MAGNETIC PHILOSOPHY

"But what is it that carries the planets around the Sun — for Tycho and Copernicus agree on this point — what then but a magnetic effluvium from the Sun? Truly, what is it that makes the planets eccentric from the Sun, that compels them to approach the Sun and to recede from it? Obviously an effluvium from the bodies of the planets themselves. . . ."

— JOHANNES KEPLER, 1605

TIME OF ORIGIN: *1600*

ORIGIN IN: *De Magnete, by William Gilbert*

HYPE FACTOR: *8 (The implications of magnetic philosophy stimulated a generation of astronomers and added heat to the cosmological debates of the early seventeenth century.)*

IMPACT FACTOR: *4 (Although its cosmological claims were incorrect, magnetic philosophy helped make Newtonian gravity imaginable.)*

The sixteenth and seventeenth centuries are a fascinating period in the history of science because they were so energetic, so eclectic, and so incredibly *un*scientific. Ideas that today would seem questionable or downright nutty were then considered thoroughly mainstream, and even the most rigorously scientific minds were not immune to them. To give just one high-profile example, Sir Isaac Newton, the man who would give us physics and calculus, also practiced alchemy and fervently believed that the time of Christ's return could be mathematically calculated. And why not? Math had already predicted the motions of the heavenly bodies. Weren't the movements of God the next logical step?

Magnetic philosophy was a short-lived but influential intellectual trend pioneered by the English physician and early scientist William Gilbert. Like many ideas of its age, magnetic philosophy had one foot in empirical science and another in magic and spiritualism. But in the period before gravity and the laws of motion were fully formulated, it offered the first physical support to the controversial Copernican astronomical model, which correctly put the Sun, not the Earth, at the center of the cosmos.

STAR WARS

To assume that the Earth is the center of all creation is a most commonsense position — after all, it's consistent with two indisputable facts: 1) Things fall down, and 2) the Sun and the planets clearly move across the sky.

That is simplicity itself. But everything else about this geocentric theory, which was most fully developed by the second-century Alexandrine astronomer Ptolemy, is extraordinarily complex. To produce an Earth-centered model that corresponds with astronomical observations requires each planet to follow two orbits: one around the Earth, modified by another, smaller orbit, or *epicycle*, that revolves around…well, nothing. To keep the Sun, the Moon, and the five (then known) planets from plummeting straight into us, each was imagined to be contained within its own invisible, crystalline shell that guided the heavenly body along its orbits and provided it with the motive power to defy gravity when it rose back up again in its daily course. Or maybe that power came from a "soul" or "intelligence" that animated each planet. It wasn't quite clear. Furthermore, to say that the Ptolemaic system was Earth-centered is itself a simplification: The actual center of the universe had to be slightly above the Earth; otherwise, there wouldn't be seasons.

In short, the Ptolemaic system was a mess. But it worked — and, considering the incredibly complex mathematics that went into turning astronomical observations into a coherent model of the cosmos, that alone was a hell of an achievement.

Sometime in the early 1500s, though, a Polish mathematician and astronomer, Nicolaus Copernicus, ran the numbers again and devised a simpler system. While the math was as difficult as ever, Copernicus's model required fewer premises — just a fixed but revolving Sun at the center of the universe and an orbiting and rotating Earth with a slightly tilted axis. On the negative side, however, Copernicus's premises could be seen as contradicting certain passages of the Bible, and they definitely violated the laws of physics as currently understood, which raised troubling questions for which there was no answer, such as, "Why do the planets spin?" "Why don't we fall off the Earth?" and, for that matter, "What keeps the planets from spinning off to God knows where?"

Mindful of these potential theological and scientific heresies, Copernicus kept his new cosmological model on the down-low. As rumors of his audacious idea inevitably spread, though, Copernicus yielded to pressure from fellow intellectuals and, in 1543, published his theory. Despite its daring argument, *De Revolutionibus Orbium Coelestium* (*On the Revolutions of the Heavenly Orbs*) was not censored nor did its author face censure from the church — but the book did ignite a roaring intellectual debate.

WHAT'S SO BIG ABOUT MATH?

One reason that the church did not object to Copernicus's theory is that it was regarded as merely a mathematical model. There was nothing preventing anyone from using the Copernican system as a convenient predictive tool while still acknowledging that Earth was *really* the center of the universe. It was just math, nothing more.

