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Astronomically Large Lenses Measure the Age and Size of the Universe

Using entire galaxies as lenses to look at other galaxies, researchers have a newly precise way to measure the size and age of the universe and how rapidly it is expanding, on par with other techniques. The measurement determines a value for the Hubble constant, which indicates the size of the universe, and confirms the age of the universe (within 170 million years) as 13.75 billion years old. The results also confirm the strength of dark energy, responsible for accelerating the expansion of the universe.

These findings, to be published in The Astrophysical Journal in March, are the work of researchers at the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) at the U.S. Department of Energy's SLAC National Accelerator Laboratory and Stanford University, the University of Bonn, the University of California, Santa Barbara, the University of California, Davis, and the Kapteyn Astronomical Institute in the Netherlands. The researchers used data collected by the NASA/ESA Hubble Space Telescope, and showed the improved precision they provide in combination with the Wilkinson Microwave Anisotropy Probe (WMAP).

UCSB's Tommaso Treu, associate professor of physics, and Matthew Auger, postdoctoral physics scholar, were among the researchers. The team also includes Sherry Suyu and Stefan Hilbert (Bonn), Phil Marshall and Roger Blandford (Stanford), Leon Koopmans (Kapteyn), and Chris Fassnacht (UC Davis).

The team used a technique called gravitational lensing to measure the distances light traveled from a bright, active galaxy to the Earth along different paths. By understanding the time it took to travel along each path and the effective speeds involved, researchers could infer not just how far away the galaxy lies but also the overall scale of the universe and some details of its expansion.

Often, it is difficult for scientists to distinguish between a very bright light far away and a dimmer source lying much closer. A gravitational lens circumvents this problem by providing multiple clues as to the distance light travels. That extra information allows them to determine the size of the universe, often expressed by astrophysicists in terms of a quantity called Hubble's constant.

"We've known for a long time that lensing is capable of making a physical measurement of Hubble's constant," Marshall, a KIPAC Kavli Fellow, said. However, gravitational lensing had never before been used in such a precise way. This measurement provides an equally precise measurement of Hubble's constant as long-established tools such as observation of supernovae and the cosmic microwave background. "Gravitational lensing has come of age as a competitive tool in the astrophysicist's toolkit," Marshall said.

Though researchers do not know when light left its source, they can still compare arrival times. Marshall likens it to four cars taking four different routes between places on opposite sides of a large city. Like automobiles facing traffic snarls, light can encounter delays, too. "The traffic density in a big city is like the mass density in a lens galaxy," Marshall said. "If you take a longer route, it need not lead to a longer delay time. Sometimes the shorter distance is actually slower."

The gravitational lens equations account for all the variables such as distance and density, and provide a better idea of when light left the background galaxy and how far it traveled.

In the past, this method of distance estimation was plagued by errors, but physicists now believe it is comparable with other measurement methods. With this technique, the researchers have come up with a more accurate lensing-based value for Hubble's constant, and a better estimation of the uncertainty in that constant. By both reducing and understanding the size of error in calculations, they can achieve better estimations on the structure of the lens and the size of the universe.

"This result was made possible by combining data from the best observatories in the world: the W.M. Keck Telescope, NASA/ESA's Hubble Space Telescope, and the Very Large Array Telescope," Auger said. Added UCSB's Treu: "We are lucky as UC astronomers to have access to the best telescopes in the world."

There are several factors scientists still need to account for in determining distances with lenses. For example, dust in the lens can skew the results. The Hubble Space Telescope has infrared filters useful for eliminating dust effects. The images also contain information about the number of galaxies lying around the line of vision; these contribute to the lensing effect at a level that needs to be taken into account. Marshall said that several groups are working on extending this research, both by finding new systems and further examining known lenses. Researchers are already aware of more than 20 other astronomical systems suitable for analysis with gravitational lensing.

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