

Astronomers reveal new details about 'monster' star-forming galaxies

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Artist's impression of the monster galaxy COSMOS-AzTEC-1. This galaxy is located 12.4 billion light-years away and is forming stars 1,000 times more rapidly than our Milky Way galaxy. ALMA observations revealed dense gas concentrations in the disk, and intense star formation in those concentrations. Credit: National Astronomical Observatory of Japan

An international team of astronomers from Japan, Mexico and the University of Massachusetts Amherst studying a "monster galaxy" 12.4 billion light years away today report that their instruments have achieved a 10 times higher angular resolution than ever before, revealing galaxy structural details previously completely unknown. They also were able to analyze dynamic properties that could not be probed before. Details appear in *Nature*.

So-called "monster galaxies" or extreme starburst galaxies are thought to be ancestors of [massive galaxies](#) like the Milky Way in today's universe, so these findings about the galaxy known as COSMOS-AzTEC-1 pave the way to understanding their formation and evolution, the researchers say.

Co-author Min Yun, professor of astronomy at

UMass Amherst and a member of the team that discovered this galaxy using a UMass-built instrument named AzTEC in Chile in 2007, adds, "A real surprise is that this galaxy seen almost 13 billion years ago has a massive, ordered gas disk that is in regular rotation instead of what we had expected, which would have been some kind of a disordered train wreck that most theoretical studies had predicted."

That said, he adds, they did observe that this gas disk is dynamically unstable now, which means the entire gas disk that makes up this galaxy is fragmenting and undergoing a gigantic episode of starburst, which helps to explain its enormous star formation rate, more than 1,000 times that of the Milky Way galaxy.

These most recent observational discoveries of COSMOS-AzTEC-1 were made possible by the Atacama Large Millimeter/submillimeter Array (ALMA), a telescope and facility operated by an international partnership in Chile. Ken-ichi Tadaki is lead author of this week's paper and a postdoctoral researcher at the Japan Society for the Promotion of Science and the nation's National Astronomical Observatory. He says, "One of the best parts of ALMA observations is to see such far-away galaxies with unprecedented resolution."

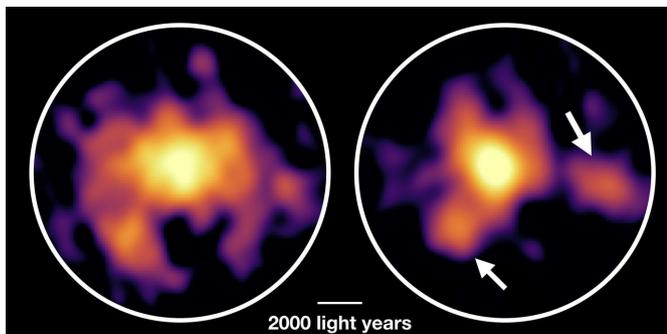
Astronomers have long wondered why monster galaxies can form stars at such a startling pace. To begin to understand, they needed to characterize the environment around stellar nurseries. Drawing detailed maps of molecular clouds is an important step, they say.

Tadaki and the team found that COSMOS-AzTEC-1 is rich in the ingredients of stars, but it was still difficult to figure out the nature of the cosmic gas in the galaxy. They used ALMA's high resolution and high sensitivity to observe the galaxy and obtain a detailed map of the distribution and the motion of the gas to make the highest

resolution molecular gas map of a distant monster galaxy ever made.

"We found that there are two distinct large clouds several thousand light-years away from the center," explains Tadaki. "In most distant starburst galaxies, stars are actively formed in the center. So it is surprising to find off-center clouds."

Yun adds, "How these galaxies have been able to amass such a large quantity of gas in the first place and then essentially turn the entire gas reserve into stars in the blink of an eye, cosmologically speaking, was a completely unknown question about which we could only speculate. We have the first answers now."



ALMA revealed the distribution of molecular gas (left) and dust particles (right). In addition to the dense cloud in the center, the research team found two dense clouds several thousand light-years away from the center. These dense clouds are dynamically unstable and thought to be the sites of intense star formation. Credit: ALMA (ESO/NAOJ/NRAO), Tadaki *et al.*

He says, "Until this result came in from ALMA, nobody knew how Nature created massive, young galaxies formed only 1 billion years after the Big Bang. Finding them first using AzTEC instrument 10 years ago was a real discovery, but it defied explanation."

With the new observations, team members now believe that the monster galaxy is powered by "an extremely gas-heavy disk that is somehow kept stable until enough gas is amassed. We still don't

know yet how so much gas is collected so quickly and what kept this enormous gas reserve from igniting and turning into stars, as gas is known to do in the local universe," Yun adds.

The astronomers found that the gas clouds in COSMOS-AzTEC-1 are very unstable, which is unusual. In a normal situation, they point out, the inward gravity and outward pressure are balanced. Once gravity overcomes pressure, the gas cloud collapses and forms stars at a rapid pace. Then, [stars](#) and supernova explosions at the end of the stellar life cycle blast out gases, which increase the outward pressure. As a result, the gravity and pressure reach a balanced state and star formation continues at a moderate pace. In this way star formation in galaxies is self-regulating.

But in COSMOS-AzTEC-1, the pressure is far weaker than gravity and hard to balance. Therefore this galaxy shows runaway star formation and has morphed into an unstoppable monster galaxy. Tadaki, Yun and colleagues estimate that the gas in COSMOS-AzTEC-1 will be completely consumed in 100 million years, which is 10 times faster than in other star forming galaxies.

Why the gas in COSMOS-AzTEC-1 is so unstable is not clear yet, but a phenomenon called "galaxy merger" is a possible cause. Galaxy collision may have efficiently transported the gas into a small area and ignited intense [star formation](#). Tadaki says, "At this moment, we have no evidence of merger in this galaxy. But by observing other similar galaxies with ALMA, we want to unveil the relation between galaxy mergers and monster [galaxies](#)."

More information: A gravitationally unstable gas disk of a starburst galaxy 12 billion years ago, *Nature* (2018). DOI: [10.1038/s41586-018-0443-1](https://doi.org/10.1038/s41586-018-0443-1), <https://www.nature.com/articles/s41586-018-0443-1>

Provided by University of Massachusetts Amherst

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