Opinion Page: ***Touching Reality: Philosophical Lessons from Contemporary Cosmology***

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Scientific realism

The universe is vast, and the longer we observe it, the more we learn about its composition and structure. Additions to knowledge of this sort are what the popular science writers usually have in mind when they talk about 'scientific discoveries.'

But historians of science tell us that periods of steady growth in science tend to last only so long: they are interrupted by revolutions during which the old assumptions are thrown out and a radically new set are brought in. The initial decades of the twentieth century witnessed a number of such episodes. Classical mechanics and electromagnetism were replaced by quantum electrodynamics, Newton's theory of gravity and motion was replaced by Einstein's. The changes in these theories were so radical that even basic concepts like mass and time acquired fundamentally new meanings.

But it has been rather a long time since a major shift of this sort took place, and it is natural to wonder whether scientific revolutions are a thing of the past. Some philosophers seem to think so. For instance, John Worrall wrote in 2007 that "it is reasonable to believe that the successful theories in mature science–-the unified theories that explain the phenomena without ad hoc assumptions . . . are, if you like, approximately true."

Worrall's view, which is one aspect of what is now called '(critical) scientific realism', is widely held among the current generation of philosophers. Scientific realists do not just postulate a mind-independent reality. They believe in addition that the central claims of our best scientific theories are probably, or approximately, true, even when it comes to claims about entities that are not directly observable—what philosophers call 'theoretical entities.' In the words of Stathis Psillos, scientific realism entails that "the entities posited by [mature theories], or, at any rate, entities very similar to those posited, do inhabit the world".

The current, standard theory of cosmology—the so-called **Λ**CDM model—postulates the existence of just such an entity: dark matter. (CDM stands for 'cold dark matter.') Dark matter is not a *minor* component of the standard model; in fact, *most* of the matter in the universe is said to be dark. And while the detailed properties of the dark matter are not specified, cosmologists almost universally assume that it is composed of some kind of elementary particle. Considerable effort (and money) have been expended over the last four decades in attempts to detect the dark particles, so far without success. Absolutely none of this dark matter, which supposedly constitutes most of what exists, has ever been observed.

Two cosmological paradigms

But there is an alternate cosmological theory, called MOND, that does not postulate the existence of dark matter. Observations that are explained under **Λ**CDM using dark matter are explained under MOND by postulating a modification to Newton's (or Einstein's) theory of gravity. (MOND stands for 'MOdified Newtonian Dynamics'.) It has become clear over the last few years that MOND is at least as successful as **Λ**CDM at explaining our observations of the universe, including those data that are believed by standard-model cosmologists to require the existence of dark matter.

Indeed a compelling case can be made that MOND is the *preferred* theory, in the sense that MOND has a stellar record of successfully *predicting* new facts in advance of their observational discovery (as documented here). The **Λ**CDM theory has rarely, if ever, managed to do that; its 'successes' are almost all successes of post-hoc accommodation, not prior prediction.

One might suppose that philosophers of science would be fascinated by this state of affairs, since it has all the earmarks of an incipient paradigm shift. But to the puzzlement of many scientists, the philosophers have mostly declined to engage with the issue. I think that a partial explanation can be found in their ideological commitment to 'scientific realism':

1. The existence of *empirical equivalents* to existing theories—that is, theories that differ in important ways from accepted theories but that make the same, or nearly the same, predictions about observable phenomena—is difficult to reconcile with a belief in scientific realism. Realist philosophers tend to assume that such equivalents (in this case, MOND) must be contrived or artificial, if they exist at all.

2. Scientific realists acknowledge that the descriptions of the unobserved entities that appear in scientific theories tend to change over time. To maintain their commitment to realism, they are motivated to search for *referential continuity*: to argue that the 'same' entities are

present in a theory, even if the detailed descriptions of those entities, or the detailed manner in which the entities are related to observable phenomena, should change over time. But this is clearly not going to be the case if the standard model is replaced by MOND, since the latter contains no component that could plausibly be related to the dark matter of **Λ**CDM.

