The aim of every artist is to arrest motion, which is life, by artificial means and hold it fixed so that a hundred years later, when a stranger looks at it, it moves again since it is life.

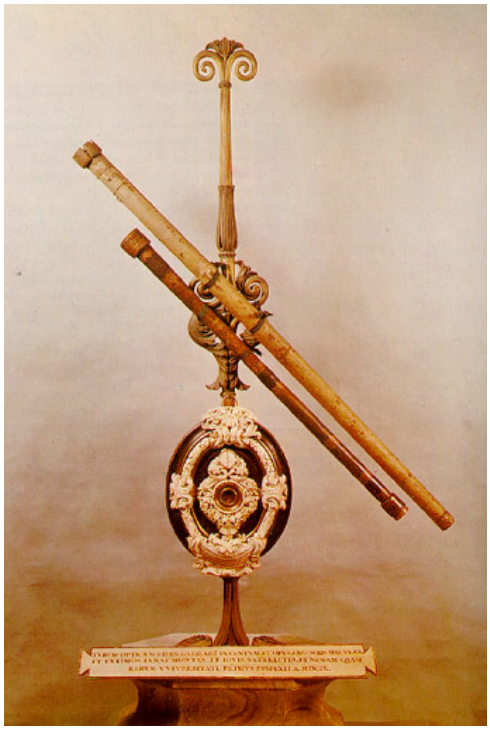
William Faulkner

Eppur Si Muove (And yet it moves)

Hi everyone In this module, we'll continue our investigation into the revolution that took place in astronomy, and in society in general, that we are not the center of the solar system/universe.

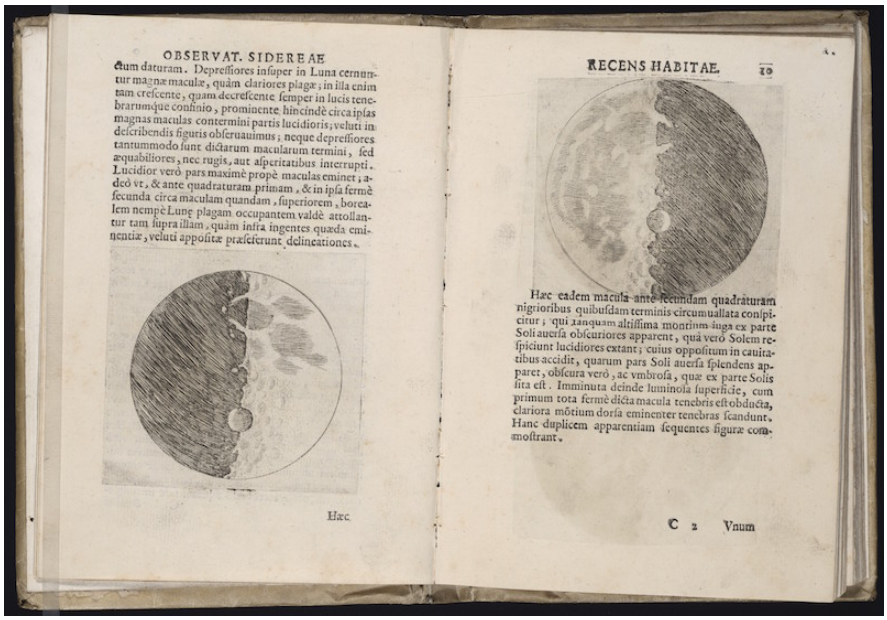
We've met the character who had the great idea, Nicholas Copernicus. We met a great observer, Tycho. We met somebody who could make sense of all that data, Kepler. But this was all happening in a rarefied intellectual environment. For any good idea to reach the masses, you need a public relations person. You need to get it out there to people and let them know what's going on. And in this revolution, the PR guy was Galileo Galilei.

