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Diving into Jupiter's northern lights

Randy Gladstone

The Juno mission will use an unusual polar orbit to examine Jupiter's deep atmosphere and the mechanisms generating its powerful aurora.

Several spacecraft have flown by Jupiter in the past, and one—Galileo—orbited the gas giant from 1995 to 2003 and dropped a probe in as well. After all this examination, one would think we must certainly have all the data we need to settle any remaining questions about how Jupiter works. However, these earlier missions were confined to low, near-equatorial latitudes. While they could look at Jupiter's polar regions obliquely and from a distance, they couldn't sample them. For scientists interested in Jupiter's impressive auroras (∼1000 times as energetic as Earth's), that isn't enough.

Juno,[1,2] a National Aeronautics and Space Administration New Frontiers mission, is scheduled for launch in August 2011 on a five-year cruise, including a flyby of Earth in October 2013 for a gravity boost. Juno will then spend 14 months around Jupiter after arriving in August 2016. The spinning, solar-powered Juno will study Jupiter from a very stretched-out orbit, in which (for about six hours once every 11 days) the spacecraft dives down over the north pole, skims the outermost atmosphere, and rises back up over the south pole. This unusual orbit will allow Juno to regularly get close to Jupiter while avoiding most of the potentially damaging particle radiation surrounding the planet (Jupiter's Van Allen belts). An artist's conception of Juno in orbit around Jupiter is shown in Figure 1. Figure 2 details the layout of the science instruments.

Getting in close to the planet is essential for mapping the high-order structures in Jupiter's gravitational and magnetic fields. This will answer long-standing questions about interior structure, e.g., Does Jupiter have a rocky core? and Where is the dynamo generated?[3] Juno's orbit will also allow for pole-to-pole microwave sounding of the deep atmosphere's composition, which will constrain theories about Jupiter's origin (and settle another long-standing question about water abundance, i.e., Did the Galileo probe just hit a dry spot?).[4] But for auroral scientists, the great thing about Juno's polar orbit is that it provides face-on viewing of the aurora and in situ sampling of the high-latitude, near-planet regions where the aurora-producing particles are thought to be energized.

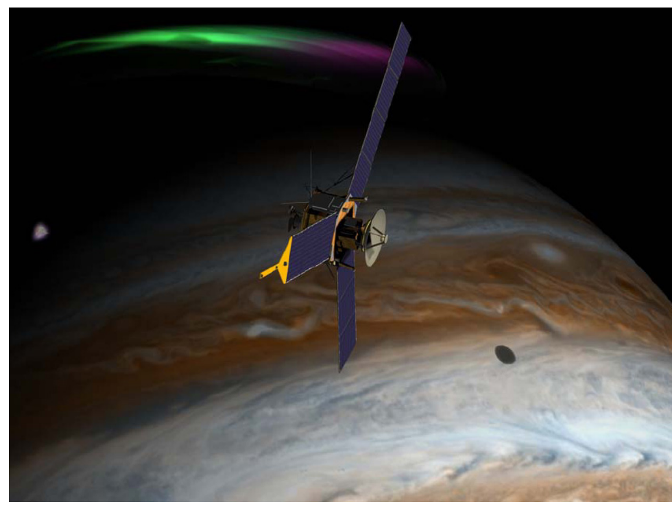

Figure 1. *Artist's conception of the Juno spacecraft at Jupiter.*

Part of the exploration of Jupiter's polar magnetosphere will involve remote spectral imaging of the far-UV H and H_2 auroral emissions, which result when energetic particles, mainly electrons, slide down along magnetic field lines near the poles and collisionally excite atmospheric hydrogen.[5] The spectral distribution of H_2 emissions contains information about temperatures in the auroral atmosphere. Also, overlying hydrocarbon gases in Jupiter's upper atmosphere, such as methane and acetylene, add their absorption signature to the H_2 emissions. This hydrocarbon absorption can be used to estimate the energy of the precipitating electrons, because more energetic electrons will go deeper into the atmosphere and the UV emissions they produce will show more absorption.

Juno will carry a UV spectrograph (UVS) to make spectral images of Jupiter's aurora. By taking advantage of the hydrocarbon absorption, UVS scientists will produce images showing how

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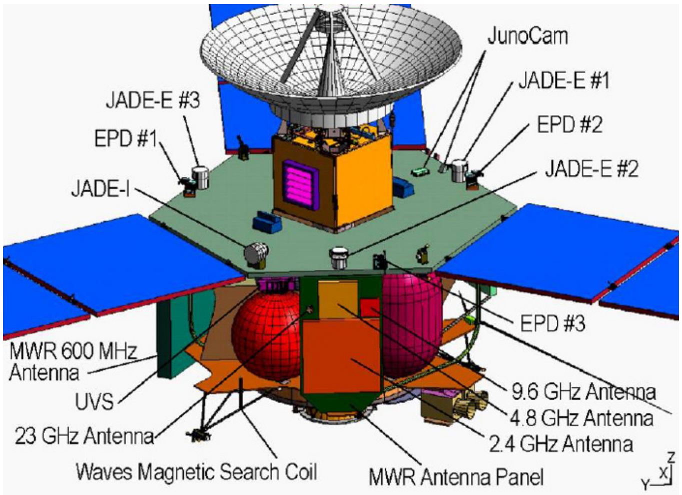

Figure 2. *Layout of the science instruments on the Juno spacecraft. (The magnetometers are on the yellow wedge at the end of the left solar panel in Figure 1.) JADE: Jovian Auroral Distributions Experiment. MWR: Microwave radiometer. EPD: Energetic particle detector.*

the precipitating electron energy and flux vary over Jupiter's aurora, and map these back to their source regions in the magnetosphere. Since these results depend on imperfect models of Jupiter's atmosphere, a very important ground truth observation will be that of Juno's footprint. This is the region in the atmosphere on the same magnetic field line as the spacecraft, for which in situ measurements by Juno will provide detailed particle and field data to characterize the precipitating auroral particles. Comparing the particle energies measured at Juno with the energies inferred from observing the UV emissions they produce in the footprint should help us understand where the particles are being accelerated.

The Juno UVS uses a Rowland-circle design, based on similar Alice instruments now flying on the Rosetta (comet) and New Horizons (Pluto) missions. On Juno, the UVS will face new challenges. The intense penetrating radiation environment near Jupiter can damage electronics and swamp the detection of auroral photons. Also, the fact that the spacecraft is spinning (rotating once every 30s) greatly limits the time spent looking at the aurora. Finally, the spacecraft must operate over a great range of distances during each perijove pass. The spacecraft undergoes a huge change in altitude, from ∼300,000 to ∼30,000km, in the period from 3h to 30min before closest approach, when auroral observations will be made.

To address these challenges, the Juno UVS will use shielding to protect its microchannel plate detector and associated electronics. Other electronics are kept safe in a spacecraft-provided vault. It will also employ a spectrograph slit with narrow and wide sections and time tagging of photon events to provide good sensitivity and spatial/spectral resolution. (The data will be binned on the ground, according to the signal-to-noise ratio.) The spacecraft will also use a front-end scan mirror to target specific auroral features or Juno's footprint.

The Juno mission is currently nearing the end of its definition phase (Phase B), and will soon enter the design and development phase (Phase C/D) where instrument and spacecraft subsystem prototypes (engineering models) and eventually flight models are built and tested under flight-like conditions. The Juno UVS design and its interfaces to the spacecraft are being finalized, and a preliminary design review is around the corner.

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