The Great Ptolemaic Smackdown and Down-and-Dirty Mud-Wrassle

Michael F. Flynn

History must be curved, for there is a horizon in the affairs of mankind. Beyond this horizon, events pass out of historical consciousness and into myth. Accounts are shortened, complexities sloughed off, analogous figures fused, traditions "abraded into anecdotes." Real people become culture heroes: archetypical beings performing iconic deeds. (Vansina 1985)

In oral societies this horizon lies typically at eighty years, but historical consciousness endures longer in literate societies, and the horizon may fall as far back as three centuries. Arthur, a late-fifteenth-century war leader, had become by the time of Charlemagne the subject of an elaborate story cycle. Three centuries later, troubadours had done the same to Charlemagne himself. History had slipped over the horizon and become the stuff of legend.¹

This suggests that seventeenth-century history has already become myth. Jamestown is reduced to "Pocahontas," and Massachusetts boils down to "the First Thanksgiving." And the story of how heliocentrism replaced geocentrism has become a Genesis Myth, in which a culture-hero performs iconic deeds that affirm the rightness of our modern worldview.

_Eppur non si muove_

In "What Science Means to Me," Jerry Oltion states that the geocentric model was based on "argument from first principles," needed continual "patching" to account for new data, and owed more to dogma than to science (Oltion 2012).

So goes legend. History begs to differ. Geocentrism was an empirical model based on observation, and lasted for two millennia because it accounted for the sensible motions of the stars. Go outside. You can watch the heavens travel in perfectly circular motions from east to west, as if each heavenly body were embedded in a framework of some "dark matter" turning around the Earth.

But (I hear you say) they aren't! They don't! Oh, yeah? Prove it!

_Heliocentric Woo-woo_

This isn’t as easy as you may think, especially if all you have are "eyeballs and telescopes." We believe the Earth moves because we’ve been taught that. Most folks have no clue how to demonstrate it.²

But... didn’t Aristarchus and the Pythagoreans propose heliocentrism in ancient times? If only they had prevailed, we might have had Real Science millennia sooner. What was their evidence?

Well, you see, Fire is nobler than earth and the center is a nobler position. So Fire has to be in the center. QED.

There are many names for this sort of thinking, but "scientific" is not one of them. Aristotle says of the Pythagoreans:

In all this they are not seeking for theories and causes to account for observed facts, but rather forcing their observations and trying to accommodate them to certain theories and opinions of their own.

—Aristotle, _On the heavens_ II.13.29a

So heliocentrism, not geocentrism, was "dogma deduced from first principles." Sure, they guessed right; but if science was just lucky guesses, we’d credit Jonathon Swift with discovering the moons of Mars.

_How could astronomers have been so stupid?_

Heliocentrism was falsified because it entailed observations that were not in fact observed.

1. If the Earth turns, "we and the trees and houses are moved toward the east very swiftly, and so it should seem that the air and wind blow continuously and strongly from the east... But the contrary appears by experience.

2. If we shoot an arrow straight up, the earth will move to the east below it, so it should fall a good distance to the west. But the contrary is clear.

3. If the Sun were at the center of the World, heavy objects would fall toward the Sun, not to the Earth as we commonly see.

4. If the Earth were revolving around the Sun, there should be visible parallax among the fixed stars. There is none.

A further objection was introduced by Giovanni Riccioli in his _Almagestum Novum._

¹ In AD 778, a Basque war party ambushed the Carolingian rear guard (Annales regni francorum). Forty years later, Einhard, a minister of Charlemagne, mentioned "Roland, prefect of the Breton Marches" among those killed ("Histoire de l’Empereur Charlemagne," trans. J. Loquin, _Annales Carolingi,_ p. 92). But by 998, Roland had become the central character; the Basques had become Saracens, and a magic horn and tale of treachery had been added (10 Chansons de Roland). Compare the parallel fate of a Hopi narrative concerning a Navajo ambush (Vansina, pp. 19-20).

² Analog readers may be a partial exception. Take a moment and jot down how you would do it.

³ An ancient version of the Michelson-Morley experiment!

⁴ Based on brightness and apparent diameter, stellar distance was an incredible 73 million miles (Camarus de Novara, ca. 1250). Even so, parallax should have been visible to the naked eye. (Edward Grant, _Cosmology_, in Lindberg 1978, p. 292.)
5. If the Earth is rotating, objects dropped from a great height should fall east of the plumb line because they have a greater horizontal velocity. No such deflection is observed.

