**Jupiter’s gravity field is North-South asymmetric**

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**Original article**

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**Short description**

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 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 into the planet.

**General introduction**

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. Since Jupiter contains 71% of the total mass of the solar system (Sun excluded), a solid knowledge of its interior is fundamental for the advance of planetary formation theories. In fact, a large fraction of the elements of the original protoplanetary disk is contained in the planet. The study of Jupiter’s interior is one of the main objectives of NASA’s Juno mission. The deep space exploration probe has been orbiting around the planet in a highly-eccentric orbit since July 4th, 2016. Before the arrival of Juno, Jupiter’s interior structure was poorly understood. In particular, the depth of the surface zonal winds, which divide the planets into differently-colored bands, with speeds up to 360 km/h, was unknown.

**Introduction to study**

One of the most powerful tools used to probe the interior of a planet is its gravity field, which is determined by the interior density distribution. A measurement of the gravity field constrains the radial density inside Jupiter, thus providing information on its composition. The gravity field of Jupiter is dominated by two main contributions. On the one hand, the uniform, fast rotation (about 10 hours) deforms and flattens the planet. The contribution of uniform rotation, symmetric in the northern and southern hemisphere, can be noticed only in the even-degree coefficients of the spherical harmonic expansion of the gravitational potential. On the other hand, the surface winds, by penetrating into the planet, perturb the density profile, thus the gravity field, according to their depth. The flows are not hemispherically symmetric, and so is the gravity disturbances they generate. Therefore, the winds affect both the even- and odd-degree spherical harmonic coefficients.

**Methodology**

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 at two different bands (X-band, used for telecommunications, and Ka-band, used for precision gravity science measurements) to accurately measure the Earth-Juno relative velocity, which is perturbed by Jupiter’s gravity field. The key instrument onboard Juno is the Ka Translator System (KaTS), which enables the far more accurate Ka-band radio link. 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.

**Results**

The analysis of the data acquired in the first two gravity orbits (PJ03 and PJ06 in the Project’s jargon) allowed Jupiter’s gravity field to be determined with exquisite accuracy. The low-degree odd harmonics, related only to the wind dynamics, have been obtained for the first time with a signal-to-noise ratio larger than ten. 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.

**Conclusions**

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 been achieved by looking at the asymmetric part of Jupiter’s gravity field. The gravity anomalies have been explained with the thermal winds model, which balances the gravitational acceleration with the pressure gradient induced by the winds. 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).

**General conclusions and future perspectives**

The first data received from the Juno spacecraft shed light on the interior of Jupiter by suggesting the presence of a diluted core. Then, 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. Additionally, the depth of local features of Jupiter’s surface winds, such as the great red spot, may be constrained by determining their gravitational signature.