How to Make the Earth Orbit the Sun in 1614

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Abstract
In 1614 the Jesuit astronomer Christoph Scheiner and his student, Johann Georg Locher, proposed a physical mechanism to explain how the Earth could orbit the sun. An orbit, they said, is a perpetual fall. They proposed this despite the fact that they rejected the Copernican system, citing problems with falling bodies and the sizes of stars under that system. In 1651 and again in 1680, Jesuit writers Giovanni Battista Riccioli and Athanasius Kircher, respectively, considered and rejected outright this idea of an orbit as a perpetual fall. Thus this important concept of an orbit was proposed, considered, and rejected well before Isaac Newton would use an entirely different physics to make the idea that an orbit is a perpetual fall the common way of envisioning and explaining orbits.

Keywords
Orbit, gravity, Locher, Scheiner, Riccioli, Kircher, Newton, Jesuit

Introduction
In the second decade of the seventeenth century, well before the birth of Isaac Newton, a German Jesuit astronomer and his student proposed a physical mechanism to explain how the Earth could orbit the sun: Earth could be likened, they said, to a massive ball, perpetually falling towards the sun. A few decades later, while Newton was just a boy, an Italian Jesuit astronomer dismissed the idea in its entirety, and the explanation of an orbit being a perpetual fall would wait for Newton to revive it.

The student was Johann Georg Locher, whose thesis, the 1614 book *Disquisitiones Mathematicae de Controversiis et Novitatibus Astronomicis*, or *Mathematical Disquisitions Concerning Astronomical Controversies and Novelties*, was a well-illustrated but short (less than 100 pages) work. Little is known about Locher himself other

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than what he says in Disquisitions: he was from Munich, and he studied at Ingolstadt under the Jesuit astronomer Christoph Scheiner. This is the same Scheiner with whom Galileo debated regarding sunspots and who would go on to write a monumental 1630 book based on his long-term, detailed solar observations: Rosa Ursina Sive Sol. Disquisitiones, whose title page states that Locher has put it forth “Christoph Scheiner presiding,” has always been seen as being essentially Scheiner’s work. It was common for a student to defend, and often pay the publication costs of, a thesis written by the presider. The title page of such a work typically featured the presider’s name uppermost, in the most prominent type, with the student’s name lower and smaller, and such was the case with Disquisitions (Figure 1). Thus Giovanni Francesco Sagredo, in a 27 August 1616 letter to his friend Galileo, described it as “the work of Jesuit P. Cristofforo Scheiner, who is that friend of S.r Velser, whose head you once washed without soap, because of
the disrespectful manner in which he wrote of me.” Sagredo added that he did not care for “the teachings of this most pretentious man.”2 Galileo himself devoted quite a few pages of his 1632 Dialogue Concerning the Two Chief World Systems—Ptolemaic and Copernican to making sport of Disquisitions. It was the “booklet of theses, which is full of novelties”3 that Galileo had his less-than-brilliant character Simplicio drag out in order to defend one or another wrong-headed idea.

**Orbit as perpetual fall**

But Disquisitions was not so wrong-headed.4 It reported on all the telescopic astronomical discoveries that were new in 1614: spots on the sun, Venus showing phases, Saturn having “attendants” (not yet understood to be rings), moons circling Jupiter. It devoted much attention to Jupiter. It featured representations of the Jovian system as seen through the telescope on different nights – representations that depicted the positions and brightnesses of the four moons with remarkable accuracy. It showed the Jovian system and the Jovian shadow as seen from above the plane of the orbits of the moons (Figure 2). Indeed, in other works by Scheiner I have found nothing comparable to these Jovian system diagrams, nor to many of the other illustrations in Disquisitions, and nothing like the falling ball work, so I am inclined to think that Disquisitions is not essentially Scheiner’s work, but rather reflects a real contribution from Locher, and for the purposes of this paper I will generally refer to “Locher” rather than “Scheiner and Locher.” Thus, Locher proposed a method by which timings of the passages of the Jovian moons through the Jovian shadow could be used to calculate the angles needed to trigonometrically determine Jupiter’s distance to the sun. He called for astronomers to come together to engage in a cooperative programme of observations to do this. “All astronomers should turn their efforts toward refining the observations of [the Jovian system],” he wrote, “… exact knowledge of the first emergences of the satellites from the shadow of Jupiter … will require diligent and frequent observations.”5

