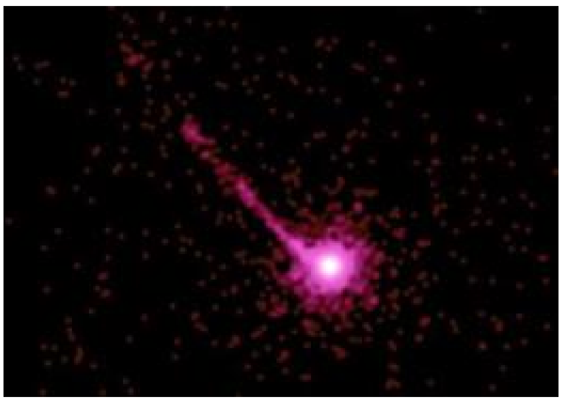
Variations in fine-structure constant suggest laws of physics not the same everywhere

September 6 2010, by Lisa Zyga



An X-ray image of the quasar PKS 1127-145, located about 10 billion light-years from Earth. Credit: NASA.

(PhysOrg.com) -- One of the most controversial questions in cosmology is why the fundamental constants of nature seem fine-tuned for life. One of these fundamental constants is the fine-structure constant, or alpha, which is the coupling constant for the electromagnetic force and equal to about 1/137.0359. If alpha were just 4% bigger or smaller than it is, stars wouldn't be able to make carbon and oxygen, which would have made it impossible for life as we know it to exist. Now, results from a new study show that alpha seems to have varied a tiny bit in different directions of the universe billions of years ago, being slightly smaller in the northern hemisphere and slightly larger in the southern hemisphere. One intriguing possible implication is that the fine-structure constant is continuously varying in space, and seems fine-tuned for life in our neighborhood of the universe.

The physicists, John Webb from the University of New South Wales and his coauthors from Swinburne University of Technology and the University of Cambridge, used data from two telescopes to uncover the spatial dependence of the fine-structure constant. Using the north-facing Keck telescope in Mauna Kea, Hawaii, and the south-facing Very Large Telescope (VLT) in Paranal, Chile, the researchers observed more than 100 quasars, which are extremely luminous and distant galaxies that are powered by massive black holes at their centers.

By measuring the quasar spectra, the researchers could gather data on the frequency of the electromagnetic radiation emitted by quasars at high redshifts, corresponding to a time about 10 billion years ago. During the time the light traveled through space to reach the telescopes, some of it was absorbed at specific wavelengths by very old gas clouds that today can reveal the chemical composition of the clouds.

The cloud compositions could help the scientists determine the fine-structure constant in those areas of the universe at that time, since alpha is a measure of the strength of the electromagnetic force between electrically charged particles. As the coupling constant for the electromagnetic force, it is similar to the constants for the other three known fundamental forces of nature: the strong nuclear force, the weak nuclear force, and gravitational force. Among its important implications, alpha determines how strongly atoms hold on to their electrons.

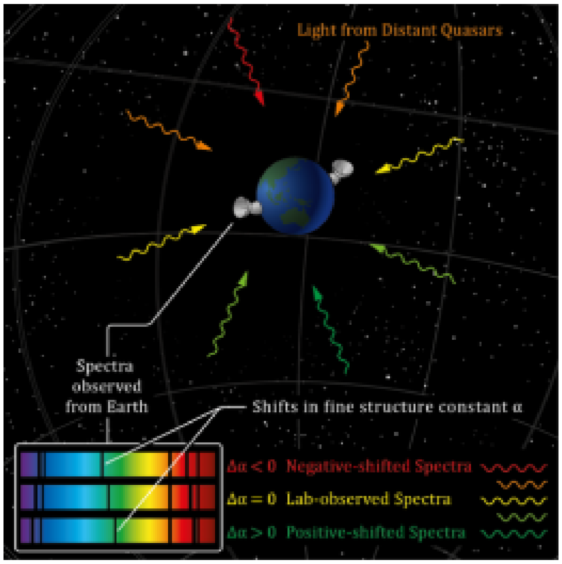


Illustration of the dipolar variation in the fine-structure constant, alpha, across the sky, as seen by the two telescopes used in the work: the Keck telescope in Hawaii and the ESO Very Large Telescope in Chile. Copyright Dr. Julian Berengut, UNSW, 2010. May be used with appropriate attribution.

By combining the data from the two telescopes that look in opposite directions, the researchers found that, 10 billion years ago, alpha seems to have been larger by about one part in 100,000 in the southern direction and smaller by one part in 100,000 in the northern direction. The data for this "dipole" model of alpha has a statistical significance of about 4.1 sigma, meaning that that there is only a one in 15,000 chance that it is a random event.

At first, the data surprised Webb and his colleagues, since it seemed to contradict previous results that the scientists had published in 1999. At that time, the scientists had used the north-facing Keck telescope to find that alpha became slightly smaller the further away (and older) the quasars were. So when the scientists first looked at equally distant quasars from the southern hemisphere using the VLT, they were surprised to find the slight increase in alpha. After eliminating any possible bias, though, they realized that they were looking at hemispherical differences of alpha.

While the data from just one telescope seemed to suggest that alpha varies in time, data from the two telescopes show that alpha also seems to vary in space. Such a discovery could have major implications, starting with shattering the basic assumption that physical laws are the same everywhere in the universe. The results also violate the Einstein Equivalence Principle, and suggest that the universe may be much larger than currently thought - or even infinite in size. Right now, the scientists want to confirm the results with other experimental methods, and see if the fine-structure constant could truly lead scientists to a very different understanding of our universe.

More information: J. K. Webb, et al. "Evidence for spatial variation of the fine structure constant." Submitted to *Physical Review Letters*. Available at arXiv:1008.3907v1 [astro-ph.CO]