18 Galileo and the Church II

Galileo's *Dialogues Concerning the Two Chief World Systems* is probably the greatest scientific polemic ever written. It does not propose a new system, but it is an entertaining, witty, sarcastic scathing and clever book. It is polemical in that it attacks and virtually destroys the Aristotelian system of astronomy and natural philosophy, but the question is how many people actually believed in a truly Aristotelian system of astronomy anyway in 1633. Many had switched to a Tychonic system. It is also polemic because it does not mention Tycho's system seriously or propose his system as a third option. The book is a trialogue with three characters: Salviati, who is a Galilean philosopher; a Venetian nobleman named Sagredo (who at the beginning of the dialogue is open-minded and objective and does not favour one system over the other and by the end of the Dialogue becomes a convert to the Copernican system. It is known that he is supposedly modelled on a free-thinking Venetian nobleman). Thirdly, Simplicio, who is the Aristotelian. There is a little bit of ambiguity here, a play on words for in the 6th or 7th Century AD there had been a great commentator upon Aristotle, known as Simplicius. But in the Dialogue, Galileo's Simplicio is a rigid and rather unimaginative Aristotelian, and some people thought that the character was not named after the earlier philosopher, but rather was a slap at the Pope, especially since at the end of the book, Simplicio makes a lame claim that the Pope had made to Galileo back in 1623, to the effect that, after all, God could have designed the universe any way He willed, and we do not know for sure which way he did.

There are three pillars of argument upon which the *Dialogues Concerning Two Chief World Systems* rests as a Copernican argument. The first, which we will not go into in much detail, has to do with the telescope and Galileo's telescopic discoveries, which he details in the book in a forceful, forthright, pro-Copernican way, much more so than in his earlier telescopic writing. This is one pillar which we know how to deal with on the basis of Chapter 14. One of the two other pillars is the tactical deployment of the main concepts of Galileo's mathematical physics. Galileo does not give much of the meat of his new mathematical physics in *The Two Chief World Systems,*; rather, he waits to put this in another book that he was to write in 1638 whilst he was under house arrest. The third pillar is a surprise, because it is supposedly the crucial proof of his theory, which he had hinted about in correspondence and discussions and publications over the previous 15 years or so).

Galileo uses, in his *Two Chief World Systems*, some concepts from his mathematical physics in a limited, defensive deployment. He does not use his new physics to prove Copernicanism. He uses his concepts to blunt the force of argument against Copernicanism. Let's look at two of them. The first we have dealt with in connection with Popper's method. Here is an experiment that proves that the Earth does not spin. Imagine the Earth is spinning from west to east, it would mean that during the couple of seconds of fall, this room would shift a few hundred metres to the east. This means if I drop an object and everything below it is moving eastwards then the object would fall onto whatever is under its fall at that point. But, of course an object dropped down like that, falls straight down and does not drift to the west -- so the Earth does not move. Here is another example. We shoot a cannon due north towards a target on the horizon. The canon can shoot several hundred metres at least. Everything is lined up and the target is hit. This proves the Earth does not spin, for if it did spin toward the east whilst the cannonball was in flight, the cannonball would not hit the target but a target several hundred metres to the west.

As we said in the chapter on Popper's method, Galileo has some concepts that are central to his new physics which he intends using to deflate these experiments. The central one is inertia or inertial motion. (It is not a term he uses but it comes into vogue shortly afterwards). In general, inertial motion, in Galilean physics or Newtonian physics, (ie. Classical, pre-Einstein physics), is a type of motion, which, in the absence of external forces, continues on forever, exactly the same. It is the paradoxical and non-commonsensical claim that some motions, in ideal proper circumstances, could go on and on with no cause. According to Newton in 1687, and for all Classical Physics after that, inertia is explained this way: in the absence of external forces, a body moving in a straight line and at uniform speed will continue in that straight line and at that speed; if nothing ever happens to that body, it will continue forever to an infinite distance for an infinite time and duration. What is causing it to go? It is in a state of inertial motion. Newtonian inertial motion operates in a straight line.