Today, we have answers to these (and other) objections, but those answers depend on measurements or concepts not then available, like inertia or inverse squares. For example, we could count the first hypothesis by claiming common motion and many did. But you cannot save one unproven hypothesis by "parching" on another unproven hypothesis. (Christie. But it doesn't move! 2011)

Another fine math you've gotten us into

There were only two practical reasons for studying the heavens: to prepare calendars and to cast horoscopes. Later, oceanic navigation became important. For these, you need more than a "designated center," you need a complete mathematical model, Claudius Ptolemaeus perfected such a model with Syntaxis Mathematiké (a.k.a. The Almagest)—including the method we still use today to record stellar positions. So calendars could be made, and the fates of kings predicted.

One wee problem; it conflicted with Aristotelian physics.

The Ptolemaic model was not strictly geocentric. The planets are carried by their orbs along a circular path called a deferent, but to account for the changes in speed that we now associate with Kepler's equal area law, the deferent was centered not on the Earth but on a point halfway between the Earth and an imagined focus called an equant. Each planet was solved separately, so each had a different center. To account for retrograde motion and changes in size and brightness, planets moved on a second circle called an epicycle centered on the deferent, on deferent, on deferent. Worryingly, Ptolemy seems to be going circles to act like ellipses.

These mathematical devices really, really bugs the physicists, in Aristotelian physics all the orbs were homocentric on the Earth. The orbs were like nested ball bearings made of aether, which carried the planets within them. There was no room for such foo-foo as epicycles, and no philosophical justification for the @68% equants.

The astronomers' only excuse was that their calculations worked. The physicists groused, "Sure, they work in practice, but do they work in theory?"

There was only one solution.

Astronomy was not physics!

Moderns find this hard to grasp, but the ancients did not consider astronomy a physical science. It was a specialized branch of mathematics. Except to Pythagorean woo-woos, the devices of astronomy did not imply physical existence. Retrograde motion was physical, but epicycles were merely convenient algorithms to calculate that motion.

Grains of medieval salt

After digesting Aristotle, the medieval began to eliminate parts. Bradwardine, demolished Aristotelian motion using the "new math" (fractions) and coined terms like "instantaneous motion" to explain it. Anticipating Duns and Quine, Thomas Aquinas noted the underdetermination of science regarding astronomical models:

"The theory of epicycles and epiceptics is considered as established because thereby the sensible appearances of the heavenly movements can be explained, not however, if this proof were sufficient, forasmuch as some other theory might explain them."

—Summa theologica, I, q. 32, a. 1, ad. 2.

That is, the same finite set of facts might be explained by different theories. The medievals knew about the Pythagorean model, and also the geo-heliocentric model of Hieroclydes of Pontus, which accounted for the constrained motions of Mercury and Venus by having them circle the Sun while the other planets circled the Earth.

By the fourteenth century, astronomers had begun thinking not only in terms of mathematical devices, but of physical reality. Nicholas Oresme and later Nicholas of Cusa began to consider the possibility of a rotating Earth. Using Witeo's principle of relativity, Oresme subverted the best positive evidence for the geostationary Earth—the apparent motion of the heavens.

...one cannot demonstrate by any experience whatever that the heavens are moved with daily movement, because, regardless of whether it has been posited that the heavens and not the earth, are so moved or that the earth and not the heavens is moved, if an observer is in the heavens and sees the earth clearly, the earth would seem to be moved; and if the observer were on the earth, the heavens would seem to be moved. (Oresme 1999)

He also showed how scriptural references to a stationary Earth could be read. Unlike a certain Tuscan layman who later got in deep kimchee for amateur exegesis, Oresme was a pro: "a theologian and bishop. If only he'd had a telescope!"

The medieval Church taught that naiveté-literate readings should be abandoned when they conflicted with something known for certain, as St. Augustine had pointed out in Late Antiquity.

"In the Gospel we do not read that the Lord said: 'I send you the Holy Spirit so that He might teach you all about the course of the Sun and the moon.' The Lord wanted to make Christians, not astronomers. You learn at school all the useful things you need to know about nature."

