NEWS RELEASE

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Alaknanda: JWST Discovers Massive Grand-Design Spiral Galaxy from the Universe's Infancy

Fully-formed spiral galaxy found just 1.5 billion years after the Big Bang challenges understanding of early galaxy formation

Indian astronomers using NASA's James Webb Space Telescope (JWST) have discovered one of the most distant spiral galaxies ever observed—a massive, beautifully structured cosmic pinwheel that existed when the Universe was only 1.5 billion years old. Named **Alaknanda** after a Himalayan river, this grand-design spiral galaxy challenges our understanding of how quickly complex galactic structures could form in the early Universe.

The discovery, reported by researchers Rashi Jain and Yogesh Wadadekar at the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research (NCRA-TIFR) in Pune, India, reveals a galaxy that looks remarkably similar to our own Milky Way, despite being present when the Universe was only 10% of its current age. The research has been published in the leading European astronomy journal *Astronomy & Astrophysics*.

The researchers chose the name Alaknanda—a Himalayan river that is one of the two main headstreams of the river Ganga— for a specific reason. Alaknanda is a spiral galaxy located about 12 billion light-years away and has a prominent grand design spiral structure just like our own galaxy – the Milky Way. "Just as the Alaknanda is the sister river of Mandakini river, which is also the Hindi name for our own Milky Way galaxy, we thought it fitting to name this distant spiral galaxy after the Alaknanda river" explains Jain.

A Cosmic Time Machine

Alaknanda lies at a redshift of approximately 4, meaning its light has traveled for over 12 billion years to reach us. "We're seeing this galaxy as it appeared just 1.5 billion years after the Big Bang," explains lead author Rashi Jain. "Finding such a well-formed spiral galaxy at this early epoch is quite unexpected —it tells us that sophisticated structures were being built in our universe, much earlier than we thought possible."

Massive, Star-Forming, and Perfectly Structured

Using JWST's unprecedented infrared sensitivity and resolution, the team found that Alaknanda is an impressive cosmic powerhouse. The galaxy contains approximately 10 billion times the mass of our Sun in stars, and is actively forming new stars at a rate of about 63 solar

masses per year—roughly 20-30 times faster than our Milky Way's current star formation rate.