Galileo's notion of inertia is different from Newton's, so from a Newtonian standpoint Galileo is quite wrong. Just as Newtonian inertia is wrong from an Einsteinian standpoint. Galileo explains inertia thus: In the absence of any disturbing bodies or forces, a body moving with a constant speed in circular motion around a centre towards which heavy bodies tend to fall, will continue to move in a uniform speed in a circle forever. In other words Galileo's inertial motion is uniform circular motion! Imagine, he says, a perfectly spherical, smooth Earth (frictionless); and imagine a ball-bearing also perfectly smooth, perfectly frictionless, spherical. Although the ball-bearing has weight and tends to fall down, there is no friction at the interface. (Galileo believes that all bodies on Earth have weight but we Newtonians know that bodies do not have weight they have mass.) If we give the ball-bearing a little push (if there are no obstacles, or impediments, no resistance, or friction) it will continue to go at the constant speed at which it set off. This is Galileo's concept of inertia.

Galileo found this concept, not by discovering it--for it is not 'something' in the world that can be discovered -but by constructing it. Its an intellectual construct like all theoretical concepts. How did he get it? Galileo reasons that when you drop a heavy body it accelerates down faster and faster. When you throw a heavy body up it decelerates to zero and starts to accelerate downwards. Acceleration down--deceleration up. Imagine an inclined plane, which is perfect, with no air resistance or friction--everything is perfectly flat or spherical. If a ball-bearing is let loose it will accelerate down the inclined plane. If the ball-bearing is given a push it will head up the inclined plane and decelerate as it travels further up the incline.

What happens when the inclined plane is not so severe: the ball-bearing will decelerate less severely and roll down at a more gentle speed. If there is hardly any inclination at all, the acceleration down will be very gentle and the deceleration (upwards) will also be very gentle. What would happen if the inclined plane is the smallest possible inclined plane--that is the 'plane' zero incline? If I push the ball-bearing is it going up--acceleration? No. Is it going down--deceleration? No. There is no friction, so if the ball-bearing is given a small bump it will just go and there will be no reason for it to speed up or slow down-- therefore, its speed would remain the same, and if there is nothing to stop it, then it will go on forever--inertial motion. However, what is a plane? A 'zero' inclined plane is a tiny segment of the surface of the perfect Earth. There is much mathematical abstraction in his theory. From an Aristotelian standpoint this theory is crazy for you do not argue through mathematical abstractions to reality. From a Newtonian viewpoint as well this theory is completely wrong about inertia.

How does Galileo's circular inertial motion take away the force of the experiments of the tower and the cannonball? Imagine not one body moving inertially, but a system of bodies moving inertially. Maybe a ship on the ocean or a train on a train track. In such an 'inertial system', if you look outside the system (ie: in a train, looking out) you cannot tell whether you are moving or the environment is moving backwards. Galileo states you cannot judge the motion of an inertial system from inside it. (You can judge who is moving inside the train, because you are all inside the train--but the train itself if it sits next to another train you cannot be sure at low speeds which train is moving or stationary).

According to Galileo the Earth is spinning uniformly; the Earth and everything on it is in an inertial framework and therefore if you look out from the Earth to the heavens we cannot tell whether the heavens spin around the Earth or the Earth spins on its axis. (By the way this is wrong from Newton's viewpoint) This, then, is Galileo's argument. Returning to the tower experiment, we all observe the object falling straight down to the ground, but, that is consistent with either of two interpretations of the experiment: (1) nothing is moving (the Earth is at rest) and the thing is moving straight down; or (2) everything is moving inertially--the floor, tower and the object are all moving inertially because they are part of an intertial system with the Earth. The same argument applies to the cannon ball experiment: whilst the shot is in the air, everything is moving to the east, including the shot ball. Galileo is not proving that the Earth spins, rather he is proving that it is *possible that the Earth spins* and that the Earth could be spinning and that you would observe the ball to fall straight down anyway!

This is a very good example of the anti-Popperian tactic of attacking the test that falsifies your theory. As we saw in Chapter 14, Galileo states that the Aristotelian tests are not definitive tests because the test can be interpreted in a different way using the theory of inertia. The Galilean physics of inertial motion is entirely wrong from a Newtonian standpoint: cannon shots will deviate, as will falling bodies, because the Earth spins and is not an inertial system. But Galileo did not have a theory to explain deviation. Newton takes the opposite viewpoint and says there is deviation because the Earth spins. Galileo's tactic is absolutely brilliant but merely defensive and entirely wrong *from the later Newtonian standpoint*.

So much for defensive tactics. In the *Dialogues,* Galileo's culminating proof that the Earth spins is based on the following line of argument. Is there a phenomenon (that can be agreed to by everybody) which can *only* be explained if the Earth is spinning, and not explained any other way? Yes, Galileo says, citing the phenomena of the tides.