—Contra Faustum manichaeum, I,10

With the right equipment, they might have had a renaissance. Instead, they got the Renaissance.

The return of mystical woo-woo

The Italian Renaissance was a humanist reaction against Aristotelian obsessions with logic, reason, and natural philosophy. Greco-Roman art and literature were "rediscovered." Ptolemaic mysticism was revived, along with astrology, magic, and Pythagoreanism. Natural science faltered, but since astronomy was only mathematics, it prospered.

Nicholas Copernicus, a canon lawyer at Frauenberg cathedral, was a medical practitioner, financial advisor, and was once short-listed for the bishop's seat. He was also a gifted "mathematics." But he was not a scientist in our modern sense. He made few empirical observations, instead doing new math on existing data: Ptoebach's Epitome in Almagestem and Gerard of Cremona's twelfth century Latin translation of the Almagest. He defended heliocentrism by quoting Hermes Trismegistus, "a nonexistent propagator of more woo than you pack into an articulated truck," according to Thony Christie. He wanted to save the Platonic axiom of purely circular orbits by ridding the World of those @68% equants.

Cardinal Nicolaus von Schönberg and Bishop Giese urged him to publish, but he had already been satirized on the stage and dreaded the mockery of those who "on account of their natural stupidity hold the position among philosophers as drones among bees." De revolutionibus, caused great excitement among mathematicians with it appeared. However, the enthusiasm quickly died down; and for a reason that starts us Moderns.

The new system was no improvement.

The failure of Copernicam

Folks know only the Legend suppose the transition to heliocentrism was simply a matter of putting the center where instead of there. But it's not enough for a new model to equal the standard model; it must do better. And the Copernican model did not.

Nor were its calculations simpler. To preserve Platonic circles, Copernicus used twice as many circles as Peuerbach's then-current edition of Poliomy! The Earth revolved around the Sun on two circles; the Moon ran on an unprecedented double epicycle, and Mercury was liberated idiosyncratically by the Sun. The center of an epicycle. Try explaining that to your seven-year-old. Is the concept of universal gravitation "self-evident"? If it truly was, then heliocentrism wasn't even necessary. The "off-center, and planetary sphere advanced to the center of the Earth" and is.

...
stead. And because each planet was solved as a separate problem, each planet orbits a different center!

At least he got rid of those @$% equants.

There were two reasons for the failure:
• Copernicus insisted on Platonic circles, and
• Accumulated copystyle errors in the Alphonsine Tables carried into his Prussian Tables.

What a let-down. If only the data were better!

Anything you can do I can do better

Irritated by both models, Tycho Brahe set out to gather new, precise data. He designed and calibrated new instruments and compiled meticulous observations with errors as small as the width of a quarter seen from a football field away.

And produced a geo-heliocentric system regarded today as a kludge.

How did he manage that? Like any good scientist, he followed the data. (Grane, 2012)

Procyon appeared the same diameter and brightness as Saturn. If it were much farther than 100 times Saturn’s distance, simple geometry proved its actual size would dwarf the Sun. All the stars would dwarf the Sun, which would then be the only pea in a universe of melons. [11] But if Procyon were any closer, there would be visible parallax if the Earth revolved around the Sun. Lack of parallax coupled with the apparent size of the stars therefore required a stationary Earth.

Because Tycho otherwise admired Copernicus’ treatment, his solution was an updated Heracleidan model: all planets circling the Sun, and the Sun and Moon circling the Earth! His great kludge was thus the best model that accounted for the data. Further, it was mathematically equivalent to the Copernican model. Anything the one model could do the other model could do as well.

Hey (I hear you say) Procyon doesn’t have a date!

Right. It’s atmospheric aberration. Tycho knew about it, but underestimated its effects away from the horizon.

The Imperial Mathematician, Nicolaus Reymers Ban, styled “Ursus,” proposed a similar model—but with a rotating Earth. Tycho accused him of plagiarizing his data and a feud developed that caught a young math teacher named Johann Kepler smack in the middle.

Like many new authors, Kepler had sent copies of his book to famous people, hoping for blurs. [12] Ursus used Kepler’s thank-you note to make it seem that Kepler favored the Ursine over the Tychonic model. Since Kepler was asking Tycho for a job at the time, this caused problems.

