Northumbria University NEWCASTLE

Katie Knowles of Northumbria University

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Telescope reveals surprising secrets in Jupiter's northern lights

An international team of scientists, led by a PhD researcher from Northumbria University, has made groundbreaking discoveries about a spectacular feature of Jupiter's northern lights, revealing a never-before-seen temperature structure and dramatic density changes within the top of the giant planet's atmosphere.

The research, published in Geophysical Research Letters, provides the first detailed spectral measurements of the infrared auroral footprints of Io and

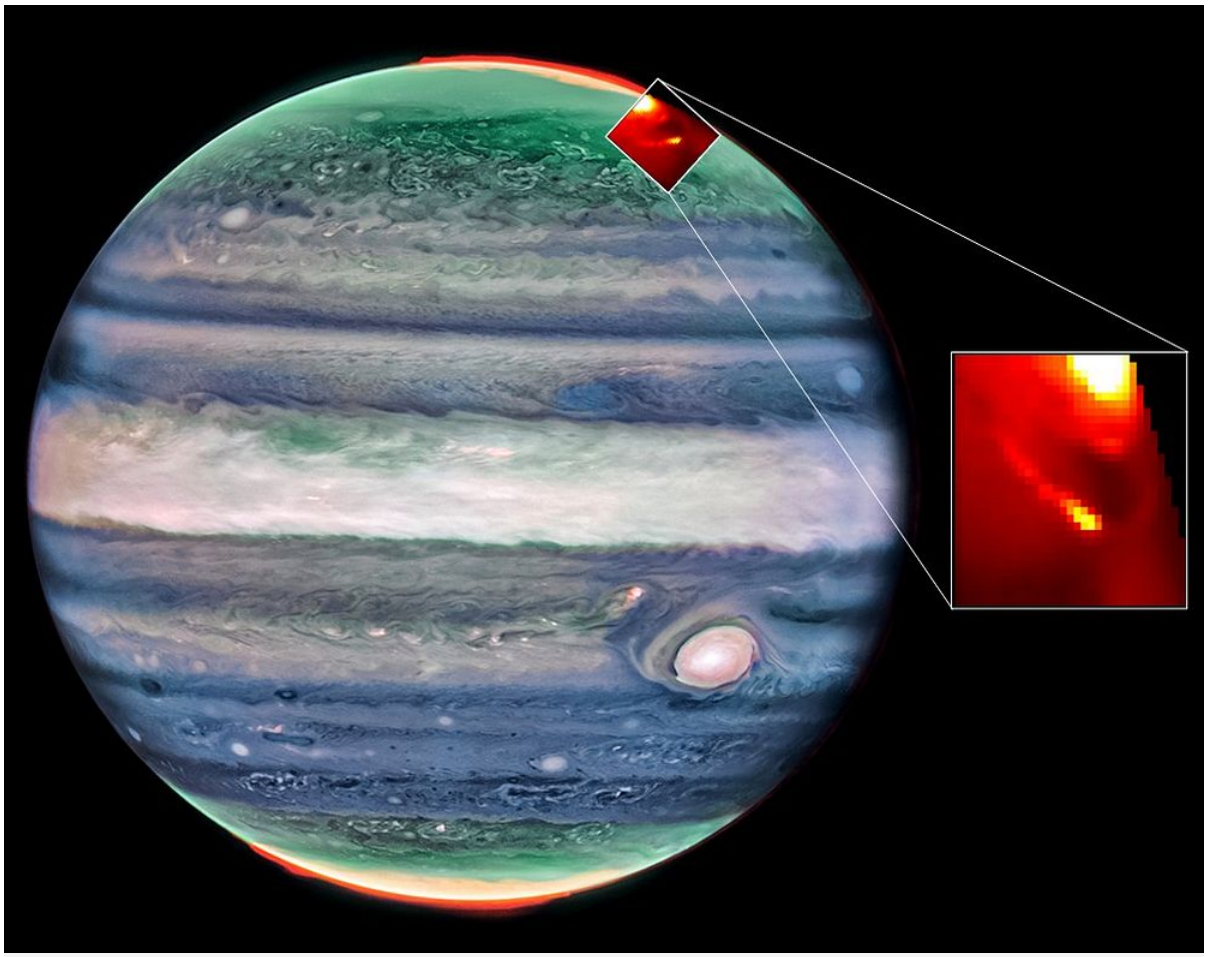
Europa – brilliant glowing patterns in Jupiter's aurora caused by its Galilean moons interacting with Jupiter's powerful magnetic field.

The images were captured using the James Webb Space Telescope (JWST), an international partnership between NASA, the European Space Agency, and Canadian Space Agency, which uses infrared radiation to look deep into space.

Speaking about the findings, lead author Katie Knowles, a PhD Researcher in Planetary Physics at Northumbria University, explains: "These emissions have been measured before at ultraviolet and infrared wavelengths, but only how brightly they shine. For the first time, we've now been able to describe the physical properties of the auroral footprints – the temperature of the upper atmosphere and the ion density, which has never been reported on before."

Unlike Earth's northern lights, which are primarily driven by the solar wind, Jupiter's aurora includes the impact of its four large Galilean moons – Io, Europa, Ganymede, and Callisto – which create their own 'mini aurora' on the planet.

