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Jupiter's gravity field is North-South asymmetric

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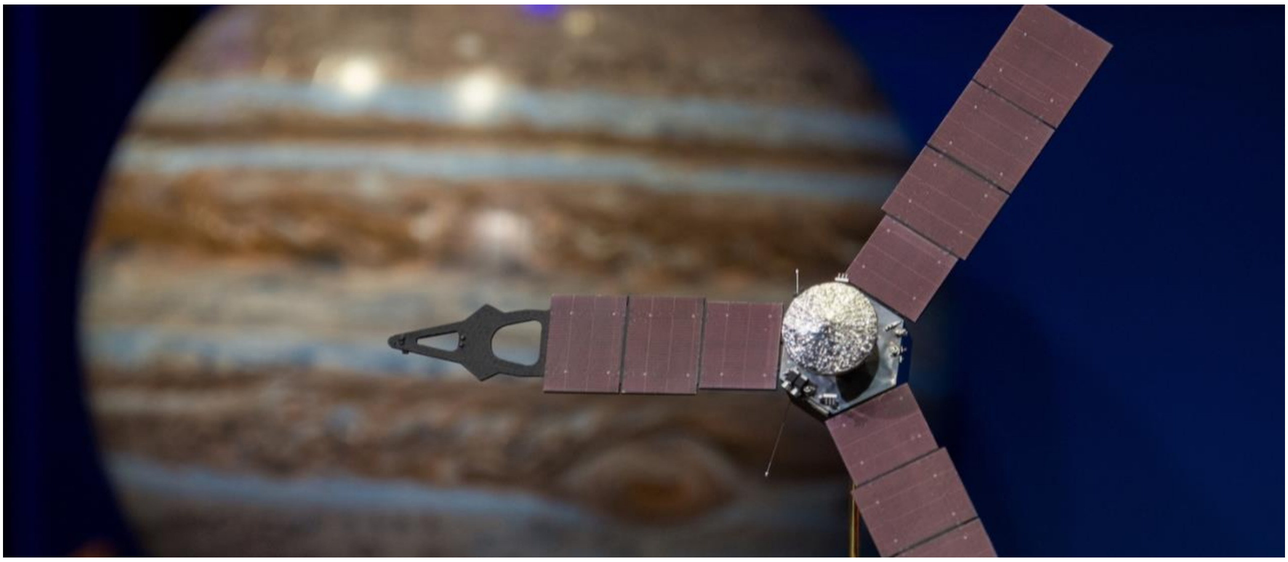
ABSTRACT

One of the main goals of NASA's Juno mission is the study of the interior of Jupiter, the largest planet in the solar system. The analysis of Juno's data provided the best ever measurement of Jupiter's gravity field. The North-South asymmetry of Jupiter's gravity field, revealed for the first time, indicates that the zonal flows visible on Jupiter's surface penetrate deep



Jupiter is the largest planet in the solar system, with an equatorial radius of 71,492 km (about 11 times that of the Earth). Like the Sun, Jupiter's interior is mainly composed of hydrogen and helium. In fact, the planet is catalogued as a gas giant, and does not have a well-defined surface like the Earth. Thus, Jupiter is a huge ball of gas, without a well-defined atmosphere. Gaining knowledge of its interior is fundamental for the advance of planetary formation theories. The study of Jupiter's interior is one of the main objectives of NASA's Juno mission. As part of this mission, a deep space exploration probe has been orbiting around the planet in a highly-elliptical orbit since July 4th, 2016. Before the arrival of Juno, Jupiter's interior structure was poorly understood. In particular, the depth to which the surface zonal winds extend was unknown.

One of the most powerful tools used to probe the interior of a planet is its gravity field, which is determined by how the density is distributed inside the planet. In fact, the distribution of materials in the interior is not always even – one area could be denser than another. This can be seen in the external gravity field through which the spacecraft moves. The gravity field of Jupiter is mainly affected by two separate phenomena. On one hand, the fast rotation of the planet (about 10 hours for a complete spin) deforms and flattens the planet. On the other hand, the surface winds, by penetrating into the planet, affect the mass distribution and therefore the gravity field. The strength of this perturbation depends on the penetration depth of the winds.

The determination of Jupiter's gravity field is made possible by Juno's radio-science experiment. The experiment works by observing the Doppler shift of a microwave signal sent from a ground station on the Earth. The transmitted signal, after travelling from 600 to 900 million kilometers, is received by Juno with a different frequency due to the Earth-Juno relative velocity, which can therefore be accurately measured and related to Jupiter's gravity field. The key instrument on board Juno capable of taking these measurements is the Ka Translator System (KaTS). The Ka-band radio link enables an accurate determination of the spacecraft's radial velocity down to accuracies of about 0.015 mm/s, which corresponds to about one thousandth of the speed of a snail. The Doppler measurements are then analyzed with an orbit determination code to precisely estimate Juno's trajectory and accelerations, revealing the fine details of Jupiter's gravity field.

The data were acquired during the first two orbits which were dedicated to studying Jupiter's gravity – PJ03 and PJ06 in the Project's jargon. Their analysis allowed Jupiter's gravity field to be determined with exquisite accuracy. The perturbation related to the wind dynamics has been clearly determined for the very first time. One of the main goals of Juno's gravity experiment was to measure the depth of the surface winds, which has remained unknown until today. This goal has now been achieved by studying the asymmetric gravity field that could be observed between the northern and southern hemispheres of Jupiter. The large North-South asymmetry of the gravity field indicates that the flows involve large masses, as expected if the winds penetrate deep into the planet, well below the clouds seen in camera images. The model relates the gravity field to the surface winds, predicting a wind depth of about 3000 km. Furthermore, Juno data revealed that a mass approximately equal to that of the Earth rotates differentially with respect to the deep interior of the planet (Jupiter's mass is about 300 Earth's masses).

The first data received from the Juno spacecraft has thus shed light on the interior of Jupiter by suggesting the presence of a diluted core. The analysis of the first two gravity-dedicated passes revealed a North-South asymmetry in Jupiter's gravity field, which has been explained by the wind dynamics. In the future, Juno will unveil many other details about Jupiter's interior. For example, the gravity science experiment may reveal the extension of the Great Red Spot.