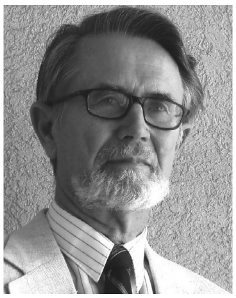
The Changing "Reality" of our Universe

By Ernst Behrens



After earning his doctorate in physics in 1961 from the University of Göttingen in Germany, and a fellowship at the Nuclear Research Center in Grenoble, France, Ernst Behrens became a nuclear reactor physicist with the Siemens Corporation in Erlangen, Germany.

Upon coming to the U.S. in 1966 as a materials scientist, he worked first with the Lockheed-Georgia Company and then in 1969 with Armstrong World Industries in Lancaster, Pennsylvania, where he was a group leader and later a Research Fellow. He has been pursuing an interest in astronomy and cosmology ever since his retirement in 1994.

His work has previously appeared several times in *The Torch*, most recently in the Spring 2015 issue, with "Paddling the Boundary Waters Then and Now."

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"What we call 'reality' consists of an elaborate papier-mâché construction of imagination and theory filled in between a few iron posts of observation" (Wheeler 358). This quotation from John Archibald Wheeler, one of the foremost authorities on gravity and general relativity, characterizes in a nutshell his and other scientists' understanding of "reality." Careful observations and experiments become a permanent record of the knowledge base and are seldom questioned. Controversies arise, however, over the way these "iron posts" are connected. These controversies are usually accompanied by theories that give rise to a "papier-mâché" of a frequently updated system of thought. Nowhere else is this situation more apparent than in the turbulent evolution of cosmology from Aristotle through Copernicus to Einstein.

Cosmology before Copernicus (1543)

Shortly before the Copernican Revolution, Petrus Apianus (1495-1552), alias Peter Bienewitz, a well-known German humanist and cartographer, summarized the cosmology of his time in a book titled *Cosmographia* (1524) by a famous drawing ("Petrus Apianus"). It shows the Earth, composed of the four Aristotelian elements—earth, water, air, and fire—in the center. Surrounding it are eight spheres or "heavens" that are occupied by the Moon, the Sun, the five known planets, and the firmament of the fixed stars. All these are objects of direct observation and part of Aristotle's *Physics* or Wheeler's "iron posts." The "papier-mâché" of imagination starts in Book 8:4-6, where Aristotle postulates an "unmoved mover" as the cause of all motion in the universe. As its name implies, it moves other things while remaining motionless itself. Book 12 of *Metaphysics* continues to speculate about the divine, eternal, unchanging, and immaterial nature of this "prime unmoved mover" ("Unmoved Mover"). It occupies the tenth heaven in Apianus' drawing, just above a 'crystalline sphere' on heaven number nine. Finally, located on top of everything, is the "Empireum," the "Habitation of God and all the Elect." Other beliefs imagine "only" the seventh heaven to be the highest, representing a state of great happiness.

The ancient Greeks were very good at working with straight lines and circles. Claudius Ptolemy (90-168 CE), the talented mathematician from Alexandria, described in his *Almagest* an elaborate system of circles and epicycles, which enabled him to predict planetary positions with an accuracy of one degree. However, regarding the postulates of geocentricity and uniform circular motion handed down to him by Aristotle, Ptolemy had to make compromises. The center of the Universe was not exactly occupied by the Earth but by the center of the Deferent adjacent to the Earth. The center of the Epicycle moved uniformly on the Deferent only from the vantage point of the Equant near the Earth on the opposite side of the center. The Epicycle and any inferior planet (Mercury or Venus) moving on its periphery remained always between the Earth and the Sun. This complicated ancient analog computer represented, almost incredibly, the accepted cosmological "reality" for 1,500 years. Other astronomical analog computers existed that were even older, like the Antikythera Mechanism (Schaefer 2), but their accuracy was not nearly as good as Ptolemy's.

Cosmology from Copernicus to Einstein (1543-1915)

Western cosmology entered a new era with Nicolaus Copernicus (1473-1543). He was a church official in the Kingdom of Poland with an interest in astronomy. After decades of hesitation for fear of ridicule by the science community, he allowed his book *De revolutionibus orbium coelestium, libri VI* to be published shortly before his death. His ideas about the circular orbital movements of the planets around the Sun had precedents in ancient Greece (Aristarchos of Samos, about 310-230 BCE) and were much simpler than Ptolemy's, but they were purely philosophical without any observational backing or "iron posts." The Church allowed and even encouraged their discussion as long as they were presented as hypotheses only and not as "reality."

