

As Constant As Polaris

Should we expect the “constants of nature” to be constant?

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News

by GOVERT SCHILLING

Conference Idea: Should we expect the “constants of nature” to be constant??

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I am as constant as the Northern Star,” Julius Caesar declares in Shakespeare’s play. Indeed, to the Bard and his contemporaries, few things looked as steadfast as the Universe.

But Polaris is now known to be a variable star, and the Universe an ever-changing place. Physicists and cosmologists are even considering the possibility that the so-called ‘constants’ of Nature – like the strength of gravity, or the mass of the proton – are actually variable.



AVI LOEB
Harvard-Smithsonian Center for Astrophysics

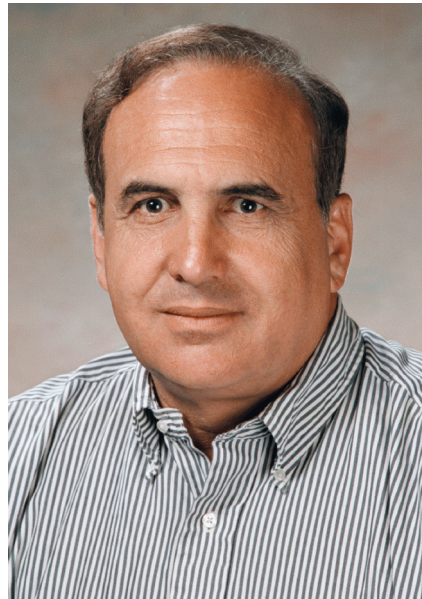
A discovery that one or more ‘constants’ are variable would shake the foundations of science, but, as theoretical astronomer Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, says: “There’s nothing sacred in physics.”

Observational Variability

The idea of variable constants is not new. In the 1930’s, British physicist Paul Dirac suggested that Newton’s gravitational constant might have been different in the past.

“Although Dirac’s argument is no longer taken serious by physicists, the idea of varying constants has come up again and again ever since,” says high-

energy physicist Tom Banks of UC Santa Cruz and Rutgers University. “It’s definitely a theoretical possibility. The question of course is whether or not this possibility is realized in the real world.”



TOM BANKS
UC Santa Cruz

So far, observations have remained inconclusive. A few years ago, measurements of distant quasars at the edge of the observable universe seemed to suggest that the fine structure constant – a measure of the strength of the electromagnetic force – was slightly smaller in the very distant past. But the claim has met with skepticism.

“If true, this change would have given rise to a markedly different expansion history of the universe,” says Banks, whose team studied the consequences of a variable fine structure constant. Adds Loeb: “Most cosmologists do not believe that this observation and the subsequent analysis is really robust.”

So should we just accept that the constants of Nature are truly constant? Maybe not, says theoretical astrophysicist Fred Adams of the University of Michigan in Ann Arbor. “There’s no *a priori* reason why they couldn’t change,” he says, “so it’s a possibility we should consider.”



FRED ADAMS
University of Michigan

Physicist Dmitry Budker of the University of California at Berkeley, who carries out laboratory experiments to check possible variations of the fine structure constant, agrees. So far, experimentalists have only been able to set upper limits to possible changes in the constants of Nature, but “at this point, non-observation of variation is a very weak argument in favor of one theory over the other,” says Budker.

And so the search goes on.

Theoretical Variability

Indeed, the whole idea of variable constants is rooted in theory, not observations. According to the current Standard Model of particles and forces, the constants of Nature are just that – constant. But the Standard Model fails to unite

two pillars of 20th-century physics – general relativity and quantum mechanics – so it must be incomplete. And most contenders for the long-sought theory of quantum gravity (a.k.a. the Theory of Everything) allow the constants to vary over time or from one place to the other. In fact, says Loeb, there are no viable extensions to the Standard Model that predict the constants to be constant.

