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Abstract

The idea that science is the only valid guide to truth is not itself a scientific statement, but rather the fundamental dogma of scientism. It is the purpose of this paper to show this claim to be unwarranted and scientism untenable, through a consideration of what science can and cannot

say, illustrated from the history of science itself. Discussion of criteria for selecting among models making equivalent predictions is highlighted by examples of common reactions of the scientific community when new observational data conflict with well-accepted theory: to deny the observations, to adapt or replace the theory (often at the expense of added complexity), or to seek factors not yet taken into account. Although it excels at providing possible explanations for phenomena, science is inherently incapable of proving that an explanation is true, and thus the foundation of scientism is flawed. In contrast, the Biblical worldview provides a consistent foundation for knowledge and a rationale for the extent to which science is a viable means of learning about the universe, although incomplete and contingent on revelation.

History Highlights the Fundamental Limitations of Science

Science is often thought of today as being the only valid way of “proving” universal truths. Explicit claims of this type occur in the popular press, but the idea even more commonly appears as a pervasive underlying assumption, generally unstated but beyond appeal, and foundational to all discussion. This claim is not a scientific one at all, being a statement about science rather than a result of science. It is the fundamental postulate of scientism, a dogma that goes far beyond any valid implications of science, making unjustifiable claims on its behalf. Proponents of scientism, whether having received scientific training or not, should not be accorded the mantle of the authority of science when making such statements, which are in fact propositions of faith, not science. It is the purpose of this paper to show, from the history of science itself, that the faith of scientism is unwarranted and untenable. The examples chosen highlight both the power and the limitations of the scientific method.

The Saga of Planetary Motion and Discovery

Humans have been fascinated by the stars since the dawn of recorded human history. Even in ancient times the patterns of motion of the heavenly bodies were considered significant, and study of the patterns led to attempted explanations. Since these explanations or models were constructed by humans to explain observations made by humans, it would have been reasonable to regard them as tentative, subject to possible future modification when new observations and discoveries did not fit with a previously accepted model. Science, although incredibly useful and powerful, never provides more than tentative conclusions, though ironically many prominent science publicists do not admit this fact. The following sections recount the saga of the intertwined processes of discovery and theory construction of the “motions of the heavens”, from the ancient Greeks to the present, and show the common alternative reactions of the scientific community when new observational data call into question well-accepted theory: denial of either the observations or the theory, or modification or replacement of the theory. The story begins, as does so much of modern thought, with the ancient Greek philosophers.

Aristotle, Ptolemy and Epicycles: An Early Scientific Model

Earthly matter falls to the Earth, heavenly matter remains in the Heavens, traveling in circles, the most perfect of all possible motions. So might be summarized Aristotle's view of the relationship – or more accurately, the distinction – between earthly and celestial things. Today we may consider the geocentric model archaic or even ridiculous, but in fact the model adequately explained much of the data available at the time (Seeds & Backman, 2010, pp. 54-55). Consider: We have repeated experience of dropping things to the ground. No matter how often I pick up a stone, no matter how high I lift it, when released the stone falls back to the ground. It returns to its proper place. Earthly things remain on Earth, or when removed, try to return to Earth. On the other hand, looking up to the heavens I see the sun, the moon, the stars, and they do not fall to the ground. It was not really so ridiculous to suppose that they were made of something different from earthly matter, something quintessentially[1] heavenly. I see the sun rise every morning, cross the sky and then set. Surely it is obvious that the sun is circling the Earth! Likewise at night I see the stars rise and set. The Moon also rises and sets. We see motion all around us, but feel the Earth under our feet, rock solid and unmoving. Based on these observations, the geocentric model looks quite reasonable: the Earth is the center of all this heavenly and earthly motion.

[1] I.e., purely or perfectly. But "quintessential" literally means relating to the "fifth essence" or element, different from the four elements of earthly matter: earth, water, air and fire.