Credit: Galileo Project, public domain



Credit: Museum of the History of Science, Florence

Above is an image of a young Galileo and his first telescope. Telescopes were invented for commerce. The idea is that you would take your telescope, and you would go up in a high point in a city, and you'd look out over the sea. And you could see when the ships were just coming over the horizon. When you saw the ships coming over the horizon, that was the right time to go out and get your crew that was going to unload the ship, or load the ship, whatever the case may be. It was a lot more efficient, i.e. it cost less money, because you didn't have to have your crew hanging out, waiting around. You didn't know where the ship was until you can make a visual line of sight. So the telescope was really invented to aid economies.



OBSERVAT. SIDEREAE

ctum daturam. Depreſſiores inſuper in Luna cernuntur magnæ maculæ, quàm clariores plagæ; in illa enim tam crescente, quam decrescente semper in lucis tenebrarumque confinio, prominente hinc indè circa ipſas magnas maculas contermini partis lucidioris; veluti in deſcribendis figuris obſeruauimus; neque depreſſiores tantummodo ſunt dictarum macularum termini, ſed æquabiliores, nec rugis, aut aſperitatibus interrupti. Lucidior verò pars maximè propè maculas eminet; adeò vt, & ante quadraturam primam, & in ipſa fermè ſecunda circa maculam quandam, ſuperiorem, borealem nempè Lunæ plagam occupantem valdè attollantur tam ſupra illam, quàm infra ingentes quædā eminentiæ, veluti appoſitæ præſeferunt delineationes.

Hæc

RECENS HABITAE. 29

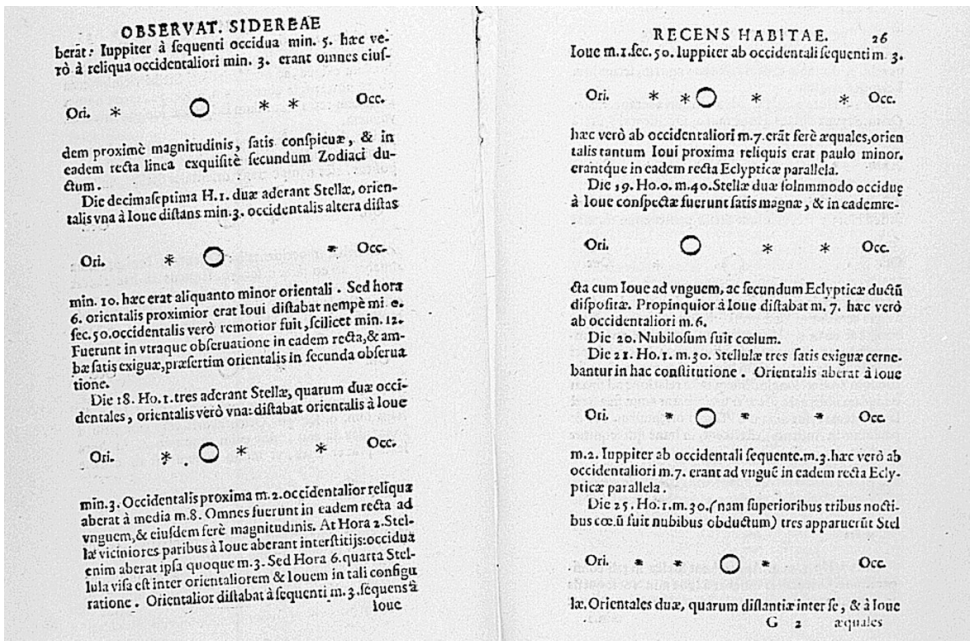
Hæc eadem macula ante ſecundam quadraturam nigrioribus quibuſdam terminis circumuallata conſpicitur; qui tanquam altiſſima montium iuga ex parte Soli auerſa obſcuriores apparent, quà verò Solem reſpiciunt lucidiores extant; cuius oppoſitum in cauitatibus accidit, quarum pars Soli auerſa ſplendens apparet, obſcura verò, ac vmbroſa, quæ ex parte Solis ſita eſt. Imminuta deinde luminoſa ſuperficie, cum primum tota fermè dicta macula tenebris eſt obducta, clariora mōtium dorſa eminenter tenebras ſcandunt. Hanc duplicem apparentiam ſequentes figuræ commoſtrant.