But the most interesting material in Disquisitions is not the discussion of Jupiter. Rather, it is the discussion on the physics of an orbit. This discussion treats an orbit in a manner not at all wrong-headed – as a perpetual fall – and it is found in Locher’s 15th disquisition. The disquisitions are not individually titled, but Disquisition 15, and Disquisition 14 before it, concern movement downward on Earth. “Everyone,” Locher writes in Disquisition 14, “even Copernicans, acknowledges heavy bodies to be pulled down toward the center of Earth along a vertical line.”6 Disquisition 14 questions how this can happen on a rotating Earth since (on account of differing distances from Earth’s axis of rotation), an object near the pole moves at a different speed than an object near the equator, and objects at different heights above a given point on Earth’s surface move at different speeds (see Figure 3). Disquisition 15 notes that the downward urge of heavy elements is the reason why the terrestrial globe exists, and why its centre of gravity coincides with its geometric centre. However, because of evaporations and eruptions and other processes, the centre of gravity is changing, and therefore “the globe itself must vacillate with a certain perpetual, but entirely insensible, trembling.” Locher then says that, “perpetual motion is not incompatible with nature.”7 And, from this statement, he launches into his discussion of orbital “perpetual motion.”8
Imagine, says Locher, an L-shaped rod – or gnomon, as Locher calls it – buried in the Earth. The asymmetry of the rod means that it would topple were it cut off at Earth’s surface. This would be all the more true, he says, were a heavy iron ball attached to the end of the rod, as shown in Figure 4(a).

Now, Locher says, imagine the rod being hinged at the Earth’s surface (at point A in Figure 4(b)). The heaviness or gravity of the ball (i.e. its action of trying to reach its natural place at the centre of the universe – Aristotelian physics being the rule in 1614, and

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**Figure 2.** Disquisitiones diagram of Jupiter (81) with its moons and shadow. Note that Jupiter is being illuminated by a sun (ε) which is itself orbiting Earth (α). Image courtesy of ETH-Bibliothek Zürich, Alte, and Seltene Drucke.
Newtonian physics lying decades in the future) presses down on the rod, but the rigidity of the rod keeps the ball from falling straight down, so the ball causes the rod to pivot about the hinge. The ball falls along an arc of a circle whose centre is A. The ball strikes the Earth at B.

Next, says Locher, imagine that the Earth is made smaller relative to the rod. The same thing still occurs – the rod pivots; the iron ball falls in a circular arc (Figure 4(c)). If the Earth is imagined to be smaller still, the rod will be what hits the ground, not the ball (Figure 4(d)), so the ball stops at its lowest possible point C, but still falls in a circular arc whose centre is A. If the Earth is imagined to be progressively smaller, the ball still falls, driven by its gravity, in a circular arc (Figure 4(e) and (f)).

Finally, Locher says to imagine the rod to be pivoting on the centre of the universe itself – the Earth vanishing to a point (Figure 4(g)). Surely, he says, in this situation, a complete and perpetual revolution will take place around that same pivot point A (*fiat revolutio integra & perpetua circa idem A*). If the rod is put into motion, it will circle...
back around to its starting point, and continue on from there again, as before, “and so on into perpetuity.”

Figure 5 is the illustration of this that Locher made for Disquisitions. Curves MN, OP, and QR are the surface of the Earth, being imagined smaller and smaller. S is the iron ball. A is the centre of the universe. Circle CHIC is the path of the orbiting ball.

In this way, says Locher, we see that perpetual circular motion by a heavy body is possible. And if we imagine the Earth being in the place of the iron ball, suspended over the centre of the universe, he says, now we have a thought experiment (cognitione percepi possit – it may be able to be perceived by thought) that shows how the Earth might be made to revolve about that centre, and therefore about the sun, which sits at the centre of the universe in the Copernican world system. The Earth would revolve about the sun.
because it would be perpetually falling into the sun, in the same manner as the iron ball would be falling into Earth.

**Rejecting the mechanism just proposed**

Today we commonly explain orbits as a perpetual fall, following Newton’s own discussion of a perpetually falling iron ball: his explanation of orbits using a cannon ball launched from atop a mountain (Figure 6). Thus the discussion in *Disquisitiones* seems prescient. However, Locher himself attributed little weight to this idea. Even if such motion could actually occur, it would not help the Copernicans, he said, because it explains no observations.