But even basic further observation reveals complexities. It appears that celestial bodies orbit the Earth daily, but there are additional cycles: the moon waxes and wanes and its rising and setting times vary on a monthly cycle; a yearly seasonal cycle describes changes in the time of sunrise and sunset, the length of the day, the height the sun reaches overhead, and which stellar constellations are in the sky, as well as their rising and setting times: these cycles are not explained by the geocentric model. More mysteriously, the five stars known to the ancient Greeks as wanderers, πλανῆται (planētai), usually move faster than the normal “fixed” stars but at intervals back up, exhibiting retrograde motion. The Babylonians were aware of the complexity of the motion of the five known planets probably as early as the second millennium B.C., but the first scientific model explaining the motion was developed during the first or second century A.D., and was fully elaborated by Claudius Ptolemy of Alexandria after about A.D. 150 (Evans, 1998, pp. 296-297). In this model, rather than orbiting the Earth directly, each planet’s path was an epicycle, a circular path whose center orbited the Earth on a larger circular path, the deferent. The motion of planet on its epicycle adds to the simple circular motion it would otherwise have in orbiting the Earth on the deferent, speeding up or slowing down its progress, and at regular intervals producing the needed retrograde motion. The epicycle model remained the standard explanation for planetary orbits for more than a millennium, allowing star watchers to know where in the sky to look for their favorite planet. Surely we must consider it an extremely successful theory! After all, science is about finding theories or models which explain and predict. Yet we no longer accept this model, now viewing it as an incorrect explanation. It has been replaced by a better theory.

What does this tell us about scientific theories? Very simply that all theories are tentative, no scientific model can be considered to be the last word. Even after years of use, something better may come along. Indeed, science is not a means of finding truth. At best we may eliminate models that make incorrect predictions, and hope that the explanations we end up with are approximately true, while keeping in mind that we may find a better approximation in the future. This does not undermine the value of science, but puts it in proper perspective: it is important to understand the uses and the limitations of any tool in order to use it effectively, and science is arguably the most powerful tool ever invented, being nothing less than a careful, logical method for exploring and finding explanations for the mysteries of the universe.

Ptolemy's epicycle model is an example of modifying an existing model to adjust to additional observation: the original geocentric model differentiated between the behavior of earthly and heavenly bodies, but failed to explain the retrograde motion of the planets. Adding epicycles added to the explanatory power of the model at the expense of additional complication. Yet sometimes that is what must be done, rather than clinging to a simpler, but demonstrably incorrect, theory. Geocentrism plus epicycles could predict planetary positions, where geocentrism alone could not. The new model did have two notable deficiencies: the arbitrariness of the epicycle/deferent concept, and the arbitrariness of the epicycle radius. First, the concept itself: It seems much more reasonable that one object orbit another than to posit a planet orbiting an empty spot in space that is orbiting the Earth. Second, the epicycle radius could simply be adjusted to make the predictions fit the observations. That might seem trivial or even desirable, but there was no other reason for the choice than to force the model to fit the data, and no additional understanding of the universe resulted. Today we say that the model had too many adjustable parameters. If a model is too flexible, it fits any data, chameleon-like (Cortez, 2014). With enough epicycles upon epicycles upon epicycles one can match any orbit, no matter how complicated. Amusingly enough, one YouTube clip uses a carefully chosen collection of epicycles to trace out a sketch of Homer Simpson (Ginnobili, 2008). There is nothing fundamental that can be learned here, just as no pattern is found by simply selecting digits of a number to match the rolls of dice rolled.

Aristotelian Dogma

More careful observations eventually revealed inaccuracies in the predictions of the geocentric model, but for thirteen centuries no-one questioned it. It was a time of unthinking reliance on the “authoritative” explanation, long considered the truth: referring to the written authority was preferred to any new observations or experiments. The geocentric model was an obvious idea to consider, and it worked to a degree, but we can only regard as lamentable the centuries of stagnation and blind acceptance of Aristotelian dogma, which was in time elevated to a level of authority akin to that of Scripture. Indeed, during the more than a millennium when Aristotle’s ideas reigned supreme, the geocentric worldview came to be regarded as Biblical, and the eventual challenge to it was seen as opposing the Bible’s authority. The next step had to await the birth of modern science. Yet even science today may not exempt us from the intellectual trap of unwarranted trust in a favorite theory; our worldview may blind us to gradually accumulating conflicting data that should have long since signaled the need to reexamine basic assumptions.