C 2 Vnum

Credit: Yale University Library

Galileo built one of the very first telescopes and was the first to aim it not at ships but at the skies. He created an absolute public sensation in 1610 when he published what he saw with his telescope in a book that he called Sidereus Nuncius, or translated, Starry Messenger. What if you see if you were the first person in history to look at the night sky through a telescope? What would you look at? What would you see?

Well, one of the first things he did is he looked at the Sun. Don't you do that. Don't look at the Sun directly with a telescope. Bad idea. But Galileo was careful and he saw Sun spots on the Sun, and he saw mountains on the Moon. The image above from Starry Messenger show is these strange circular indentations, which he didn't know what it was. Today we know that they're impact craters.



OBSERVAT. SIDEREAE

berat: Iuppiter à ſequenti occidua min. 5. hæc verò à reliqua occidentaliori min. 3. erant omnes ciuſ-

Ori. * ○ * * Occ.

dem proximè magnitudinis, ſatis conſpicuæ, & in eadem recta linea exquiſitè ſecundum Zodiaci ductum.

Die decimaſeptima H.1. duæ aderant Stellæ, orientalis vna à Ioue diſtans min.3. occidentalis altera diſtas

Ori. * ○ * Occ.

min. 10. hæc erat aliquanto minor orientali. Sed horæ 6. orientalis proximior erat Ioui diſtabat nempè mi. 6. ſec.50.occidentalis verò remotior fuit, ſcilicet min. 12. Fuerunt in vtraque obſeruatione in eadem recta, & ambæ ſatis exiguæ, præſertim orientalis in ſecunda obſeruatione.

Die 18. Ho.1. tres aderant Stellæ, quarum duæ occidentales, orientalis verò vna: diſtabat orientalis à Ioue

Ori. * ○ * * Occ.

min.3. Occidentalis proxima m.2.occidentalior reliquæ aberat à media m.8. Omnes fuerunt in eadem recta ad vnguem, & eiuſdem ferè magnitudinis. At Hora 2. Stellæ viciniores paribus à Ioue aberant interſtitijs: occidua enim aberat ipſa quoque m.3. Sed Hora 6. quarta Stella viſa eſt inter orientaliorem & Iouem in tali configuratione. Orientalior diſtabat à ſequenti m.3. ſequens à Ioue

RECENS HABITAE. 26

Ioue m.1.ſec.50. Iuppiter ab occidentali ſequenti m.3.

Ori. * *○ * * Occ.

hæc verò ab occidentaliori m.7. erāt ferè æquales, orientalis tantum Ioui proxima reliquis erat paulo minor, erantque in eadem recta Eclypticæ parallela.

Die 19. Ho.0. m.40. Stellæ duæ ſolummodo occiduę à Ioue conſpectæ fuerunt ſatis magnæ, & in eademre-

Ori. ○ * * Occ.

cta cum Ioue ad vnguem, ac ſecundum Eclypticæ ductū diſpoſitæ. Propinquior à Ioue diſtabat m.7. hæc verò ab occidentaliori m.6.

Die 20. Nubiloſum fuit cœlum.

Die 21. Ho.1. m.30. Stellulæ tres ſatis exiguæ cernebantur in hac conſtitutione. Orientalis aberat à Ioue

Ori. * ○ * * Occ.

m.2. Iuppiter ab occidentali ſequente.m.3.hæc verò ab occidentaliori m.7. erant ad vnguē in eadem recta Eclypticæ parallela.

Die 25. Ho.1.m.30.(nam ſuperioribus tribus noctibus cœlū fuit nubibus obductum) tres apparuerūt Stel

Ori. * * ○ * Occ.

