ICY GIANTS

Why so different?

Uranus and Neptune are often mentioned and treated together, under the general category of ‘ice giants’, as if they were twin planets of some sort. However, while they have similar radii (2.00 and 1.94 Earth radii, respectively) and masses (14.5 and 17.1 Earth masses), their details tell a different story. The most glaring difference comes from the axial tilt:

Neptune’s rotation axis ($\sim 28^\circ$) is quite similar to Earth’s, whereas Uranus rotates ‘on its side’ with its axis almost parallel to the ecliptic plane ($\sim 97^\circ$), which is unique among Solar System planets. In addition, while Uranus’s satellite system has a rather regular architecture (just tilted like the planet), Neptune’s capture of a large trans-Neptunian object (Triton) strongly affected the structure of its whole system of moons, half of which have retrograde or irregular orbits.

It is assumed that the two planets formed through similar processes, so such differences must be the product of subsequent evolution. The usual suspects are giant impacts — particularly in the case of Uranus — but computational constraints had so far limited the effectiveness of 3D hydrodynamic models to explore this scenario. A recent paper by Christian Reinhardt and collaborators (*Mon. Not. R. Astron. Soc.* **492**, 5336–5353; 2020) reports the results from a state-of-the-art computationally optimized giant-impact simulation. The figure shows how similarly structured icy planets hit by similar impactor bodies (the only difference being the total mass of the planet plus impactor, which are set to the current masses of Uranus and Neptune) can end up being vastly different simply by changing the geometry of impact.

The colours correspond to the different kinds of layers of the bodies: for the planet, blue is the rocky core, purple the

Credit: Reinhardt & Helled, ICS, University of Zürich

icy mantle and orange the H–He gaseous envelope; the impactor is a differentiated body with an icy (white) crust around a rocky (yellow) core. It appears that an oblique collision (top panel) works well in the case of Uranus: there is little mixing of matter except at the outer envelope, but such an impact is very effective in tilting the planet. In addition, the debris from such an impact creates the disk from which Uranus’s satellite system can form (not pictured). Therefore, the resulting moons will naturally have the same tilt as the planet. On the other hand, Neptune is best explained with a head-on collision. In this case, the axial tilt does not change significantly and a proto-satellite disk is not created (which fits with the more

irregular nature of Neptune’s moons), but the material of the impactor penetrates to well within the proto-Neptune, down to the core. This injection of mass and energy within the ice giant can also explain why present-day Neptune seems to have a lot of internal energy. In fact, while Uranus is almost at thermodynamic equilibrium (it emits nearly as much energy as it receives), Neptune emits almost 2.6 times the energy it gets from the Sun, the highest among the giant planets of the Solar System. □

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