Locher was a geocentrist. He felt that observations of both astronomical and terrestrial phenomena supported an Earth-centred world system, and opposed any motion of the Earth. He backed the world system of Tycho Brahe, in which the sun, moon, and stars circled an immobile Earth while the planets circled the sun – a system that was fully compatible with the new telescopic discoveries (in his Jupiter diagram, the Jovian system...
is being illuminated by a sun that itself circles the Earth). The moons of Jupiter he saw as supporting the old Ptolemaic concept of epicyclic motion – circles moving upon circles. Ptolemy had postulated the existence of epicycles, Locher said, in order to explain the visually observed motions of the planets. Now, however, “the optic tube has established … that the centre of the motions of the Jovian satellites is Jupiter …. Therefore epicycles do exist in the heavens” – the Jovian moons move in circles around Jupiter while Jupiter moves along its own circle.¹⁰ As noted previously, Locher also questioned at length how falling bodies could be observed to descend vertically on a rotating Earth.¹¹ And he attacked the Copernicans for their views regarding the sizes of stars. Even viewed through a telescope, stars were observed to have small but measurable discs (Figure 7), discs that in the first half of the seventeenth century were yet to be understood as spurious artefacts of the diffraction of light waves. Under the Copernican world system, stars had to be so distant that by comparison the Earth’s orbit was like a point – immeasurably small, producing no observable effects (i.e. no annual parallax). Locher noted that, since “small but measurable” is larger than “immeasurably small,” under the Copernican system every last visible star had to be larger than the Earth’s orbit. The Copernicans did not deny this, said Locher. “Instead,” he wrote, “they go on about how from this everyone

Figure 6. “Cannon on a mountain” illustration – from Newton, A treatise (ref. 9), 6. Image courtesy of Google Books.
may better perceive the majesty of the Creator,” an idea he called “laughable.” Locher did not believe that his mechanism for explaining how Earth might orbit the sun could save the Copernican system from its flaws.

No doubt this leaves the reader wondering why Locher (and Scheiner) ever developed the perpetual fall orbit mechanism in the first place. Disquisitions will not help the reader in this regard – the next disquisition (the 16th) pertains to how the sun shines hotter in the summer than in winter by reason of the angle at which its rays impinge on the ground, and in no subsequent disquisition does Disquisitions return to the subject of orbits or falling bodies. The almost free-standing discourse on the orbit mechanism is, however, entirely in keeping with the character of the book, which contains similar free-standing digressions into subjects such as infinite motion along a quarter of a circle, how light rays combine to illuminate a surface, and whether various celestial bodies would show phases like the moon were they to be seen from different locations in the planetary system.13
In 1651, Giovanni Battista Riccioli, an Italian Jesuit astronomer, took aim at the idea that *Disquisitions* described a mechanism for explaining how Earth could orbit the sun. Riccioli was another Brahe-style geocentrist. In his 1651 book *Almagestum Novum*, or *New Almagest* (referencing Ptolemy’s classic *Almagest*), he further developed the star size argument against Copernicus; he also went beyond questions about falling bodies and differing speeds on the surface of a rotating Earth, to develop arguments against Earth’s motion in which the modern reader will recognize the “Coriolis Effect” (Figure 8). But while Riccioli may have been of like mind with Locher and Scheiner on these matters, he dismissed the *Disquisitions* orbit mechanism in short fashion (Figure 9). Crediting *Disquisitions* to Scheiner, Riccioli wrote, “that most acute explorer of the sun hallucinates [hallucinatur].” Riccioli noted how his own assistant, Francesco Maria Grimaldi (also a Jesuit, who Riccioli had credited with the bulk of the work in honing the...
Coriolis arguments, and who would go on to discover the phenomenon of diffraction), said that objects fall when they can move in the direction of that point towards which they gravitate – that is, towards the centre of the Earth. The iron ball cannot move towards the centre in the *Disquisitions* discussion, said Riccioli, therefore it will not fall. Even were the ball to be set in motion it would not move perpetually, for any external impulse given to it would naturally evanesce. Riccioli and Grimaldi simply did not grasp the thought experiment presented in *Disquisitions*. Riccioli considers only the final case of the ball orbiting a point. He omits mention of the rod and ball standing on Earth’s surface and toppling. The idea of imagining the Earth to be smaller and smaller, and supposing that if the iron ball would naturally move in a circular path for an arbitrarily small Earth, then it would do so for a vanishingly small Earth, seems to have eluded the grasp of Riccioli and Grimaldi.

