EMPIRICAL STRUCTURE MODELS OF URANUS AND NEPTUNE.

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Introduction: Uranus and Neptune are the outermost planets of our Solar System. Although they represent a unique class of planets, relatively little is known about them [1], [2]. Constraining their internal structures and bulk compositions is critical for understanding their formation and evolution [3], [4], [5], [6]. Structure models are designed to fit the planet's measured mass, radius, and gravitation field. Currently, *Voyager II* is the only spacecraft that has visited Uranus and Neptune. Accordingly, the data collected (as e.g., the planetary shape, rotation periods, atmospheric dynamics,…) incorporate relatively high uncertainties that in turn allow for a relatively broad variety of internal structure models.

Aim: In this project, we investigate the effect of different rotation periods and depths of the winds of Uranus and Neptune on the prediction of the higher order gravitational coefficients J_6 and J_8, the density profiles, the normalized moment of inertia (MoI) value, and the planetary shape. We then explore how more accurate determinations of J values, MoI, or polar radii could be used to further constrain the planet's rotation periods and atmosphere dynamics. We also demonstrate that improved measurements of Neptune's J_2 and J_4, with uncertainties comparable to the ones available for Uranus, could further constrain Neptune's predicted J_6, J_8, and MoI value. Our study, therefore, can help to design a future space mission as it provides a priori estimates of the higher order gravitational moments J_6, J_8 and the MoI values and state the desirable accuracies in J values and the MoI in order to further constrain the planet's wind depth and rotation period.

Method: In this work, we represent the density profile by (up to) three piece-wise arranged polytropes. A polytrope connects the pressure P with the density ρ:

$$P = K\rho^{1+1/n},$$

where K and n are free parameters. This generous approach allows for up to two density discontinuities ('density jumps'), that can account for potential sharp compositional changes (e.g. rain-out due to immiscible materials). We call it a 'piece-wise' arrangement when different polytropes represent different radial regions of a planet (e.g. core, mantel, and envelope region).

Results: Our main results are that…

(i) … the prediction of Uranus' and Neptune's J_6 and J_8 depend strongly on the dynamics. An accurate measurement of J_6 or J_8 (with a relative uncertainty of a few per cent) is required to constrain the depth of the winds in Uranus and Neptune.

(ii) … the density distribution in the deep interiors of Uranus and Neptune depends significantly on the rotation period and is strongly affected by dynamics. For models assuming uniform rotation, it is crucial to use wind-corrected gravitational coefficients.

(iii) … more accurate measurements of J_2 and J_4 can further constrain the density distribution and narrow the range of predicted solutions in J_6, J_8, and MoI of Uranus and Neptune.

(iv) … for both Uranus and Neptune accurate determinations of the MoI could be used to distinguish between different rotation periods and constrain the depth of the winds. For the former, a relative precision of 1% is needed, whereas for the latter a relative precision of 0.1%, is required.

(v) … the generally used shapes of Uranus and Neptune do not agree with the broadly used rotation period as estimated by the *Voyager II* mission. We, hence, reiterate the necessity of a robust and independent measurement of the rotation periods and shapes of Uranus and Neptune.

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