Copernicus and the Heliocentric Model

Nicolaus Copernicus’ heliocentric model was published in his book *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*) in 1543, the year of his death (Seeds & Backman, 2010, p. 61). The new model abandoned the dogma of Earth’s central location in the universe, and did away with the unmotivated complexities of Ptolemy’s epicycles by the simple means of treating the sun as the center about which the Earth and the other planets circled. The mysterious retrograde motion was simply and elegantly explained in this model, by planets nearer the sun periodically overtaking the planets in orbits further out from the sun. The complication of the apparent path of the other planets is due to viewing a moving planet from another moving planet: it is now seen as resulting from Earth's motion. Now the rotation of the Earth on its own axis explains the motion of the "fixed" stars, its orbit around the sun explains the gradual changing of the visible constellations throughout the year, and when coupled with the tilt of its axis also explains the seasons, neither of which had been addressed by the geocentric model. In retrospect the heliocentric model explains other previously unnoticed or puzzling facts. The odd fact that the needed epicycle radii were approximately the same is now seen to imply that the extra motion is to be ascribed to the Earth, and that Earth's orbit has that radius. What had been unexplained arbitrary parameters now starts to make sense. The reason that the paths of the sun and the moon across the sky do not include retrograde motion is now obvious: the moon circles the Earth monthly, while the Earth circles the sun yearly – both simpler situations than the relationship between two planets both circling the sun.

This replacement of a widely accepted worldview by another, conceptually simpler, more "elegant" theory having greater predictive power and giving a deeper understanding of the functioning of the universe, is a textbook example of a radical and fundamental change in view, a paradigm shift, to use the term popularized by Thomas Kuhn in *The Structure of Scientific Revolutions* (1962). It bears repeating that the heliocentric model did not disagree with the Bible, only with the Aristotelian view cloaked in Biblical authority. And note also that Copernicus' new explanation was *not true*, only (perhaps) "more nearly true" than the model it replaced. Again, science does not provide a method for establishing truth, only for finding and comparing different explanations. If two alternatives explain the observations equally well and make the same predictions, it makes sense to use the one with greater internal consistency and simplicity. But ironically, although the Ptolemy's epicycles and the geocentric worldview seem strange to us today, its predictions were actually more accurate than those of Copernicus' theory, making the switch to the new model all the more surprising. We seem to have here a scientific paradigm shift unmotivated by observation and experiment! In what sense can such a model be considered as more true, if its predictions are less accurate? Simplicity alone is not enough, theory must be applicable to the data, it must fit the real world if it is to be considered science. According to this criterion, Copernicus' detractors were justified in rejecting his ideas, and Galileo might be considered to have been premature in supporting them.[2] Yet the simplistic heliocentric theory did open the way for further breakthroughs that did lead to more accurate predictions.

Galileo

Although a major contributor and even arguably the founder of modern science and inventor of the concept of inertia, the basic idea of mechanics, dynamics and special relativity, Galileo Galilei (1564-1642) comes into this account only in a somewhat peripheral way, because of his support of heliocentrism and his astronomical discoveries (Ferris, 1998, pp. 88-90). His

[2] It should be noted that Galileo's trial and his recantation of the Copernican "heresy" had more to do with politics and Galileo's abrasive personality than any ideological conflict (Ferris, 1998, pp. 98-99). Readers of his *Dialogue Concerning the Two Chief World Systems* interpreted his character Simplicio as being ridicule of Pope Urban VIII, a sufficient reason to interest the Inquisition, aside from his support of a non-Aristotelian view that some argued was contrary to Scripture.

improvements to the telescope enabled him to make several major discoveries: lunar craters, sunspots, the phases of Venus, and the four largest moons of Jupiter (Io, Europa, Ganymede, and Callisto, now known as the Galilean moons). This added new data by which existing astronomical data could be judged and significant support for the heliocentric view, although not providing direct evidence that the Earth moves.[3] Craters on the moon and sunspots indicate that heavenly bodies are not so perfect as previously assumed, the moons of Jupiter show that Earth is not the center of all motion, and the phases of Venus pointed strongly to both Venus and Earth orbiting the sun.[4] Yet for most scholars this was not enough to tip the balance in favor of heliocentrism. There was then, as now, a tendency to cling to the explanation consistent with the current popular worldview and blessed by official approval, even in the face of mounting evidence against it.

Kepler's Three Laws

Johannes Kepler's famous three laws of planetary motion, published in 1609-1619, present the first astronomical model based on a large amount of data, over twenty years' worth of observations made the Danish nobleman and scientist Tycho Brahe, and provide the needed

[3] Legend has it that after his forced recantation, Galileo murmured the phrase "Eppur si muove" (and yet it moves), but the first documented appearance of the story dates from a century after his death.