læ. Orientales duæ, quarum diſtantiæ inter ſe, & à Ioue

G 2 æquales

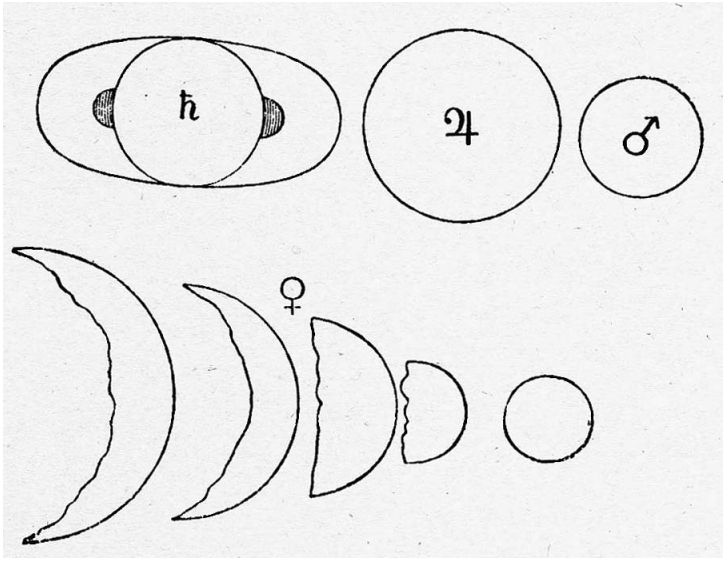
Credit:Trinity College, Cambridge

His point of this showing this -- remember, he's on a PR mission here-- is to suggest that the heavenly body were not perfect. The Sun had zits and the Moon had mountains. And therefore, maybe, elliptical orbits with the Sun at one focus were not so objectionable.

And he discovered the moons of Jupiter. Io, Europa, Ganymede, and Callisto. For the first time, there' is another center of motion in the universe. It's not just stuff going around the Earth or stuff going around the Sun, as the debate was, but here was another center of motion - moons orbiting Jupiter!

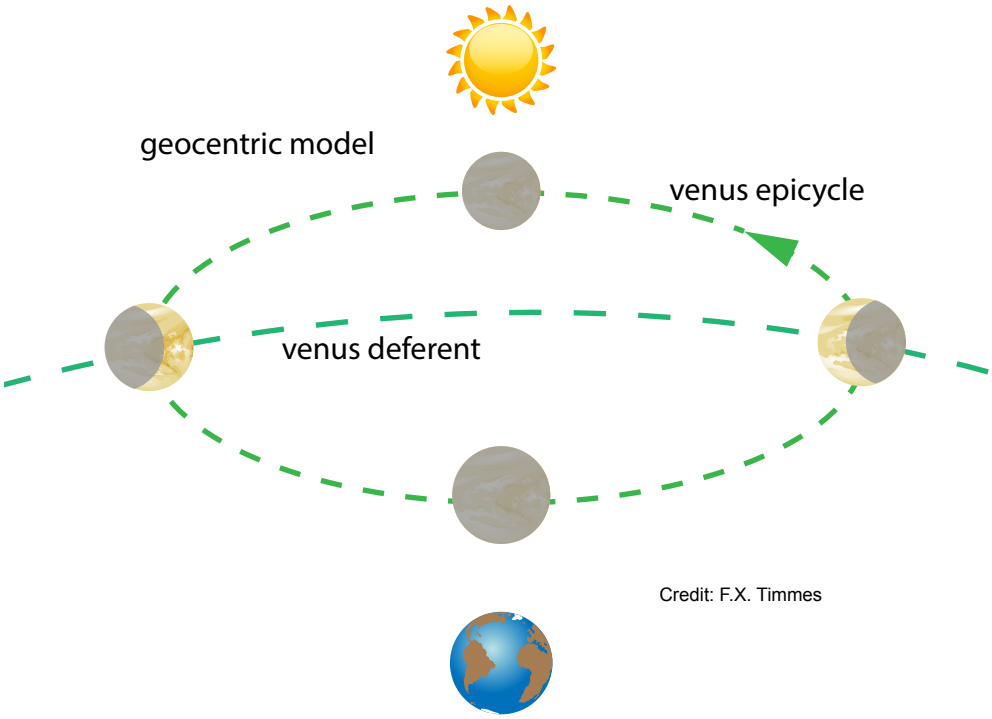
In the image above from Starry Messenger, Jupiter is the large circle, and he's got the four moons as asterisks. It took him a little while to figure out that these asterisks were actually orbiting Jupiter, as opposed to four independent pair of lights near Jupiter.

