Opinion Page

The Problem of Scientific Bias: The 1919 Astronomical Confirmation of Einstein's Theory

Daniel J. Kennefick, Physics Department, University of Arkansas, USA
Email: danielk@uark.edu

Einstein is our preeminent modern sage. This enormous fame descended upon him as a result of the 1919 eclipse expedition, as Einstein himself admitted when he wrote, "The English expedition of 1919 is ultimately to blame for this whole misery, by which the general masses seized possession of me" (*Collected Papers of Albert Einstein*, vol. 13, doc. 1263). The great New Zealand physicist Ernest Rutherford concurred and later said to Arthur Eddington, "You are responsible for Einstein's fame" (Chandrasekhar 1987, 115).

Arthur Eddington, Frank Dyson and Contrary Results

According to Subrahmanyan Chandrasekhar, who was present in the Senior Common Room of Trinity College, Cambridge, in 1933 when Rutherford said these words to Eddington, the context was some British dissatisfaction that Einstein's fame exceeded that of Rutherford's, even though Rutherford was the principal founder of nuclear physics. But such is the way of it. Rutherford himself, according to Chandra, attributed the drama of the eclipse expedition, with its message of postwar reconciliation, to Einstein's sudden rise to great fame. Chandra goes on to quote James Jeans, who divided credit for the eclipse expeditions equally between Eddington and Frank Watson Dyson, the Astronomer Royal, on the occasion of Dyson receiving the Gold Medal of the Royal Astronomical Society.

Yet here too there was room for only one scientist's name to remain in the public consciousness. Eddington, the founder of stellar astrophysics, quickly became the only name, besides Einstein's, associated with the eclipse experiment. Interestingly, this tendency to ignore Dyson is even found among scientists and historians, who have wondered if Eddington's alleged bias in favor of Einstein's theory influenced the data analysis of the Sobral plates.

The Sobral photographic plates were taken in Brazil by Dyson's assistants from the Royal Observatory, Greenwich during and after the eclipse. Precise measurements of star positions on the plates were required to test Einstein's light deflection prediction. Modern criticism of their analysis has included multiple claims that the decisions taken at the time were influenced by Eddington's bias in favor of Einstein's theory. However archival evidence shows that these decisions were taken by Dyson, who did not share Eddington's views on General Relativity. Eddington had, in all probability, nothing to do with their analysis. His work was confined to analysis of his own plates taken on Principe.

If we do acknowledge that Eddington may have been biased, what does this mean? Can a biased person do good science?

To better understand the role of bias in experimental science, let us compare Eddington with other eclipse experimenters. Bias, after all, may be a widespread phenomenon. An obvious counterpart to Eddington is Heber Curtis, who performed the 1918 Goldendale experiment. Curtis was biased the opposite way from Eddington, against Einstein and for nineteenth-century physics. Perhaps, as a result, he reported his measurements as favoring the result that light is entirely unaffected by gravity. Is this evidence that science is often merely an expensive means of confirming one’s own prejudices?

It is true that Campbell did not, in the end, feel that Curtis’ data was good enough to publish and that later on, Campbell’s own measurements of the 1922 eclipse favored Einstein. But this could be simply an example of the bandwagon effect. Undoubtedly, the existence of the British expeditions played a role in dissuading Campbell from publishing the suspect 1918 results, and working in 1922, he may have been concerned with replicating the result already made famous by previous expeditions. It is not just theory that can bias an experimenter. As anyone who has performed a laboratory experiment in school or college knows, one is expected to replicate the same result as others have done before. Recovering a different result may not be taken as evidence of an exciting new moment in science. It is more likely to be taken as evidence of an incompetent experimenter.

Experiments as Puzzle Solving

What scientists are trying to do, in performing an experiment, is get the right answer. In this respect it is like doing a crossword puzzle. Most of us know the right answer to a crossword puzzle will be published in the next day’s newspaper and keep trying until we get it. Even if we do not have a copy of the relevant newspaper, we may ask a friend for the solution. We try to agree with the result that everyone else got. Similarly, engineers strive to make their devices perform exactly like all other devices of similar type. Research scientists do not have this luxury. If you are the first ever to perform an experiment, you do not know what the correct answer is. You are essentially trying to guess what answer others will get in the future and agreeing with that!

Undoubtedly, if no previous experimental results exist, there is a temptation to agree with theory. Indeed, this tendency is obvious in the 1919 team’s presentation of their results. They repeatedly framed their experiment as being a choice between three theoretical possibilities. Logically, any result for the deflection of light might have been possible, which Eddington himself acknowledged when he wrote, “It is easy to calculate that the total deviation [due to gravity] of [a material body] on passing the Sun, if it grazed the surface, would be 0.″ 87, or half the Einstein deflection. It may happen that the ratio of weight to mass for light is not the same as matter. If so the deflection will be altered in the same proportion. The problem of the eclipse may, therefore, be described as that of *weighing light*" (Eddington 1919, 121). But the theoretical issues at stake were of such significance that it made sense to frame the experiment in such a way as to highlight its theory testing aspect.

