the professional field, obviously those colleagues are not in a position to simply say, oh yes, your theory is true, because it agrees with the facts, or no, your theory is false because it doesn't agree with the facts. Those kind of judgements can't be directly made because of all the things we have learned about the non-efficacy of method and our inability to access 'facts' directly and without shaping by prior belief and aims. We have seen that to evaluate a theory, you have to have criteria of judgement; different people have different criteria; they will weigh them differently; they will interpret them differently; and what you have is not a snap judgement, but rather a debate, a negotiation, a political interaction, in which different participants in the professional community will evaluate the bid or the claim in different ways. Some will accept it, some will reject it, some will modify it, and say that they are not modifying it, some will modify it and say that they are modifying it; different attitudes, different interpretations, different understandings of the new claim can be adopted.

Members of the professional field have different investments; that is, professional investments in their skills and reputation. And everybody who occupies a position in a professional field does not have the same skills, the same claims that they've made in the past. Each expert will tend to look at a new claim in terms of what it means in terms of their own investments. Does this claim undermine my previous investments? Does it undermine my claims or my skills? Does it not? Can I use it? Can I adopt it? Different experts will reach different opinions. This is not a matter of fraud, or bias, or not being objective. There is no alternative to people acting this way. So, we are looking at a 'micro-politics'. A micro-politics of negotiation and interpretation. There is no way that a claim can circulate and be judged in a community other than through this process of individual judgement, inter-action, negotiation.

In sum, each expert has investments in his own standing as a player in the game: so he or she carefully weighs up his/her attitude to the new claim. It is a myth to think that there is any way claims can be adjudicated other than through this 'micro-politics and negotiations' within the community. There is no method or divine revelation to tell the experts how to interpret and weigh up the new claim: they have their interest, their goals, their expertises, and they must stake their bets and play for the best outcome for them--to allow them to continue playing the game in a high status position.

What we are looking at is how the relevant experts interpreted Copernicus' claim; why they took only very small parts of it on board, and why Tycho's counter claim was so successful in dislodging Ptolemy's theory and in keeping Copernicus' claim on the periphery for another generation.

In fact what we are examining is a very small group of experts, in this case the professional astronomers of Europe, maybe 50 to 100 people at any given point in time in the sixteenth century. We are not looking at educated men in general, we are not looking at Natural Philosophers, or people who have been to the Universities in general; we are looking at the very narrow professional community of astronomers . We are trying to understand their response to Copernican theory. Now to do this, I am going to divide the period into two parts. The first period will be roughly 1543-1570; the second period will be about 1570-1600. 1600 is a convenient time, it is just before Tycho's death and it is also conveniently before the magical year of 1609, when we will learn later that the two great heroes of Copernicanism, Kepler and Galileo, both dramatically appeared on the public stage as champions of this apparently losing cause.

We now know that in the first generation after the publication of Copernicus' *De Revolutionibus* (1543), certainly through the 1570s, there was a very selective, technical response to Copernicus on the part of professional astronomers. The vast majority concluded, as we did in the Chapters on Copernicus, that the 'overall score' was so much against Copernicus, that his bid could not be taken over whole as a new truth. The score that it had compared to Ptolemy was too low.

But professional astronomers did value Copernicus as a skilled leading professional astronomer. And they thought that he had made limited advances, and these limited advances, ought to be reintegrated into the Ptolemy-Aristotle framework. It was thought, generally, within the profession, that Copernicus had been very clever indeed to get rid of the equant. You don't really have to know the details of the equant, but you remember he got rid of them. This was thought to be quite interesting; something nobody had bothered to do before and something worth doing. So, what you get is, Ptolemaic-Aristotelian astronomy being done without equants. It means you have to have more epicycles, but they get rid of equants. And that was considered very nice indeed by the professional astronomers of the day.