This is important in his PR case, because it showed that things could orbit one another without them flying off. The standard argument was that if the Earth is going around the Sun, the Moon would go flying off somewhere. The Moon wouldn't stay. But here was an example where you had objects orbiting another center of motion, and they certainly weren't flying away. They were staying with Jupiter. There were other moons besides the Moon, and new centers of motion. Stunning!

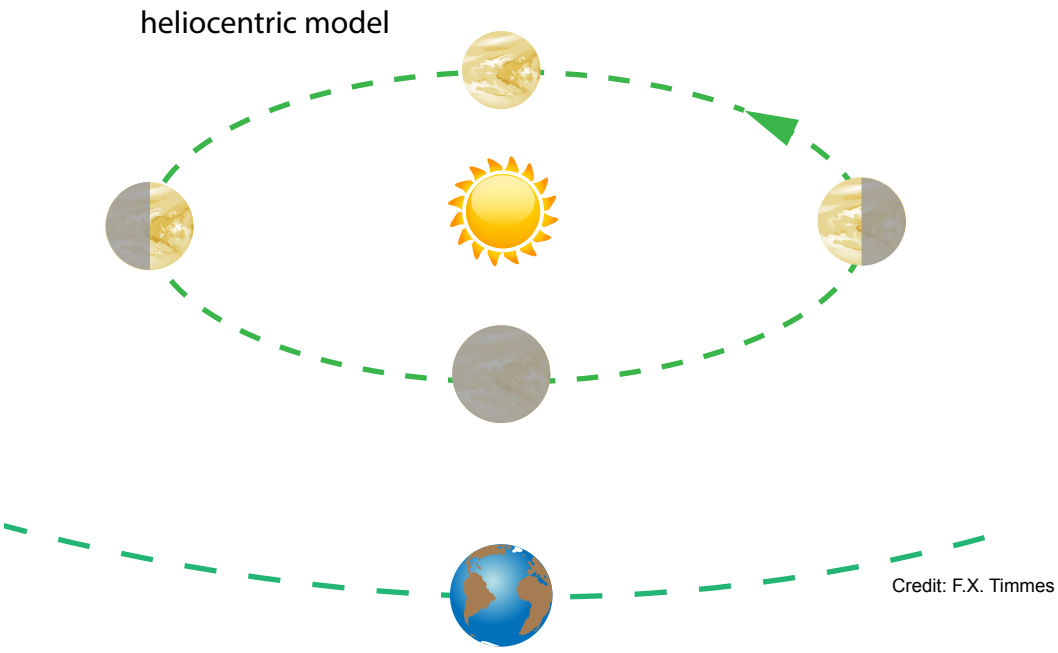


Credit:NASA

The observation though that killed the Earth-centered model of the universe was seeing all the phases of Venus - new Venus, quarter Venus, and most importantly the full phase of Venus. This observation is impossible to explain in a geocentric model. It can only happen if Venus orbits the Sun. And this single observation seriously hurt, put the nail on the coffin of the geocentric model. We were not at the center of the universe - with all its physiological implications. Let's explore both geocentric and heliocentric models for the phases of Venus.



The image above shows an Earth-centered model, so there's Earth in the middle. And there is Venus with its large circle, and then its small circle, its epicycle and its deferent, its circle-on-circle motion. As Venus goes around its small circle the image shows the phases of Venus that you would see. Venus goes from a new phase, up to a quarter phase, and then back into the new phase. So it oscillates back and forth between a quarter phase and a new phase. You never see Venus in the full phase. That would be impossible in this geometry.