Of course, theory often plays an essential role in science. It was theory that predicted the size of the effect. Had theory predicted a much larger gravitational deflection of light, Eddington and Dyson would have approached the experiment differently. Had theory predicted a much smaller deflection, they would never have embarked upon it at all. Theory must guide experiment because otherwise we would not know which experiments are interesting and achievable! In fact, had Einstein not pointed it out, most twentieth-century astronomers would never have believed that the Sun's deflection of light could even exist.

Finally, let us compare Eddington with Dyson. Dyson's case is different from Eddington's but not because he was neutral. That must be rare. Normally, the very fact that you are performing an experiment at all is because you expect a non-null result. No one went to the trouble of hauling equipment to an eclipse before Einstein came on the scene simply to prove that the stars do not change their positions because the Sun is nearby! Dyson was not neutral, but he appears to have changed his mind during the experimental process. He probably started out at least a little skeptical of relativity, like most astronomers, but he ended up confirming the theory. It is interesting that once he changed his mind, he exchanged one bias for another. For instance, he wanted to average the results from his two instruments to get an answer very close to Einstein's prediction.

Eddington had to persuade him that this was not kosher. Here we see the desire to let theory guide you to the right answer in its purest form. Dyson had no prior bias toward Einstein's theory, but once he decided in Einstein's favor, he was reasonably anxious to let the theory guide him. If you know that your error bars are large and that others will perform more exact experiments later, you may feel anxious for vindication in the future by coming as close as possible to the right result now. Theory is sometimes your only guide as to what that right result might be! And of course, once Dyson had nailed his colors to Einstein's mast, he knew his own reputation was bound up with Einstein's because Campbell's results would render a verdict not only on Einstein's theory but also on Dyson's previous experiment. So he breathed a sigh of relief when it seemed as if no "shadow of doubt" remained about Einstein's prediction, as he wrote to Campbell. Once that happened he canceled plans to repeat the test.

Communication and Appraisal is Essential for Science

Even realists, who believe that science is telling us how the world really is, must acknowledge that we do not have some inborn ability to comprehend the physical world. It takes great acquired expertise to perform scientific experiments. Unfortunately, it is of little use for these experts to do their work without telling the rest of us. By definition, the knowledge they gain about the world must then pass through society to become commonly accepted. If scientific ideas are memes, then we must accept that successful memes are not true— they are simply often repeated. Is it possible that we simply make the science that fits our preconceptions?

It is not that simple, but we can say that we do not live in a world where we are born knowing about atoms but have trouble communicating with each other. Instead, we are born into a world with little correct knowledge about its workings but with excellent abilities to communicate with each other. Science is, by necessity, a social enterprise. Only the people who have performed the difficult experiments have empirical knowledge of the way the world really is. In 1920 only Eddington and a few others had personal knowledge of whether starlight is really affected by the Sun's gravity. It follows that the rest of us must come to accept or reject Einstein's theory through social interaction with people who themselves have interacted with those who performed the measurements. For most of us, it is not observing photons move through spacetime that makes us trust Einstein's ideas. It is the way ideas move through society that makes us believe the "truth."

Ultimately, whether science is socially constructed or determined by the hard facts of reality is irrelevant. What we know is that the hard facts of reality are won with difficulty by people with unusual levels of expertise and skill. How those brave few convince the rest of us about the nature of reality is surely worthy of study, whether we are fooling ourselves about the laws of physics or whether we are on the right track. Indeed, if the social transfer of knowledge in our culture is such as to keep us on the right track, then it is all the more worthy of careful study! It is easy to assume that the study of reality must be straightforward, but it is not. Karl Popper alerted us to the difficulties of confirming a theory. While it is fine for Popper to say that we cannot prove a theory but we can falsify it, we must remember that in practice, falsifying theories is also problematic.

The fact that the light-bending experiment ceased to be performed after 1973 gives us a further clue about the way science is done. The dilemmas of research recede when experimental technology and technique mature.

Precision and the Eclipse Experiments

The eclipse experimenters, however, suffered from a peculiar malaise. Their precision failed to improve with time, undoubtedly because of the difficulties in repeating the experiment. Of course, some observers went to multiple eclipses, but the vagaries of weather and history mostly precluded them from obtaining more than one set of data. For instance, Freundlich traveled on at least six eclipse expeditions but only obtained data once. The 1973 team actually constructed a specialist observatory in the path of totality to try to overcome the problem of using transportable equipment. But they still fell afoul of the lack of repeatability when a technical problem that could have easily been fixed once discovered compromised their measurements.

In spite of it all, we have seen that science can progress even when scientists are handicapped by circumstances. But can it progress when they are biased? Progress in science is not guaranteed, and certainly, scientists sometimes change their minds, or have to backtrack. One can accuse many people in our story of bias, so why has Eddington attracted so much criticism over the decades? Primarily, it is because of his fame, of course, but also because he was perceived to have unscientific biases affecting this particular measurement. Some scientists are outraged, for instance, at the idea that he might have favored relativity because he sought reconciliation between English and German science after the war. But given how unpopular Eddington's antiwar views were, this accusation rings false to me. It is true that pacifism gained in popularity after the war as a reaction to its horrors, but this was not predictable in 1919.

