mission control

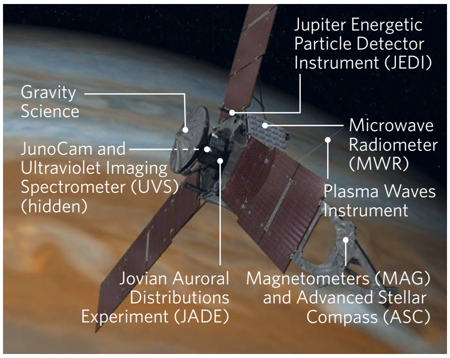
Juno celebrates a year at Jupiter

NASA's Juno mission to Jupiter has just returned its early science results after spending a year orbiting the 'King of the Solar System'. Principal Investigator **Scott Bolton** summarizes what we have learnt.

Launched in August 2011, NASA's Juno spacecraft arrived at its target, Jupiter, on 4 July 2016. Its unique polar orbit provided our first up-close view of the largest planet in the Solar System. Although only at the early stages of Juno's original mapping strategy, the mission has already provided us with a view of Jupiter that shatters decades-old concepts of how giant planets work. Juno's closest approach varies from orbit to orbit, but stays within 3,500–8,000 km of the cloud tops. With an orbital period of approximately 53 days, the spacecraft screams past the planet, passing over both poles in only 2 hours. The highly elliptical trajectory carries Juno away from Jupiter's harsh radiation, reaching a distance of nearly 8 million kilometres (113 Jovian radii) before returning. The result is a series of 32 close flybys, providing essentially a complete map of Jupiter by arranging each close pass at a different Jovian longitude.

Juno (pictured) is equipped to investigate Jupiter's interior and polar magnetosphere. To avoid contamination from the spacecraft field, Juno's magnetometers (MAG) are located at the end of one of the solar arrays. They are co-located with a set of non-magnetic star cameras (ASC) that are capable of detecting any movement of the arrays. The Gravity Science experiment uses the high-gain antenna at both X-band and K_a-band frequencies that eliminate effects from interplanetary and Jovian plasma environments. The six-channel Microwave Radiometer (MWR) probes Jupiter's deep atmosphere beneath the visible cloud tops. Juno's polar orbit is ideal to explore Jupiter's magnetosphere and aurora, characterizing the charged particles and plasma waves responsible for stimulating the aurora (with Waves, JADE and JEDI) while simultaneously imaging both in the ultraviolet (UVS) and infrared (JIRAM). Extensive ground-based observations complement the measurements from the spacecraft.

Juno's first views beneath the clouds show a seemingly complex world with atmospheric composition that varies with depth and latitude. The ammonia abundance changes significantly at depths corresponding to 30 bars or more, with a deep band feature of high abundance penetrating down over 350 km, just north of the Jovian equator. Jupiter's deep atmosphere clearly revealed an unexpected discovery[1,2]: beneath the cloud tops, giant planets are not uniform in composition or temperature. This new paradigm sheds doubt on the concept of using *in situ* probes to determine the global abundances of elements in the giant planets — necessary for constraining planetary formation theories. Juno's discoveries will compel a revised strategy if we are to obtain this information with confidence in the future.



An artist's impression of the Juno spacecraft with its science instruments. Jovian Infrared Auroral Mapper (JIRAM) is not shown. Image: NASA/JPL-Caltech.

Juno's initial observations of Jupiter's gravitational and magnetic fields have yielded significant insights as well. The early gravity field measurements — obtained by tracking the Doppler shift of Juno's radio signal acquired by the NASA Deep Space Network — hint that the core structure is not what was expected. Instead of seeing evidence of a compact core, or no core, the data appear more consistent with a large, possibly diffuse or fuzzy core. There are indications of deep internal motions, raising new possibilities for how giant planets form and evolve[3,4].

The magnetic field observations from Juno's first perijove were obtained much closer to the planet than any previous measurements and revealed higher-order terms of the magnetic field that drop off rapidly with distance. The magnetic field is both stronger and more spatially complex[1,5] than previously modelled. How this insight contributes to our understanding of the planetary dynamo will depend on observations from future perijove passes.

A primary objective of the Juno mission is to combine remote sensing of Jupiter's aurora with the first *in situ* measurements of the particles and fields over the polar regions. Early results show that Juno passed through the high-latitude regions where particles were beamed along the magnetic field[6], but, surprisingly, did not detect the field perturbations associated with the expected field-aligned electrical currents. The lack of evidence of strongly accelerated downward electron beams is puzzling; it appears that Jupiter's auroral processes are not as similar to Earth's as previously thought. Rather, upward loss cones, suggestive of diffusive aurora, are reported[7].

Juno's survey of Jovian radio emissions provides the first opportunity to pass directly through the radio-source regions at Jupiter[8]. Kilometric, hectometric and decametric emissions were all observed. Juno seemingly passed through as many as six sources of auroral radio emissions during the close pass over Jupiter's poles. ❐

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