Kepler also received an unsolicited fan letter from an unknown mathematic professor at Padua whose name amused him. “His forename and family name are the same!” Kepler wrote to a friend. “Galileus Galileus.” In Italian, Galilei Galilei.

The Last Hurrah of Tyveball Astronomy

Copernicus had really messed up his analysis of Mars. Tycho had already eliminated one Copernican error—the “trepidations of the equinoxes” was simply observational error—now he hired Kepler to fix the orbit of Mars; though, remembering Ursus, the secretive Tycho would not allow Kepler to make copies of the data. But when Kepler succeeded Tycho (who had succeeded Ursus) as Imperial Mathematician in 1601, he negotiated better access with Longomontanus, Tycho’s long-time assistant.

Kepler worked Mars in the Tychonic, Copernican, and Tychoptic models, and none of them gave a good account. He assumed (as Copernicus had not) that all orbital planes passed through the Sun, which reduced the error to eight or nine arc minutes. Not good enough. He tried re-introducing the @$% & equants, though his heart wasn’t in it. [13]

A Neoplatonic mystic, Kepler was convinced that physics must reduce to simple mathematical forms, but he was more liberal than either Copernicus or Galileo. He began to try out.

This bugger Longomontanus, who accused Kepler of shovelling shit. [14] Kepler replied:

If you are angry that I cannot eliminate the oval path, how much more ought you to be angry with the spirals [epicycles], which I abolished.

This is like being punished for leaving behind one barren foot full of shit although I have cleaned the rest of the Augean stables. [15]

The mathematical difficulty of oval had led Kepler to complain earlier to David Fabricius:

[lack something: knowledge of the geometrical generation of the oval path ... if the figure were a perfect ellipse ... ?] Yeah, if only.

One of the difficulties in falsifying an established theory is that there is never just one assumption in the theory. [16] Kepler decided to chuck two basics of physics: that planetary motion was a) uniform around b) circles. The reason why Mars seemed to speed up or slow down was that—wait for it—it was speeding up and slowing down, and not moving uniformly around a circular epicycle riding along a circular (but off-center) deferent. This almost worked. In 1604 he gave up Platonic circles.

He was able to show geometrically that movement along an ellipse was mathematically equivalent to movement along an epicycle on a deferent. Shazam!—the Martian orbit suddenly made sense!

Without Tycho’s precise new data, Kepler would never have found his ellipse. The old tables were too badly corrupted. And a good thing too that Tycho had assigned Kepler to

[11] In response, the Copernicans cried God forbid! “Who cares how big the stars are?” wrote Christoph Rothmann, since an infinite Creator God is far bigger still.

[12] Mysterium Cosmographicum was called by Christie “a strange Renaissance piece of Platonic Pythagorean mathematical mysticism that however revealed its author to be a very good mathematical astronomer.”


[14] Literally. In a letter of 6 May 1604, he told Kepler he was submerged in shit in the Augean stable of old...


[16] Falsification: If theory $p$ THEN consequence $q$ and NOT$q$, then NOT$p$. But Duhem pointed out that no physical theory consists of a single $p$. Instead we have $p$ and $p$, and ... $p$, then $q$ and NOT$q$. Thus, when no scalar parallax was observed, it was not heliocentrism that was falsified, as Archimedes and the rest believed, but the assumed scalar distances. But they had way yet of confirming that empirically. (And just to keep things interesting, Carnap pointed out that there is never just one $q$, either (Wallace 1996, pp. 244-249).

** Comparison of Ptolemaic and Copernican/Modern Values

<table>
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<tr>
<th></th>
<th>Ratio of Radii ** (Ptolemaic)</th>
<th>Mean Distance (from Sun, in AU) (Copernican)</th>
<th>Modern Value</th>
<th>Ptolemaic Angular Velocity ** (deg/day)</th>
<th>Modern Value</th>
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</table>

Epicycle/Deferent for the interior planets; deferent/epicycle for the superior. The Sun had no epicycle.

** Along epicycles for the interior planets and along deferents for the superior.
work on Mars rather than Venus! Venus’ orbit is nearly a perfect circle, while Mars has the most elliptical orbit of the then-known planets.17

Kepler wrote this up in *Astronomia nova* (1609). Since he believed mathematics caused physics, he decided that there must be a universal cause of planetary motions: the Sun projected a field, which by rotating would elastically push the planets around their ellipses which in turn are inversely proportional to their distance. Okay, you can’t get everything: but this prepared the way for Newton. He thought the field was the Holy Spirit, which proceeded from the Father (the Sun) toward the Son (the fixed stars). This did not prepare the way for Newton.