That attitude might puzzle us denizens of the data-driven era, when numbers speak for themselves and with their own authority. But let's try moving the burden of proof: Why *should* any reasonable person believe that mathematical equations can explain the phenomena we see around us? What guarantees that strings of abstract numbers have *any* relationship with objective reality?

As early as the age of the pharaohs, humankind recognized the practical value of geometry. Applied to everything from drawing property lines to constructing temples and diverting water, it was an invaluable science. But even the ancient Greeks, who made a fetish of bisecting angles and attempting to square the circle with nothing more than a straight edge and a compass, knew that geometry was an abstraction. The world was far too sloppy and unruly to be captured in points, lines, and angles. And so they had to invent another world, one that consisted only of ideas and existed only there as well. It was in this ideal realm where logic and math reigned and philosophers spun their theories — but in the coarse, material world, we applied them the best we could.

Why should this resistant Earth be any more submissive to algebra? And even if it were, what could be the significance of any mathematical equation? Math might *describe* the mechanics of some action — but what could it *tell* us about that action, what could it reveal about its meaning and its purpose? Nothing.

But in the slow unfolding of what's called the Scientific Revolution, natural philosophy and math were united. It's probable that Copernicus believed not just that his system worked but that it was also an accurate representation of reality. It's certainly true that his successors — Kepler, Galileo, Newton, and so many others — did. And that's why the heliocentrism-vs.-geocentrism debate became so fierce in the seventeenth century: It wasn't just numbers that were being argued anymore; it was reality.

WILLIAM GILBERT AND THE BIRTH OF EXPERIMENTAL SCIENCE

Okay, maybe that heading is a little hyped. We inquisitive humans have been experimenting since the dawn of time. How else did we learn that it's all right to eat slimy oysters but not the orange-like fruit of the strychnine tree? But empirical testing, like math, has not always been an accepted part of the scientific project. The world was simply too complex and our means of measurement too imprecise to make experimentation an especially reliable avenue to knowledge. To the Aristotelian scholastics who dominated the universities until the seventeenth century, a much more reliable approach to understanding was provided by deductive reasoning, which is bulletproof, so long as you start with valid premises. The problem was that during the Renaissance more and more long-standing premises were being questioned and found to be not especially valid.

When William Gilbert entered Cambridge University in 1558, at the age of 14, he received a typical late-medieval education. Studying for his MD, he read the canonical books of Galen, the second-century Roman physician who had continued to dominate medicine. Gilbert also was taught Aristotelian logic and physics and Ptolemaic astronomy, complete with epicycles and crystal shells and planetary intelligences.

You may have noticed, as Gilbert himself did, that all his intellectual authorities had been dead for at least 1,300 years. A lot had happened in that time — and most of it had hardly penetrated the universities. More congenial to the curious and independent-minded Gilbert was the intellectually engaged and innovative atmosphere of late-Elizabethan London. The center of a kingdom rapidly growing into a global maritime empire was a magnet for capable and practical men such as skilled civil and military engineers and veteran sailors with tales of new worlds.

Gilbert made a success of himself, eventually rising to become president of the Royal College of Physicians and personal physician to Queen Elizabeth I and to her successor, James I. But when he wasn't doctoring, Gilbert devoted himself to his hobby, magnetism. Unlike the typical academic of his time, Gilbert actually went out to consult experts: the craftsmen who worked with magnets to make compasses, and the experienced navigators who used them and had collected data from all over the world.

Stranger still, he invested in scientific apparatus, particularly *terrellae*, or "little Earths," spheres carved out of lodestone, that he used to plumb the mysteries of magnetism firsthand. Placing his *terrellae* on small wooden ships, he documented a free-floating magnet's tendency to rotate; by painstakingly moving a small compass over the surface of another magnetic sphere, he attempted to duplicate the anomalies and variations that old sea hands had related to him; by rubbing pieces of amber, he produced an attractive effect, which he called *electricitas* and which we know by its Anglicized name: electricity. (Although Gilbert was pleased to lambaste the narrow-mindedness and conservatism of his professors, he, like every other serious thinker of his era, wrote in Latin.)

DE MAGNETE

As the engine that drove the compass, the essential tool for ocean navigation, magnetism was of considerable practical interest in the era of sea exploration that followed the discovery of America, but the phenomenon was very poorly understood. Gilbert spent a purported 18 years and £5,000 (a fantastically large sum back then) to write the definitive book on the magnet — in fact, he called it *De Magnete*, or *On the Magnet* — which he published in 1600. Although Gilbert's book is hardly remembered anymore, *De Magnete* is the first ever work of experimental science.