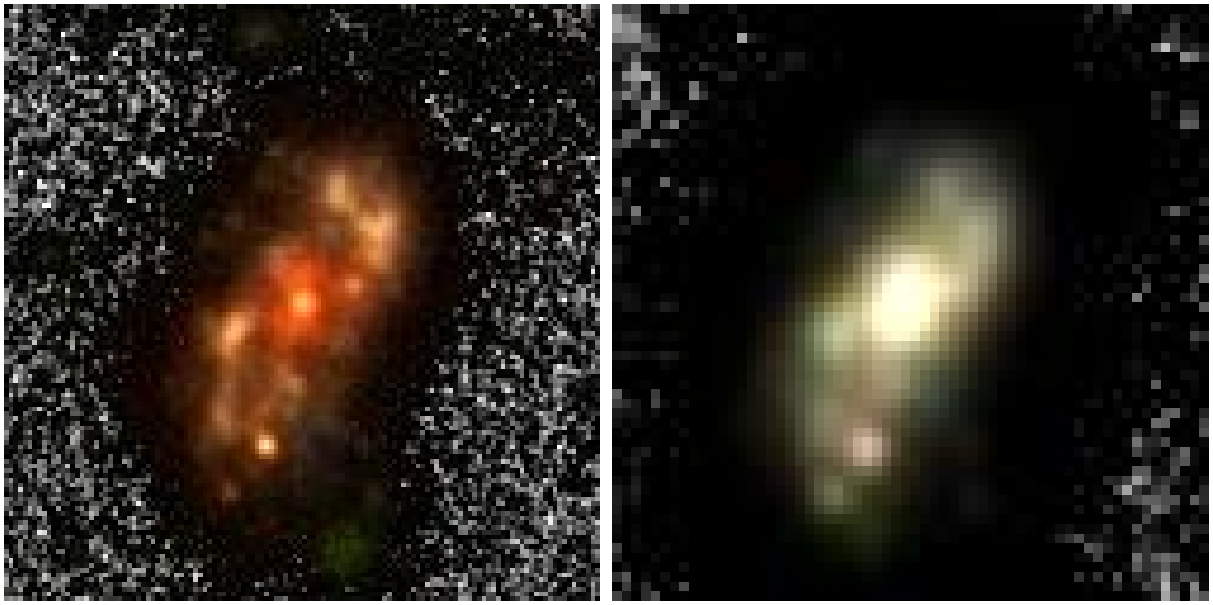

Figure 1: Left panel: Image of Alaknanda in rest-frame near-ultraviolet filters. The star-forming regions in the spiral arms form a beads-on-a-string pattern, characteristic of UV emission from massive stars in star-forming regions. Right panel: Alaknanda as seen in rest-frame optical filters. The spiral arms are less prominent and the underlying disk is clearly seen.

What makes Alaknanda particularly striking is its textbook spiral structure. The galaxy displays two well-defined spiral arms wrapping around a bright central bulge, spanning approximately 30,000 light-years in diameter. In the galaxy's ultraviolet light—actually observed in infrared wavelengths due to its extreme distance—astronomers can see the characteristic "beads-on-a-string" pattern of star-forming regions along the spiral arms, similar to what we observe in nearby spiral galaxies today.

Too Perfect, Too Soon?

Before JWST, astronomers believed that galaxies in the early Universe should be chaotic and clumpy, with stable spiral structures only emerging when the cosmos was several billion years old. The predominant theory suggested that early galaxies were "hot" and turbulent, requiring time to cool down and settle into well-formed rotation-dominated disks capable of maintaining spiral patterns.

"Alaknanda tells a different story," says Wadadekar. "This galaxy had to assemble 10 billion solar masses of stars and simultaneously form a large disk with spiral arms, in just a few hundred million years. That's incredibly rapid by cosmic standards."

The discovery of Alaknanda adds to a growing body of evidence from JWST that the early Universe was more mature than previously thought. Several disk galaxies have been found at similar distances, contrary to what most models from the pre-JWST era predicted. Alaknanda stands out the clearest example of a disk galaxy with well-defined spiral arms at such a high redshift.

The Mystery of Its Formation

How did Alaknanda form its elegant spiral arms so early in cosmic history? The researchers

consider several possibilities:

- Gravitational instabilities caused by density waves traveling through the galactic disk could create and maintain the spiral pattern that typically happens in cool disks growing via smooth accretion rather than violent interactions.

- Tidal disturbances caused by gravitational interactions with smaller nearby galaxies might have triggered the formation of the spiral structure. In such cases, the spiral structures are short-lived and dissolve over time.

The galaxy's low bulge-to-total luminosity ratio (only 14-18% of its light comes from the central bulge) suggests it grew primarily through smooth gas accretion rather than major galaxy collisions, which typically produce bulge-dominated systems. The catch is that this galaxy formed its stars within a period of about 600 million years, while spiral arms take about a billion years to form via smooth accretion at high redshift. This prompts us to revisit the theories of spiral arm formation in galaxies.

JWST's Breakthrough Capabilities

The discovery was made possible by JWST's exceptional sensitivity and resolution in infrared wavelengths. The team used observations from the UNCOVER (Ultradeep NIRSpec and NIRCam Observations before the Epoch of Reionization) survey, which imaged the galaxy cluster Abell 2744. The massive galaxy cluster acts as a natural gravitational lens, magnifying background galaxies like Alaknanda by a factor of more than two.

"The combination of JWST's power and gravitational lensing allowed us to see incredible detail," notes Jain. "We have flux measurements in 21 different filters, including specialized medium-band filters that act as a proxy for spectroscopy, allowing us to pinpoint the galaxy's distance with remarkable precision."