Game, set, and match, dudes! Except for one thing. He had only Platonic number mysticism. He had no empirical evidence that his model was physically true. It predicted the heavens; but so did the Tycho system.

Kepler sent a copy of *Astronomia nova* to Galileo—but Galileo never read it.18

The Magnificent Seven

In case you’re keeping tabs, there were by this time seven models in play (Christie, Galileo’s great blunder 2010).

Herculean. Geocentric, heliocentric. Mercury and Venus circle the Sun; everything else circles the Earth.


Gilbertian. Geocentric, rotating Earth (William Gilbert, in *De Magnete*). Tycho. Heliocentric, Sun and Moon circle the Earth; everything else circles the Sun.

Ursine. Tychoatic, with rotating Earth.

Keplerian. Heliocentric, with elliptical orbits.

The Tycho-Nic model blew away the Herculean model, but to decide among the remainder required not simply new data, but new kinds of data.

The far-saying look-glass

Astronomers from Hipparchus to Tycho had been able to gauge only the position, movement, brightness, and size of the stars and planets.19 That all changed with the look-glass and the era of God! Wow! Look, astronomy, Harriot and Galileo saw mountains on the Moon. Galileo and Marquis saw moons around Jupiter. Later, Harriot, the Fabrici, Scheiner, and Galileo saw sunspots, all within months of one another.20

Lunar mountains? Jovian moons? Hooray for Copernicus! Down with Ptolemy!

In March 1611, Galileo went to Rome to promote *The Sidereal Message* and was celebrated in a round of parties and banquets. On 15 May, the Jesuits (who had confirmed Galileo’s observations with their own telescopes) threw a big shindig for him at the Roman College. Afterwards Galileo could be called a “celebrated” astronomer.

But that Jupiter has moons does not prove that the Earth circles the Sun. It only proves that not everything directly circles the Earth—and Tycho had already dealt with that. The physics problem was not where the Sun and Earth are situated, but whether the Earth is in motion.

Neither discovery laid a glove on Ptolemaic astronomy.

The Last Hurrah of Claude Ptolemy

Try telling that to Galileo. In a letter to his former student Castelli (Dec. 1610), he wrote that those not convinced of the truth of Copernicus...were bookish philosophers who cared only for the empty applause of the vulgar crowds.21 He was a charmer, all right. Lacking evidence, he wanted Copernicanism accepted on faith.

The true telescopic revolution was to convert the planets from lights in the sky to objects about which physical discoveries could be made. Astronomy began to transition from the math department to the physics department.22

In September 1610, Galileo discovered that Venus went behind the Sun. This was predicted by the Copernican model, but was incompatible with the Ptolemaic (God-Guido) model. Two thousand years of scientific consensus went on the ash heap of history.

But the phases of Venus were also predicted by the Tychonic/Ursine models. So Ptolemy was down for the count, but not the stationary Earth.

Bellarmino throws a flag

Because they agreed with long-settled science, certain Scripture passages regarding the fixity of the Earth had been read by the second and third century Church Fathers as narrative—literary. And while the Church had abandoned such readings when there was certainty that they could not be literal, they did not do so when there was merely plausibility. The Protestant Reformation was in high gear, and everyone was gunshy about Scripture. Consequently, when Carmelite priest Paolo Foscarini wrote a book in 1615 defending Copernicanism, and explained how the Scriptures could be read contrary to the Church Fathers, he sounded an awful lot like Martin Luther and had to be reminded that he was not actually a theologian. Bellarmino wrote to him:

[If there were a true demonstration that the sun was in the center of the universe and the earth in the third sphere, and that the sun did not travel around the earth but the earth circled the sun, then it would be necessary to proceed with great caution in explaining the passages of Scripture which seemed contrary, and we would rather have to say that we did not understand them than to say that something was false which has been demonstrated. But I do not believe that there is any such demonstration; none has been shown to me. It is not the same thing to show that the appearances are saved by assuming that the sun really is in the center and the earth in the heavens. I believe that the one demonstration might exist, but I have grave doubts about the other, and in a case of doubt, one may not depart from the Scriptures as explained by the holy Fathers. (Bellarmino 1999)]

In short: Show me the proof. Until then, stick with the settled science.