[4] In crescent phase Venus is always larger than when in full phase, easily explained if Venus orbits the sun in an orbit smaller than Earth's, so we only see its unlit side when it is on our side of the sun, and only see the full sunlit side when we are on opposite sides of the sun.

correction to the heliocentric model (Ferris, 1998, pp. 73-81). At the price of a slight increase in complexity and the abandoning of the unsupported assumption of the perfection of the circle, his laws explain planetary motion to a much improved degree, allowing more accurate predictions of planetary positions. This is the first clearly justifiable paradigm shift in astronomy. (But being the best of available explanations is not proof of truth!)

Kepler's first law is that the orbits of the planets are not circles but ellipses, with the sun at one focus of each ellipse. The second law states that a planet's speed does not remain constant, but varies in such a way that a line connecting sun and planet sweeps out equal areas in equal times, implying that the planet's speed will vary inversely with its current distance from the sun. The third law states that the square of the period of the orbit is proportional to the cube of its semi-major axis, the average of the closest and farthest distances to the sun. These three general statements fit all the data available to Kepler from past observations of the planets, and allowed predictions of where they would be in the future, with better accuracy than that provided by the Ptolemaic or Copernican models, the acid test of a scientific theory. Comparing the data to the various models' predictions, we now have a clear winner: Kepler's theory could be recognized as true, the others false.

Yet at this point it must be apparent that no guarantee of truth could reasonably be given to Kepler's model of the solar system, any more than to its predecessors. All that could be said is that it fit the data better than the others considered at that time. But truth cannot be dependent on the selection of theories that humans have thought up. One must acknowledge that a better model providing even more accurate predictions and better fit to the data might be invented at any time.

Kepler follows the lead of Copernicus in banishing Earth from the center of the cosmos, making Earth and the other planets orbit the sun, but now also abandons the previously assumed but untested idea that all heavenly bodies move in perfect circles. His three laws seem arbitrary, but predicting all planetary motion from only three assumptions was a remarkable tour de force. Explaining a large quantity of observations in a concise way is the hallmark of a good scientific theory. And the best was yet to come!

Newton and Universal Gravitation

Isaac Newton (1642-1727), English mathematician, "natural philosopher", amateur theologian, and one of the most influential scientists in any era and perhaps the greatest of all time, laid the foundations for classical mechanics and much of the rest of physics in his *Principia Mathematica* (Ferris, 1998, pp. 103-122). To treat physical phenomena mathematically he had to invent calculus, the credit for which he shares with Gottfried Leibniz, working independently. He formulated the law of universal gravitation $\left(F = \frac{Gm_1m_2}{r^2}\right)$ and showed that all three of Kepler's laws, and much more, follow from this hypothesis that the force between any two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them: a huge triumph for science. Kepler's "laws" turn out not to have been fundamental after all, giving a valuable insight into the tentative nature of so-called "natural laws". While Newton himself recognized the incompleteness of his explanation for gravity – he admitted that he "framed no hypothesis" for the cause of the gravitational force – his "law", a single hypothesis, predicts Kepler's "laws" and thus fits the astronomical observations and makes the same predictions. It is therefore a better theory, not (at first sight) because of better predictions but because it requires simpler and fewer assumptions, and because of its greatly increased potential for understanding the universe. Rather than merely identifying certain features of planetary orbits and using them to explain and predict positions, we now have an overarching unity in nature: gravitational attraction keeps the planets, comets and asteroids orbiting the sun (in elliptical paths, not circles), keeps Earth's moon orbiting Earth and Jupiter's moons orbiting Jupiter, makes the apple fall from the tree to the ground below, causes the tides, and even pulls the Earth into a spherical shape (or more exactly, an oblate spheroid) – a genuinely new and unexpected idea. In short, Newton's model explained all known observational data of the time either as well as or better than previous paradigms, and as it was used additional implications became apparent, new predictions were made and confirmed by experiment and observation, and the stage was set for a new era of astronomical discovery.

