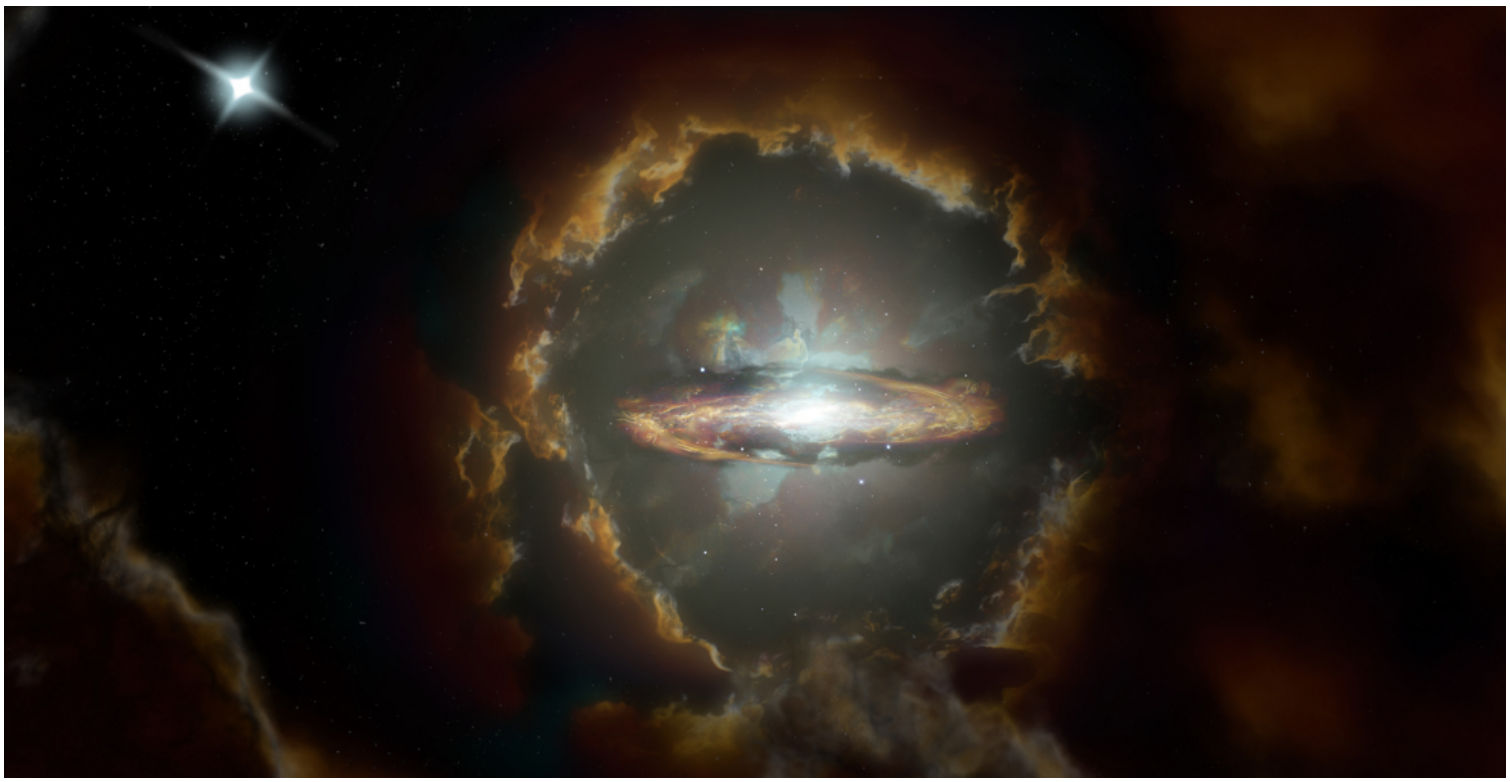
News Release: May 20, 2020 at 11:00 am EDT

ALMA Discovers Massive Rotating Disk in Early Universe

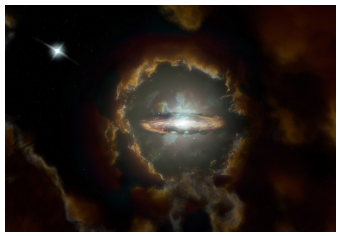


Credit: NRAO/AUI/NSF, S. Dagnello

In our 13.8 billion-year-old universe, most galaxies like our Milky Way form gradually, reaching their large mass relatively late. But a new discovery made with the Atacama Large Millimeter/submillimeter Array (ALMA) of a massive rotating disk galaxy, seen when the universe was only ten percent of its current age, challenges the traditional models of galaxy formation. This research appears on 20 May 2020 in the journal *Nature*.

