

Discovery of Farthest Lensing Galaxy Yields Clues to Early Universe

Using imaging from NASA's Hubble Space Telescope, an international team of astronomers, including researchers from the Academia Sinica Institute of Astronomy & Astrophysics (ASIAA), has discovered the most distant lensing galaxy to date: a monster elliptical galaxy whose light has travelled roughly 9.6 billion years to reach Earth. The galaxy is so massive that its gravity acts like a giant cosmic lens, bending, magnifying, and distorting light from objects behind it, a phenomenon called gravitational lensing. The study was published online on June 23 in *The Astrophysical Journal Letters*.

The object behind the newly discovered cosmic lens is a tiny galaxy whose light has taken 10.7 billion years to arrive here. Seeing this chance alignment at such a great distance from Earth is a rare find, only one [<http://adsabs.harvard.edu/abs/2013ApJ...777L..17V>] other lensing galaxy has been found at that epoch. Finding more of these distant lensing galaxies will offer insight into how young galaxies in the early universe built themselves up into the massive dark-matter-dominated galaxies of today. Dark matter cannot be seen, but it accounts for the bulk of the universe's matter.

"When you have a lensing galaxy, you can calculate its total mass from the amount of light bending that occurs, including any dark matter in the galaxy," said first author Kenneth Wong of ASIAA. "This allows us to study the nature of dark matter, which accounts for most of the matter in the Universe but whose composition remains a mystery."

Finding such a distant gravitational lens also makes this system a unique opportunity for studying galaxies at different epochs. "We know of hundreds of lens galaxies, but most of them are relatively nearby," explained Wong. "To find a lens so distant is a very special discovery because we can learn about the amount of dark matter in galaxies in the distant past and how the amount changes over time"

"It's very difficult to see an alignment between two galaxies in the early universe," explained collaborator Kim-Vy Tran of Texas A&M University. "Imagine holding a magnifying glass at arm's length. The chances that you will see an enlarged object are high. But if you move the magnifying glass across the room, your chances of seeing the magnifying glass nearly perfectly aligned with another object beyond it diminishes."

Wong, together with Sherry Suyu, an Assistant Research Fellow at ASIAA, used the gravitational lensing from the chance alignment and weighed the giant galaxy's total mass to be 180 billion times more than our Sun. By estimating and subtracting the mass of all the visible stars from the total mass of the lensing galaxy, the team could determine the amount of dark matter in the lensing galaxy. In comparison to our Milky Way, which has most of its mass locked up in dark matter, the lensing galaxy is underweight in terms of its dark matter content.

"The unusually small amount of dark matter in this massive elliptical lensing galaxy is very surprising," remarked Suyu. "Other elliptical galaxies that are closer to us have much

more dark matter and have inventories of stars that appear to be different from this super distant lensing galaxy.”

Tran and her team stumbled upon the gravitational lens in a distant galaxy cluster called IRC 0218. While analyzing spectrographic data of the massive galaxy from the W.M. Keck Observatory in Hawaii, Tran spotted hot hydrogen gas, which is unusual for such giant elliptical galaxies. The mystery was resolved when collaborator Ivelina Momcheva of Yale University analyzed high-resolution Hubble images, which revealed the lensed background source that produced the hot hydrogen gas. “We discovered that light from the lensing galaxy and the background galaxy were blended in the ground-based data, which was confusing us,” Momcheva said. “Only with Hubble’s high resolutions were we able to separate the two. We needed the combination of imaging and spectroscopy to solve the puzzle.”

As Wong and Suyu continue their research on gravitational lenses, they anticipate future discoveries of similar systems. “Here at ASIAA, we are very excited about the Hyper Suprime-Cam survey that will map out a large area of the sky,” Wong said. “Lensing galaxies are fairly uncommon, but this survey is so large in area that we should find hundreds of them. Maybe a handful of them will be these ultra-rare lenses at extreme distances that will provide insights into galaxies in the early universe.”

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