It is also interesting to note a further philosophical shift: now even the sun is moved from its position of centrality. All objects attract all others, and although the sun as the largest mass in our neighborhood exerts the largest influence on the Earth, even the sun is affected by other masses and orbits the center of mass of the whole solar system, somewhat offset from the center of the sun in the direction of Jupiter. Eventually we learned that the sun is one of the at least 100 billion stars of the Milky Way galaxy, all orbiting their common center of mass, and our galaxy is one 50 some galaxies in a loose gravitational grouping, one of the billions of galaxies in the known universe (Seeds & Backman). We have moved away from the idea of physical centrality, replacing it by the conceptual centrality of ideas such as symmetry, conservation laws, etc., of which universal gravitation can be considered an early example.

Discovery of Uranus and Neptune

The accidental discovery of Uranus by Sir William Herschel in 1781 was an important milestone in astronomical observation and theory. The planet had been seen in passing many times before, but thought to be a dim star or a comet (Standage, 2000, pp. 1-21). Once identified by Herschel as a planet, it provided an excellent test for Kepler's laws and Newton's law of universal gravitation. The new planet was tracked and found to obey the same laws proposed for the already known planets, which provided the first new supportive evidence – but not proof – for the new model.

But over the following years more precise observations showed a discrepancy between theory and experiment, leaving astronomers in a quandary. They could ignore the conflicting observations, perhaps the default human reaction much of the time, or in the light of this new evidence, they could abandon the theory and seek a new explanation, as Copernicus had done. It might be possible to adapt the theory slightly, adding complexity, but ensuring agreement with experiment, a strategy showcased by Kepler's use of ellipses rather than simple circles and indeed by Ptolemy's epicycles. The remaining option was to trust the theory and deduce the existence of factors not yet taken into account. That is what was actually done by John Couch Adams and Urbain Jean-Joseph Le Verrier, working independently in the early 1840s, in predicting the existence and position of a previously unsuspected planet beyond the orbit of Uranus (Simon & Malsberg, 1962). Adams, a young tutor at the University of Cambridge, had difficulty getting his calculations and conclusions published, whereas Le Verrier already had established a reputation as a mathematician and had published work on the cometary orbits. Le Verrier presented his final prediction for the location of the unknown planet to the French Academy on 31 August 1846, and in private communication to Johann Gottfried Galle of the Berlin Observatory on 18 September 1846. The same evening the letter arrived, on 23 September 1846, Galle and an assistant, Heinrich d'Arrest, discovered Neptune, at a point within 1° of the predicted position. The discovery was acclaimed by the observatory's director, Johann Franz Encke, as "the noblest triumph of theory" (Standage, 2000, p. 122) and provided further support for Newton's theory of universal gravitation and motion. No serious doubts now remained about the truth of Kepler's laws and Newton's explanation in terms of gravity. Yet it is still worth insisting on the distinction between supporting evidence and proof.

Search for "Planet X", Discovery of Pluto

History repeats itself. Astronomers tracking the orbits of Uranus and the newly discovered Neptune reported a slight divergence from the theoretical orbits predicted by Newton's model, by now so thoroughly established that the most natural thing in the world was the prediction of yet another planet in orbit beyond Neptune. The search for "Planet X", spearheaded by American mathematician and astronomer Percival Lowell, only ended years after his death when Clyde Tombaugh discovered Pluto on 18 February 1930 (Simon & Malsberg, 1962). But in this case the true explanation for the discrepancy between theory and observations was quite different: human error. It became clear that Pluto's discovery near the predicted location had been mere coincidence, it is not massive enough to have any significant effect on the outer planets' orbits (Standage, 2000, p. 181), it is only one member of the class of objects orbiting the sun in what is now known as Kuiper Belt, and that the primary source of the disagreement was an incorrect estimate of Neptune's mass, eventually corrected from data collected by the Voyager flyby mission. In 2006 Pluto itself was reclassified by the International Astronomical Union as a dwarf planet, a new classification including several large asteroids and Kuiper Belt bodies, all smaller than the smallest now-recognized planet, Mercury, and indeed even smaller than Earth's moon (Seeds & Backman).

Thus the past success of a theory, coupled with erroneous data, led to an incorrect interpretation and a discovery hailed as a further confirmation of the theory, but which turned out to be only wishful thinking. This is a real but often unrecognized danger of over-reliance on any given scientific model, and a weakness of the way humans think: too often ignoring any data seeming to disagree with a cherished model, while considering as confirmation (or even as proof) any data that seem to agree.

