Essays

RECLAIMING PHYSICAL REALITY

Thomas Davenport, O.P.

Take a moment and think about what a genius looks like. There's a pretty good chance you're imagining an elderly man with shock white unkempt hair. In fact, chances are you're looking at Albert Einstein, and given the two separate revolutions in modern physics he helped initiate, you'd be right for doing so. What you may not realize is that, although he was productive in physics until late in life, Einstein's most significant work came well before he even started to go gray, and much of it he produced in one year, 1905, at the age of 26.

In this *Annus Mirabilis*, as physicists have dubbed it, he published four papers that profoundly shaped the course of modern physics. The first, for which he won the Nobel Prize, explains a puzzling experimental result known as the photoelectric effect by proposing that light is composed of discrete packets of energy, paving the way for quantum mechanics. The second provides an explanation of Brownian motion as the random motions of atoms in a liquid, confirming the reality of atoms then still disputed. The third lays out the theory of Special Relativity, completely changing the way physicists think about space and time. The fourth draws out the implications of Special Relativity for matter, including the famous mass-energy relation popularly expressed as $E=mc^2$.

The boldness of the young Einstein is a particularly apt example of a common conception: the best science pushes the frontiers of our understanding, perhaps beyond the frontiers of our comfort. While the particular experimental results that Einstein addressed had been known for some time, they did not fit into known physical theories. Other physicists were beginning to stretch the boundaries of these theories and would almost certainly have come to the same conclusions arrived at by Einstein, but he got there first—not just for one problem but for a plethora of them. Einstein's work opened new vistas that previous generations of physicists could never have dreamt of, and without disrespect for his predecessors, he set aside some of their most cherished principles.

One might think that these *Annus Mirabilis* papers of Einstein would be required reading for any serious student of physics. One would be wrong. Sure, some do go back and read these and other historic physics papers out of a certain historical curiosity and reverence. But, in terms of understanding the physics they established, there are better, clearer, and fuller explanations of all of Einstein's results in modern physics textbooks. Great physicists like Einstein are not honored because they gave the best arguments, but because no one had made such arguments before.

The Difference between Physics and History

I remember being shocked to find out that a friend had graduated from Stanford with a degree in history without ever having taken a standard history course. There were requirements for the degree, of course, but they were broad enough to be filled by any number of courses ranging from "Russian History from 1875 – 1890" to "Food in America." The focus of the curriculum and the courses was less on content and more on method. One learned how to "do" history by reading primary and secondary literature and placing various ideas and events in their social, political, technological, and other context. These are important issues, but the lack of some defined common content bothered me. It seemed so . . . fuzzy.

To someone schooled in the perspective of the hard sciences, the fact that two history students could graduate from the same department without taking any common courses is unthinkable.

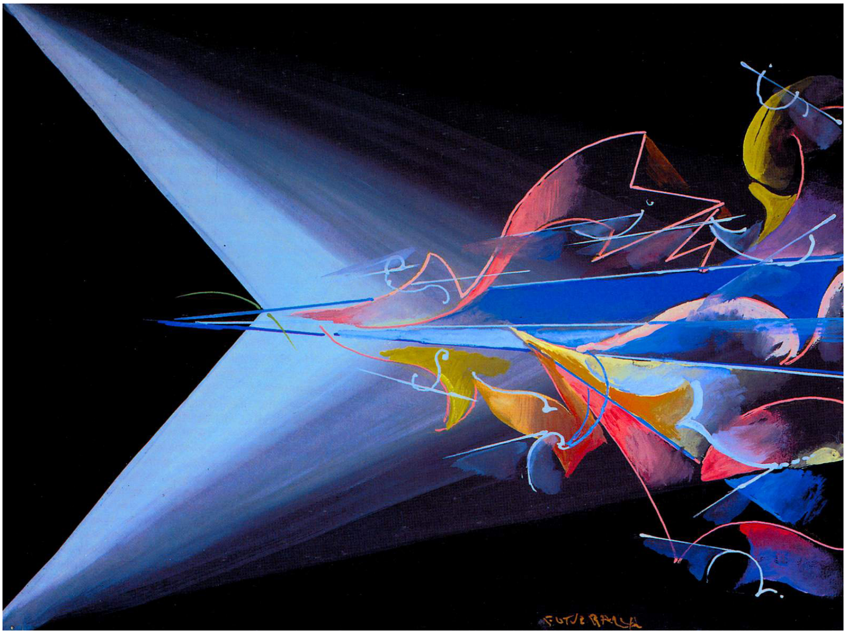
One could take any sophomore physics major from around the country, perhaps around the world, and if they are not taking similar math and physics classes it is because they took them the year before. There is a method to be learned in physics but you learn the method by grappling with the content, doing calculations, solving mathematical problems. There is no historical context to worry about; whatever historical observations led to a particular idea in physics could be reproduced today, and often are, in lab classes.