In six volumes, the author summarizes previous approaches to the topic — most of which he gleefully eviscerates — then he adds the reports that he has himself collected and verified, and, finally, he offers the results of his own experimentation along with his conclusions, which were remarkably correct — including his observations on the all but unheard of phenomenon of electricity.

But Gilbert had a broader vision than merely aiding navigation or explaining static cling. His chief aim in publishing was to promulgate his cosmological vision, which he called "magnetical philosophy." The Aristotelian physics he had learned in college posited two sets of physical laws: one that governed the rarified celestial realm and another for our fallen and imperfect Earth. Gilbert, on the other hand, believed that the Earth was as noble as any other planet, that it was regulated by the same principles, and that it, too, possessed a soul. Flowing forth spontaneously from the heart of Mother Earth (his expression) was her soul, the wellspring of the magnetic force. It was this power that caused the Earth to rotate, and, by Gilbert's reckoning, this argument of his was the first to demonstrate the physical evidence supporting Copernicus's model of the solar system. It was no longer just a mathematical abstraction; it reflected a physical reality.

Talk of planetary souls is well out of bounds of today's science, which is one reason why Gilbert is largely forgotten. But even if on the larger points Gilbert was partially or wholly incorrect, his attempt to substantiate heliocentrism with physical arguments inspired a generation of astronomers, and it's no exaggeration to say that he set them on a path that made Newton's formulation of gravity all but inevitable.

MAXIMUM MAGNET

Gilbert's book became an intellectual must-read. As an emerging technology, the magnet suggested seductive possibilities — could a modification of the compass somehow allow sailors to determine their latitude as well as their direction? Since magnets produced spin, could they be made into engines? Were there medical applications?

Galileo was among those influenced by the ideas in *De Magnete*, and so, especially, was Johannes Kepler. In the same works where he lays out his laws of planetary motion, Kepler argues from analogy to Gilbert that the Sun must be a magnet, radiating, just as it does heat and light, some other force that impels the planets along their orbits.

But for all the intellectual boost he gave to the Copernican system, Gilbert also indirectly raised the heat of the controversy. Now that the Copernican partisans — such as that infamous pain-in-the-neck Galileo — were undeniably making truth claims about reality, the Catholic hierarchy was forced to choose between science and dogma. Caught up in the reactionary zeal of the Counter-Reformation, the church sided with dogma.

In 1616, the Vatican banned Copernicus's *De Revolutionibus* and all other books advocating heliocentrism. In the wake of this ruling, at least five books were published by Jesuit intellectuals specifically attacking magnetic philosophy, which had provided intellectual support to heliocentrism. Rather than cause the Earth to rotate, these defenders of the faith argued, a magnetic core would fix the planet even more immovably in place; moreover, magnetism itself could not account for the orderly movement of the planets; and, most irrefutable of all, an Earth-size magnet, as envisioned by Gilbert, would attract all iron objects to itself with irresistible strength.

Nevertheless, the religious objection to magnetism extended only to its support for a Sun-centered universe. Father Athanasius Kircher, who launched a particularly trenchant refutation of Gilbert's and Kepler's magnetic ideas, had mastered his material so thoroughly because he was also a great enthusiast of magnetism. Something of an eccentric genius, or perhaps just a crackpot, Kircher alluded in florid language to the wondrous potential of magnets and hinted that he was engaged in breakthrough research that would revolutionize surveying…or maybe communications. In the end, however, nothing panned out.

In fact, after the initial hype, magnetism turned out to be a general disappointment. None of the projected magnetic innovations emerged — no motors, no medicines, no telecommunications devices. By 1660, the trend was over. There was no decisive repudiation, just years of unfulfilled promise. Eventually, people just lost interest and went on to the next big thing.

GRAVITY: THE NEW MAGNETISM

In 1687, Isaac Newton published his laws of motion in *Philosophiæ Naturalis Principia Mathematica* (*The Mathematical Principles of Natural Philosophy*), which was simultaneously the culmination of seventeenth-century natural philosophy and the cornerstone of fully fledged, math-based, and empirically focused modern science.

Among Newton's achievements was his equation for gravity, which, taken with the laws of planetary motion formulated by Johannes Kepler, at last gave a comprehensive physical explanation for how a Sun-centered cosmos would work and provided devastating proof of why an Earth-centered arrangement would not.

Newton had done the math, but the idea that the cosmos is bound by an insubstantial force that varies with the mass of an object and acts instantly over distance is pure magnetic philosophy, minus the magnet. ●