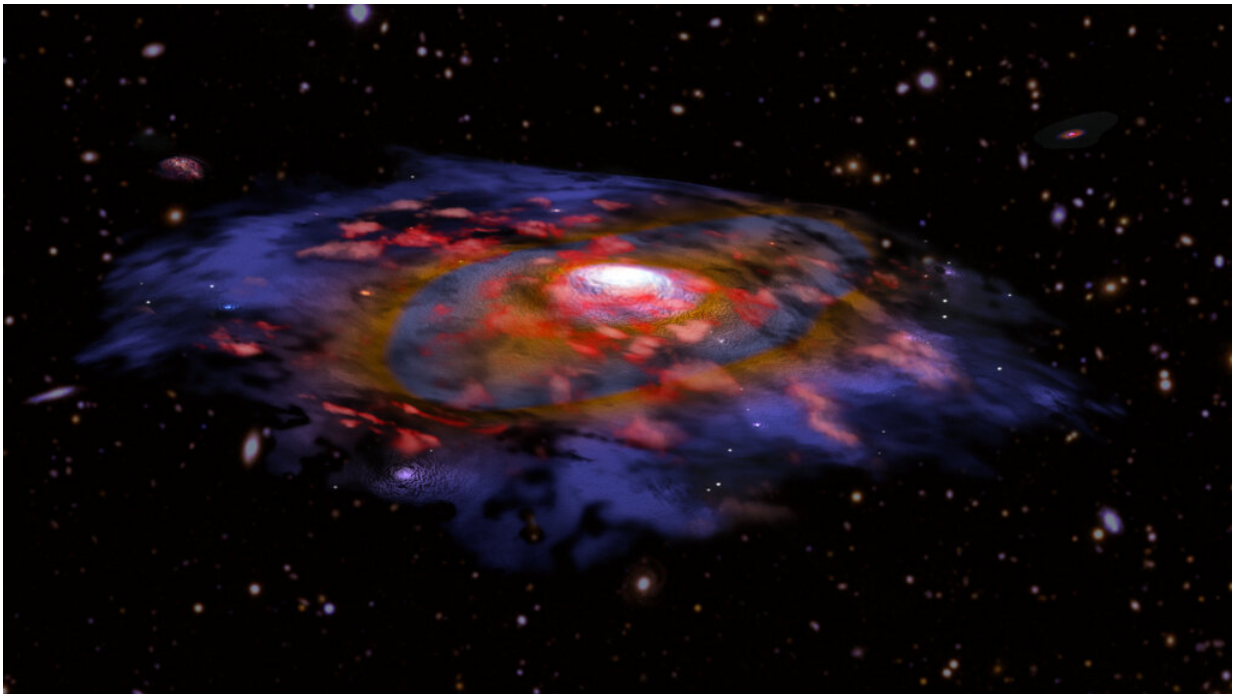


# Galaxies in the infant universe were surprisingly mature

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Artist's illustration of a dusty, rotating distant galaxy Credit: B. Saxton  
NRAO/AUI/NSF, ESO, NASA/STScI; NAOJ/Subaru

Massive galaxies were already much more mature in the early universe than previously expected. This was shown by an international team of astronomers who studied 118 distant galaxies with the Atacama Large Millimeter/submillimeter Array (ALMA).

Most [galaxies](#) formed when the [universe](#) was still very young. Our own galaxy, for example, likely started forming 13.6 billion years ago, in our 13.8 billion-year-old universe. When the universe was only ten percent of its current age (1-1.5 billion years after the Big Bang), most of the galaxies experienced a "growth spurt". During this time, they built up most of their stellar mass and other properties, such as dust, heavy element content, and spiral-disk shapes, that we see in today's galaxies. Therefore, if we want to learn how galaxies like our Milky Way formed, it is important to study this epoch.

In a survey called ALPINE (the ALMA Large Program to Investigate C+ at Early Times), an international team of astronomers studied 118 galaxies experiencing such a "growth spurt" in the [early universe](#). "To our surprise, many of them were much more mature than we had expected," said Andreas Faisst of the Infrared Processing and Analysis Center (IPAC) at the California Institute of Technology (Caltech).