Galileo’s former pupil Castelli meanwhile had been questioned at dinner by the Grand Duchess Christina, the mother of Galileo’s boss, on the matter of Scripture. Galileo, typically, decided Castelli had not answered as well as Galileo would have had in his place, so he wrote to Castelli and explained how Scripture could be interpreted in the light of Copernicanism. Big mistake.

After reading a copy of this letter, Dominikan Niccolo Lorini denounced Galileo and his followers to the Holy Office (7 February 1615) for “taking upon themselves to explain the Holy Scriptures according to their private lights.” Copernicanism was cited as only Galileo’s motive for private interpretation.

Getting wind of this, Galileo asked his friend Archbishop Pietro Dini to scope things out. Dini replied 7 March:

As to Copernicus, [Cardinal Bellarmine] said that he could not believe his work would be forbidden, and that the worst possibility, in his opinion, would be the insertion of a note stating that the theory was introduced save the celestial appearances, or some similar expression, in the same way as epicycles had been introduced. With this reservation, he continued, you would be at liberty.

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17 Except Mercury, which was hard to observe by eyeball.

18 This was typical of Galileo. Even after his friend Cesi wrote him (21 July 1612) extolling the need for ellipses, Galileo stuck with Copernicus’ perfect Platonic circles—and epicycles.

19 Aristotle, quite aware of this, cautioned against accepting his cosmology as certain.

20 Galileo discovered the first three moons of Jupiter on 7 January 1610. Simon Marius, court mathematician in Ansbach Franconia, discovered them independently one day later. But Marius was using the Julian Calendar while Galileo was using the Gregorian, so Marius erroneously claimed priority. Galileo went into a deep mood and accused him of plagiarism, but their notebooks made clear that their observations were independent. Marius’ words were more precise.

21 Because to be a celebrity there had to be a formal celebration.
Urban renewal

Suddenly, in August, 1623, the news burst like a star shell over the bleak landscape. Maffeo Barberini had been elected Pope. There was rejoicing in Florence. Urban VIII, as he was now, was a friend of the arts and a Lycean academic himself...[O]nly three years before, following the Discourse on the Comets, he had written his "Adulatio perniciosa" in honor of Galileo. When Prince Cesare was to congratulate Urban on his election, the Pope interrupted him eagerly: "Is Galileo coming? When is he coming?"

Galileo rushed to Rome to meet with his old friend and benefactor—six audiences in six weeks!—to address the System of the World. Urban pointed out that it was not enough to show that a replacement model was plausible, or even that it worked better than the standard model. He had to show that if the replacement model were false it would lead to a contradiction. Then he made a suggestion: Hey, dude, why not write a book setting out the arguments for and against each system? Galileo thought that was a keen idea.

The Pope later told Cardinal Zollern (and Zollern told Galileo) that "the Church had not condemned nor was about to condemn Copernicanism as heretical but that the theory was rash and that, furthermore, astronomical theories were of such a kind they could never be shown to be necessarily true."

Dialogue of the Dead

Galileo intended all along not to weigh the pros and cons, but to demonstrate Copernicanism beyond all doubt. This was a daunting task, since the Copernican model was in fact wrong. Galileo's refusal to consider eclipses (or to credit Kepler in any way) was a major obstacle.

Meanwhile, Galileo set about alienating his biggest fans: the Jesuit astronomers. He had already called Scheiner over the sunspots; now it was Grassi's turn. Grassi had meticulously observed the three Comets of 1518 and concluded (as Tycho had in 1577) that comets were on non-circular orbits originating beyond the Moon. Offended that Grassi didn't mention him in the book, Galileo marked up his copy: "piece of asininity," "buffoon," "evil poltroon," "ungrateful," and in The Assayer (1627), he addressed Grassi:

“You cannot blame it that it was granted to me alone to discover all the new phenomena in the sky and nothing to anybody else...

So much for Harriot, Marius, Fabricius, Scheiner, and the rest. He also referred to Tycho's "alleged observations" and to comets as "Tycho's monkey-planets." Then, although he had not observed them himself, he confidentially proclaimed that comets were emanations in the Earth's atmosphere! Starting a flame war had paid off. Starting one when you're dead wrong is worse.