We must understand the mechanism of the tides, he insist, and the way to begin to do this is to have a laboratory scale model of the tides. Galileo invites his readers to consider a rectangular shallow flat bottomed basin of water: 'just like' the water in the ocean basin. Galileo asks: "What happens if I rhythmically push the basin forward and pull the basin back?" If the rhythm is correct, Galileo states you will get an oscillating wall of water moving back and forth, which is a model of the tides. This motion is the alternate acceleration and deceleration of the water. But how is this alternately accelerating and decelerating motion of the seas and oceans produced on Earth?

In figure 1, we look down on the orbit of the Earth and the spinning Earth's north pole. We shall assign speeds to the Earth's motions: its orbital speed around the Sun, Vo, and its speed of axial daily rotation Vd. Now consider a point on the surface of the Earth at noon time. What is the speed of that point in space at noon? It is Vo+Vd. What about at midnight when the same point has moved around with the spinning

Earth? What is the speed of that point in space? It is Vo-Vd. So, your maximum speed is at noon time and the minimum speed is at midnight. And every day every point on the Earth undergoes a variation of speed from a maximum Vo+Vd to a minimum Vo-Vd If every point on the Earth goes from a maximum to minimum speed once every 24 hours that means that every point on Earth is alternately accelerated and decelerated, accelerated and decelerated, and so on. And Galileo's conclusion is that in the oceans and seas, subjected to this daily alternation of acceleration and deceleration, you would get the sloshing of the tides!

This theory is wrong in terms of the later Newtonian physics, and Galileo was also wrong in the eyes of his friends who would not accept his theory of the tides. One of the reasons Galileo's theory was not convincing was that there were other theories of the tides. For example, Kepler said "The Moon affects the oceans and causes the tides". Galileo disagreed with Kepler, asking how this occurred, by some 'magical' action at a distance. Another person to dispute his theories was the magician, alternative Natural Philosopher and Dominican, Tommaso Campanella who asked why humans, trees and houses, were not accelerated and decelerated all the time. Galileo's motion of the tides also completely contradicts his inertial motion theory. So, his theory of the tides did not convince many people.

Galileo's book was published and he was put on trial for it. We can dispute (and it has been disputed, ad infinitum) why that happened but I would caution you that there were people within the Church who were out to get Galileo. On the other hand, Galileo had friends in the Church who thought it a ridiculous idea to put him on trial. These people tried to manipulate things so that he would get the least possible sentence. It is also true that the Pope did not like Galileo's book especially after their conversations of 1623/4. But the Pope's anger at the book does not explain the massive machinery and action that had to be done to get Galileo to trial. It does, however, explain why the Pope did not lift a finger to assist Galileo to stop the trial once the wheels of the bureaucracy were turning.

Another pertinent fact is this: if the Church was correct in ruling Copernicus theory heretical in 1616, then the decision that Galileo was guilty of heresy in 1633 was correct. But, Galileo was not pursued on that issue. He was framed on a slightly different charge and this is where the proceedings become very murky.

Back in 1616 when the decree of the Holy Office was announced, Galileo's friend Cardinal Bellarmine called Galileo to his residence to have a talk. What Galileo states happened (and probably did happen) is that Bellarmine said the decree was not directed at Galileo personally but against Copernican's theory, taken as the literal truth. Galileo gained a certificate to that effect, for there were people who in 1616 were stating Galileo was a heretic because of his Copernican views. At his trial in 1633 a forged document was produced dated from that evening with Bellarmine. We now know from the study of the water marks and the nature of the paper that the document does indeed date from the 1616 and it was inserted in the Vatican records in before 1632, possibly in 1616. The other document says that Galileo rejected the decree and therefore, because of his views on Copernicanism he was directed not to mention the Copernican theory at all. According to this document he was violating an injunction that had been placed upon him previously. Therefore, Galileo was framed in 1632.