Another, perhaps more significant, technical achievement of Copernicus' theory was, its ability to give a relative ordering of the distances of the planets from the sun. So, in his theory, you can actually assign relative distances to Mercury, Venus, the Earth, Mars, Jupiter and Saturn from the Sun. You couldn't really do that in Ptolemy's theory. So this was also thought to be very clever by the professional astronomers of the day. This was 'tamed', or integrated back into Ptolemaic astronomy by the following argument:

> Look, it's nice to have the relative distances. So what if you have to assume the earth goes around the sun to figure out the relative distances. It's not true! It's absurd. But assuming that as a hypothesis, work out the distances, and then put the earth back in the middle and the sun in the third orbit, and apply the earth/sun distance in reverse. And so, Copernicus must have been very clever to figure out this little trick, for getting an order into the planets -- from the central earth that is!

Copernicus' arguments about the 'celestial harmonies' were not seen as particularly significant. First, because of the weight of other evidence against the earth moving, and secondly because of the fact that Copernicus made those arguments in Book One of *De Revolutionibus* not in the technical parts of the book where he builds models for each planet's motions--and it was the technical material which interested hard headed professionals. A professional astronomer was not too concerned with Book One. What you want to do it, is open *De Revolutionibus* to, say, the Chapter on Mars. Or you open it to the Chapter on the moon. Or you open it to the Chapter on Jupiter. You really want to see how to set up the models. You want to see how to get rid of the equant. You want to see how he sets up the circles. All this stuff about the cosmos and the harmonies, this is not real astronomy, this is waffling. Who thinks that the theory is true? It's not serious, its just a calculating tool.

This professional response was not stupid, nor was it conservative in some unthinking, reactive sense of the term. (You can say that if you want to make Copernicus into a misunderstood hero--but people at the time were saying he's not misunderstood, he's just very likely wrong, although he did a few good technical things). This professional response was reasonable: a shrewd professional judgement about just how far (not very) they were willing to go with Copernicus.

That's what professional scientists almost always do. They are always judging how far they want to go with their professional colleague's latest claim. And they are saying, "we will take some of the technical stuff, we'll turn it back into the terms of our own system. In the larger picture, well, you know, he wasn't serious. I mean, we don't really have to consider this." And accordingly, the professional view was not that Copernicus was a wild man or crazy, but that he had been an excellent technical astronomer, who had, unaccountably put some unacceptable views in the beginning of his book.

Now, this latter view was helped (but not entirely caused) by the fact that Copernicus' book had come before the reading public under a false disguise. Andreas Osiander, a Lutheran pastor and friend of Copernicus, had seen the book through the press in 1543. He had added an anonymous preface to the work--without the knowledge or approval of Copernicus, and in it he stated that the theory put forward was to be taken as a calculating device only; *that it was not really meant to be true*. And, as already you know, that is standard stuff about Ptolemy. As we saw in Chapter 6, the details of the Ptolemaic system were not thought to be able to be true. They were too complicated. You need to have that level of complication in order to get the predictions sufficiently accurate, but it can't be physically real. Perhaps Osiander was trying to save Copernicus from some embarrassment (or worse) which he, Osiander, imagined would greet the work. Maybe he thought he was saving Copernicus from religious sanctions; I don't really think that Copernicus was in danger of any such religious danger, and we'll see why that is when we turn to Galileo, much later. But, in any case, most of the reading public naturally assumed that Copernicus himself had written the preface.

The Osiander Preface made a nonsense out of Book One of *De Revolutionibus* where Copernicus quite clearly argued for the truth of his system, on the basis of the existence of the 'cosmic harmonies'. Professionals could read the preface and conclude, "well Copernicus didn't really mean it, so why should we take the truth claim seriously, let's get on with getting some technical benefit out of his work." Beyond this there was another large professional issue causing astronomers to read Copernicus the way they did: it was part of their professional culture (or grid) to assume that Natural Philosophers had the last say about physical reality. Everybody knew that astronomy (Ptolemy) did not fully match up to reality (Aristotle), so again, why buy into this curious attitude of Copernicus that his theory of astronomy was not only new and wild, but exactly true of physical reality?