Unfortunately for Locher and Scheiner, Riccioli carried the day. The *New Almagest* came to be “the most important literary work of the Jesuits during the seventeenth century.” Robert Hooke read it, and discussed with Newton some of the “Coriolis Effect” ideas within it. England’s first Astronomer Royal, John Flamsteed, used it as a textbook.
for public lectures at Gresham College in 1665 (certainly anyone carrying a copy of the *New Almagest* to a lecture would have looked quite learned for, compared to *Disquisitions*, the book was huge – two volumes, each the size of one of today’s large coffee-table books, together comprising over 1,500 pages of dense text and diagrams). Perhaps Riccioli’s dismissal is why another prominent Jesuit author, Athanasius Kircher, included in his 1680 book *Physiologia* a copy of the orbit diagram from *Disquisitions* (Figure 10), along with an insultingly dismissive discussion. “Here I cannot disregard,” wrote Kircher, not mentioning Locher or Scheiner by name, “the vain fabrications and manifest paralogisms
of some, which they believe—no, they assert—to demonstrate artificial perpetual motion to be able to be made by a sure way around the center of earth, and which they strive to show by this reasoning ....” After providing a synopsis of the mechanism (a synopsis that again overlooked the concept of Earth being made smaller and smaller), Kircher continued, “I can hardly keep from laughing at the deceitful fallacies of the human imagination.” According to Kircher, this whole idea was the equivalent of saying that, were a trough built that encircled the globe, a ball would roll around it, or water would continuously flow around it, forever.

Of course, by the time Kircher wrote this, Isaac Newton was already building the physics we now use. Unlike Locher and Scheiner, Newton departed from Aristotelian physics entirely, but he and they both agreed that an orbit is essentially a perpetual fall. It seems useful then to at least consider the question of whether Newton ever encountered and perhaps might have even been inspired by the ideas found in Disquisitions. There are indeed hints suggesting that he might have encountered them, at least through Riccioli. Newton had a copy of the Almagestum Novum in his library. He and Robert Hooke exchanged letters in 1679–1680 regarding the easterly deflection that a heavy ball, suspended by a cord and then released, should exhibit were Earth rotating – one of the “Coriolis” arguments advanced by Riccioli against Earth’s rotation (the apparent absence of such deflection indicating Earth’s immobility to Riccioli). Newton references Riccioli in his first edition of the Principia, but only in relation to the distance to the moon. Evidence that Newton ever encountered Disquisitions itself, however, is difficult to turn up, and it seems doubtful that Riccioli’s perfunctory discussion of the Disquisitions orbit mechanism would have provided inspiration to anyone. Nonetheless, the question of a Disquisitions-Newton connection might be worth further investigation.

Conclusion

Locher seems to have left no scientific trace after 1614. I can find no other published reference to him, despite significant searching. References to Disquisitions mention Scheiner if they mention an author. Perhaps Locher died shortly after publishing Disquisitions, or went off to missionary work in some far-flung place. Had he remained active in the scientific community, perhaps he might have developed his physics further. After all, he (and Scheiner) came up with the idea that an orbit is a perpetual fall.

We see from the works of Locher and Scheiner, Riccioli, and Kircher that the idea of an orbit being a perpetual fall was proposed as early as 1614 by a Jesuit astronomer and his student, and that the idea did circulate among knowledgeable readers – it came to the attention of and was discussed by two prominent Jesuit authors. However, the idea of an orbit as a perpetual fall was dismissed by those authors, and it had never been further developed by its originators. It would be proposed again by Isaac Newton, under a new physics, and would come to be a common explanation of how an object remains in an orbit.

Note on contributor

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Notes

1. Johann Georg Locher, Disquisitiones mathematicae, de controversiis et novitatis astronomici (Ingolstadt, 1614); complete English translation in C.M. Graney, Mathematical Disquisitions: The Booklet of Theses Immortalized by Galileo (Notre Dame, IN: University of Notre Dame Press, 2017).