There is a sense that Eddington is in the dock with Einstein on charges of behavior inappropriate for a scientist. Both are theorists accused of being too guided by theory and insufficiently respectful of the role of experiment. When Einstein pitied the dear Lord, who must put nature, his humble creation, to the test against the certainty of Einstein's theory, he reinforced the image of the cocksure theorist who disdains the humdrum work of experimental confirmation. Eddington also, during his career, played to the gallery in this way. Yet we know that Einstein worked hard to encourage astronomers to test his theory. He discovered the possible tests and calculated his theory's predictions. He published papers and wrote letters to leading astronomers to publicize what would need to be done. He collaborated with Freundlich and others and helped raise funds for their efforts. He did everything practical that was required.

Eddington did all this and participated in the observational work. It seems strange that all of this practical involvement in the effort to test the theory is ignored, and we are instead confronted with a playful remark clearly meant in jest. This does not mean that Einstein would immediately have capitulated if Curtis and Campbell had published their 1918 results vindicating Newton's theory. He would have insisted that the theory was correct and that their experiment was wrong, and he would have been justified in doing so. Experimenters are sometimes wrong! It was only over the course of many years that it became clear that relativity's prediction of the light deflection was completely correct. But that does not mean the public were wrong to lionize Eddington and Einstein in 1919. A new result is exciting, even if we acknowledge the possibility that it could later be overturned. When it comes with the dramatic overthrow of a famous theory, it is all the more exciting.

Karl Popper's Epiphany

In this respect it was the fame of the 1919 eclipse experiment that created the problem. Karl Popper was so impressed by Einstein's willingness to put his theory to empirical test that it prompted his, perhaps too hasty, commitment to falsification as the demarcation criterion for science and pseudoscience. Popper's ideas have been highly influential, to the point where they now stigmatize a characteristic aspect of Einstein's approach to science. He was famous in his day for being willing, as a theorist, to challenge the validity of experimental results. He did so against early experiments that appeared to falsify special relativity and again against Dayton Miller's ether drift experiments. One lesson learned from modern science studies is that scientists fight hard for their beliefs. Science is not about being willing to drop one's beliefs at the first sign of trouble. In fact, it depends on advocacy because in the absence of advocates an idea may be prematurely discarded.

We should not show disdain at Eddington and Dyson's skill at artfully presenting their science to the public. It is mistaken to believe that the truth needs no advocate. This need for advocacy applies not only to the public but also within science. Of course, advocacy is often partial and biased. But that is the price we pay for having it. In this respect science is like a court of law. Failing to find an advocate for the innocence of the accused will merely condemn them to conviction. Points of view that are not argued for will go unheard and unconsidered. It was a good thing that a leading theorist was, unusually, involved in the 1919 eclipse expedition because without Eddington, the theorists' insight—that Newton's theory was no longer tenable in its original form—would not have been represented. Without Eddington the importance of the test might not have been properly recognized.

The only issue setting Eddington apart is that his hopes were related to a theoretical tool rather than an experimental one. He hoped that general relativity would prove itself and open up the vistas that Einstein's innovation of metric theories promised. One of the many roles of a theory is as a simple tool for theoreticians. Just as an experimenter may hope that an experimental result will vindicate the use of a favorite tool, so a theorist may hope for the same thing. We need to recognize that the theoreticians' art is just as important as the experimenters' and just as likely to evolve. In essence, Eddington was in that uncomfortable position of being between paradigms. The old worldview had been overthrown. A new one was not yet firmly in place. The eclipse was exciting just to the extent that it might give a clue to the right path forward.

Science and Myth

Does it seem troubling that scientists believe in their theories and that this belief lets them work wonders? Does this reduce science to the status of another myth, something that vanishes when people cease to believe in it? The term *myth* has a pejorative aspect today and is more or less synonymous with falsehood. But it also refers to a way of explaining the world around us, and one of the attractive aspects of myth is the way that good myths are fecund. A myth builds on itself, generating new stories about its characters. Viewed in this way, a myth is a good model for science.

One of the most important attributes of a scientific theory is its fecundity. If it fails to give rise to new questions, new concepts, and new research, then it is of little practical value. In this way relativity has been an extraordinarily fecund theory. It has given birth to ideas about the world that never existed before, such as gravitational waves, black holes, neutron stars, and a cosmology in which the geometry of the universe is not necessarily Euclidean. Some of these ideas were still hidden from view in 1919, but Eddington and Einstein knew enough to see the outlines of great discoveries ahead.

Looking back a century later, we can certainly imagine that they would be proud of the successes of modern gravitational theory, all made possible by the observations of 1919.

Chandrasekhar, Subramanian. (1987), *Truth and Beauty: Aesthetics and Motivations in Science,* University of Chicago Press.

Eddington, Arthur Stanley. (1919), "The Total Eclipse of 1919 May 29 and the Influence of Gravitation on Light." *The Observatory* 42: 119–122.

The foregoing is an edited version of the concluding chapter 15 of Daniel Kennefick *No Shadow of a Doubt*, Princeton University Press, 2019.
https://press.princeton.edu/titles/17193.html