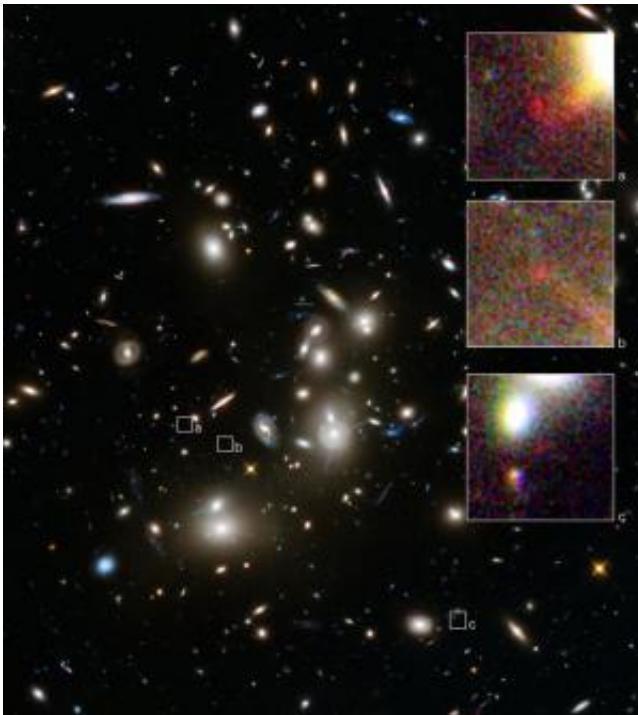


Probing the past: Most reliable remote distance measurement yet

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This is a NASA/ESA Hubble Space Telescope image of the huge galaxy cluster Abell 2744, taken using the Wide Field Camera 3 and Advanced Camera for Surveys. Credit: NASA, ESA

Using the NASA/ESA Hubble Space Telescope astronomers have made what may be the most reliable distance measurement yet of an object that existed in the Universe's formative years. The galaxy is one of the faintest, smallest and most distant galaxies ever seen and measuring its

distance with this accuracy was possible due only to the incredibly detailed mapping of how giant galaxy clusters warp the space-time around them.

Astronomers often use gravitational lensing—the magnifying power of galaxy clusters—to find distant galaxies [1]. However, when it comes to the very early Universe, distance measurements can become inaccurate as the objects are so dim [2]. Now, a team of astronomers has combined a traditional method of [distance measurement](#) with some clever reverse engineering to vastly improve accuracy.

The lensing power of the mammoth [galaxy cluster](#) Abell 2744, nicknamed Pandora's Cluster, focussed the light from the faraway galaxy that was being studied, making it appear about ten times brighter than it otherwise would have been, and allowing astronomers to see it. The lensing also produced three magnified images of the same galaxy.

"We were able to spot the galaxy's multiple gravitationally-lensed images using near-infrared and visible-light photos from Hubble," explained study leader Adi Zitrin of the California Institute of Technology, USA. "But at first we didn't know how far away it was from Earth."

By analysing the colour of the faraway galaxy the team could estimate its distance. Since the light left the galaxy the Universe's expansion has stretched its wavelength, shifting its colour towards red in the spectrum, and this colour change can be measured and quantified as a redshift. For this object, the team estimated a redshift of 10, almost a record-breaking value and meaning the light from this object has taken over 13 billion years to reach us. But this is hard to do for faint and distant objects, and the method has some limitations, so can be inaccurate, misleading, and in some unfortunate cases, completely wrong.

To be sure their measurement could be trusted the team took advantage

of the multiple images produced by the lens. The angular separations of the three magnified images of the galaxy in the Hubble photos were measured. The astronomers had already characterised the cluster and the distorting effects of the gravitational lens so well that they could tell how far the remote galaxy was behind the lensing cluster. They did this by comparing these angular separations to those of the less distant galaxies lensed by the cluster—the greater the angular separation, the further away the object is.

"This is a demonstration of the power of relativistic optics," remarked team member Tom Broadhurst, from the University of Basque Country & Basque Foundation for Science, Spain. "We now understand these lenses so well that we can use them to measure distances. It is the equivalent of using your camera to focus on an object, and then reading its distance from you on the lens focus ring. Being able to do this kind of reverse engineering at these distances is a huge accomplishment for us."

By combining the traditional analysis of the colours with the reverse engineering of the lens, the team calculated a robust distance measurement. "We are about 95 percent confident that this object is at redshift 10," said Zitrin. "The lensing takes away any doubt that this might be a heavily reddened, nearby object masquerading as a far more distant object."

The galaxy appears as a tiny blob only a small fraction of the size of the Milky Way, but it offers a peek back to a time when the Universe was only about 500 million years old, roughly three percent of its current age of 13.8 billion years. Although about ten other galaxy candidates have been uncovered at this early era, astronomers say this newly found object is significantly smaller and fainter than most of those other remote objects.

"This object is a unique example of what is suspected to be an abundant,

underlying population of small and faint galaxies at about 500 million years after the Big Bang," explained Zitrin. "The discovery is telling us that galaxies as faint as this one exist, and we should continue looking for them and even fainter objects so that we can understand how galaxies, and the Universe, have evolved over time."

Analysis of the galaxy shows that it measures 300 light-years across and is estimated to have a mass of 40 million times that of the Sun. Tiny when compared to our own galaxy, which spans more than 100 000 light-years. It was also discovered that the galaxy is forming about one star every three years [3]. Although this is only one third of the star formation rate in the Milky Way it is actually pretty prolific for a galaxy this size and shows that the galaxy is rapidly evolving and efficiently forming stars.

"Galaxies such as this one are probably small clumps of matter that are starting to form stars and shine, but they don't have a defined structure yet. Therefore, it's possible that we only see one bright clump magnified due to the lensing, and this is one possible reason why it is smaller than typical field galaxies of that time," Zitrin explained.

Astronomers have long debated whether such early galaxies could have provided enough radiation to warm the hydrogen that cooled soon after the Big Bang. This process, called reionisation, made the Universe transparent to light, allowing astronomers to look far back in time without running into a fog of cold hydrogen [4].

"We tend to assume that galaxies ionised the Universe with their ultraviolet light. But we do not see enough galaxies or light that could do that," Zitrin explained. "So we need to look at fainter and fainter [galaxies](#), and the Frontier Fields and galaxy cluster lensing can help us achieve this goal" [5].

The team's results appeared in the online edition of *Astrophysical Journal Letters* on 4 September 2014.

More information: iopscience.iop.org/2041-8205/793/1/L12/

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