EPSC Abstracts
Vol. 13, EPSC-DPS2019-1709-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Splitting in the static k_2 of the Neptune-Triton system

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Abstract

We present fluid Love number k_{nm} values for the Neptune-Triton system as a function of the uncertainty in Neptune's J_4 value and rotation rate. We discuss the unexpected found splitting in k_2 for assumed slow and fast rotation, respectively, in regard to differences in the contribution functions of J_2 and k_2.

1. Dissimilar Ice Giants?

The Ice Giants Uranus and Neptune have similar mass, radius, gravity field (J_2, J_4), and similar magnetic fields. On the other hand, they differ in luminosity and rotation period $P_{\rm rot}$. This poses the question of perhaps dissimilar interiors of the ice giants. Here we investigate if an observed fluid number k_2 value for the Neptune-Triton system could help to further constrain the interior structure of Neptune.

2. Splitting in I and k_2

Table 1: Some observational constraints.

Parameter	Value	Ref.
	Neptune	
$P_{\rm rot,\,1}$ (fast)	16h 6m 40s	[5]
$P_{\rm rot,\,2}$ (slow)	17h 27m 29s	[2]
$R_{\rm eq,\,1}$ at 1 bar	24,766 km	[5]
$R_{\rm eq,\,2}$ at 1 bar	24,787 km	[2]
$q_{\rm rot}$	0.02608	
	Triton	
$M_{\rm Tri}/M_{\rm Nep}$	0.0048	
$q_{\rm tid}$	$-2.13\,10^{-7}$	

The rotation rates of Uranus and Neptune are not even well known, with estimates differing by 40 min for Uranus and 1 h 21 min for Neptune, see Table 1. For Neptune, the faster rotation rate known as the *Voyager* rotation rate was inferred from radio and magnetic field data while the slower value is a prediction from interior models that fit the shape data and minimize the observed wind velocity and dynamical heights [2].

In Ref. [6] it was found that interior models for the different rotation rates yield different normalized moment of inertia values $I_{\rm slow} = 0.2410(8)$ and $I_{\rm fast} = 0.2555(2)$ although the models would fit the same J_2 value. In Ref. [7] a similar splitting was obtained for k_2. This is surprising since k_2 is extraordinarily insensitive to different internal density distributions once J_2 and J_4 are fit, as has been shown for Jupiter [8] and Saturn [9].

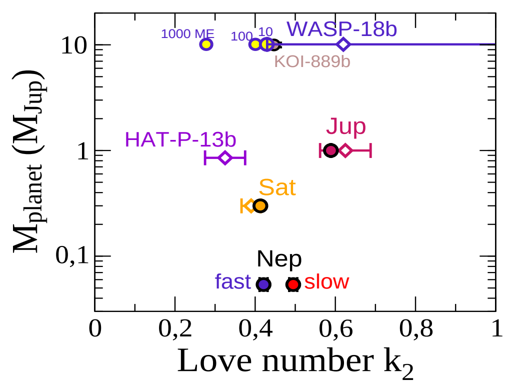

Figure 1: Observed (diamonds) and calculated k_2 values of individual planets and brown dwarfs, plotted over their mass.

In Figure 1 we plot observed k_2 values for Jupiter [3], Saturn [4], the hot Jupiter HAT-P-13b, and the massive hot Jupiter WASP-18b [1] in comparison to model predictions. For Neptune, the splitting in k_2 between slow and fast rotating models is large; it is of same size as for changing the core mass of a 10 $M_{\rm Jup}$ planet from 0 to $\sim 300 M_{\rm E}$.

In contrast, models for Jupiter and Saturn that are constrained by J_2 and J_4 yield tight (0.02%) k_2 ranges [8, 9], currently in agreement with the Juno and Cassini data based measurements.

3. Outlook

In order to understand the behavior of k_2 as a function of rotation rate we calculate the contribution functions of k_2 and J_2 in this work. We also explore whether different scalings could be responsible for the splitting. Gaining a better understanding of the behavior of k_2 and the moment of inertia is important because at present, our results suggest that both parameters could be useful for inferring the solid rotation rate independently on radio or magnetic field data.

However, further effects may influence the planetary tidal response, such as internal oscillations or atmospheric dynamics. The tiny overlap in k_2 between interior model predictions and the observed value for WASP-18b may indicate that our static approach is too simplistic.

Observing k_2 at Neptune might require a polar orbiter that covers different longitudes.

Acknowledgments

The work was supported by the German Science Foundation (DFG) within the Research Unit FOR 2440 (Matter under Planetary Interior Conditions (High-Pressure, Planetary, and Plasma Physics) under grant No. NN1734/2-1.

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