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The new theory faced many ideological obstacles, but one purely scientific argument against a moving Earth was the absence of visible star parallaxes (Seeds 57-58). Of course, as we know today, stars are too far away for their parallaxes to be noticed by the naked eye (Friedrich Bessel was the first who measured a star parallax, in 1838-39). The enormous contrast between the vastness of the physical Universe and the smallness of our own existence must have been unthinkable in those days. Only much later were the radical consequences of Copernicus' ideas fully appreciated as "reality." and from then on the word "revolution" acquired a second meaning as the overthrow of an established order. In 1616 the publication was placed on the index of prohibited books, pending further revision. It took until 1758 for the original unrevised version to be removed from that list.

The indisputable moment of truth for the two world models came as early as 1610. According to Ptolemy, Venus would never pass behind the Sun, so it would always be illuminated from behind or from the side; therefore, it should appear to us only as crescent-shaped. One morning in October 1610, Galileo Galilei (1564-1642), professor at the University of Pisa and court mathematician for the Grand Duke of Tuscany, was waiting with his home-made telescope for Venus to rise. He had to look very carefully to see the gibbous phase of the planet, but he instantly knew that he was looking at a decisive argument against the Ptolemaic system. Galileo also knew that anyone else with a telescope and the idea to observe Venus could steal his show. By December 1610, Venus had waned to a half-lit phase. To gain some extra observing time while protecting his priority of discovery, Galileo issued a Latin anagram that he promised to unscramble later: "*Haec immatura a me iam frustra leguntur o.y.*" ("These are at present too young to be read by me".) Finally, on New-Year's Day 1611, he lifted the secret and wrote to his fellow-astronomer Johannes Kepler: "*Cynthiae figuras aemulatur mater amorum*"; in English, "The mother of loves emulates the phases of the Moon" (Maury 88-90).

The discovery of the phases of Venus was Galileo's greatest triumph. It was the only scientific observation that directly contradicted and thus invalidated the Ptolemaic world model. Galileo wisely refrained from publicly drawing this conclusion, but he shared his observations with his former student Benedetto Castelli and with Christopher Clavius, a German Jesuit in charge of papal astronomy (Palmieri 109-29). His observations were soon confirmed by the scientists of the Collegio Romano, who awarded him an honorary degree. He was also a guest of honor to cardinals and princes, had an audience with Pope Paul V, and was made a member of the prestigious Lincean Academy. Only the year before, Galileo had written to Kepler: "My dear Kepler, what would you say of the learned here, who, replete with the pertinacity of the asp, have steadfastly refused to cast a glance through the telescope? What shall we make of all this? Shall we laugh, or shall we cry?" (Santillana 9).

As a freethinking maverick, Galileo liked to mingle with the common people and learn from hands-on experience. Instead of devoting his time like his peers to studying and writing scholarly comments on ancient literature, he would focus on practical matters and publish in his vernacular Italian rather than in Latin. His strong will and occasional arrogance made him more enemies than friends, not only in the Church hierarchy but also in academia.

Galileo's 1623 book *Il Saggiatore* ("The Assayer") laid the groundwork for modern research by emphasizing observation and experimentation as primary sources for scientific truth rather than old wisdom handed down in scriptures. This shift from religious to scientific "reality" in the Renaissance period has been appropriately called a "secularization of thought" (Santillana vii). Based on telescopic observations of sunspots, hills and valleys on the moon, Jupiter's satellites, and the phases of Venus, Galileo became a proponent of the heliocentric world view while still remaining faithful to the Church. In his 1615 *Letter to the Grand Duchess of Tuscany* he argued at great length that the "new astronomy" of Copernicus is compatible with the Holy Scripture, including Joshua 10:1-15. The manuscript was widely circulated, but it did not convince the important personalities in the Church hierarchy, who were already on the defensive against the ongoing Reformation movement.

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One of them was Cardinal Robert Bellarmine, a leading figure in the Counter-Reformation and instrumental in sentencing Giordano Bruno to die at the stake. He gave Galileo a stern warning in 1616 to stay in his field of science and not to enter what he considered to be the Church's exclusive domain of theological interpretation. His message was loud and clear: You do the observations—we draw the conclusions! Galileo complied formally at first, but in 1624 the new Pope Urban VIII granted him permission to describe the two world systems in the form of a dialogue, provided his (the Pope's) views would be included.