Galaxy DLA0817g, nicknamed the Wolfe Disk after the late astronomer Arthur M. Wolfe, is the most distant rotating disk galaxy ever observed. The unparalleled power of ALMA made it possible to see this galaxy spinning at 170 miles (272 kilometers) per second, similar to our Milky Way.

Images & Videos



Artist impression of the Wolfe Disk, a massive rotating disk

"While previous studies (https://public.nrao.edu/news/2017-alma-z4-galaxies/) h[illegible] the existence of these early rotating gas-rich disk galaxies, thanks to A[illegible] now have unambiguous evidence that they occur as early as 1.5 billion years after the Big Bang," said lead author Marcel Neeleman of the Max Planck Institute for Astronomy in Heidelberg, Germany.

How did the Wolfe Disk form?

The discovery of the Wolfe Disk provides a challenge for many galaxy formation simulations, which predict that massive galaxies at this point in the evolution of the cosmos grew through many mergers of smaller galaxies and hot clumps of gas.

"Most galaxies that we find early in the universe look like train wrecks because they underwent consistent and often 'violent' merging," explained Neeleman. "These hot mergers make it difficult to form well-ordered, cold rotating disks like we observe in our present universe."

In most galaxy formation scenarios, galaxies only start to show a well-formed disk around 6 billion years after the Big Bang. The fact that the astronomers found such a disk galaxy when the universe was only ten percent of its current age, indicates that other growth processes must have dominated.

"We think the Wolfe Disk has grown primarily through the steady accretion of cold gas," said J. Xavier Prochaska, of the University of California, Santa Cruz and coauthor of the paper. "Still, one of the questions that remains is how to assemble such a large gas mass while maintaining a relatively stable, rotating disk."

Star formation

The team also used the National Science Foundation's Karl G. Jansky Very Large Array (VLA) and the NASA/ESA Hubble Space Telescope to learn more about star formation in the Wolfe Disk. In radio wavelengths, ALMA looked at the galaxy's movements and mass of atomic gas and dust while the VLA measured the amount of molecular mass – the fuel for star formation. In UV-light, Hubble observed massive stars. "The star formation rate in the Wolfe Disk is at least ten times higher than in our own galaxy," explained Prochaska. "It must be one of the most productive disk galaxies in the early universe."

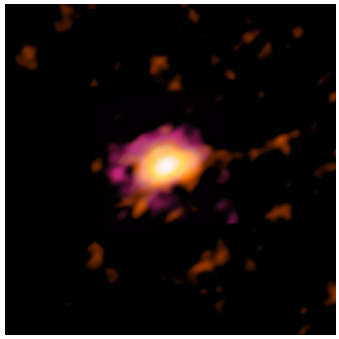
A 'normal' galaxy

The Wolfe Disk was first discovered by ALMA in 2017 (https://public.nrao.edu/news/2017-alma-z4-galaxies/). Neeleman and his team found the galaxy when they examined the light from a more distant quasar. The light from the quasar was absorbed as it passed through a massive reservoir of hydrogen gas surrounding the galaxy – which is how it revealed itself. Rather than looking for direct light from extremely bright, but more rare galaxies, astronomers used this 'absorption' method to find fainter, and more 'normal' galaxies in the early universe.

"The fact that we found the Wolfe Disk using this method, tells us that it belongs to the normal population of galaxies present at early times," said Neeleman. "When our newest observations with ALMA surprisingly showed

galaxy in the early, dusty universe. The galaxy was initially discovered when ALMA examined the light from a more distant quasar (top left).

Credit: Dagnello



ALMA radio image of the Wolfe Disk, seen when the universe was only ten percent of its current age.

Credit: ALMA (ESO/NAOJ/NRAO), M. Neeleman; NRAO/AUI/NSF, S. Dagnello

Video Press Release

Brief video (1:20) explaining this research result.

Credit:

that it is rotating, we realized that early rotating disk galaxies are not as rare as we thought and that there should be a lot more of them out there."

"This observation epitomizes how our understanding of the universe is enhanced with the advanced sensitivity that ALMA brings to radio astronomy," said Joe Pesce, astronomy program director at the National Science Foundation, which funds the telescope. "ALMA allows us to make new, unexpected findings with almost every observation."

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

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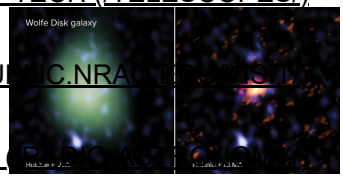
This research was presented in a paper titled "A Cold, Massive, Rotating Disk 1.5 Billion Years after the
Big Bang," by Marcel Neeleman & J. Xavier Prochaska, et al., appearing in the journal *Nature*. DOI: 10.1038/s41586-020-2276-y (https://www.nature.com/articles/s41586-020-2276-y)

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the Ministry of Science and Technology (MOST) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.



