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A Supernova Quadrupled

The sky is filled with “magnifying glasses” that allow astronomers to study very distant objects barely visible with even the largest existing telescopes.

Using NASA’s Hubble Space Telescope, an international group of astronomers, including three from UC Santa Barbara, has found that one of these lenses — a massive galaxy within a cluster of galaxies that gravitationally bends and magnifies light — has created four separate images of the same distant supernova.

The scientists’ findings appear in a March 6 special issue of the journal Science, marking the centennial of Albert Einstein’s general theory of relativity. Einstein’s theory predicts that concentrations of mass in the universe will bend light like a lens, magnifying objects behind the mass when seen from Earth — exactly what the astronomers found in their new images.

“With four perspectives, you can actually measure the difference in the light paths,” explained co-author Kasper Schmidt, a postdoctoral fellow in the Department of Physics. “You can think of these time-variable source images of the supernova as trains. Each leaves the station at the same time but arrives at different times because the ‘routes’ and the ‘landscape’ they travel through are not the same.”

When light from a background object passes by a mass, such as an individual galaxy or a cluster of galaxies, the light is bent. However, when the background object is almost exactly behind the mass, “strong lensing” smears extended objects (like galaxies) into an “Einstein ring” surrounding the lensing galaxy or cluster of

galaxies.

Strong lensing of small, pointlike objects often produces multiple images. When the alignment of the source and lens is ideal, images are seen in a formation dubbed the Einstein cross, which will help astronomers refine their estimates of the amount and distribution of dark matter in the lensing galaxy and cluster. Dark matter cannot be seen directly but is believed to make up most of the universe's mass.

"The locations of the images of the supernova tell us something about the 'landscape' the light is traveling through," said co-author Curtis McCully, a postdoctoral researcher who has a joint appointment with the Department of Physics and the Las Cumbres Observatory Global Telescope Network. "The shape of the landscape coupled with the difference in the arrival times — which we expect to be a few days to a few months for the four images we discovered — allows us to infer how far the light traveled. That lets us compare the size of the universe 5 billion years ago to the size of the universe today, so we can measure how fast the universe is expanding."

The scientists have nicknamed the distant supernova Refsdal in honor of Sjur Refsdal, the late Norwegian astrophysicist and pioneer of gravitational lensing studies. The supernova is located about 9.3 billion light years away (redshift = 1.5), near the edge of the observable universe, while the lensing galaxy is about 5 billion light years (redshift = 0.5) from Earth. The galaxy that is splitting the light from the supernova into an Einstein cross is part of a large cluster, called MACS J1149.6+2223, which has been known for more than 10 years.

Although astronomers have discovered dozens of multiply imaged galaxies and quasars, they have never seen a stellar explosion resolved into several images. In 2009, astronomers reported that the MACS J1149.6+2223 cluster created the largest known image of a spiral galaxy ever seen through a gravitational lens. The new supernova is located in one of that galaxy's spiral arms, which also appears in multiple images in the foreground lensing cluster. The supernova, however, is split into four images by a red elliptical galaxy within the cluster.

"These gravitational lenses are like a natural magnifying glass. It's like having a much bigger telescope," said lead author Patrick Kelly, a postdoctoral scholar at UC Berkeley. "We can get magnifications of up to 100 times by looking through these galaxy clusters."

Given the peculiar nature of gravitational lensing, astronomers predict that they will have an opportunity for a supernova replay in the next 10 years. This is because light can take various paths around and through a gravitational lens, arriving at Earth at different times. Computer modeling of this lensing cluster shows that the researchers missed opportunities to see the exploding star 50 and again 10 years ago, but images of the explosion will likely repeat in the next decade.

“What we’ve found tells us something about the gravitational potential, which we can link to the basic equation of the universe and the expansion rate of the universe,” said Schmidt. “This relates to the big bang model as we believe it is right now. In that sense, it’s a very essential and fundamental quantity that we can estimate from this discovery. At least that’s our goal.”

Tucker Jones, a postdoctoral fellow in the Department of Physics, is another co-author.

About UC Santa Barbara

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