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A view into the deep interior of Mars from nutation measured by InSight RISE

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We report the results of more than 2 years of monitoring the rotation of Mars with the RISE instrument on InSight. Small periodic variations of the spin axis orientation, called nutations, can be extracted from the Doppler data with enough precision to identify the influence of the Martian fluid core. For the first time for a planetary body other than the Earth, we can measure the period of the Free Core Nutation (FCN), which is a rotational normal mode arising from the misalignment of the rotation axes of the core and mantle. In this way, we confirm the liquid state of the core and estimate its moment of inertia as well as its size.

The FCN period depends on the dynamical flattening of the core and on its ability to deform. Since the shape and gravity field of Mars deviate significantly from those of a uniformly rotating fluid body, deviations from that state can also be expected for the core. Models accounting for the dynamical shape of Mars can thus be tested by comparing core shape predictions to nutation constraints. The observed FCN period can be accounted for by interior models having a very thick lithosphere loaded by degree-two mass anomalies at the bottom.

The combination of nutation data and interior structure modeling allows us to deduce the radius of the core and to constrain its density, and thus, to address the nature and abundance of light elements alloyed to iron. The inferred core radius agrees with previous estimates based on geodesy and seismic data. The large fraction of light elements required to match the core density implies that its liquidus is significantly lower than the expected core temperature, making the presence of an inner core highly unlikely. Besides, the existence of an inner core would lead to an additional rotational normal mode the signature of which has not been detected in the RISE data.

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