The Scientific Revolution: Crash Course History of Science #12

Crash Course: History of Science
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You've probably heard about a Scientific Revolution in Europe, lasting from roughly the mid-1500s to 1700.

And we have some very good stories to tell from this period. But first, let's talk historiography, or how historians have told history differently over time.

The trope of the Scientific Revolution is a useful tool for organizing events in our story. But it also obscures other possible framings. In fact—as we pointed out in episode one—the term "science" wasn't used in its contemporary sense until the mid-1800s!

So did a "Scientific Revolution" take place at all? [INTRO MUSIC PLAYS] Philosopher, historian, and trained physicist Thomas Kuhn had a lot of thoughts on what makes a revolution in science. He wrote a book called The Structure of Scientific Revolutions, published in 1962. And in it, Kuhn argued that different sciences undergo "revolutions" when scientists gather enough data that they can't explain using their current paradigm, or unstated, world-organizing theory about how the universe works.

Kuhn's ideas have animated a lot of debates in the history and philosophy of science, so let's make sure we're clear about them. Normal science is the kind of knowledge that professional scientists—or natural philosophers—make most of the time. They have a combined research program and philosophy about what counts as valid knowledge called a paradigm.

Anomalies are things that the paradigm can't explain. Too many anomalies and… we have a scientific revolution! Galileo and Newton overturn Aristotle!

Einstein overturns Newton! Or, jumping back to the mid-1500s, Copernicus overturns Ptolemy! Historians of science often associate the start of the Scientific Revolution with a Polish politician and all-around smarty-pants named Nicolaus Copernicus. (Nick—keep waiting in the green room until we need you!) But we could just as easily begin with another Nick—Nicole Oresme.

Oresme argued for heliocentrism, or the theory that the earth might revolve around the sun, one hundred and sixty six years before Copernicus! Oresme was born around 1320 in Normandy, France. He attended the College of Navarre, rather than the prestigious University of Paris, so he probably came from a humble background.

But he was very intelligent, becoming grand master of the College of Navarre and then a bishop. Oresme spent a lot of time trying to answer one of our big questions: "where are we?" He went about this rationally, for example, lining up arguments for or against an earth that rotates on its axis in his book Livre du ciel et du monde, or The Book of Heaven and the World, in 1377. He noted that it made more sense for the earth to move than for all of the heavens to move around the earth.

Nevertheless, Oresme concluded that the bible dictates that the earth must remain still and chill. So close! Oresme also criticized astrology as a predictive science, noting that the lengths of days don't line up perfectly with years, making the recurrence of certain astronomical phenomena very rare.

My dude even noted that farmers and sailors are better at predicting the weather than astrologers! And Oresme contributed a lot to math and physics. He pioneered the use of mathematical graphs to describe how objects move through space over time.

And he scooped Galileo on the physics of falling objects, again by well over a century! Oresme's theories could have helped jump-start a revolution in the physical sciences… but they didn't. Why?

Maybe because he didn't really push them, and his contemporaries didn't see them as particularly important. A little over a century later, another polymath named Copernicus worked on some similar problems with more radical results. Historiography strikes!

There is so much cool history out there, historians have to make hard choices about when to "start" a big idea and whose name to pin to it. Okay, Nick—now we're ready for you! Nicolaus Copernicus was born in 1473 in what is now Poland to a family of well-off merchants.

We don't have a ton of documents by Copernicus, up until his major work on astronomy. But we know that he went to school around 1500 to be a humanist. Copernicus probably spoke Latin, German, Polish, Greek, and Italian, and he translated Greek poetry.

He studied arts, math, and astronomy at the University of Kraków. And he visited the Universities of Bologna and Padua. Along with the liberal arts, Copernicus also studied medicine.

He would later work mostly as a sort of private physician-slash-economist for the high-ups back in Poland. But the reason that we're talking about this Nick is that he took up astronomy. He decided that retrograde motion—planets seemingly traveling around in loopty-loops!—was an "astronomical monster," an obvious impossibility.

Copernicus also repudiated Ptolemy's "equant point"—an imaginary mathematical point that helped earlier astronomers see planets move at uniform speeds. Ultimately, Copernicus proposed a heliocentric universe of the cosmos: in this model, the earth rotates on its axis once every twenty-four hours, and the Earth revolves around the sun once every year. Copernicus first wrote about heliocentrism in his Commentariolus, or mini-commentary, in 1514.

He was afraid that many people—being devout Aristotelians, Ptolemy-ians, and Christians—would ridicule his life's work. Most people thought heliocentrism was wrong, and many found the idea downright blasphemous. So for years, the only source of Copernicus's radical new theory was the outline that his protege Rheticus published in 1540, called Narratio prima, or The First Account.

When he was facing the end of his life, however, Copernicus relented. On his deathbed in 1543, he received the first copy of his book, which I'm going to attempt to pronounce now... De revolutionibus orbium cœlestium, or what all the cool cats call "De rev"—On the Revolutions of the Heavenly Spheres.

According to legend, Copernicus woke up from a coma, took one look at the published De rev, smiled—and died peacefully, knowing that his great work would finally reach a wider audience. And also that he couldn't get persecuted for it cause he was super dead! As happens often in the history of science, Copernicus's contribution wasn't really coming up with a new idea, but taking a non-mainstream idea and explaining it in a way that made people paid attention.