In the second generation after Copernicus, from about 1570 onward, things began to change among professional astronomers. One element here was the growing awareness that Copernicus had not written the Preface. This rumour began to circulate in professional circles, and later Johannes Kepler virtually proved that Osiander had been the author. This meant that professionals had to face the fact that Copernicus, who was in their view a very good astronomer, *had actually believed in the truth of his own odd theory!* This raised interest in his arguments although it didn't lead to great numbers of complete converts. The professional community had already decided that Copernicus was a good guy, a good technical astronomer. Now they had to take seriously that he was for real in claiming that the earth moved, and that the harmonies were the basis for this claim. This raised interest in the arguments about the harmonies, but it did not create a great number of converts to this theory. By the way, throughout this period, 1540-1600, I believe you can count the number of dedicated, complete Copernicans on two hands.

The other fact that began to emerge was the work on Tycho Brahe who did take the issue of physical truth and the role of the harmonies seriously, and who had great professional authority, because of his definitely precise observations, and who, moreover, went on to propose a counter theory, a theory that won a very large amount of support (the Tychonic revolution preceded and almost prevented the Copernican one!)

Tycho Brahe was a Danish Lutheran gentleman, an unlikely candidate to be a professional astronomer in the 16th century: gentlemen do not have to be doctors, lawyers, clergymen or astronomers, but he became a professional astronomer. He was vain, egotistical, and almost pathologically meticulous. He also had a nose made of silver/gold alloy...a chunk of his original one having been removed in a youthful dual -- a major preoccupation of young gentlemen in his time.

Tycho started with an interest in alchemy, but he was converted or drawn over into the study of astronomy and of course astrology, by the appearance of a large comet in 1577. This comet's behaviour was followed with interest all over Europe. Observing it lead Tycho to the first of many theoretical innovations in astronomy.

The comet of 1577 was not the first notable new, odd, celestial phenomenon of the 1570's. In 1572 there had appeared what we now call a super-nova. That is, in modern terms, a star that has reached the end of its life expectancy and has exploded. But they called such a event a nova, a new star. The particular star that exploded had not been visible before. So all of a sudden there was this new, large, bright star. It grew brighter and brighter, then began to wane and finally disappeared after several months. What they thought they had was a new star that had come, been born, and died.

This was interesting because the experts agreed -- because they were smart -- that this super-nova was in the sphere of the fixed stars. This thing was a star. It showed no parallax. But it had just been born, and died. Now, everybody thought there was no change, or as they would say, ‘generation and corruption’, in the heavens. The heavens were perfect and unchanging. And so it was a little puzzle for Aristotle's cosmology, but you know, cosmologies or philosophies of nature are not overthrown by individual facts, one-off facts. There were many explanations for the nova that could bring it back into the basic Renaissance world view.

For example, it might be some kind of sign from God. In the normal course of things there is no change in the heavens, but maybe God is trying miraculously to signal something to us. Some Protestants reckoned that it was a sign to the Catholics to become Protestants. And a lot of Catholics reckoned that it was a sign to the Protestants to become Catholics again. There is always a lot of latitude for interpretation of the facts, as we learnt from our visit to Tiananmen Square a few Chapters ago.

Well, the timing of this debate is interesting too, the fact that the nova was noticed at all. Back in the mid eleventh century AD, a nova had appeared, it was really a big one, it's the thing whose remnants are now the Crab Nebula. This event was noted by Chinese astronomers, but not seen in the west or in the Islamic world except apparently by some monks one night in Europe, but it wasn't systematically studied.

It is possible that in the 1570's, what with the religious atmosphere being very hot, and also the possibility perhaps amongst professional astronomers of the Copernican question being in the back of their minds, that this super-nova was more closely noted and discussed. But, let's remember that the super-nova did not overthrow Aristotle's Natural Philosophy. It simply gave an extra piece of evidence for those who were disposed against Aristotle's Natural Philosophy to start with, and there were a few of them. But they obviously would have been convinced beforehand.

Well, back to the 1577 comet. Tycho calculated the orbit of this comet and had some interesting results. Aristotle and all other astronomers and Natural Philosophers up to this time had said that comets occur in the atmosphere, that comets are a meteorological phenomenon. Tycho and other astronomers concluded that the 1577 comet was not in the atmosphere. It was in an orbit in the heavens. And that in itself is interesting because later, when we come to Galileo, we are going to find that Galileo went out of his way to claim that comets are not in the heavens. He agreed with Aristotle, and there's a good reason. Galileo thought, incorrectly, that if comets are in the heavens, then the Copernican theory can't be correct. The details are not important here. This is an example of how people place their bets in the course of a micro-political negotiation of scientific facts. So, even though everybody had virtually agreed that the 1577 comet was in the heavens, Galileo was later to argue, like Aristotle, that comets are not in the heavens.