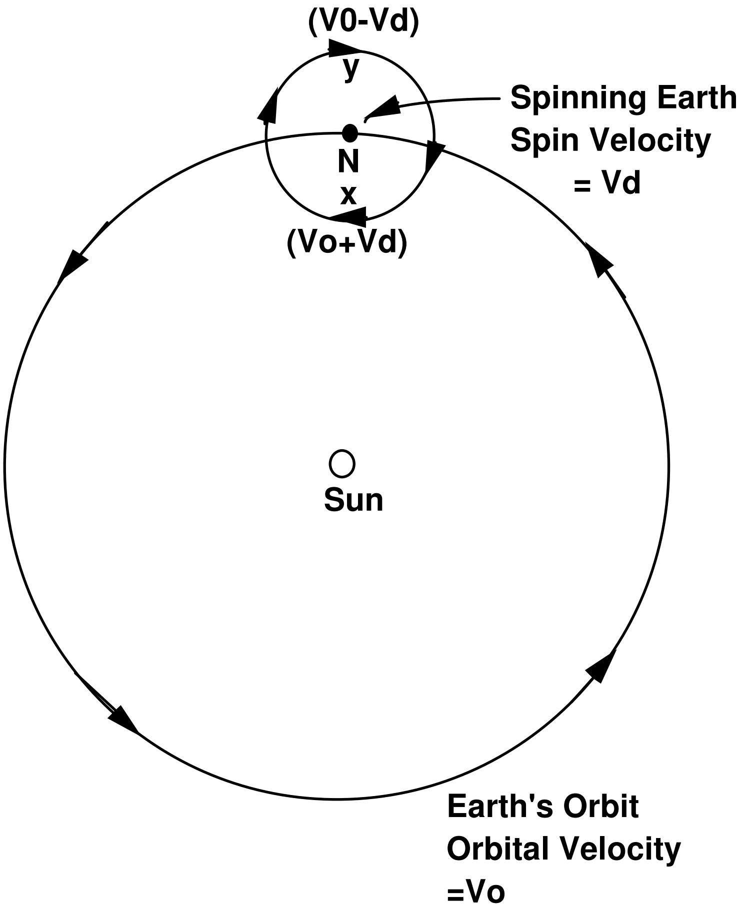
What are the ramifications of the Galileo affair? Firstly, in terms of scientific research in Italy, astronomical and cosmological speculation was hindered by Galileo's trial. But, science continued in Italy with some degree of its Renaissance strength throughout the 17th century and it was powered in part by students and disciples of Galileo. They did mechanics, experimented with air pumps and barometers, pursued mathematics, but they did not conduct much research on astronomy. In the rest of Europe the actual proceedings against Galileo did not stop astronomy. Protestants tended to find this an opportunity to berate the Catholics, so therefore the Galileo can even assists Protestant astronomers in their own cultural contexts. As to the other Catholic countries, there were many Copernican followers in France who had no fear of prosecution, for there was no effective Inquisition in France. Rene Descartes was then about to publish the first systematic treatment of the Mechanical Philosophy of Nature, which included support for the Copernican system. He was a Frenchman, a Catholic, living in Holland and in 1633 he decided not to publish his system because Galileo had been condemned, but this was not because he was scared of religious ramifications, but worried that he would not get the widest possible dissemination of his published thought in light of Galileo’s trial. Anyway he waited ten years then he published anyway. So the Galileo affair did not really stop astronomical debate and controversy, except in Italy.

Now what about the meaning of the Galileo affair? There are certain points that are true in this affair for observers of varied persuasions: Firstly, Galileo was presenting a fragmentary set of arguments against an established world view. Galileo was not a Natural Philosopher in the systematic sense of say, Aristotle or later on Newton, or Descartes. Galileo had his telescope, his theory of the tides and his theory of motion -- his physics. He could persuade people of his theory but he could not replace, system for system, the existing total picture. This is one of the drawbacks for Galileo.

On the other hand, there is no doubt that Galileo was framed at his trial, that some people were determined to get him and that in general the Church’s proceeding against him was at the least, ill timed and ill considered and not absolutely necessary considering the politics of the time.

Yet, we must also consider that it was perfectly reasonable in 1633 that Tycho’s system could be proved right and that Aristotle's could be patched up to agree with the Tychonic system. Galileo’s trial comes down to a political value judgement and the balance of the judgement was something like this: Do you follow Galileo without a system into a new view which may have religious or political repercussions. Or, do you stick with an old view, which is under criticism, but which has not been overthrown and which seems to be successful in helping to solidify the political and institutional order on the Catholic side. These were value judgements. A frame-ups of Galileo aside, it would seem perfectly reasonable to have adopted the latter position. There was no reason in some supposed scientific method, or 'the nuggety facts' that would seem to have favoured one or the other position in 1633, and that is the fundamental point that we have been trying to come to grips with in these two Chapters on the Galileo affair.

Figure 1 Galileo's Abortive Theory of the Tides



Point x on Earth at high noon has a net velocity of Vo + Vd (maximum for day)

Point y on Earth at midnight has a net velocity of Vo - Vd (minimum for day)

Thus any point on Earth goes in 24 hours from Max (Vo + Vd) to Min (V0 - Vd) speed and back again - alternately accelerating and decelerating.