In proposing a sun-centered cosmos, Copernicus was working on a theory that had never really caught on in Europe but had also never really gone away. Besides his fellow-Nick, Oresme, Copernicus knew about the heliocentric model espoused by the ancient Greek astronomer, Aristarchus of Samos, who was born around 310 BCE, about a decade after Aristotle died. Aristarchus was waaay ahead of his his time: he put the sun in the center of the solar system, and then put the planets in their correct order around it.

He guessed that other stars were like the sun, just farther away. He even deduced that the earth rotates on its axis. But most

astronomers rejected Aristarchus's ideas… until Copernicus.

If there's any guy in history that told us where we were the best, it was that Greek dude that everyone forgot about. But people paid attention to Copernicus. ThoughtBubble, shine some light on why his book about revolutions was revolutionary: De rev was not based on new observations, and it did not prove heliocentrism.

In it, Copernicus hypothesized that his theory must be a better-fit model for the cosmos than the geocentrism of Ptolemy, because a sun-centered model was more "pleasing to the mind." And Copernicus's theory was so pleasing! In his heliocentric model, retrograde motion disappeared. Copernicus dictated a definite order of the planets: Mercury, Venus, Earth, Mars, Jupiter, and then Saturn.

Copernicus's theory also made the universe twenty times wider across than Ptolemy. Which turned out not to be big enough, turns out the universe is very big—but still so big that most people didn't believe it. But Copernicus didn't revolutionize everything about the Christian–Aristotelian cosmos.

For one, Copernicus's math was a disaster. And, in his theory, the Earth and other planets revolved around a center point that was near the sun, but wasn't exactly the sun. And the planets were still embedded in crystalline spheres.

For Copernicus, the idea that the earth rotates on its axis was the "third motion." That is, along with the rotation of the whole sphere, defining a year, and a transition from day to night, defining a day. The third motion explained the other stuff. Thanks Thought Bubble, Nick's grand theory fit into the first twenty-four pages of his book.

The rest was dense and, frankly, not very revolutionary astronomy. Copernicus used Ptolemy's fifteen-hundred year old data to build his system. So maybe Copernicus wasn't a revolutionary within science, just one more in a long line of good astronomers.

The Scientific Revolution is sometimes positioned as a break in Europe between a Christian concept of knowledge and a secular or worldly one. Certainly, Copernicus's cosmos doesn't look like Dante's. But if De rev was a break, it wasn't very sharp.

Copernicus was a diplomat, a religious person, and generally risk-averse. He was a canon in the church—a position just below bishop. He dedicated De rev to Pope Paul III.

Protestant leader Martin Luther did reject heliocentrism. But this didn't become a public controversy until Galileo's time, a hundred years later. In fact, Copernicus's publisher, Andreas Osiander, added an anonymous preface to De rev, saying that the book was only a thought experiment: it didn't need to be true to help astronomers better understand the math behind the motions of the planets, and thus make better predictions about them.

It didn't even need to be probable. This was… not exactly a battle cry challenging conventional cosmology. Regardless—according to a common version of the history of science—this is how the Scientific Revolution started.

Was it a revolution? The majority of people on earth didn't know the Scientific Revolution was starting when De rev appeared. They didn't see any armies forcing them at gunpoint to think about the fact that—plot twist—the earth revolves around the sun.

The "battles" about this, when they occurred at all, took place in the halls of universities or between the covers of books that most people couldn't even read! It's true that, by 1700, European thinkers had pretty much moved away from the science of Aristotle and Ptolemy, or at least many parts of it. But the concept of the Scientific Revolution comes from the nineteenth century.

Historians looked back and said: "How Europeans answered big questions such as 'where are we?' really started to change around the middle of the 1500s. By the middle of the 1600s, natural philosophers had developed new methods of making all kinds of knowledge. We dub this shift, 'the Scientific Revolution!'" This idea of a break makes sense when you remember the motto of the Royal Society, "nullius in verba"—don't believe something just because Aristotle said it!

Natural philosopher such as Francis Bacon and Robert Boyle pushed for experiments and published their results in journals. And more people had access to books like De rev, thanks to Gutenberg. So you can call it either way: a revolution didn't take place, because the number of people involved at the time was small, and not much changed in daily life due to new ideas in science.

Or a revolution did take place, because Galileo got in trouble for looking at Jupiter, Newton invented calculus, and French and English natural philosophers could argue via journal. We're gonna talk about all these stories soon! In conclusion: people named Nick make the best astronomers.

Two of them helped catch medieval Europe up to the astronomical knowledge level of India, or classical Mesoamerica. (Remember how the Maya were really, really into astronomy, centuries ago?) So the idea of "the" Scientific Revolution, in early modern Europe, doesn't make as much sense as the idea of many scientific revolutions in different places at different times. And finally—and this is so critical!—just as science is an active area of research today, history is too. Historians have to choose what stories to tell and how to most accurately frame them for their own times and places.

Next time—we'll accompany science-boss Tycho Brahe on a duel and meet Copernicus's historical brother from another mother, Johannes Kepler. Crash Course History of Science is filmed in the Dr. Cheryl C. Kinney studio in Missoula, MT and it's made with the help of all these nice people. And our Animation team is Thought Cafe. Crash Course is a Complexly production.

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