While the close analysis of primary texts is crucial for good history, it is not so for good physics. Studying Newton's writings will not change the fact that F=ma or that gravitational attraction obeys the inverse square law. Even if one thinks that some particular discipline of science has gone wrong along the way, arguments will not be based on a reinterpretation of foundational documents. Instead, the dissatisfied scientist must give a new theory and produce the data that shows the weakness of the previous theory.

Sola Scientia Moderna

This ahistorical perspective (that the historical developments that led to any scientific discovery and the particular form in which it was initially expressed are secondary) gives priority to the objectivity of the scientific theory, especially when expressed in mathematical language. This perspective has not only advanced our understanding of the order and structure of the natural world, it has also changed the way scientists think about knowledge in general and, unfortunately, the way society does as well.

Modern science has become the gold standard by which all knowledge is measured; any "knowledge" that is not presentable in scientific language is counted as mere opinion at best and sophistry at worst. Rigorous scientific knowledge is, or should be, the only real knowledge.



Giacomo Balla - Science Against Obscurantism

This hegemony of scientific knowledge pledges to ensure a solid grasp on the truth and a correct understanding of reality. Thus it is not shocking these days to hear someone like Stephen Hawking, a preeminent theoretical physicist, making the claim "philosophy is dead" and asserting that only science can give us access to the real. What *is* surprising is his statment on the next page: "the universe itself has no single history, nor even an independent existence." That doesn't sound like science at all.

Hawking claims that this is a preeminently scientific statement, a logical conclusion from his study of physics. He claims that physics can only give us different models to describe our observations and that there is no way to distinguish different models that describe it equally well. The best we can do is simply use whichever one is most useful at the moment. This agnosticism about reality seems to fly in the face not only of common sense, which does not bar it from being true in modern physics, but also of the professed rigors of scientific knowledge. It seems so . . . fuzzy.

To be sure, there are many who would disagree with Hawking, not so much on his physics, but on his interpretation of the physics, a philosophical interpretation. Even so, he is a well-respected physicist and his views carry no small weight. So what happened? How did scientists, with their ever more precise and detailed theories and experiments, lose the ability to speak confidently about reality? The answer, I claim, lies exactly where most scientist do not bother to tread: the foundational documents and the discussions that built up around them.

Retracing Steps: Einstein

Hawking explicitly links his claims about reality to the sort of weirdness that physicists are forced to deal with in quantum mechanics. Looking back to Einstein's first *Annus Mirabilis* paper, one can see that the seed of the confusion is already present. Einstein admits that the theory describing light as a continuous wave is extremely well grounded by a variety of experimental regimes, but he observes that a growing number of newer experiments are better explained if light is treated as discrete packets, or particles, of energy. He did not attempt to reconcile the two disparate perspectives on light (wave or particle) but simply presented the usefulness of the particle view in describing the results of *some* experiments.

As more and more new experiments failed to settle the issue, sometimes displaying wave properties and sometimes particle properties, a certain familiarity with the oddity of light and electrons developed. Eventually a coherent mathematical description of what to expect from various experiments came together: what we now call quantum mechanics.

Unfortunately, rather than settle the issue, quantum mechanics simply clarifies how different these new observations were from the common understanding of physics since the time of Newton. While it brilliantly describes the results of all of the experiments on light, atoms, and electrons, it simply does not describe the particular trajectory they took to get that result.

There is a fundamentally probabilistic nature to the theory that is not the result of the problem being too complicated, but is part and parcel to the theory itself. This does not stop physicists from arguing over the exact physical meaning of the mathematical formalism and developing a variety of interpretations of what happens at the subatomic level, but such explanations require leaving the realm of physics for philosophy.

As the mathematical results for all of these interpretations were the same, physics simply carried on developing the theory of quantum mechanics; leaving aside the question of interpretation, perhaps musing on it over a beer here or there. True physics was the mathematical formalism, which everyone agreed upon, so there was no real urgency to settle what was, to physicists, simply a philosophical question about reality.

Retracing Steps: Newton

Einstein was confident that adhering closely to the coherent mathematical description of physical observations would lead to a fuller understanding of the phenomena in question. And it did, to a certain extent, but not in a way he expected or was particularly happy about. Confidence in mathematics to explain the natural world had been developing since the scientific revolution of the 17th century. This confidence is part of what set apart the groundbreaking work of Isaac Newton, particularly his work on gravity in the *Philosophiæ Naturalis Principia Mathematica* ("Mathematical Principles of Natural Philosophy"). In this work, Newton lays out his argument for the existence of universal gravitation—the fact that all massive bodies are attracted to other massive bodies with a force that varies with the inverse of distance squared.

Interestingly enough, Newton's theory met with plenty of resistance when it was published in 1687. Objectons were raised not because of any mistake in his mathematical argument but because Newton had not sufficiently demonstrated the cause of gravity. His peers were not looking at his claims as modern scientists, but as natural philosophers. For them, true science was really about knowledge of causes, about reality itself.