3. If current theories are assumed to accurately describe the physical universe, it follows that the methods scientists use to arrive at those theories must be reliable. This leads realist philosophers to favor a gradual, typically *inductivist*, model for scientific progress—as opposed to progress via bold new conjectures, like the conjectures that led to quantum mechanics or relativity (or MOND).

Gradual change or bold leaps?

Number three is, I think, the most interesting. So let me elaborate:

The model of scientific methodology that dominated in the early twentieth century was called 'logical positivism', and it was based on the old idea that scientists proceed inductively: i.e. that they make (hopefully valid) generalizations from finite data. But it soon became obvious that scientists like Einstein, Bohr and Schrödinger had *not* proceeded inductively; rather, they made bold conjectures that went far beyond the data that were available at the time.

Starting around 1930, the philosopher Karl Popper argued convincingly that inductive inference simply does not exist, and so could not possibly serve as the basis for a scientific method. He proposed an alternative methodology, which he called 'conjectures and refutations': one makes proposals and accepts them only if they stand up to rigorous testing–-that is: if they make novel predictions that turn out to be correct.

Popper argued (contrary to the claims of the inductivists) that it did not matter in the slightest how a scientific hypothesis was arrived at. All that mattered was how well it stood up to critical appraisal. And he argued that *bold* hypotheses–-which go far beyond any available data–-were preferable to ad hoc ones that did little more than address a known anomaly.

The attitude of the modern scientific realist is, apparently, "That was then, this is now." Since they maintain that fundamental changes to our 'mature' theories are no longer to be expected, scientific realists have little use for a methodology that encourages bold theorizing. They are motivated instead to favor methodologies that never take theories very far beyond their current (presumed nearly correct) forms.

To find a satisfactory methodology, realist philosophers have had to reach back in time—to the mid 19th century at least, before the time of Karl Popper. And their currently favored stand-in for Popper is the American philosopher Charles Sanders Peirce (1839 – 1914).

Peirce operated in a world that had not yet experienced the early twentieth century revolutions due to Einstein and Bohr that so strongly influenced philosophers like Popper and Kuhn. Peirce argued that one could claim correctness of a hypothesis simply on the basis that it explains whatever data it was designed to explain. Peirce called this methodology 'abductive inference.'

Even admirers of Peirce have acknowledged Popper's point that *multiple* hypotheses will always be consistent with any finite set of data, and hence that there is a need to select between them. But rather than follow Popper's advice (bold conjectures followed by critical testing), they have chosen to modify Peirce's abduction into what is usually called *inference to the best explanation*, or IBE. Roughly speaking, IBE tells the scientist to accept the 'best' explanation among the many possible ones. And (this is the key point) 'best' is usually defined as the explanation that requires *as little change as possible to accepted theories*.

It is easy to see how a methodology like abduction or IBE fits hand-in-glove with scientific realism, which posits that major changes to accepted theories are no longer to be expected. And indeed, promoters of abductive inference, like philosopher Ilkka Niiniluoto, have explicitly stated that dark matter is a better explanation than MOND simply because "the theory [of gravity] is kept constant". Inference has seemingly been reduced, here, to the uncritical acceptance of whatever the majority of scientists believe; Niiniluoto gives no weight to MOND's enormously greater success at anticipating the data – at making successful, new predictions.

All of this smacks of putting the cart before the horse, epistemologically speaking. Fortunately, it is quite possible to be a realist—in the sense of accepting the existence of a mind-independent, objective reality—without signing on to the additional ism's that are currently lumped together under the rubric of 'scientific realism'. Popper, a lifelong realist, argued that the existence of a falsifiable, i.e. testable, theory implies the existence of a reality with which it can clash: "Our falsifications thus indicate the points where we have touched reality". Perhaps 'touching reality' ought to be the most we expect from our theories.