Galileo kept looking for the knock-out punch. At first he thought the path of sunspots proved the Earth's motion. They traced a straight line across the Sun's face only during Earth's solstices. If the Earth circled a Sun inclined to the ecliptic, this semiannual cycle made sense! But in 1629, for reasons account for sunspots paths more accurately and deduced the Sun's inclination while retaining a stationary Earth. It made sense the Tychonic way, too.

Galileo thought he had answered the parallax problem, too. The stars were much farther away and the parallax too small to see. But stars seen through telescopes of small aperture, such as those used in the seventeenth century, "appear as well-defined, albeit entirely spurious, disks," which argued against the Copernican model for the same reasons Tycho had given. Theoretical resolution wasn't yet up to the task. (Graney, 126 Arguments Concerning the Motion of the Earth 2011)

Galileo proposed a test. Find an optical double: a small dim star right next to a large bright star. Like everyone else, he thought small and dim meant farther away and the optical double was therefore a near-by star with a small angular distance from a far-off star. You ought to see parallax. But his notebooks tell us that he had already tried such an observation and had found no parallax. By his own test, he had falsified heliocentrism. So he did what any Renaissance scholar worth his salt would do and kept his mouth shut.

Finally, Galileo devised the Argument of the Tides: the dual motions of the Earth caused the oceans to slish about. Belatedly, Galileo learned that real-world tides followed a twelve-hour cycle rather than the twenty-four hour cycle his theory predicted, but "his faith in his theory was greater than his trust in what sailors reported." He wrote the Dialogue anyway.

...and used Medici muscle to wrangle the necessary permissions. The political maneuvers need not concern us. Fr. Ricciardi, Master of the Palace, had enthusiastically approved The Assayer but was now being asked "to buy a pig in a poke." He hadn't read The Dialogue. "Manipulating Father Riccardi, always so anxious to please, did not seem to them be objectionable. Hoodwinking Cardinal Francesco Barberini or, worse still, the pope, however deplorably, was another matter."

When the Dialogue finally came out in 1632, Urban's cautions about the uncertainty of astronomical theories had been placed in the mouth of Simplicio, in a very prominent position in the text. A social climber like Galileo was not foolish enough to do this on purpose, but he may have been vain enough to suppose that no one would notice. He never could resist a zinger.

Which was not a good idea in Machiavellian Italy.

[21] On 21 December 1614, Tommaso Caccini had preached a sermon denouncing Copernican views. Caccini's outraged brethren had then denounced him to the Dominican Master General, who promptly apologized to Galileo. As this and other sources demonstrate, there was no overriding theological concern.


[24] To be fair, Kepler later said that he had tried to read his own book and found it impossible to follow. Kepler was the better mathematical astronomer, but Galileo was by far the better writer.

[25] "In an exchange of letters passing through Marcus Welser, Scheiner and Galileo had, in today's parlance, crossed swords. If rash judgment were an Olympic sport, Galileo would have been the gold medalist. Sunspots are a side-show in this story, but Scheiner went on to develop the notation still used for sunspot observations and to discover the differential rotation of the Sun's hemispheres.


Got Troubles on My Mind

Urban had other concerns. The Thirty Years War was fourteen years old and the Papacy favored the French Bourbons. While trying not to annoy the Spanish and German Hapsburgs too badly. The German Hapsburgs ruled Milan and the Spanish the Two Sicilies, with the Papal State smack between. The Spanish cardinals, especially Gasparo Borgha, were in open dissent from the Franciscan policy. Galileo's friend and supporter, Vittor Gampacci, was discovered to be in league with this faction, while Galileo's patron, the Grand Duke of Florence, was an ally of the Austro-German Hapsburgs. And Florence had claims on Roman territory, the Duchy of Urbino.

Domestically, the Roman public was disgruntled with the Barberini family, and horoscopes were being cast against them predicting an early fall from power. On 18 May 1629, the Roman gospel sheet Avviso had reported that Galileo had cast horoscopes on the Barberini family foretelling the Pope's imminent death. Not good.

The last thing Urban needed was some pilddling hoo-hah over astronomical mathematics.

Then someone pointed out the apparently gratuitous insult offered in the conclusion of the Dialogue.

And the rest is history.