Further Failures and the Triumph of General Relativity

The Pluto fiasco was only a failure of observation and interpretation, it did not shake the universal acceptance of Newton's model as the truth about celestial mechanics. But as early as 1859 Le Verrier noted a discrepancy in the orbit of Mercury, a slow precession of the axis of its orbit that could not be explained by Newton's theory (Standage, 2000, pp. 163-166). Again, the obvious solution was to interpret the results as evidence, not against the accepted theory but for the existence of an as-yet undiscovered planet, presumed to be inside the orbit of Mercury, so near the sun as to make its detection difficult. So certain were the searchers of their eventual success that the proposed new planet was given a name, Vulcan, after the Roman god of the forge. But Vulcan was never found: the search ruled out the existence of even a house-sized asteroid inside Mercury's orbit.

Although not realized at the time, this was the death-knell for a so-called "Universal Law". Modifications of the theory that were attempted and found to fail, included slight corrections to Newton's law, such as replacing the exponent in the denominator (r^2) by a decimal close to 2, such as 1.99 or 2.01. But only by abandoning Newtonian theory in favor of another could the scientific explanation of planetary motion be saved. The model that eventually replaced Newton's gravity, the General Theory of Relativity published by Albert Einstein in 1916, delivers more accurate predictions and additional predictive power, explaining the discrepancy in Mercury's orbit as well as smaller orbital precessions of Venus, Earth and Mars that have been measured since (Ferris, 1998, pp. 196-204). It explains the cause of gravity itself, about which Newton refused to speculate. In Einstein's view, the fabric of spacetime itself is warped by the presence of mass, in a way somewhat analogous to the dimple formed on the surface of a trampoline when a large weight is set on it. Just as a marble rolling on the trampoline might be caught in the depression and orbit the central weight, the planets are actually travelling "straight ahead" in the region of curved spacetime caused be the sun. Each planet in turn creates a smaller warped region in its neighborhood, allowing moons to be captured and to orbit around it along the straightest possible path for movement, called a geodesic. There is no action at a distance, no force reaching out from one mass to another across empty space. Strictly speaking, in this view gravity is no longer a force at all, the orbits and accelerations are caused by spacetime curvature. The central idea of General Relativity (GR) can be summarized as: mass warps space, warped space tells matter (and light, and everything else) how to move. Einstein's Equivalence Principle states that it is impossible to distinguish locally between acceleration and gravitation: inside an accelerating rocket in empty space objects would "fall to the floor" as if under the influence of gravity; in a free-falling elevator objects would "float" (as compared to other things in the elevator) just as if gravity had been turned off, at least until reaching the bottom of the elevator shaft. What we experience as gravity on Earth is only the interaction of objects that follow a geodesic and spiral in towards the center of the rotating Earth until prevented from continuing by coming in contact with the planet's surface where they experience the electromagnetic repulsion of atoms in close proximity. GR also explains phenomena undreamed of in Newton's day, such as gravitational red shift, the stretching of the wavelengths of light emitted by a star as the light races away through regions with varying spacetime curvature; gravitational lensing, the deflection of light as it passes close to a large mass, an effect predicted by Einstein and first measured in 1919 during a solar eclipse;

gravitational time dilation, the dependence of clock rate on the local spacetime curvature; and the predicted and actively sought-after gravity waves, a periodic change in curvature that propagates at the speed of light. Not only does theory of General Relativity give the right answers whenever it disagrees with Newton's model, it has all the earmarks of being truth about how the universe operates: unification of ideas previously thought separate, ramifications of conceptually simple concepts giving deep and often surprising insights into the nature of reality.[5]

Although Newton's explanation of gravity was tested and trusted over hundreds of years and is today still called the Law of Universal Gravitation, the irony here is that a so-called "natural law" was replaced by a "mere theory". But the theory is right where the "law" was wrong. Despite the insights that came from using Newton's explanations, despite the fact that they gave the right answers (agreeing with GR) most of the time, the Newtonian view of the universe was simply not true.

Is this better model, General Relativity, now – finally – true? In fact, we already know it is not. At the very small scale, at distances comparable to or smaller than the size of molecules and atoms, both Newtonian (classical) physics and GR give wrong answers. Quantum physics must be used. But it too must be considered only an approximation to the truth, and attempts to generalize quantum theory to include relativistic[6] situations have so far been only partly

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[5] In a similar way, Einstein's Special Theory of Relativity published in 1905, extended simple concepts such as inertia and led to the realization that space and time are part of a unified whole.

