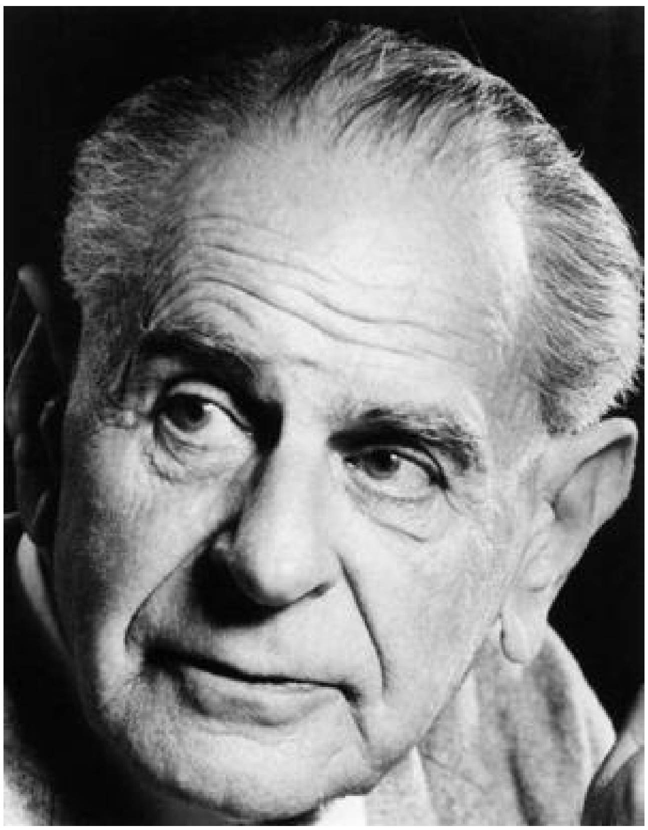
When science and philosophy collide in a 'fine-tuned' universe

April 3 2014, by Jonathan Borwein And David H. Bailey



Karl Popper. Credit: Wikimedia Commons

When renowned scientists now talk seriously about millions of multiverses, the old question "are we alone?" gets a whole new meaning.

Our ever-expanding universe is incomprehensibly large – and its rate of growth is apparently accelerating – but if so it's actually in a very delicate balance.

It's then incredible that the universe exists at all. Let us explain.

In a 2004 review in Science of Searle's Mind a Brief Introduction, neuroscientist Christof Koch wrote:

Whether we scientists are inspired, bored, or infuriated by philosophy, all our theorising and experimentation depends on particular philosophical background assumptions. This hidden influence is an acute embarrassment to many researchers, and it is therefore not often acknowledged. Such fundamental notions as reality, space, time and causality – notions found at the core of the scientific enterprise – all rely on particular metaphysical assumptions about the world.

This may seem self-evident, and was regarded as important by Einstein, Bohr and the founders of quantum theory a century ago, but it runs against the grain of the views of working scientists in the post-war period.

Indeed, 21st-century mathematicians and scientists seem to have little need of philosophy.

The glory days of Karl Popper, who argued that falsifiability was a hallmark of good science, and Thomas Kuhn, who noted the phenomenon of paradigm shifts, are long gone—in science, if not in the humanities.

For many years, scientific philosophy as practised by scientists has languished, punctuated only by lapses such as the Sokal hoax, when NYU physicist Alan Sokal wrote a tongue-in-cheek article with a lot of scientific nonsense that was accepted by a leading journal in the postmodern science studies field (and launched a cottage industry of similar hoaxes).

But maybe the tide is finally turning. Perhaps modern science really needs philosophy after all.

Cosmic coincidences

The main drivers here are some truly perplexing developments in physics and cosmology. In recent years physicists and cosmologists have uncovered numerous eye-popping "cosmic coincidences," remarkable instances of apparent "fine-tuning" of the universe.