As forTycho, he concluded that the 1577 comet was in the heavens, and he calculated its orbit and came to a very big surprise, which was that the comet moved through or across the orbits of some of the planets. Now this was problematical, because in an Aristotelian framework, in an Aristotelian grid, you believe that the planets sit on hard, transparent, perfect crystal spheres, which turn and carry them around. Well obviously these things can't be hard because the comet goes through them.

So Tycho made what we might term a ‘progressive adjustment’ in the Aristotelian world view. (Who says that Aristotelians don't respond to evidence.) Tycho says look, the heavens can't possibly be hard, because this thing goes through them, the heavens must be liquid--fluid. But of course, a very special kind of fluid which we don't have on earth. Well that's obvious, because things don't move around in circles on earth do they? But this fluid does, to carry the planets around. The fact that it's a fluid means that the paths of things can cross. They aren't stuck in one radial surface, as it were.

That theory that the heavens are fluid, and a special kind of ethereal matter, was commonly taught in the Universities of Europe in the first third of the seventeenth century. So, when Galileo came along and said, boy, you guys are dumb to think that the heavenly spheres are solid, he was actually setting up a straw man, because many people already knew that there were no solid spheres. But that's typical of Galileo's way or arguing. He liked to argue with straw men and not with strong adversaries, like Tycho. He hardly ever mentions Tycho. There's a good reason. Tycho is hard to attack.

In order to pursue astronomy, as Tycho now wanted to do, he needed a base. And Tycho, being an aristocrat and having patronage from the King of Denmark, was able to organise the first high-level planetary observatory in Europe. There had been organised observatories in Islam, in the 8th, 9th, 10th centuries, but Tycho started the first one in Christian Europe. The king of Denmark gave him an island, (there are a lot of islands in Denmark so it wasn't all that generous), and on that island Tycho built an observatory called Uranibourg. Cosmos city.

Figure 1 is a picture of Uranibourg along with some of the instruments that he had there. Now, Tycho, in his meticulous monomaniacal way, hit on a very modern sounding idea, (maybe modern science is founded on this kind of monomania), that if we are going to resolve this conflict of theories we need much, much better data. The only way to get that data was to build and calibrate and use much, much more accurate observing instruments. Not telescopes, because the telescope was not used in astronomy before 1609.

Typical of Tycho's instruments is his mural quadrant. (fig. 2) It is built into a wall, so that it is solid; it is also very large and very accurately and narrowly calibrated. This is the way to push naked eye observations to the very limit of human visual acuity, which is about plus or minus four minutes of arc.

Tycho eventually fell out with the King of Denmark, and he went to work for a Catholic. At the higher, more aristocratic levels of society, there was no problem with Catholics getting along with Protestants or Protestants getting along with Catholics, if you knew the right people, and so Tycho went to Prague, to the capital of the Hapsburg Austrian empire, to work for the Emperor, Rudolph the Second, (mad Rudolph as he is known to historians, because his court was a virtual zoo of astrologers, alchemists, magicians, hangers-on, and Tycho Brahe). Tycho worked there for a number of years, and along the way he hired Kepler as his assistant. When Tycho died in 1601, Johannes Kepler became the Imperial Astronomer, which is the point at which Kepler got a hold of his data.

You can't observe in astronomy without a working theory. Tycho was very interested in devising a theory to guide his observations, a theory that could be further perfected by his observations. And the theory he invented over the years, came to be a very successful and widely accepted one. Tycho's theory succeeded in winning a lot of expert support, and was probably the leading one in the period 1600-1630.