[6] In this context, "relativistic" means involving high speed and/or large mass, requiring special or general relativity, respectively.

successful. Candidates for this further unification include string theory and loop quantum gravity, but there is still no evidence (i.e., successfully explained observations and deep insights into the fundamental nature of reality) that these attempts are on the right track (Matsubara, 2013).

Take-Home Lessons

The historical sequence of scientific models and paradigm shifts considered here should bring home a fundamental truth about science itself and about the very human nature of the enterprise which renders it inadequate as a epistemological foundation, a means of reliably finding truth: Science is tentative, limited and cannot guarantee truth.

Science is and must be tentative, in regard to both observations and theory. Time after time new experiments have revealed errors in past observations and past explanations. History gives us no reason to believe that all errors of observation or interpretation have now been eliminated. Our current paradigm governs the types of observations we think to make and even the way we look at the world, so whole classes of experiments that would reveal other features of reality may never be investigated. The increasing precision of measurements and observations may also bring to light places where our explanations turn out to be only approximately correct, often necessitating a new paradigm, which is also only tentative. A good theory should explain the available data and it is natural and human to notice patterns in our observational data and to construct scenarios or hypotheses to explain them, but deciding which data are to be considered reliable always involves a value judgment.

The tentative nature of scientific inquiry is highlighted by the various historical reactions to discrepancies between theory and observation reviewed above. The long reliance on Aristotelian dogma and the fruitless search for “missing planets” in an effort to retain a trusted model or trusted data at all costs demonstrate varying and conflicting choices of what to believe. Ptolemy's epicycles and Kepler's ellipses may be thought of as modifications of an existing model, or abandoning some premises of the current model while keeping others, in an effort to explain things the current model could not. Newton's gravity and Einstein's relativity involved reexamining fundamental concepts and constructing new explanations from a chosen set of basic ideas, and also succeeded in explaining more than previous models, giving a wider domain of applicability and new connections, new relationships, more about the functioning of reality. It is inevitable that we consider such productive theories as approaching truth more closely, even though the theories are known to be incorrect or at best approximations to truth.

Science is limited, not only by the factors that cast doubt on our conclusions, but by our inability to ever know whether we have considered the true explanation yet. Science includes successful identification of patterns and discovery of some explanation for them, but there is more to science than that. Ptolemy's epicycles were adequate for predicting planetary positions, but description and prediction are not enough: in a very real sense the epicycle model was false. From among models giving the same predictions we elect to use the one with fewer premises and variable parameters – a criterion known as Occam's Razor or the principle of parsimony, and it is true that simpler and more mathematically elegant models tend to uncover previously unnoticed relationships, but there too we have no guarantees. It is perfectly possible that the next great theoretical step forward will be a more complicated option, rather than less complicated one. It is even conceivable that the real explanation(s) of reality might be more complicated than our finite minds can understand.

With an infinite amount of time available for research and theory construction, science could give us a never-ending sequence of possible answers, and allow us to eliminate an infinite number of incorrect models, while yet leaving an infinite number of candidates for the true answer, and no reliable way to decide between them. Ultimately this means that the results of science are undoubtedly useful, but need not be true in any real sense. As a way of learning truth, as an epistemological foundation, science is inadequate.

It is ironic that today many claim that science has proved the atheistic-materialistic worldview that many associate with it. Nothing could be further from the truth. Not only can science not prove metaphysical statements, as we have seen, science cannot even prove the current theories/models that we use. Any use of it as a means to find the true nature of reality is hopeless from the outset, and as been argued elsewhere, the materialistic worldview contains significant internal inconsistencies that give reasonable grounds for discounting it.

Explaining the Success of Science

In view of these limitations, how are we to explain the great success of science? This success is real, and needs an explanation. The technological fruits of science are ubiquitous, our modern society is based on technological innovation and engineering, the application of scientific theory to practical problems. Science itself cannot justify this success, the paradigm of atheistic materialism does not explain it,[7] but the Biblical worldview provides acceptable philosophical answers for why science works. Indeed, it actually provided the fertile ground for the historical development of science, because, in the words of the Christian philosopher and apologist Francis Schaeffer, it taught "that there is a reasonable God, who had created a reasonable universe, and thus man, by use of his reason, could find out the universe's form"

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[7] Nor indeed does atheistic materialism explain or allow the possibility of rational thought, but that goes beyond the scope of this paper.