In the *Dialogo sopra i due massimi sistemi del mondo* ("Dialogue Concerning the Two Chief World Systems"), which was finally published in 1632, the simple-minded Simplicio represents Ptolemy and appears to be a caricature of the Pope and his arguments. This was a fatal mistake, because it unnecessarily alienated many of Galileo's former admirers, including the Pope himself. The hard-liners in the Vatican saw it as an insult and a violation of the 1616 injunction against passing judgment in matters of religion. They promptly tried him for suspected heresy, forced him to recant, and placed him under house arrest for the rest of his life.

Even then, the stubborn professor managed to issue *Discorsi e Dimostrazioni Matematiche Intorno a Due Nuove Scienze* ("Dialogues Concerning Two New Sciences") in 1638, in which he formulated the law that all objects take the same time to fall to the ground in the absence of air resistance and friction. In an earlier unpublished book titled *De Motu* (On Motion), he had presented an interesting logical argument in support of his thesis: Assume Aristotle is right by saying that heavier bodies fall faster than lighter bodies. Now then, let's tie one of each together with a string and drop them to the ground. The lighter body should fall slower than the heavier one, so the string will become taut and the heavier body will be retarded. The two together should therefore take more time than the heavier body alone to fall to the ground. On the other hand, the combination of both bodies is heavier than each of its components and should fall faster than either one—obviously a contradiction. In his subsequent experiments, Galileo used inclines to slow down the process for accurate timing by a water clock, not the leaning tower of Pisa as is commonly believed (Maury 75). The manuscript was smuggled out of Italy and published in Holland, away from Roman control, because it again contradicted Aristotle.

Johannes Kepler (1571-1630) was a German protestant far removed from Rome, with a strong background not only in mathematics, but also in astrology and mysticism. He was fortunate in becoming the assistant to the Danish nobleman Tycho Brahe (1546-1601) and gaining access to his non-telescopic but high-quality observational data. After Tycho had died, Kepler succeeded him as the official astronomer for Emperor Rudolf II in Prague. He then developed the three famous laws of planetary motion (*Astronomia Nova* [1609], *Harmonices Mundi* [1619]) using ellipses instead of the formerly sacrosanct circles to represent the planetary orbits around the Sun. Kepler's introduction of ellipses must have been quite shocking to traditional astronomy, because it did away with the paradigm that only perfect circles could adequately describe the motion of heavenly bodies. Kepler also produced new "Rudolphine" astronomical tables that were considerably more accurate than the old "Alphonsine" tables of the Ptolemaic system, which had been in use since 1252. By 1627, when Kepler's tables were published, the heliocentric view was already catching on, while the Roman inquisitors would be clinging to their outdated "reality" for another two hundred years.

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Isaac Newton (1643-1727) synthesized isolated observations and principles from his predecessors into a comprehensive theory of mechanics that is still being taught in schools today. It consists of three Laws of Motion plus the Universal Law of Gravitation as described in his *Philosophiae Naturalis Principia Mathematica* (1687). The story goes that one of his famous "experiments" was sitting under an apple tree and watching an apple fall to the ground, which gave him the brilliant idea that the planets are held in their orbits by the same force of gravity. Newton also conducted pendulum experiments with a precision of one part in one thousand to demonstrate that the inertial and the gravitational mass of a body are equal. Modern researchers confirmed this result with accuracies of better than one part in one trillion (Will 58-62). Nobody until Einstein could account theoretically for this fact, which Galileo had already discovered with his falling-body experiments and which also lies at the heart of Kepler's third law of planetary motion.

After Newton, generations of excellent mathematicians gave rational mechanics its present rigorous form, eventually replacing the geometry of the ancient Greeks as the prototype of an exact science.

Nevertheless, Albert Einstein (1879-1955) developed reservations against classical mechanics, such as questioning the artificial distinction between inertia and gravity (Clark 114-19). Their equivalence, while having been established many times experimentally, still had no theoretical foundation. Einstein gave it a more general form and made it a fundamental principle of his *General Theory of Relativity* (1915). A famous illustration of this principle imagines a closed box in which the occupants experience weightlessness. They cannot tell whether their box is floating in outer space or falling freely in a gravitational field. In another illustration, the occupants of a rocket feel a force toward the back of the vehicle. They do not know whether their rocket accelerates in interstellar space or stands motionless on the surface of the Earth. In relativistic mechanics, a simple coordinate transformation between reference frames converts inertia into gravity and vice versa using only one type of mass (Misner et al. 17).