Old fashioned history of science, based on the myth of method does not like this fact: the triumph of Copernicus must be smooth and obvious -- why would some other non-Copernican theory have become popular just when Copernicanism was supposed to be appealing to the best minds? Old fashioned history of science has therefore concentrated on Tycho as an observer--an under-labourer to Kepler and Galileo. But Galileo so feared the power of Tycho’s alternative theory that, as we shall see, he studiously avoided attacking it openly all through his career. Galileo was involved in a real struggle with the apparent truth of Tycho’s theory--a fact that method-bound historical myths need to avoid and suppress. Indeed, one can say that when the big crisis over Copernicanism finally occurred, in the period 1610-40, the battle was between Tychonism and Copernicanism, rather than between the latter and Ptolemy. So let’s look at Tycho’s theory, and its high ‘score’ circa 1600.

Tycho’s theory works as follows (fig. 3). We again have that outer sphere of the fixed stars (what else?); the earth is back in the centre of the system (thank God). The moon and the sun go around the earth, as in Ptolemy, the moon in about 28 days, the sun in about 365. But, and here is the tricky move, where are the planets--this is the master stroke: mercury, venus, mars, jupiter and saturn, circle around the sun, as the sun circles the earth. It's as though the orbits of the planets are big epicycles, all centred on the sun as it moves around its orbit, the deferent circle for all the planets.

So, for example, take the sun going around the earth, and consider Venus, going around the sun as an epicycle as the sun goes around the earth. It's epicyclic motion around the sun. And guess what? Venus is going to retrogress every once in a while, when it is between the sun and the central earth. What then would an outer planet look like? Well, consider Mars going around the sun, as the sun goes around the earth. Mars will be seen to retrogress when it is opposite the sun in the sky as seen from the Earth. And by the way, Mars never bumps into the sun even thought their orbits cross, because Mars is always one sun-mars distance away from the sun.

Well, this system seems lopsided and absurd to us and especially to Whiggish historians, (Whiggish historians love to either ignore this or to say how stupid it was), because if it was very successful, it destroys the story of the good guys driving out the bad guys, since if anything, this looks even more stupid than Ptolemy. But that is because Whigs judge this retrospectively from a Newtonian standpoint where the dynamics of such a system would be 'impossible'. It was arguably the best of the three contenders, on all criteria (Newtonian ones not having been invented or accepted in the community.)

First, he had the earth at rest in the centre of the universe, so a coherent, Aristotelian earth physics, based on the 'facts' was restored. Secondly, his system accords with a literal reading of the Bible, and although that was not a key issue for everyone, it was a criterion of some import (about to become more important) and again, here Tycho beats Copernicus.

Thirdly, and surprisingly, this system actually has within it all of the Copernican cosmic harmonies! Now that really is clever. And it does, for the simple reason that Tycho demonstrated that this theory is geometrically equivalent to the Copernican system. It is simply a matter of where you place your god-like index finger. Do you place it on the earth, and have the system go around the earth, or do you place it on the sun, and allow the earth to move around the sun with the other planets. It is geometrically equivalent, therefore all geometrical facets of the Copernican theory are preserved geometrically in the Tychonic system. You get your retrogressions, you get your explanation of elongation from the sun, you get your ordering of the planets, you get your 'harmony of harmonies'. You get everything, it's all there.

Now clearly, this is the theory of choice. This is the theory for rational progressive people to believe in, if they have seriously thought about the issues in 1600. Tycho had succeeded in making a brilliant new bid--a bid that overcame the main objections to Copernicus, whilst embodying Copernicus' most important and radical arguments for his own system -- the harmonies.

Whig history, always wants to ignore this. Because as I said, it's a kind of a gap in the nice, Whiggish, story. The way that Tycho is usually dealt with can be parodied like this:

> Well, he had a kind of a silly theory that was kind of a stupid compromise between the two other theories. He was obviously, you know, kind of too conservative to go all the way with Copernicus. But he provided this data and the data was the basis upon which the Copernican theory triumphed.

That's the usual story. But this is absurd. Because amongst knowledgeable people, the Tychonic system was the most the most widely accepted one in that generation in 1600-1630. They were acting 'rationally' in context, because it fitted the criteria of the day, and it was completely supported by Tycho's data.