Here are just three out of many that could be listed:

1. **Carbon resonance and the strong force.** Although the abundance of hydrogen, helium and lithium are well-explained by known physical principles, the formation of heavier elements, beginning with carbon, very sensitively depends on the balance of the strong and weak forces. If the strong force were slightly stronger or slightly weaker (by just 1% in either direction), there would be no carbon or any heavier elements anywhere in the universe, and thus no carbon-based life forms like us to ask why.
2. **The proton-to-electron mass ratio.** A neutron's mass is slightly more than the combined mass of a proton, an electron and a neutrino. If the neutron were very slightly less massive, then it could not decay without energy input. If its mass were lower by 1%, then isolated protons would decay instead of neutrons, and very few atoms heavier than lithium could form.
3. **The cosmological constant.** Perhaps the most startling instance of fine-tuning is the cosmological constant paradox. This derives from the fact that when one calculates, based on known principles of quantum mechanics, the "vacuum energy density"

> of the universe, focusing on the electromagnetic force, one obtains the incredible result that empty space "weighs" 1,093g per cubic centimetre (cc). The actual average mass density of the universe, 10-28g per cc, differs by 120 orders of magnitude from theory.

Physicists, who have fretted over the cosmological constant paradox for years, have noted that calculations such as the above involve only the electromagnetic force, and so perhaps when the contributions of the other known forces are included, all terms will cancel out to exactly zero, as a consequence of some unknown fundamental principle of physics.

But these hopes were shattered with the 1998 discovery that the expansion of the universe is accelerating, which implied that the cosmological constant must be slightly positive.

This meant that physicists were left to explain the startling fact that the positive and negative contributions to the cosmological constant cancel to 120-digit accuracy, yet fail to cancel beginning at the 121st digit.

Curiously, this observation is in accord with a prediction made by Nobel laureate and physicist Steven Weinberg in 1987, who argued from basic principles that the cosmological constant must be zero to within one part in roughly 10^{120} (and yet be nonzero), or else the universe either would have dispersed too fast for stars and galaxies to have formed, or else would have recollapsed upon itself long ago.

The Anthropic Principle

In short, numerous features of our universe seem fantastically fine-tuned for the existence of intelligent life. While some physicists still hold out for a "natural" explanation, many others are now coming to grips with the notion that our universe is profoundly unnatural, with no good explanation other than the Anthropic Principle—the universe is in this exceedingly improbable state, because if it weren't, we wouldn't be here to discuss the fact.

They further note that the prevailing "eternal inflation" big bang scenario suggests that our universe is just one pocket in a continuously bifurcating multiverse.

Inflation cosmology, by the way, got a significant experimental boost with the March 17, 2014 announcement that astronomers had discovered gravitational waves, signatures of the big bang inflation, in data collected from telescopes based at the South Pole.

In a similar vein, string theory, the current best candidate for a "theory of everything," predicts an enormous ensemble, numbering 10 to the power 500 by one accounting, of parallel universes. Thus in such a large or even infinite ensemble, we should not be surprised to find ourselves in an exceedingly fine-tuned universe.

But to many scientists, such reasoning is anathema to traditional empirical science. Lee Smolin wrote in his 2006 book The Trouble with Physics:

We physicists need to confront the crisis facing us. A scientific theory [the multiverse/ Anthropic Principle/ string theory paradigm] that makes no predictions and therefore is not subject to experiment can never fail, but such a theory can never succeed either, as long as science stands for knowledge gained from rational argument borne out by evidence.

And even the proponents of such views have some explaining to do. For example, if there are truly infinitely many pocket universes like ours, as physicists argue is the case, how can one possibly define a "probability measure" on such an ensemble? In other words, what does it mean to talk of the "probability" of our universe existing in its observed state?

But others see no alternative to some form of the multiverse and the Anthropic Principle. Physicist Max Tegmark, in his recent book Our Mathematical Universe, argues that not only is the multiverse real, but in fact that the multiverse *is* mathematics—all mathematical laws and structures actually exist, and are the ultimate stuff of the universe.

Modern science needs philosophy

With this backdrop, a growing number of scientists are calling for head-to-head interactions with philosophers. In a recent New Scientist article, cosmologist Joseph Silk reviews these and other issues now faced by the field, and then notes that such problems, probing the meaning of our very existence, are closely akin to those that have been debated by philosophers through the ages.

Thus perhaps a new dialogue between science and philosophy can bring some badly needed insights into physics and other leading-edge fields such as neurobiology. (Indeed, there is a burgeoning sub discipline of neurophilosophy.)

As Silk explains, "Drawing the line between philosophy and physics has never been easy. Perhaps it is time to stop trying. The interface is ripe for exploration."

Provided by The Conversation