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The promise and limitations of improved-accuracy gravity field measurements for Uranus and Neptune

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Uranus and Neptune present unique challenges to planetary modelers. The composition of the so-called ice giants is very uncertain, even more so than the composition of the gas giants. For instance, it is far from clear that either planet's composition is dominated by water. Instead, the composition of Uranus and Neptune likely includes water and other refractory elements in large quantities as well as a substantial H/He envelope. Furthermore, formation models also predict that composition gradients are likely in the interiors of these planets, rather than a neat differentiation into layers of homogeneous composition. (See Helled and Fortney 2020 and references within.)

A key question that impacts the science case for a potential orbiting mission to Uranus or Neptune is how will more precise measurements of the gravitational field better constrain either planet's interior density profile and composition. Surprisingly, there is yet no published answer to this question. Here, we present new work that explores this issue, using a Bayesian framework that allows exploration of a wide range of interior density profiles.

Our approach, which builds off our previous work for Saturn (Movshovitz et al., 2020) and that of others (e.g. Marley et al., 1995, Helled et al., 2011) takes a relatively unbiased view of the interior structure by employing so-called empirical density profiles. A parameterization is applied to the density profiles directly (via mathematical base functions) instead of to an assumed layered composition (H/He, water, rocks). While some of these empirical density profiles may imply unrealistic compositions, they can also probe solutions that would be missed by the standard layered-composition approach.

Here we will present models of Uranus and Neptune constructed with this approach, and ask two questions: 1) How large is the space of possible solutions today? 2) How much will it be reduced should a future mission to Uranus and Neptune improve the precision on their gravity field measurements by several orders of magnitude, to the level now available for Jupiter and Saturn?