And, by the way, you could fit Tycho's data into anything you like: You could use it to plug into Ptolemy's models, you could plug it into Copernicus' models, it did not make any difference: you would just juggle your circles and get your predictions to match it, as close as possible. The data didn't make any difference. The data didn't pick a theory, in this case. It hasn't done so throughout this whole debate. The data doesn't make a difference. Tycho just made everything more accurate for everybody. Everybody can use the data, so everybody's got more accurate data. It doesn't resolve the debate.

So this is your theory of choice, clearly in 1600.

And what, finally of Tycho? Rather than being a mere observer, or a timid, compromising, conservative, wimp, Tycho is a perfect example of a brilliant professional. What is Tycho doing? Tycho is playing the professional game. He is saying in effect,

> Okay, Copernicus has a point, he has a point about the harmonies. Fine. That doesn't mean you'd be a Copernican. That means you design a theory that's got those harmonies, but that also makes physical sense -- the earth does not move. And this is it, guys.

He is a clever, skilful and imaginative negotiator of bids, of claims. And I think that sort of genius is the most you can ask for in a professional scientist. So Tycho is not to be denigrated for not being a Copernican, in some Whiggish sense. He is to be understood as a very adept and clever, and imaginative, working, professional scientist. Perhaps typical of the best of what working professional scientists are all about. Not some silly figure out of the history of science. But a very good example of what actually happens in professional science. That in turn means we have now to look at the 'wild men' of Copernicanism -- Kepler and Galileo and how they possibly could have brought it about, that the Copernican system came back from the dead. Because it is very close to being dead at this point, in 1600.

**Figure 1**

**Figure 2**

Engraving of the great mural quadrant at Uraniborg; the observer is Tycho.

Figure 3

**Revolving azimuth quadrant had an arc radius only 15 inches smaller than that of quadrant at left. Tycho advised astronomers "to consider this construction as particularly commendable."**

