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The shape of Jupiter is redefined by radio-occultation data from the Juno spacecraft

Juno's radio occultations have been used to refine the shape of Jupiter with sub-kilometre precision, revealing equatorial and polar radii that are slightly smaller than long-used values. The results tighten constraints on the planet's interior structure and its winds.

The question

How accurately can the size and shape of Jupiter be determined, and what does such a measurement reveal about its deep interior and winds? Because Jupiter is a gas giant with no solid surface, its 'size' is usually defined at the level in the atmosphere where the pressure is 1 bar, comparable to surface pressure on Earth. Although the general shape of Jupiter can be determined from its orbital parameters, the most accurate method is to map the planet using radio occultations. In this technique, radio signals exchanged between a spacecraft and Earth skim the planet's limb and are refracted by the atmosphere, enabling the local radius to be inferred as a function of pressure. By repeating these measurements at different latitudes, the full three-dimensional shape can be reconstructed.

The radii that have long defined Jupiter's 1-bar figure[1] were derived, in the 1980s, from only a few Voyager and Pioneer radio occultations. Although groundbreaking at the time, that shape had uncertainties of several kilometres and was biased by the omission of dynamical effects. The quest for a refined 1-bar figure is more than taxonomy: it constrains mass distribution, rotation, and wind depth, and reduces degeneracies in interior models.

The measurements

Juno, a NASA spacecraft, has been in a polar orbit around Jupiter since 2016 and is designed to investigate the planet's origin and evolution by measuring its gravity and magnetic fields, probing its deep atmospheric composition, and exploring its polar magnetosphere. Its payload includes a microwave radiometer, magnetometers, particle and field instruments, and a radio-science system that tracks the spacecraft's motion with high precision. The radio-science experiment is used to conduct radio occultations: radio signals exchanged between Juno and Earth skim Jupiter's limb and are refracted by the atmosphere; temperature, density and radius profiles can be retrieved along the ray path.

We have used this set of Juno radio-occultation measurements to re-measure Jupiter's 1-bar shape with sub-kilometre precision. We analysed the two-way radio links using a two-way ray-tracing inversion across hundreds of plausible spacecraft trajectories — consistent with navigation uncertainties — to derive pressure–radius profiles that probe the atmosphere from the upper troposphere to the lower stratosphere, with 1σ errors of only tens of metres at 1 bar, far below instrumental and Doppler-noise limits[2,3]. These profiles, aggregated over more than twenty occultations across different latitudes, enabled a direct fit to the planet's shape while accounting for the effects of atmospheric winds. The fit residuals of roughly 0.4 km indicate a high level of internal consistency.

Our new shape shows that Jupiter's equatorial and polar radii are smaller by 4 km and 12 km, respectively, rendering the planet slightly more oblate than previously estimated (Fig. 1a). Re-evaluation of interior models[4,5] indicates a modest increase in mean density and atmospheric metallicity, consistent with a slightly cooler 1-bar temperature. The extent of the dilute core remains unchanged. Dynamical-height analysis based on occultation-derived winds reproduces the observed figure of the planet with sub-kilometre precision (Fig. 1b), confirming that the cloud-tracked zonal flows extend from a level of roughly 100 mbar to 1 bar in the planetary atmosphere. Together, these results unify Jupiter's gravity, shape, winds, composition and thermal structure into a consistent physical picture.

The implications

The refined shape provides a more accurate reference surface for Jupiter, linking its gravity field and atmospheric dynamics more directly than ever before. Our approach has reduced long-standing uncertainties in interior modelling and offers a template for studying other rapidly rotating planets. The same methodology could also be applied to exoplanets, where radius–density relationships rely on similar assumptions.

There are limitations, which stem from Juno's restricted latitude coverage, the need to assume how winds influence the planet's shape, and small residual systematics from instrument calibration and spacecraft navigation. Although the low fit residuals confirm consistency, the retrieved radii remain model-assisted reconstructions of a dynamic atmosphere whose short-term variability is not yet fully resolved.

Future Juno occultation experiments, and also those of ESA's JUICE (Jupiter Icy Moons Explorer) mission from 2031, will broaden spatial and temporal coverage, combining radius, temperature and wind data to track changes in Jupiter's atmosphere and further refine comparative-planetology models of the gas giants.

