URANUS AND NEPTUNE: QUESTIONS AND POSSIBLE ANSWERES

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Uranus and Neptune are of special interest for theories of the origin of the solar system, because they represent a special class of objects intermediate in composition between the giant hydrogen-rich planets Jupiter and Saturn, and the small, rocky, terrestrial planets. Their structure and composition should provide important clues to the origin of the solar system (1,2). In order to compute models of the internal structure, using high pressure equations of state for the materials believed to constitute those planets, it is necessary to measure several parameters characterizing these palnets. Their masses and radii have been known to sufficient accuracy for many years, and recently J_2 and J_4 (respectively the quadrupole and 16-pole moments of the gravitational field) have been determined for Uranus (3) and moments J_2 for Neptune (4). Until the Voyager flyby, however, the rotation period for Uranus was not well constrained and various observations placed it in the neighborhood of 16 hrs. (5). It is interesting that, although this is a shorter period than the 18 hrs determined photometrically for Neptune (5), Neptune has the larger J_2.

We have constructed a detailed set of theoretical models which consist of a core of "rock" (MgO, SiO, Fe, and Ni in solar proportions), surrounded by an envelope of "ices" (H_2), CH_4 and NH_3 in solar proportions), surrounded, in turn, by an envelope of these same "ices" mixed with H_2 and He (6). We found although the ratio of "ices" to "rock" was nearly the same for the two planets, the internal arrangement was very different in the two cases, a situation very difficult to explain in terms of current pictures of planet formation. We suggested (7) that the period measured photometrically for Neptune is influenced by surface features caused by the motion of Rossby waves in the upper atmosphere, and , in fact, the body of the planet rotates more quickly. Such a shorter period is, indeed, indicated by new measurements of the oblateness (8). The recent Voyager flyby of Uranus has fixed its rotation period at just over 17 hours, narrowing the difference between the two models, but by no means eliminating it. Hopefully, the Voyager encounter with Neptune will help resolve the issue.

The new improved rotation period, combined with the latest values for J_2 and J_4 have raised problems in the understanding of Uranus' structure independently of a comparison with Neptune. We have found that none of the models computed previously (fig.1) could be made to fit with this new set of observational data. Instead it was necessary to assume that Uranus has an anomalously high ratio of "ices" to "rock", some five times the solar value (9)! Such a high value (fig. 2) may be a natural outcome of an accretion mechanism we have begun to investigate. As a planetesimal approaches a protoplanetary atmosphere with some impact parameter, it may (depending on its composition) lose a significant amount of mass and be captured by the protoplanet, or lose very little, and escape to space. Since ice is more volatile, an icy planetesimal will lose mass at larger impact parameters, and hence the cross section for capture will be larger for icy planetesimals than for rocky ones. This provides a possible mechanism for greatly enhancing the ice to rock ratio over the solar value. This mechanism is currently being explored.

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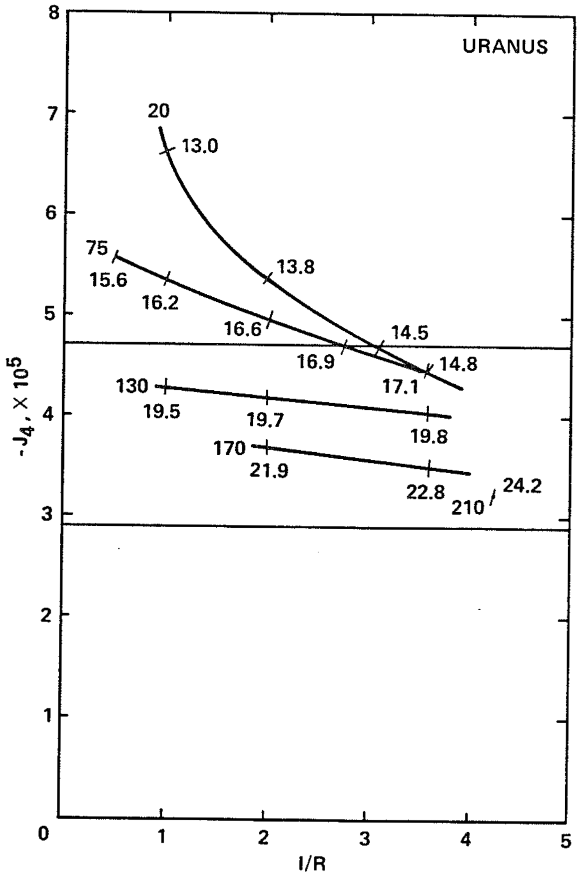

Fig. 1 J4 as a function of the ice/rock ratio for former Uranus models. Parameter on right gives enhancement of volatiles in envelope over solar composition. Tick marks along curve give rotation period required for fit to J2. Horizontal lines show former limits on observed value of J4.

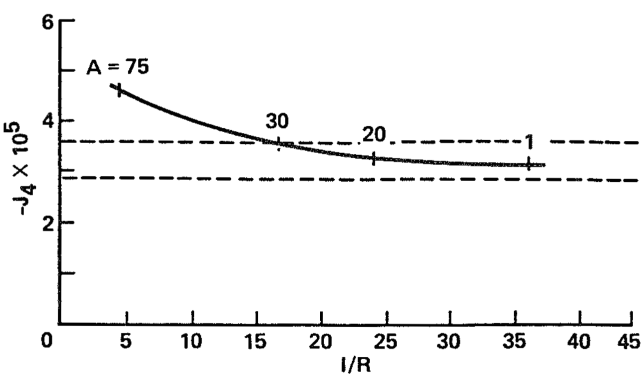

Fig. 2 J4 as a function of the ice/rock ratio for current Uranus models with 17.24 hr period. Tick marks show enhancement of volatiles in envelope. Horizontal dashed lines show current limits on J4.