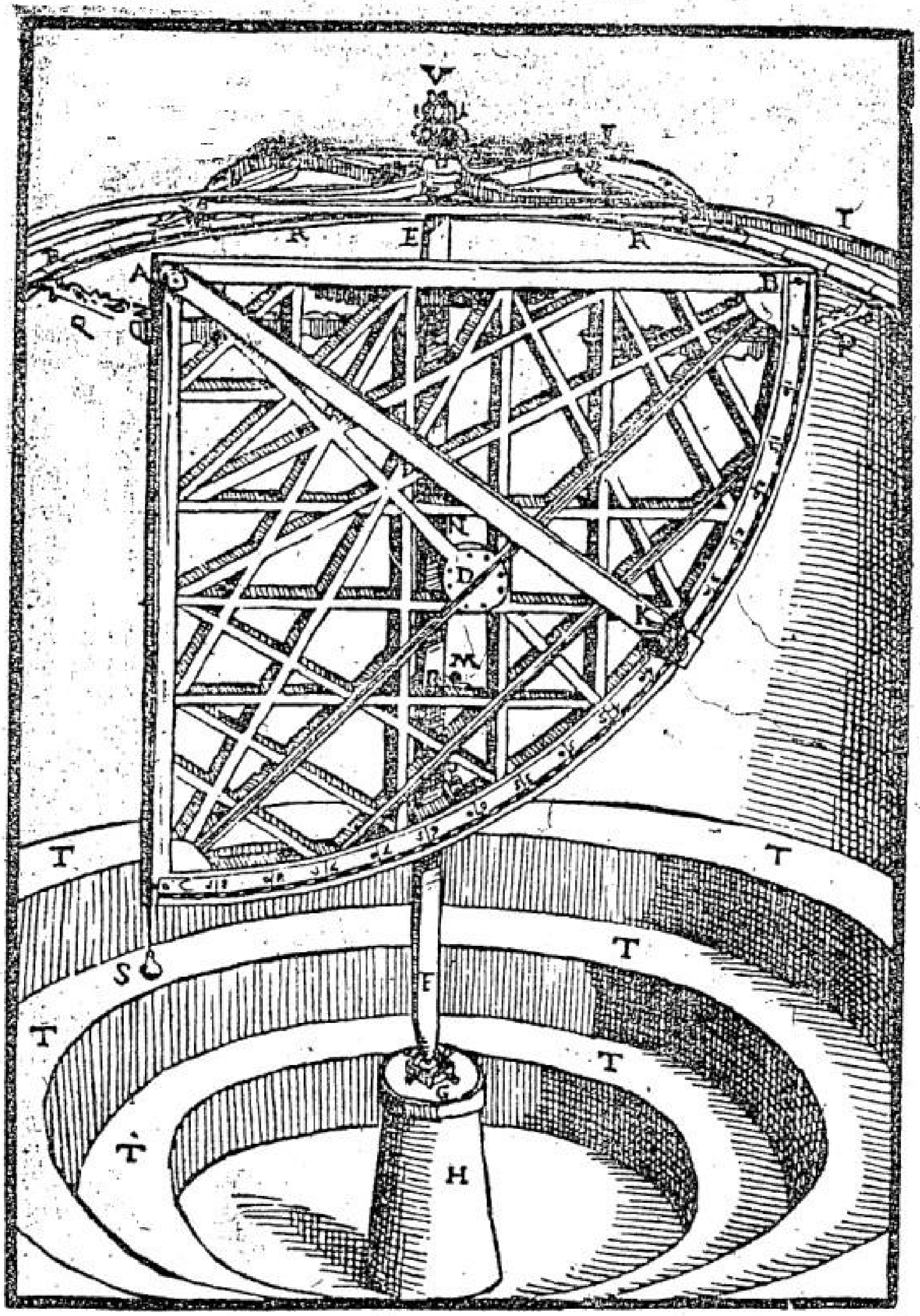

Fig 4  The Tychonic System

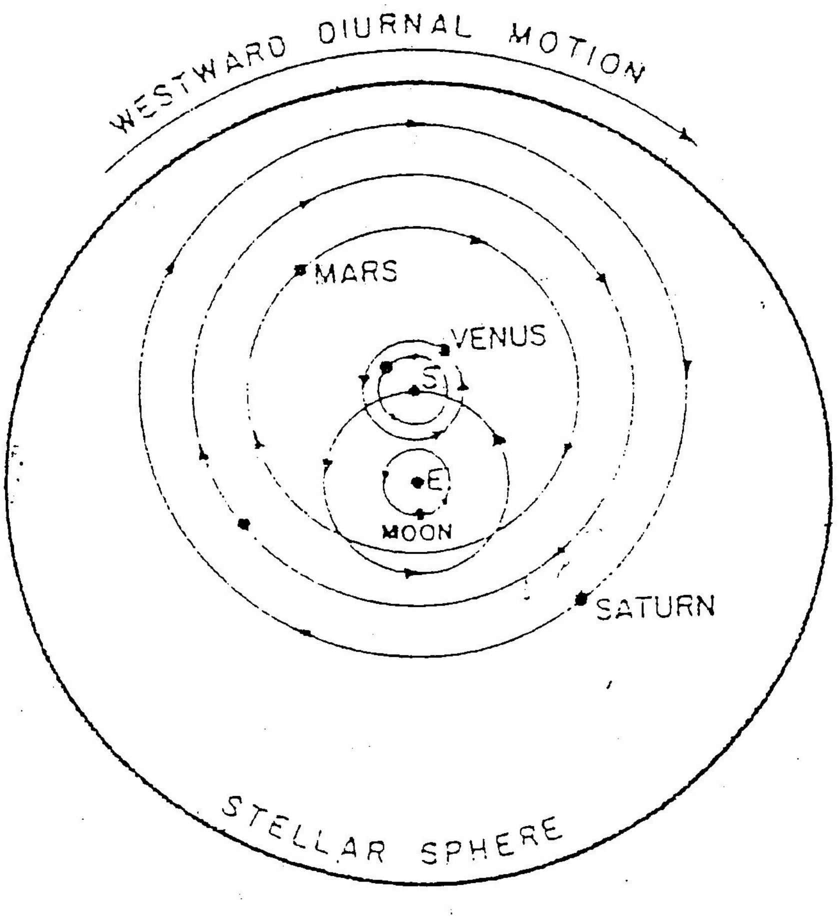

Figure 5  Picture of Tycho Brahe

Tyge Brahe, Astronomer, (1546-1601)