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EXPERT OPINION

"This paper, authored by members of the Juno working group, provides an important update for Jupiter's fact list: the radius and shape. The conclusion, that Jupiter's polar, equatorial and mean radii are about 12 km, 4 km and 8 km smaller, respectively, than previously modelled, is interesting and will be useful for future researchers." **Moritz Heimpel, University of Alberta, Edmonton, Alberta, Canada.**

FIGURE

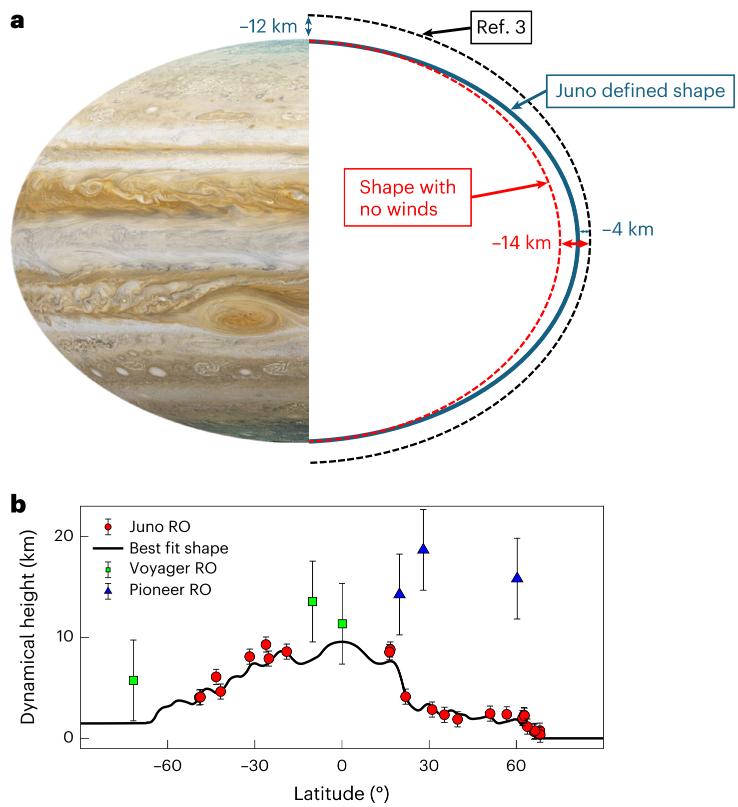

Fig. 1 | Radio occultations from the Juno spacecraft are redefining the shape of Jupiter. **a**, We have derived radii of Jupiter's 'surface' (defined as the level at which the atmospheric pressure is 1 bar) from Juno radio-occultation (RO) data. The Juno-derived shape (blue) is compared – and contrasts – with the wind-free reference (red) and an earlier model from Lindal et al.[1], which has a larger, less oblate Jupiter (black, here labelled 'Ref. 3'). **b**, Dynamical height is calculated by subtracting the no-wind shape from the Juno radio-occultation shape; these data points have much lower uncertainties than similar points from the earlier Voyager and Pioneer missions. The latitude-dependent variations in dynamical height – kilometres in scale – are caused by zonal winds. © 2026, Galanti, E. et al.

BEHIND THE PAPER

This project began as a simple cross-check: could the Juno radio occultations alone recover Jupiter's canonical shape? When the residuals lined up into a latitude-dependent 'wobble', we realized winds were sculpting the cloud-top-level surface by kilometres — a small amount in absolute terms, but decisive for interior fits. That caused us to pivot from geometry to dynamics. A second inflection point came when a slight decrease in equatorial radius consistently improved the shape fit to the measurements, while maintaining alignment with gravity solutions within the differential-rotation envelope.
We stress-tested navigation and Doppler error budgets, then asked what the shape shift meant for composition and thermal structure: the metallicity and temperature trends emerged naturally. The most satisfying moment was seeing independent datasets — radio occultations, winds and gravity — come together to form a coherent picture. Next up: extending this recipe to Saturn and the ice giants. **E.G. & Y.K.**

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FROM THE EDITOR

"Determining the precise shape of a planet might sound like a menial task, but as this paper shows, even small variations can have important consequences. A Jupiter radius around 10 km smaller than the previous reference — a mere 0.014% of the mean radius — provides more stringent constraints on its interior properties." **Luca Maltagliati, Senior Editor, *Nature Astronomy*.**