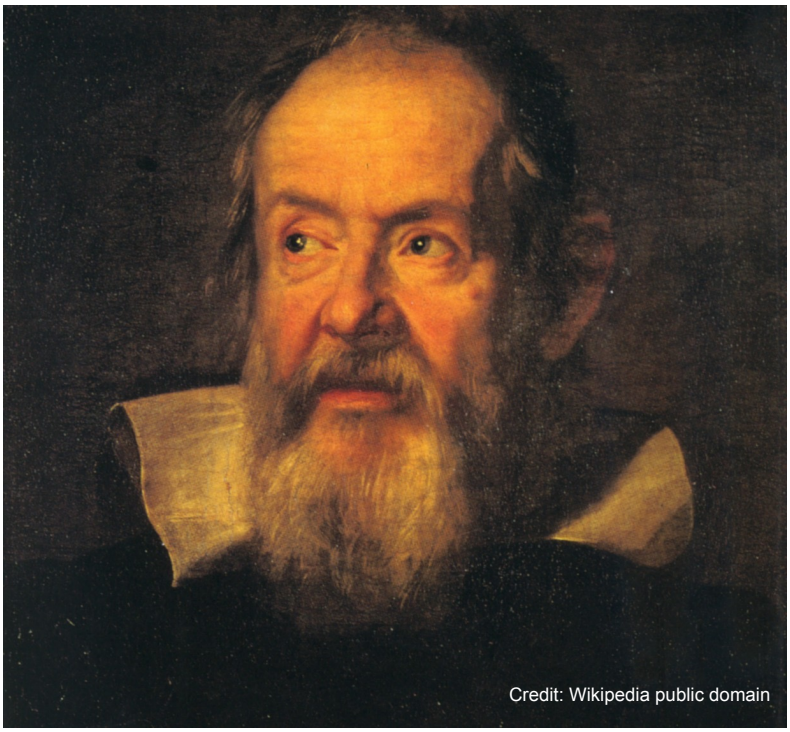


The image above shows the situation in a heliocentric model. As Venus orbits the Sun, one naturally gets all the phases of Venus - including a full Venus phase. When Galileo reported seeing all the phases in Starry Messenger, the conclusion was inescapable - the Sun was at the center. Case closed.

Credit: Wikipedia public domain

Now, Galileo, is a PR whirlwind. He doesn't want to keep this strictly in intellectual circles (Latin). So he writes what becomes his scientific and the literary masterpiece, The Dialogue Concerning Two Chief World Systems. The two chief world systems are the geocentric and heliocentric models. He wrote it in Italian, a common language of the people, so that he could take the case to the people and let them see and debate the evidence for themselves.

In Dialogue, the merits of both the Ptolemaic and the Copernican systems are discussed by Filippo Salviati, who's a committed Florentine Copernican. He’s the ultra cool modern guy. He's going with the Copernican theory. Then you have Gio Francesco Sagredo, who's an open minded Venetian, so he's initially neutral. He's not sure which model is right, but he's going to weigh the evidence, and make a rational judgment. Finally you have, well, Aristotle Simplicio, whose is staunch unmovable follower of the prevailing Ptolemaic theory. If Aristotle (the original) said so, so it must be true. I'm not going to look through a telescope. I'm not going to look at the evidence. Aristotle said so, it must be true. These three characters were a reflection of the state of the times.



It's a great book. Its not that long at about 180 pages. I invite you to read it sometime in your life. The image above is the book cover.

The book created a lot of problems for Galileo, particularly since the Aristotle Simplicio had several of characteristics of the Pope who was a friend friend of Galileo.That landed him in a bit of political hot water. And so he was condemned in 1633 for the principles on which The Dialogue rested upon. He was eventually pardoned in 1992.

The real story is a little bit more complex than that kind of a popular account. Galileo did promote some ideas that were politically embarrassing to the Pope, who I said was his friend. He also aired some marginally heretical ideas. But most of all, he didn't possess a super agreeable personality. He didn't suffer fools lightly. If he thought you were being dense and weren't getting it, he would let you know. It was kind of a combination of all these things that led to his condemnation in 1633. Under house arrest after his condemnation, by several independent sources, he stomped his foot on the ground and said “Eppur Si Muove”, or in English ”And yet it moves”. Meaning the Earth orbits about the Sun, despite what punishments you dole out.

Ultimately, through his PR campaign, we see in retrospect that Galileo nailed shut the case for a Sun-centered solar system.

Carpe Diem! Bye Bye.