The team used sophisticated spectral energy distribution modeling to determine Alaknanda's properties. They found that the galaxy contains moderately high dust extinction and has a mass-weighted age of only 199 million years, meaning half of its stars formed within 200 million years before the observed epoch—when the Universe itself was only about 1.5 billion years old.

What's Next?

While Alaknanda's photometric redshift is well-constrained, Jain & Wadadekar suggest that follow-up observations with JWST's NIRSpec integral field unit or the Atacama Large Millimeter/submillimeter Array (ALMA). These observations would measure the rotation of the galaxy's disk and determine whether it is dynamically "cold" (with slow internal motions, favorable for stable spiral structure) or "hot" (with rapid, chaotic motions of stars resulting in high velocity dispersion).

"Understanding whether Alaknanda's disk is cold or hot will tell us which formation mechanism created its spiral arms," explains Wadadekar. "It will also tell us whether such galaxies represent a different evolutionary pathway that existed in the early Universe."

The discovery of Alaknanda and other early spiral galaxies suggests that the cosmic timeline for galaxy maturation may need revision. As JWST continues to peer deeper into space and time, more Alaknanda-like galaxies will surely be discovered. At the moment, Alaknanda is the highest-redshift disk-dominated system showing a characteristic spiral pattern that we see in

the nearby universe.

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Expert Contact

Name: Ms. Rashi Jain
Institution: National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
Email: rjain@ncra.tifr.res.in
Office: +91-20-2571-9240

Name: Prof. Yogesh Wadadekar
Institution: National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
Email: yogesh@ncra.tifr.res.in
Office: +91-20-2571-9238

About NCRA and JWST

The **National Centre for Radio Astrophysics (NCRA-TIFR)** is the leading Centre in India for research in radio astronomy and related areas. It is a part of the Tata Institute of Fundamental Research, Mumbai. NCRA operates the Giant Metrewave Radio Telescope (GMRT), one of the world's most sensitive low-frequency radio telescopes, located near Pune, India.

The **James Webb Space Telescope (JWST)**, is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe. Webb is an international program led by NASA with its partners, the European Space Agency (ESA) and the Canadian Space Agency (CSA).

Notes for Editors

- Additional high-resolution images of Alaknanda from JWST are available upon request for media use.
- This work was led by Ms. Rashi Jain, originally from Bharatpur, Rajasthan as part of her PhD research at NCRA-TIFR, under the supervision of Prof. Yogesh Wadadekar.
- The discovery represents a significant achievement for Indian astronomy, showcasing the capability of Indian researchers to make major contributions to cutting-edge space science using international facilities like JWST.
- The name “Alaknanda” refers to the famous Himalayan river, one of the two main headstreams of the Ganga River. The other headstream is the Mandakini, which is also the Hindi/Sanskrit name for the Milky Way galaxy. By naming this distant spiral galaxy Alaknanda, the researchers honor both India’s cultural heritage and the galaxy’s resemblance to our own Milky Way.
- A redshift of $z \sim 4$ corresponds to a lookback time of approximately 12.2 billion years, when the Universe was only 1.5 billion years old (compared to its current age of 13.8 billion years).
- The galaxy is located in the southern constellation of Sculptor, in the field of the massive galaxy cluster Abell 2744, also known as “Pandora’s Cluster,” which is one of the primary targets of JWST’s UNCOVER survey. Alaknanda is much farther away than the cluster itself, and its light has been gravitationally lensed and magnified by the cluster’s mass.
- Alaknanda’s angular size (about 1.5 arcseconds) is extremely small—about the size of a 1 rupee coin viewed from 3 km away.
- Spiral galaxies are classified into several types: grand-design spirals have two prominent, well-defined spiral arms; flocculent spirals have patchy, fragmented arms; and multi-arm spirals have more than two major arms. Alaknanda is classified as a grand-design spiral.