The Wolfe Disk as seen with ALMA (red), VLA (left - in green) and the Hubble Space Telescope (both images - blue). In radio light, ALMA looked at the galaxy's movements and mass of atomic gas and dust and the VLA measured the amount of molecular mass. In UV-light, Hubble observed massive stars. The VLA image is made in a lower spatial resolution than the ALMA image, and therefore looks larger and more pixelated.

Credit: ALMA (ESO/NAOJ/NRAO), M. Neeleman; NRAO/AUI/NSF, S. Dagnello; NASA/ESA Hubble

More News From Atacama Large Millimeter/submillimeter Array

New Images Reveal Magnetic Structures Near Supermassive Black Hole

March 24, 2021

The Event Horizon Telescope (EHT) — the worldwide collaboration that produced the first image of a black hole in 2019 — has produced a new image showing details of the magnetic fields in the region closest to the supermassive black hole at the core of the galaxy M87. The new work is providing astronomers with important clues about how powerful jets of material can be produced in that region.

(https://public.nrao.edu/news/magnetic-structures-black-hole/)

Featured Video: Rotating Galaxy Disks in the Early Universe

February 10, 2021

Episode 6 of The Baseline Series explores how galaxies form ordered rotating disks in the early Universe.

(https://public.nrao.edu/news/featured-video-rotating-galaxy-disks/)

ALMA Takes First Step Toward Return to Service

January 14, 2021

The process of returning ALMA to operational status has begun by powering up the first few antennas for the first time since the COVID-19 shutdown in March of 2020.

(https://public.nrao.edu/news/alma-takes-first-step-toward-return-to-service/)

Quasar Discovery Sets New Distance Record

January 12, 2021

Astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA), along with other telescopes, have discovered the most distant quasar yet found. The bright quasar, powered by a supermassive black hole at the core of a galaxy, is seen as it was only 670 million years after the Big Bang, and is providing valuable clues about how such huge black holes and their host galaxies formed in the early Universe.

(https://public.nrao.edu/news/new-distance-record/)

More News Related to Galaxies

IMAGE RELEASE: Cosmic Lens

Most Distant Cosmic Jet

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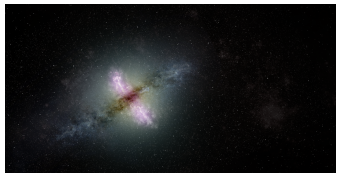

VLA Sky Survey Reveals Newborn

Reveals Faint Radio Gala

M[illegible], 2

Astronomers using the VLA took advantage of the gravitational lensing provided by a distant cluster of galaxies to detect an even more-distant galaxy that probably is the faintest radio-emitting object ever found.

(https://public.nrao.edu/news/cosmic-lens-reveals-faint-radio-galaxy/)

Providing Clues About Early Universe

March 8, 2021

Astronomers using the VLA and VLBA have found the most distant cosmic jet yet discovered, material propelled at nearly the speed of light by a supermassive black hole in the core of a galaxy some 13 billion light-years from Earth.

(https://public.nrao.edu/news/distant-cosmic-jet/)

Early Universe

December 22, 2020

Observations with the continent-wide Very Long Baseline Array (VLBA) reveal previously unseen details in a jet of material ejected from the core of [illegible] seen as it was when the universe was only about 7 percent of its current age.

(https://public.nrao.edu/news/blazar-in-the-early-universe/)

Jets in Distant Galaxies

November 19, 2020

Comparing data from VLA sky surveys made some two decades apart revealed that the black hole-powered "engines" at the cores of some distant [illegible] launched new, superfast jets of material during the interval between the surveys.

(https://public.nrao.edu/ne jets-distant-galaxies/)

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Tweets by @TheNRAO

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Got a question about black holes?

Join our panel of black hole experts from the Very Large Array and @USNRL (representing the Fermi Gamma-ray Space Telescope) for @NASAUniverse Black Hole Week

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The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

Founded in 1956, the NRAO provides state-of-the-art radio telescope facilities for use by the international scientific community. NRAO telescopes are open to all astronomers regardless of institutional or national affiliation. Observing time on NRAO telescopes is available on a competitive basis to qualified scientists after evaluation of research proposals on the basis of scientific merit, the capability of the instruments to do the work, and the availability of the telescope during the requested time. NRAO also provides both formal and informal programs in education and public outreach for teachers, students, the general public, and the media.

(https://www.nsf.gov/)

The National Science Foundation (https://www.nsf.gov/) (NSF) is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense..."

(http://www.aui.edu/)

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