Summary and Conclusions

Astronomy and cosmology have been around since ancient times, but new discoveries are still being made at an unprecedented rate. What we understand about the Universe today is certainly "more real" than what people believed in the Middle Ages and before. Each time we establish a new "iron post of observation," we look, as Aristotle did, for the "mover" behind it. Not satisfied with just passive observations, we want insight and knowledge that enable us to control and change things. This is the creative, man-made part of our "reality," which is always in danger of losing touch with its "iron posts" and degenerating into dogmatism or wishful thinking. Wheeler thus leads us to the conclusion that there is no "reality out there" independent of us. Instead, "reality," as we now understand it, owes its existence to human participation. The anthropocentric Universe has thereby returned through the backdoor of human imagination. The naïve young man in the following poem apparently did not get that message.

By the sea, at night by the
  wild sea
stands a young man,
his heart full of sadness,
his head full of doubt.

With sober lips he asks the
  waves:
"O unravel the mystery of life
  for me,
the painful age-old mystery,
that has been pondered by
  many brains,
brains covered by
  hieroglyphic caps,
brains covered by turbans
  and black berets,
brains under wigs and a
  thousand other
unhappy, overworked human
  brains!
Tell me, what is the meaning
  of man's existence?
From where did he come?
  Where does he go?
Who resides up there on
  those golden stars?"

The waves are murmuring
  their eternal sound,
the wind is blowing, the
  clouds are passing,
the stars are blinking,
  indifferent and cold,
and a fool is waiting for an
  answer.

—Heinrich Heine,
"Fragen" ("Questions"),
translated by the author

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Upcoming Club Events

Please check with individual clubs to confirm these dates. (Clubs: Submit your events to be published here! Send information, or the link to your published schedule online, to info@torch.org.)

CENTRAL PA

February 13: A Philosophical Tribute to Muscle
Scott Kretchmar
March 13: What is a mosque?
Louise & Art Goldschmidt
April 10: Gentleman Genius: C.N.Myers and His English Setters
Carl Sillman
May 8: Renewable Energy: the intersection of technology, economics and politics
John Golbeck

DURHAM-CHAPEL HILL, NC

February 20: The Lumbee Indians: An American Struggle
Malinda Maynor Lowery
March 20: How ER Medicine has Changed OR Medical Ethics
Todd Morrell
April 17: Opera in North Carolina
Tom Kunz
May 15: Survival of the Friendliest
Brian Hare

FOX VALLEY, WI

February 14: Kayaking the Upper Fox: Paddling Through History
Richard Schoenbohm
March 14: TBD
Sue Bennett

FREDERICK, MD

February 25: Why is there no Socialist Party in the United States?
George Du Bois, PhD
March 25: Gene Sharp: The Machiavelli of NonViolence
Meg Menke
April 29: Home Funerals and Natural Burial
Penny McDougal
May 20: The Evolution of America's Baby Boom Generation
Jack Topchik

HAGERSTOWN, MD

February 19: From John Brown to James Brown
Ed Maliskas
March 19: TBD (on the nature of good and evil)
Nick Long

MONTGOMERY COUNTY, VA

February 12: What Would Genghis Do: Travels in the Land of the Great Khan
Dave Notter
March 12: Inside the State Department
Bob Beckman
April 9: German Resistance in WWII
Jeff Graf
May 14: The Other Campus of Virginia Tech Forty Miles Away
Harry Dorn

ROCHESTER, NY

February 12: How Cosmic Collisions Shape the Universe
Jeylan Kartaltepe
March 13: Cut Twice: Operate Once. An Innovative Approach to Safer Surgery
Ahmed Ghazi
April 9: Fusion: Making a star on Earth and the Quest for the Ultimate Energy Source
E. Michael Campbell
May 9: Mars Landing Updates
Nick Warner

ST. CATHARINES, ON

February 13: Life at the St. Catharines PAC
Sarah Palmieri
March 13: Dead Lives Matter
Lissa Paul
April 11: Gem Fraud
David Warren
May 8: The Morningstar Mill
Carla Mackie