Aftermath

But this is the story of how heliocentric models overthrew geocentric ones, and Galileo's Dialogue didn't do that. In it, he referred to his opponents as "dumb idiots" and "mental pygmies, hardly deserving the name of human beings," but while that might pass for Renaissance wit, it will not do for scientific

models and Kepler's model, with the Uranus model being "ahead on points." Galileo did not mention them.

Galileo's book "proved popular amongst literati who were not astronomers [and] who enjoyed his very obvious polemic writing skills; but contrary to popular opinion it didn't play a significant role in the contemporary scientific discussion." (Christie, Galileo's great bluff 2010)

In 1651, Fr. Giovanni Battista Riccioli SJ published Almagestum novum, in which he gave 49 arguments in favor of the Copernican model and 77 arguments against, with rebuttals of each. This was the book Galileo was supposed to write. Contrary to popular belief, Riccioli did not simply count the number of arguments, since they were of unequal weight; nor did he decide on the Tychoic model for religious reasons. Rather, he emphasizes again and again the need for sensible evidence as the deciding factor.

Both sides present good arguments as point and counter-point. Religious arguments play a minor role in the debate; careful, reproducible experiments a major role. To Riccioli, the anti-Copernican arguments carry the greater weight, on the basis of a few key arguments against which the Copernicans have no good response. Given the available scientific knowledge in 1651, a geocentric hypothesis clearly had real strength, but Riccioli presents it as merely the "least absurd" available model... (Graney, 126 Arguments Concerning the Motion of the Earth 2011)

The "key arguments against which the Copernicans had no good response were the lack of parallax and Coriolis effects. Graney states, "Today, a new theory which predicts observable effects that are not observed, while requiring the ad hoc creation of an unprecedented new type of object [gigantic stars], would have limited appeal; even if it were mathematically elegant." The Tychoic model fit the data better. It predicted all the same phenomena as the Copernican, plus it explained why there was no visible parallax or Coriolis.

But by 1660, nearly 120 years after heliocentrism had been formally proposed, Kepler's elliptical model had won the contest. Kepler's Rudolphine Tables were just easier. In the Platonist Renaissance, that carried weight.

The astronomical community accepted the epilines with nary a murmur and the Third Law was widely accepted. However, the Second Law (the Equal Area Law) has rejected as ugly and Kepler's proof was deficient. Not until 1672 did Nicolas Mercator develop a correct mathematical derivation. (Christie, Galileo's great bluff 2010)

Then, in 1687, Newton presented his theory of Universal Gravitation. It's hard for the Late Modern to grasp what a stunning achievement this was. Suddenly, everything made sense! There was a solution to all the planets, to all the motions! Finally, a simple, elegant reason why Kepler's model ought to be true.

Just one problem: or rather two:

- There was still no parallax.
- There was still no Coriolis effect. Dang! But we can't let inconvenient facts get in the way of a really cool theory.

Fat lady finally sings

By this time the telescopes were good enough that the stars were clearly pinpoint. That meant they really could be much farther away without being gigantic new entities. Everybody supposed the parallax was simply too small to detect.

The lack of Coriolis was more troubling. Even though a rotating Earth had been more easily accepted than a revolving Earth, the motion was still undetected. Newton had described an experiment—dropping a musket ball from a tower—and Hooke had carried it out. But he reported finding no deflection.

53 Summarized in capsule form in (Graney, 126 Arguments Concerning the Motion of the Earth 2011)
54 This is about par for the course for new scientific paradigms. Both relativity and quantum mechanics needed a century to go from "wild hypothesis overthrowing the wisdom of the ages" to "standard model."
In the Legend, the conflict was between Science and Religion. But in the History, the conflict was between two groups of scientists, with churchmen lining up on all sides. Copernicanism was supported by humanist-literati and opposed by Aristotelian physicists; so it was a mixed bag all around.

Science does not take place in a bubble. International and domestic politics and individual personalities roll the pot as well. The mystery is not why Galileo failed to triumph—he didn’t have good evidence, made enemies of his friends, and stepped into a political minefield. The real mystery is why Kepler, who actually had the correct solution, constantly flew under the radar. A devout Lutheran working in a Catholic monarchy, he pushed Copernicanism as strongly as Galileo, but he had no one else to blame over it. Too bad he couldn’t write his way out of a paper bag.  

Bibliography: