# SCIENTISTS USE BENT LIGHT TO MEASURE THE UNIVERSE

Scientists in Switzerland and the United States have confirmed the age and expansion rate of the universe using a promising and relatively new technique independent of the methods most commonly used.

Their technique is based on gravitational lensing, or the way light can bend around a galaxy. This technique has provided measurements consistent with those found by other methods. With more data, the scientists say, this could offer the most precise means to measure these most basic yet important parameters of the universe.

The team determined the age of the universe to be 13.5 billion years, with an uncertainty of about 15 percent. The universe is expanding (and most galaxies are receding from us) at a rate of about 70 kilometers per second per megaparsec.

Dr. Andrea Maccio of the Institute for Theoretical Physics at the University of Zurich is one of the authors of an article describing this result in The Astrophysical Journal Letters. "This is an important step in what promises to be a straight-forward way to measure the universe," said Maccio. "There are several independent ways of measuring the Hubble time, and techniques using variable stars in other galaxies, supernovae, or the cosmic microwave background have reached an accuracy of 5 to 10 percent. Gravitational lensing gets close to that accuracy and, with more data, has the potential to surpass it."

According to the generally accepted paradigm of an expanding universe dominated by dark energy and dark matter, the age of the universe is basically the inverse of the expansion rate of the universe. The former is called the Hubble time and the latter the Hubble constant, named after Edwin Hubble, who in the 1920s discovered the expansion of the universe.

The universe, from our perspective, is not expanding uniformly. The more distant a galaxy, the faster it seems to be receding from us. The rate is typically described in kilometers per second per megaparsec. A megaparsec, or a million parsecs, is a distance equal to about 3.26 million light-years. So a galaxy that is 200 megaparsecs away is receding from us twice as fast as a galaxy only 100 megaparsec away.

"Our method is rather consistent with other measurements," said Prof. Liliya Williams of the University of Minnesota, a co-author. "For example, the best estimate derived from the cosmic microwave background by NASA's WMAP satellite for the age of the universe is 13.7 billion years. The Hubble constant is about 73 kilometers per second per megaparsec, also close to our measurement. The consistency from very different methods inspires confidence that astronomers are on the right track."

Scientists and philosophers have speculated about the bending of light by gravity since the eighteenth century. But it was Albert Einstein, who as a young man spent time both as a student and as a professor at the University of Zurich, who quantitatively explained the effect of gravity on light in 1916.

Einstein and his contemporary, Fritz Zwicky, another physicist who had worked in Zurich, realized that sometimes light can take different paths around a galaxy, causing us to see multiple mirage-like images of an object behind it. Connecting the effect with the age of the universe fell to Sjur Refsdal of Norway in 1964. Yet the subject remained purely theoretical until Dennis Walsh, Bob Carswell, and Ray Weymann discovered the first double image in 1979.

Since 1979 and especially since the advent of the Hubble Space Telescope, dozens of multiple-image gravitational lenses have been discovered and mapped. In these systems, the background light sources are most often quasars, which are black hole galaxies known for their flaring properties. As the distant quasar flares, so too do all the mirages produced by the lensing galaxy. But the light, depending on the length of the path it has taken, will flare at different times in the mirages. The "time delays" between the mirages are weeks to months, depending on the galaxy, and they are the key to measuring the age of the universe.

"We selected ten gravitational lenses having accurate time delays and other properties in the literature, and for each one we compared the observations in detail with Einstein's 1916 field equations to calculate the gravitational field involved," said co-author Jonathan Coles of the University of Zurich. "These calculations let us convert the observed time delay into a measurement of the Hubble time."

"Sjur Refsdal's insight that gravitational lens time delays are fast-forward versions of the age of the universe is a seductive idea, and researchers have been applying it to observations for many years," said co-author Prasenjit Saha, also of the University of Zurich. "However, previous studies used only one or a few lenses, and this left the results very uncertain. Doing simultaneous calculations with ten lenses narrows down the uncertainty to 15 per cent around 13.5 billion years."

Preprints of the paper are available at http://arxiv.org/abs/astro-ph/0607240 .