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The origin of Uranus and Neptune elucidated?

A team of French-American researchers led by the UTINAM Institute (CNRS/Université de Franche-Comté)[1] has just proposed a solution to the problematic chemical composition of Uranus and Neptune, thus providing clues for understanding their formation. The researchers focused on the positioning of these two outermost planets of the Solar System, and propose a new model explaining how and where they formed. Their results have been published in *The Astrophysical Journal* on September 20.

Uranus and Neptune, the outermost planets in the Solar System, each have a mass approximately fifteen times that of the Earth, consisting of up to 90% ice, and highly enriched in carbon. Because of these particular characteristics, the origin of the two planets remains unresolved today. Earlier models for their formation, as well as observations of the outer Solar System, could not explain how they formed in the area where they are found today. This area, which is located very far from the Sun, did not contain sufficient building blocks to form Uranus and Neptune quickly enough before the dissipation of the protosolar nebula. Once the nebula dissipated, it became impossible for the two planets to accrete gaseous envelopes.

The Herschel Space Observatory recently focused on the isotopic composition of Uranus and Neptune, and especially on the deuterium-to-hydrogen ratio (D/H), a tracer used in planetology to examine the origin of the elements that formed the Solar System. This isotopic ratio is very sensitive to the temperature of the protosolar nebula, being low close to the Sun, and increasing with the distance. Dynamic models suggest that Uranus and Neptune formed in the same distant region as the comets, and should therefore have a high D/H ratio. Surprisingly though, the Herschel measurements show that the D/H ratio in the two planets is much lower than that measured in comets.

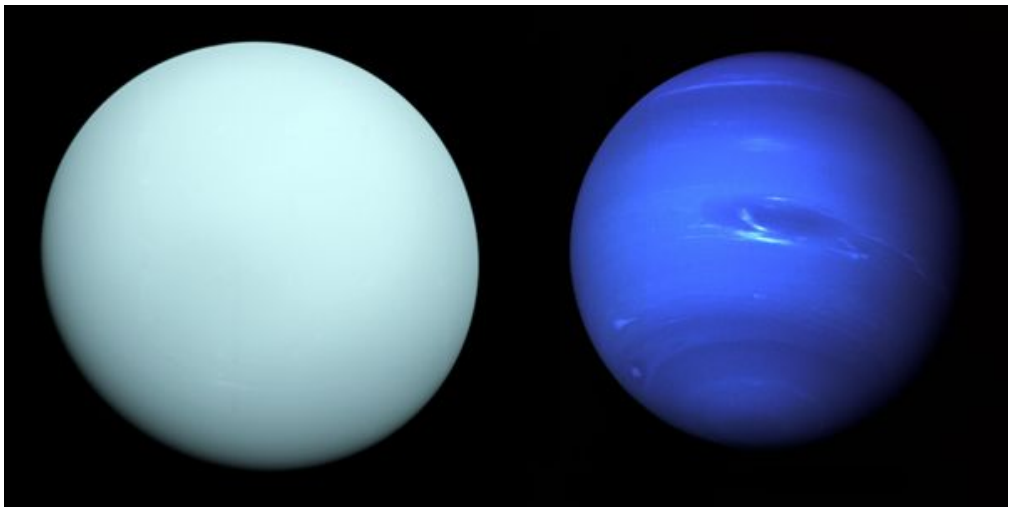
This study solves all of these problems at once, by proposing a new model based on detailed simulations of the distribution and transport of the most abundant volatile elements in the Solar System's protosolar nebula (H_2O, CO and N_2). These simulations show the presence of density "peaks" of solids in regions where nebular temperature is low enough for gas condensation (or ice lines). The results show that Uranus and Neptune apparently formed on the Carbon Monoxide (CO) ice line, which would explain why they consist of carbon-rich solids but nitrogen-depleted gas. Accretion of large quantities of CO with low quantities of cometary H_2O gives the D/H value measured in the atmosphere of these planets. Moreover, since the nitrogen ice line is located slightly farther away, the planets formed naturally poor in nitrogen. The proposed model gives carbon and nitrogen abundances that are consistent with observed values, and establishes that the formation of Uranus and Neptune took place in this distant region.

1 The UTINAM Institute laboratory (CNRS/Université de Franche-Comté) is part of the THETA Observatory of the Sciences of the Universe in Franche-Comté/Bourgogne.

Bibliography

The Measured Compositions of Uranus and Neptune from their Formation on the CO Ice Line, Mohamad Ali-Dib, Olivier Mousis, Jean-Marc Petit and Jonathan I. Lunine, *The Astrophysical Journal, Vol. 793, Issue 1, Sept. 14, doi:10.1088/0004-637X/793/1/9*

Illustrations



Uranus and Neptune as seen from NASA's Voyager mission. Credits © NASA

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