Chasing Constant Change

Scientists used to think the fine-structure constant, called alpha, was, well, constant. Dmitry Budker races to prove alpha in fact varies – a discovery that would change physics as we know it.

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by GOVERT SCHILLING

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Some people have a hard time understanding what physicist Dmitry Budker is doing.

After all, minute variations in the constants of Nature seem to be of no concern whatsoever to our daily lives. "In a lecture for non-physicists, I once explained that these are fundamental and philosophical issues, related to the big questions about the Universe," says Budker. "One woman in the audience then asked me: Why spend tax payer's money on this? You might as well fund poetry."

A professor of physics at the University of California at Berkeley, Budker is studying the so-called fine-structure constant, a.k.a. alpha (see sidebar). Alpha can be regarded as a measure of the strength of the electromagnetic force; or, as a fun little jingle goes, *It's the electron charge squared, which then you divide / by the constant of Planck times the swiftness of light.*

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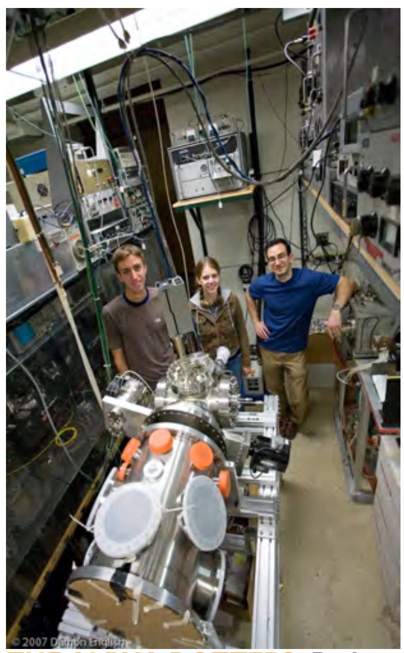
>
> *- Dmitry Budker*

Well, at least this sounds like a poem, and the discovery of a variation in the fine-structure constant might indeed be more profound than any sonnet ever written. "It would be very big news," says physicist Wim Ubachs of the Free University in Amsterdam, the Netherlands.

Bringing Down Walls

Dmitry Budker grew up in Novosibirsk in the former Soviet Union. Although his father was a physicist, his own interest in the field was kindled by his brother-in-law, who gave him physics textbook.

Budker received his master's degree at the Novosibirsk State University in 1985. In 1987, working as a junior researcher at the Institute of Nuclear Physics, Budker met UC Berkeley physicist Eugene Commins and, two years later, moved to the United States to work with him. "My future prospects in my home country weren't very optimistic," he says, adding that the collapse of the Soviet Union just after his departure came as a big surprise.



THE ALPHA DOTTERS Budker's modified version of Dysprosium experiment. Students: Arman Cingoz (right), Nathan Leefer (left), and Sarah Ferrell (center)

Commins's group made headlines in the late 1970's by experimentally confirming the theory of the electroweak interaction, a basic ingredient of the current Standard Model, which describes all known particles and most of the forces of Nature. Budker's PhD thesis built on Commins' work by studying peculiar energy levels of little-known elements like dysprosium, a silvery-white metal not discovered until 1886. Precise knowledge of these energy levels would be important for the study of certain details of atomic theory. "In fact, we were using table-top experiments to test fundamental symmetries of Nature," says Budker.

Interestingly, the same instrumental setup could be used to check on the constancy of alpha. That's because the value of alpha determines the energy levels of atoms, and, as a result, the precise wavelengths at which atoms absorb and emit light.

Although it is widely assumed that alpha is constant, a few years ago, Australian physicists John Webb and Victor Flambaum of the University of New South Wales in Sydney claimed that distant galaxies showed slightly different absorption patterns than nearby galaxies. Since the light from distant galaxies dates back to the early days of the Universe, this could hint at a tiny variation of alpha in the course of billions of years.

"I was extremely skeptical" of the results, says Budker. "If they were right, it would be a big shock. If the constants of Nature turn out to be varying, you've got to rewrite each and every physics text book."

Beta-Testing Alpha

No one thought that the fine-structure constant varied a lot: the observations by Webb and Flambaum hinted at an increase of just one thousandth of a percent in ten billion years. Still, if a fundamental constant isn't constant, there's something very wrong with our current understanding of the laws of physics. Says Amsterdam physicist Ubachs: "According to some theories, if alpha is changing, other constants should also vary."

Budker and his colleagues decided to check the Australian claim by using a modified version of their dysprosium experiment. If the change of alpha is one part in a hundred thousand in ten billion years' time, it should change one part in a quadrillion per year (assuming that the rate of change has always been the same). "With the current state-of-the-art instruments, we can achieve that precision, so we're able to study the effect in the laboratory." In fact, Budker's work on alpha boils down to measuring the energy levels of dysprosium to an extremely high precision, and repeating the measurement over a couple of years.

"It's a neat technique," says Ubachs. "One potential problem with the astronomical evidence is that something strange might have happened with the light from the distant galaxies on its way to Earth. In contrast, lab experiments are really testing the current constancy of alpha." In his own Amsterdam laboratory, Ubachs focuses on possible variations in the mass ratio of protons and electrons, another assumed physical constant. "Anyone who convincingly proves that Nature's constants are not so constant after all, is sure to win the Nobel Prize," he says.

Budker agrees, but he adds, "We don't count on it yet." Using a grant from The Foundational Questions Institute worth $85,000, he is now able to build a new, dedicated apparatus that is a hundred times more sensitive than the old one, and to hire students for another time-consuming experiment.

Meanwhile, Budker's group encounters stiff competition from physicists who use atomic clocks to check on possible variations of alpha, one of them his former student Jason Stalnaker of the National Institute of Standards and Technology in Boulder, Colorado. "We have only a couple of years to do this," says Budker. "After that, the clock technique will have become better and more sensitive."

The stakes are high. "The strongest implication of varying constants is that the forces of Nature cannot be universal or eternal," says Ubachs. Budker adds: "It's hard to underestimate the importance of such a find. Scientists would have to go back to the drawing board to rewrite basic physics principles."

TESTING ALPHA Dmitry Budker

But what if the new experiment doesn't show up any measurable variation in the fine-structure constant? Would that be proof that alpha is constant? Not necessarily, says Budker: the variations could just be too small to detect with current technology. "The search probably goes on unless there's a result," he muses. "It would be sad if scientists would not yet have exhausted the limits of technology, but run out of money instead."

Which is not to say that fundamental physics is the only field that deserves funding. So, to the lady in the audience of Budker's lecture: we don't have to choose between science and poetry. Inquiring minds will always want to focus on everything valuable.

Alpha's Lure

In 1916, German theoretical physicist Arnold Sommerfeld defined the fine-structure constant (denoted by the lowercase Greek letter alpha, or α) as the square of the unit of electric charge (e) divided by the product of the so-called reduced Planck constant ($\hbar$) and the speed of light (c): $\alpha = e^2/\hbar c$

When known values of e, $\hbar$ and c are input into this equation, alpha turns out to be a dimensionless number equal to ≈ 0.00729735, or $\approx 1/137.036$.

Why α has this value is anybody's guess. Nobel Prize winner Richard Feynman described it as "one of the greatest damn mysteries of physics." Further, the fact that the inverse of α is so close to 137 led the British physicist Arthur Eddington to believe that $1/\alpha$ is indeed an exact integer, for some unknown numerological reason.

Interestingly, if the value of alpha were just a few percent smaller or larger, life as we know it could not exist in the Universe – nor poetry.