(1968, p. 42). We can go further: among competing world-views and religions, Biblical Christianity stands out from the rest, giving a consistent motivation for science and an explanation for why and to what extent it works, and how it relates to our search for truth. Science cannot give a justification for any worldview, philosophy or religion. Just as in considering scientific theories, we may justifiably eliminate inconsistent philosophies, but as usual it is impossible to affirm using the methodology of science alone that what remains is truth. Yet the internal consistency of the Biblical worldview, providing an explanation for the reasonableness of the universe and the workings of man's own reason, both given by a single, infinite-personal God, is a powerful argument in favor of Christianity and at least a partial antidote to the uncritical acceptance of scientism and misuse of science.

The Biblical worldview provides not only a consistent epistemology, a foundation for our understanding of truth which is missing in atheistic materialism, but also a rationale for why and to what extent science works as a viable means of learning about the universe, although necessarily incomplete and contingent on revelation. Its success is to be expected, based on the belief in a single, omnipotent, omniscient, loving Creator, whose creation is a unified whole, and who voluntarily reveals Himself to His creatures, made in His image and given the ability to understand, to a degree, His revelation and His works. Our study and appreciation of Nature are motivated by our worship of Nature's God.

Science on a Biblical Foundation

What then does science look like, when practiced within the Biblical worldview? First, although we understand why the universe is reasonable and also expect to be able to use our God-given intelligence to decipher and comprehend some of what we observe, we must also recognize that our finite minds will most likely never be able to acquire definitive and complete knowledge of God’s creation. Although it is possible that a finite set of laws defines all of this universe, this need not be so, since the Creator is infinite and eternal. Therefore our aim should not be complete knowledge, but understanding to the extent possible for us. We approach as humble seekers. Second, in our study we should be conscious, as were the early pioneers of modern science, that we are examining the masterworks of the Divine craftsman, and we should feel a sense of awe and delight as we contemplate the workings of creation. God created the natural order for our pleasure and edification, so we should enjoy to the fullest the wonders of the universe and the learning process itself, the unfolding of deeper understanding, the appreciation of ever more expansive vistas. The scientist should be able to say, with Kepler, “I feel carried away and possessed by an unutterable rapture over the divine spectacle of heavenly harmony.... We see how God, like a human architect approached the founding of the world according to order and rule” (as cited in Tiner & Burke, 1977, p. 193).

We can echo the words of King David, “The heavens are telling of the glory of God; And their expanse is declaring the work of His hands” (Psalm 19:1 New International Version), and again, “I will meditate on your wonderful works. They tell of the power of your awesome works—and I will proclaim your great deeds.... All your works praise you, Lord; your faithful people extol you” (Psalm 145:5-6,10).

Finally and perhaps most importantly, the Christian has the additional insight that Nature not only exhibits order and design, but levels of order, suitable for the eternal study and enjoyment of the redeemed and unfallen beings throughout eternity. The thought of coming to the end of the study of God’s creation is a strangely repellant idea. Christ promises his followers eternal life, abundant life, and surely this includes eternally understanding more of His design in the universe. In the final pages of The Great Controversy, Ellen G. White wrote of the bliss of the redeemed in heaven and on the Earth made new:

> There, immortal minds will contemplate with never-failing delight the wonders of creative power, the mysteries of redeeming love.... Every faculty will be developed, every capacity increased. The acquirement of knowledge will not weary the mind or exhaust the energies. There the grandest enterprises may be carried forward, the loftiest aspirations reached, the highest ambitions realized; and still there will arise new heights to surmount, new wonders to admire, new truths to comprehend, fresh objects to call forth the powers of mind and soul and body. All the treasures of the universe will be open to the study of God's redeemed.... Upon all things, from the least to the greatest, the Creator's name is written, and in all are the riches of His power displayed. And the years of eternity, as they roll, will bring richer and still more glorious revelations of God and of Christ. (1950, pp. 677-78)

For the student of God’s creation, although seeing in an admittedly limited and imperfect way as “through a glass, darkly” (1 Cor. 13:12 King James Version), heaven can begin now.

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