Loeb himself is a strong supporter of the popular string theory. According to string theory, a complete ‘landscape’ of different ‘universes’ may exist way beyond our observational horizon. In these innumerable domains, every constant of Nature may have a different value, leading to an infinite zoo of weird universes.

There’s nothing sacred in physics.

- *Avi Loeb*

Although this would in principle also open up the possibility of measurable changes in the constants in one or more domains, Loeb doesn’t expect to find changing constants in our corner of the Multiverse. “That would pose a very big challenge to string theory,” he says.

Granted, there are some theories floating around that *do* predict changes in the constants of Nature in our own observable universe, but, says Budker, “they are of exploratory (to avoid saying ‘speculative’) character.” Banks, for one, expects all of the constants of Nature to be really constant. And Adams concedes: “If I had to bet, I’d say it is more likely that we just will lower the limits on any possible variation. Variable constants are a theoretical possibility to consider, but I don’t have strong expectations.”

Obviously, the final word should come from future observations and experiments. “Observers should never believe theorists,” says Loeb.

Variable Variability

That leaves the question: how long should we keep looking? If future experiments leave less and less wiggle room for changes in the constants of Nature, will physicists finally conclude that they have been chasing a red herring? Not likely, according to Adams.

“You can never really *prove* they are truly constant,” he says.

Banks adds that new experiments are always worthwhile, as long as you have good new ideas. After all, he says, “our understanding of Nature is not so great. But if we had to choose between these kind of experiments and building the LHC [the Large Hadron Collider, the new big particle accelerator at the European CERN laboratory], it’d be the LHC, of course.”



DMITRY BUDKER
UC Berkeley

On the other hand, if scientists someday discover that the constants of Nature actually vary, what implications would arise? After all, scientists would be left with the question what causes the specific variability. Moreover, the detected rate of change could in principle turn out to be a new ‘constant of Nature’ – simply replacing one mystery by another.

So what’s the big deal? “The deal is that the foundations of physics would have to be revisited,” says Budker, “as all the present ‘laws’ of physics assume constancy of the constants.” According to Adams, “the final payoff is a better understanding of the Universe.”

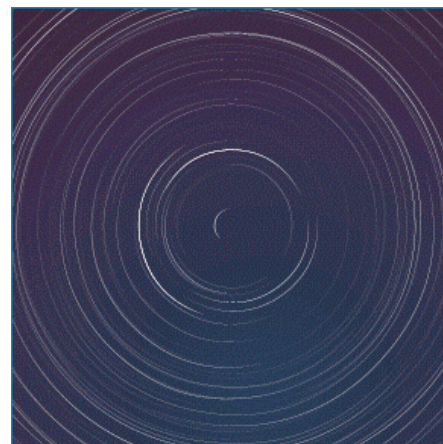
In the end, even though most physicists don’t expect to find observational evidence for changing constants of Nature, future experiments may still change all that. As Adams says: “The whole idea of the Foundational Questions Institute is to discuss these questions that regular, mainstream science doesn’t ask.”

c is for Constant?

Although it’s hard to say whether one particular constant of Nature is more likely to be variable than another, many physicists believe that *c* – the speed of light in a vacuum: 300,000 kilometers per second – may be a true constant, even within the framework of a future Theory of Everything.

Says Harvard’s Avi Loeb: “The speed of light is really very fundamental; it’s the building block of the theory of General Relativity. No other constants of Nature are like *c* in that respect.” Tom Banks at Rutgers agrees. “It’s very unlikely that we could have a changing light speed without a breakdown of the principle of relativity,” he says. “Most physicists tend to think of *c* as a constant.”

Most, but definitely not all. Scientists like John Moffat (University of Toronto, Canada), Andreas Albrecht (University of California at Davis) and, most notably, João Magueijo (Imperial College London, United Kingdom) have proposed ‘VSL cosmologies,’ where VSL stands for ‘variable speed of light’. Today, however, these ideas are extremely controversial.



POLARIS
The Northern Star