Jupiter's powerful magnetic field rotates approximately once every 10 hours along with the planet itself, carrying charged particles with it. But its moons orbit much more slowly – Io, the innermost moon, takes around 42.5 hours to complete one orbit.



The NASA/ESA/CSA James Webb Space Telescope has captured the auroral footprints of Io and Europa, providing spectral measurements for the first time, and revealing extreme changes in the physical properties within Io's auroral footprint that are likely linked to the electrons crashing into the top of Jupiter's atmosphere. Webb/NIRCam Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Judy Schmidt. Webb/NIRSpec Credit: Katie L. Knowles (Northumbria University).

As Katie explains: "The moons constantly interact with the magnetic field and plasma surrounding the planet, and that interaction leads to highly energetic particles travelling down magnetic field lines and then crashing into the planet's atmosphere, creating the auroral footprints that map to where the moons orbit around Jupiter. Jupiter's aurora is the most powerful and constant of any aurora in the Solar System. What we're seeing with the JWST gives us an unprecedented window into how Jupiter's moons directly affect the top of the planet's atmosphere."

The images captured by JWST were taken during time awarded to Dr Henrik Melin and Professor Tom Stallard - Professor of Planetary Astronomy at Northumbria and Katie's PhD Supervisor. During a 22-hour window of observation time which took place in September 2023, the research team

carried out a scan around the edge of Jupiter, chasing the northern lights as they rotated into view. It was during this observation that they also happened to capture the auroral footprints.

However, the footprints created by Io and Europa, did not have the characteristics expected from Jupiter's main aurora, which is relatively hot and contains a lot of material. Instead, in one snapshot, they discovered a cold spot within Io's auroral footprint that registered temperatures much lower than expected with extraordinarily high densities (higher than they have ever measured before).

Jupiter's moon Io is the most volcanically active body in our solar system, with its volcanoes ejecting about 1,000 kilograms of material into space every second, feeding the dense plasma surrounding Jupiter. This material becomes ionised and forms a doughnut-shaped cloud around Jupiter called the Io plasma torus. As Io moves through this environment, it generates powerful electrical currents that create the brightest spots in Jupiter's aurora.

The research team found that these auroral footprints contain trihydrogen cation (H_3^+) densities three times higher than those found in Jupiter's main aurora, with some regions showing density variations of up to 45 times within the same small area.

"We found extreme variability in both temperature and density within Io's auroral footprint that happened on the timescale of minutes," said Katie. "This tells us that the flow of high-energy electrons crashing into Jupiter's atmosphere is changing incredibly rapidly.

"The cold spot registered temperatures of just 538 Kelvin, or 265°C, compared to 766 Kelvin, or 493°C in the rest of Jupiter's aurora. The cold spot also contained material three times denser than Jupiter's main aurora."

The findings could extend far beyond Jupiter and open questions about other planetary systems. Saturn's moon, Enceladus, also creates an auroral footprint on the planet, and scientists wonder whether similar phenomena occur there.

"This work opens up entirely new ways of studying not just Jupiter and its other Galilean moons, but potentially other giant planets and their moon systems," said Katie, who is about to complete her PhD at Northumbria

University. "We're seeing Jupiter's atmosphere respond to its moons in real-time, which gives us insights into processes that occur throughout our solar system and perhaps further afar.

“We only saw this phenomenon in one of our five snapshots which leave us with questions. How often does this occur? Does it switch on and off? How does it change with different conditions?"

To answer these questions, Katie was awarded over 32 hours of observation time with NASA's Infrared Telescope Facility(IRTF) in Hawaii across six nights in January 2026. This allowed her to watch as the auroral footprint rotated with the planet. She hopes analysis of this data will allow her to determine whether this extreme variability is common or rare.

Katie has presented her findings to international scientists from across the world at the EPSC-DPS Joint Meeting 2025 in Helsinki (Finland) and was also invited to be a Young Scientist Team Member for an International Space Science Institute team meeting in Bern (Switzerland) to further discuss her work.

FURTHER INFORMATION:

Visit the Northumbria University Research Portal to find out more about Katie Knowles’ work.

The paper *Short-Term Variability of Jupiter's Satellite Footprints with JWST* was published in *Geophysical Research Letters* on 3 March 2026.

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Photo captions:

1 & 2: Katie Knowles of Northumbria University, UK. (Credit Northumbria University/Barry Pells)

3: The NASA/ESA/CSA James Webb Space Telescope has captured the auroral footprints of Io and Europa, providing spectral measurements for the first time, and revealing extreme changes in the physical properties within Io's auroral footprint that are likely linked to the electrons crashing into the top of Jupiter's atmosphere.

Webb/NIRCam Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Judy Schmidt.

Webb/NIRSpec Credit: Katie L. Knowles (Northumbria University).

4. James Webb Space Telescope observations of our solar system's largest planet, Jupiter, showing the infrared brightness of the top of its atmosphere, and revealing the auroral footprints of Io and Europa (highlighted by the white box).

Graphic Credit: Dr Henrik Melin (Northumbria University)

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