Another amazing ALMA result

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Observations with the Atacama Large Millimeter/submillimeter Array (ALMA) have revealed some of the most distant and actively star forming galaxies in our universe, thanks to an effect called gravitational lensing, which magnifies the images of these distant galaxies.

The international team of researchers, including Canadian astronomers, have published their results in three articles in the journals *Nature* and *Astrophysical Journal*.

Yashar Hezaveh (McGill University), who led the study of gravitational lensing, presented the results at the Canadian Astronomical Society annual meeting at the University of British Columbia, Vancouver. Hezaveh described the findings as "a clear demonstration of the power of ALMA, and the beginning of an exciting new phase for submillimeter astronomy."

The ALMA observatory, inaugurated earlier this year, is an international facility built at an altitude of 5,000 meters on the remote Chajnantor Plateau in the Chilean Andes.

Gravitational lensing is an effect where the light of a distant galaxy is deflected by the gravitational influence of a nearer foreground galaxy, which acts like a lens and makes the distant galaxy appear larger and brighter. For this to happen, the distant galaxy has to be almost perfectly located behind the lens galaxy, making observation of the phenomenon very rare.

"Only a few gravitationally lensed galaxies had been previously studied at submillimeter wavelengths," said Gil Holder (McGill) one of the co-authors. "The new high resolution observations with ALMA have provided new views of tens of such systems."

The international team of researchers first discovered these distant and enigmatic galaxies after surveying large areas of the sky with the 10-meter South Pole Telescope. They then used ALMA to obtain higher resolution images, which revealed the magnified images and confirmed that the galaxies were gravitationally lensed.

A second survey of these galaxies, using ALMA, was carried out to observe light from carbon monoxide molecules in these galaxies to measure their distances from Earth. The astronomers found that many of these galaxies were considerably farther away than they expected—a few so distant that their light has taken more than 12 billion years to reach us.

Analysis of the images revealed that some of the most distant star-forming galaxies are as bright as 40 trillion (40 million million) Suns and are forming new stars at a very high rate of 4,000 Suns per year only about 1 billion years after the Big Bang. In comparison, our galaxy on average makes less than 1 Sun per year. "We want to understand how and why these galaxies are forming stars at such incredibly fast rates, so soon after the Big Bang." said Scott Chapman (Dalhousie) one of the co-authors. "This could partially answer how our own galaxy, the Milky Way, was born billions of years ago."

Large quantities of the mysterious dark matter in the lensing galaxies are believed to be responsible for the strongly distorted images of the background galaxies. "Gravitational lensing allows us to measure the distribution of dark matter in the lensing galaxies in great detail. These types of studies were previously only possible at visible-light wavelengths with the Hubble Space Telescope, but now our results show

that, thanks to ALMA, gravitational lensing studies in the submillimeter domain have entered a new phase." said Yashar Hezaveh. "In the future, we will study the distribution of dark matter in the lensing galaxies with unprecedented detail."

More information: "Dusty Starburst Galaxies in the Early Universe as Revealed by Gravitational Lensing," J. D. Vieira et al., *Nature*, 495, 344. www.nature.com/nature/journal/ … ull/nature12001.html

"ALMA Observations of SPT-discovered, Strongly Lensed, Dusty, Star-forming Galaxies," Y. D. Hezaveh et al., 2013, *ApJ,* 767, 132. dx.doi.org/10.1088/0004-637X/767/2/132

"ALMA Redshifts of Millimeter-selected Galaxies from the SPT Survey: The Redshift Distribution of Dusty Star-forming Galaxies," A. Weiss et al., 2013, *ApJ*, 767, 88. dx.doi.org/10.1088/0004-637X/767/1/88

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