2. Sagredo’s letter is found in Società Editrice Fiorentina, Le opere di Galileo Galilei: opere astronomiche. 1842-1853 prima edizione completa (Firenze, 1856), p. 112. I thank Lorenzo Smerillo and Roger Ceragioli for their assistance with translating Sagredo’s letter from Italian via the HASTRO-L history of astronomy listserv on May 4, 2016. According to Smerillo, the “head wash” idiom is still in use in Italian. Eileen Reeves lists a number of early seventeenth century authors who likewise refer to Disquisitions as Scheiner’s work, including Giuseppe Biancani, Marin Mersenne, Johannes Hevelius as well as the authors discussed in this paper – see E. Reeves, Painting the Heavens: Art and Science in the Age of Galileo (Princeton, NJ: Princeton University Press, 1997), p. 205. For examples of modern authors who attribute Disquisitions to Scheiner, see A. Van Helden and E. Reeves, On Sunspots (Chicago, IL: The University of Chicago Press, 2010), a book specifically on Scheiner that speaks of Disquisitions as though it were Scheiner’s (pp. 307–8); also see S. Drake, “Galileo Gleanings III: A Kind Word for Sizzi,” Isis, 49, 1958, pp. 155–65, pp. 157–8; and J. Heilbron, Galileo (Oxford: Oxford University Press, 2010), pp. 275–6, 436. For a discussion of these, students, presiding professors and title pages at the time of Disquisitions, see W. Clark, Academic Charisma and the Origins of the Research University (Chicago, IL: The University of Chicago Press, 2006), pp. 204–10.

3. G. Galilei, Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican, trans. by S. Drake (New York: Modern Library, 2001), p. 105.

4. See Graney, Mathematical disquisitions (ref. 1), pp. xi–xxiv.

5. Ibid., p. 97.

6. Ibid., p. 31.

7. Ibid., pp. 40–41.

8. Locher’s orbit discussion is found in Conclusion 4 of Disquisition 15—Locher, Disquisitiones mathematicae (Ref. 1), pp. 36–38; Graney, Mathematical disquisitions (ref. 1), pp. 41–43.

9. I. Newton, A treatise of the system of the world (London, 1728), pp. 5–8.

10. Graney, Mathematical disquisitions (Ref. 1), pp. xviii, 55.

11. Ibid., pp. 31–39.

12. Ibid., pp. 27–31. For an illustration of certain Copernicans invoking the Creator as an answer to the star size issue, see C.M. Graney, Setting Aside All Authority: Giovanni Battista Riccioli and the Science against Copernicus in the Age of Galileo (Notre Dame, IN: University of Notre Dame Press, 2015), pp. 63–86.

13. Graney, Mathematical disquisitions (ref. 1), pp. 47–49, 87–88, 102–103.

14. See Graney, Setting Aside all Authority (ref. 12), pp. 115–140.

15. G.B. Riccioli, Almagestum Novum, vols. 2. (Bologna, 1651), p. 1:54: “Sed hallucinatur Solis ille acutissimus explorator.”

16. Ibid., p. 1:54.

17. J.J. Walsh, Catholic Churchmen in Science (Philadelphia, PA: Dolphin Press, 1969 [1909]), p. 200; The Catholic Encyclopedia, vols. 15. (New York: Encyclopedia Press, 1913), p. 13:40.

18. Graney, Setting Aside all Authority (ref. 12), pp. 121–4.

19. Athanasius Kircher, Physiologia (Amsterdam, 1680), p. 8: “Hoc loco omittere non possum non-nullorem vana technasmatata, & insignes paralogismos, qui putant, imo demonstrare contendunt, motum artificialem perpetuum, certo modo in centro terrae confici posse, idque hac ratione ostendere nituntur … fallaces humanae imaginationis illusiones non potui non ridere.”
20. Ibid., p. 9.
21. J. Harrison, *The library of Isaac Newton* (Cambridge: Cambridge University Press, 1978), p. 227; I thank an anonymous referee for suggesting that this paper include a discussion of whether Newton may have encountered Locher’s work, and noting that Newton had a copy of the *Almagestum Novum* in his library.
22. Graney, *Setting Aside all Authority* (ref. 12), pp. 118–25.
23. I. Newton, *Philosophiae Naturalis Principia Mathematica* (London, 1687), p. 413.
24. Or perhaps Locher went into charity work in a nearby place. In F.X. Freninger (ed.), *Das Matrikelbuch der Universitæt Ingolstadt-Landshut-München* (Munich: Munich University, 1872) under “Doctoren der Rechte” appears “Joh. Georg Locher, München [Munich]” for 1617 (p. 45). In G. V on Bezold (ed.), *Die Kunstdenkmale des Regierungsbezirkes Oberbayern* (Munich, 1895), there is noted a “Georg Locher, Waisenpfleger aus München” - a person who cares for orphans - as having in 1649 donated art to a certain church (p. 859).