Newton did not use mathematics to build up an *a priori* view of the world from basic principles, but used mathematical techniques to describe the observed motion of massive objects and show the universality of that description. In reaction to criticism from his contemporaries, he made a sharp, and fateful, distinction between the conclusions deduced from observation and the hypothetical causes which could not be observed, stating that the latter had no place in "experimental philosophy."

For Newton, the method of deducing mathematical order from experimental observation was the surest way to obtain knowledge about nature and to advance the project of natural philosophy.

A More Natural Perspective

Even from this extremely cursory look at how physicists consider their craft, we see a stark bifurcation occurring. Newton saw mathematics as a tool for coming to a sure knowledge of nature, a knowledge surpassing the unobservable speculation that many of his contemporaries were promoting. By the time of Einstein, physicists were so convinced of this power of mathematics applied to observable data that they were more confident in the mathematics than in the underlying reality that it was supposedly describing.

This paved the way for a prominent physicist like Hawking to confidently assert that we cannot actually say anything about reality as such; we can only propose various mathematical structures that describe our observations. Science, originally intended to give us a more accurate and complete grasp on reality, seems to have given up on describing reality at all!

If there is any hope of actually talking about the reality of a world that underlies modern science and thus restoring science to its rightful orientation to reality, modern science must be put in proper perspective. Modern science is profoundly adept at dealing with the observable, but it has lost, and in a certain sense never had, the tools to ground these observations firmly in reality.

Although Newton rightly asserted the primacy of experimental methods over pure speculation, physical objects are not simply numbers. The application of mathematics to the physical represents only a part of a much broader project of natural philosophy.

Not explicitly Aristotelian at the time, Newton's natural philosophy was still rooted in Aristotelian principles, principles that provide the tools modern science is lacking. More than a philosophy of science, which simply thinks about what mathematical science is doing, natural philosophy seeks to understand the causes and the nature of the physical or, as Aristotle put it, the mobile.

Aristotelian-Thomistic Contributions

For an example of true natural philosophy, take the concept of time. For Newton, time was measured by a single fixed clock, fit to a rigid grid of space, valid for the entire universe. In Einstein's theory of relativity, space and time are united in a fluid space-time continuum that, while consistent for the universe, has different expressions for different observers. While the theory has found experimental support, its mathematics breaks down in trying to work backwards toward the Big Bang. Drawing on quantum mechanics, Hawking and others have had great success constructing a cleaner mathematical picture using what they call imaginary time. By replacing the normal time coordinate with imaginary time, it can be treated just like a dimension of space, removing many mathematical difficulties. But Hawking goes further, saying that because the two models of time both accurately describe our observations it is "meaningless" to ask which of the two, ordinary time or imaginary time, is actually closer to reality.

Contrast Aristotle, who defined time as the number of motion in respect of before and after." Time for Aristotle is inseparable from motion or change. If there is change, there will be a before and an after—there will be time. As useful as Hawking's mathematical model may be in solving a particular problem, with its four dimensions and no time, it does not describe real change and, therefore, does not describe reality. The useful and the real are not identical. To connect mathematical scientific theories to reality, one needs solid principles of natural philosophy.

Aristotle, and St. Thomas building upon his principles, could not have imagined the amazing results achieved by modern science, but they were well aware of the usefulness, as well as the limitations, of mathematics. St. Thomas is quite explicit: "Mathematical inquiry is easier and more certain" than that of natural philosophy on its own. Yet he also maintains that mathematical objects are a limitation and simplification of the sensible objects that natural philosophy considers. The physical world is more than just measurements and numbers.

Certainly some physical conclusions that Aristotle and St. Thomas held as certain, like geocentrism and the theory of four elements, were based on faulty premises. Returning to Aristotle and St. Thomas does not entail resurrecting these false ideas. In fact, by their own principles, a serious reconsideration of modern science based on a Thomistic natural philosophy should not conflict with any of the results or conclusions that are known certainly by modern science. Nor will Aristotle and St. Thomas necessarily solve all the philosophical problems that arise in modern science. They themselves argue that there is a certain indeterminacy in the material that can never be completely removed.

A *ressourcement* of a robust natural philosophy will offer science the tools to talk coherently about reality and to interperate the findings of modern science. Aided by the principles of Aristotle and St. Thomas, modern science can be a more realistic science. Like Newton and Einstein, scientists boldly advance the boundaries of our knowledge with new experiments and new mathematical theories describing their results. But abandoning the foundational legacy of natural philosophy, especially as understood by Aristotle and St. Thomas, risks placing ourselves more and more in a world of mathematical models disconnected from reality, a world that is once again all too . . . fuzzy.

Thomas Davenport entered the Order of Preachers in 2010.