A venerable radio telescope sets new standard for universal constant

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About 150 hours of observing time on the 1,000-ft radio telescope at the Arecibo Observatory in Puerto Rico over the course of the last several years have been devoted to determining whether the most fundamental constant in physics really is constant.

The target is the so-called fine structure constant, usually known as alpha, which describes the electromagnetic interaction between elementary charged particles. Its value is crucial to understanding the nature of atomic spectra, which in turn allows astronomers to measure the radial velocity of galaxies from which these spectral lines are observed. Such observations led to the discovery that galaxies appear to be receding from one another with velocities that increase with the distance between them. This is a manifestation of the expansion of the universe following the Big Bang.

Our current model for the expansion and acceleration of the universe depends on the assumption that neither alpha nor mu, the proton-to-electron mass ratio, have changed with time. This assumption is key to our current understanding of the age of the universe. But what if alpha does change with time? Then our knowledge of the distance between galaxies or the age of the universe would have to be revised.

The Arecibo telescope has recently been used to set a new limit on how constant things are. While the latest data suggest that there may be a small change in alpha, it is still too early to be sure. With an uncertainty on the measurement of about one part in a million, it is not yet time to celebrate, nor to heave a sigh of relief.

The Arecibo observations have been carried out by Nissim Kanekar and Jayaram Chengalur of the National Center for Radio Astrophysics in India, and Tapasi Ghosh, a Universities Space Research Association (USRA) astronomer at the Arecibo Observatory. Their experiment makes use of a marvelous concordance of cosmic circumstances involving quasar PKS 1413+135, which is located about 3 billion light-years away. In front of that quasar, and probably surrounding its radio-bright nucleus, is a cloud of OH molecules (OH is also known as hydroxyl).

The atomic properties of hydroxyl are extremely well known from laboratory and theoretical studies. The OH cloud in the Arecibo experiment is observed in two spectral lines, one at 1612 MHz and the other at 1720 MHz. What is unusual is that one of the lines (1612) is seen in absorption and the other (1720) in emission. These lines are said to be conjugate, that is, they are mirror images of one another, which assures that they originate from the same gas cloud.

This is a crucial factor in reducing systematic uncertainties in the measurement of alpha. From the Arecibo spectra, we can measure the observed frequency difference between the two lines and compare that with the laboratory results. Because this quasar is seen as it was 3 billion years in the past and our laboratory is in the present, we can determine just how truly constant alpha is over time.

The 150-hour integration at Arecibo allows the two spectral lines to be compared with very high accuracy. The result implies that alpha has not changed by more than 1.3 parts in a million, in these 3 billion years.

To make the measurements even more accurate would require either more telescope time or the good fortune to find a more distant quasar with a similar OH cloud in its neighborhood. For example, to improve the accuracy by a factor of 10 would require 100 times more observing time than has already been devoted to the project. That is not a realistic possibility.

"We are hopeful that current searches for more quasar candidates showing the necessary OH lines will be successful," noted Dr. Tapasi Ghosh. "These could provide even tighter constraints on any possible variations of this atomic constant."

Until then, the Arecibo measurement is the new gold standard in defining how certain we are that a key physical constant—a constant that sets the very size and scale of the universe—is truly constant.

Provided by USRA

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