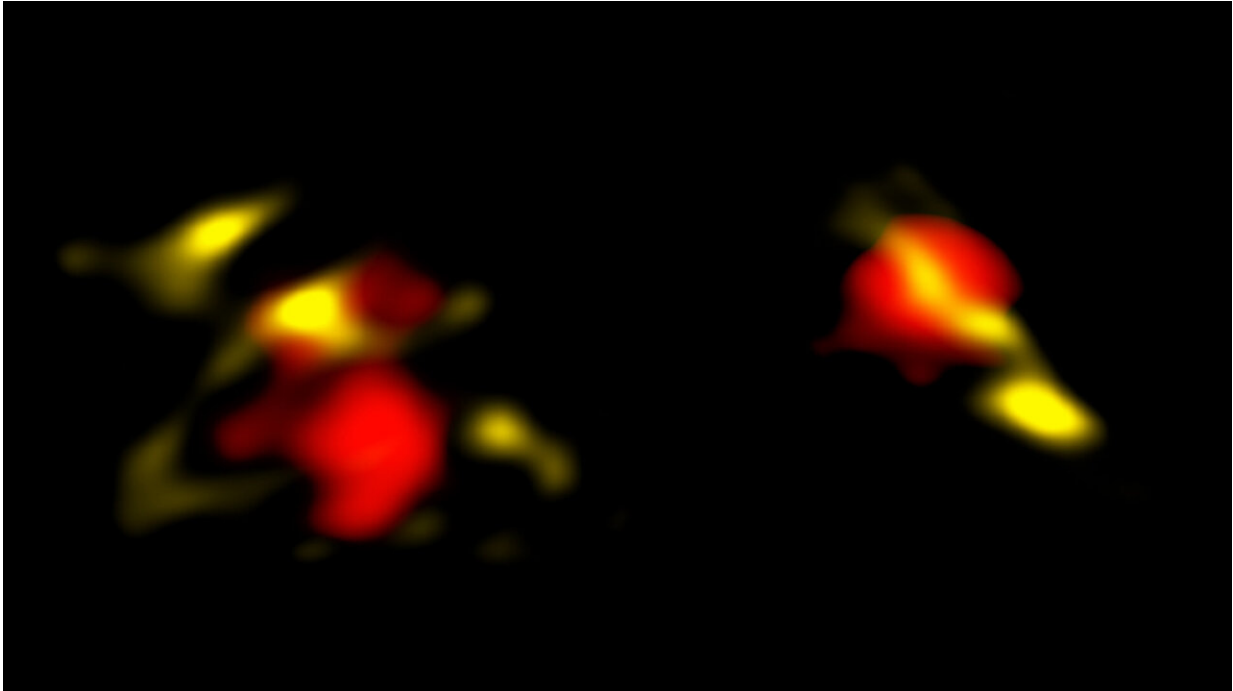
Galaxies are considered more "mature" than "primordial" when they contain a significant amount of dust and [heavy elements](#). "We didn't expect to see so much dust and [heavy elements](#) in these distant galaxies," said Faisst. Dust and heavy elements (defined by astronomers as all elements heavier than hydrogen and helium) are considered to be a by-product of dying stars. But galaxies in the early universe have not had much time to build stars yet, so astronomers don't expect to see much dust or heavy elements there either.

"From previous studies, we understood that such young galaxies are dust-poor," said Daniel Schaerer of the University of Geneva in Switzerland. "However, we find around 20 percent of the galaxies that assembled during this early epoch are already very dusty and a significant fraction of the ultraviolet light from newborn stars is already hidden by this dust," he added.

Many of the galaxies were also considered to be relatively grown-up because they showed a diversity in their structures, including the first signs of rotationally supported disks—which may later lead to galaxies with a spiral structure as is observed in galaxies such as our Milky Way. Astronomers generally expect that galaxies in the early universe look like train wrecks because they often collide. "We see many galaxies that are colliding, but we also see a number of them rotating in an orderly fashion with no signs of collisions," said John Silverman of the Kavli Institute for the Physics and Mathematics of the Universe in Japan.

ALMA has spotted very distant galaxies before, such as [MAMBO-9](#) (a very dusty galaxy) and the Wolfe Disk (a galaxy with a rotating disk). But it was hard to say whether these discoveries were unique, or whether there were more galaxies like them out there. ALPINE is the first survey that enabled astronomers to study a significant number of galaxies in the early universe, and it shows that they might evolve faster than expected. But the scientists don't yet understand how these galaxies grew up so fast, and why some of them already have rotating disks.

Observations from ALMA were crucial for this research because the radio telescope can see the star formation that is hidden by dust and trace the motion of gas emitted from star-forming regions. Surveys of galaxies in the early [universe](#) commonly use optical and infrared telescopes. These allow the measurement of the unobscured star formation and stellar masses. However, these telescopes have difficulties measuring [dust](#) obscured regions, where stars form, or the motions of gas in these galaxies. And sometimes they don't see a galaxy at all. "With ALMA we discovered a few distant galaxies for the first time. We call these Hubble-dark as they could not be detected even with the Hubble telescope," said Lin Yan of Caltech.



These are two of the galaxies in the early universe that ALMA observed in radio waves. The galaxies are considered more "mature" than "primordial" because they contain large amounts of dust (yellow). ALMA also revealed the gas (red), which is used to measure the obscured star-formation and motions in the galaxies. Credit: B. Saxton NRAO/AUI/NSF, ALMA (ESO/NAOJ/NRAO), ALPINE team

To learn more about distant galaxies, the astronomers want to point ALMA at individual galaxies for a longer time. "We want to see exactly where the [dust](#) is and how the gas moves around. We also want to compare the dusty galaxies to others at the same distance and figure out if there might be something special about their environments," added Paolo Cassata of the University of Padua in Italy, formerly at the Universidad de Valparaíso in Chile.

ALPINE is the first and largest multi-wavelength survey of galaxies in

the [early universe](#). For a large sample of galaxies the team collected measurements in the optical (including Subaru, VISTA, Hubble, Keck and VLT), infrared (Spitzer), and radio (ALMA). Multi-wavelength studies are needed to get the full picture of how [galaxies](#) are built up. "Such a large and complex survey is only possible thanks to the collaboration between multiple institutes across the globe," said Matthieu Béthermin of the Laboratoire d'Astrophysique de Marseille in France.

**More information:** Y. Fudamoto et al, The ALPINE-ALMA [CII] survey, *Astronomy & Astrophysics* (2020). [DOI: 10.1051/0004-6361/202038163](#)

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