ON THE ATMOSPHERIC HELIUM ABUNDANCE IN URANUS FROM HE/H PHASE SEPARATION.

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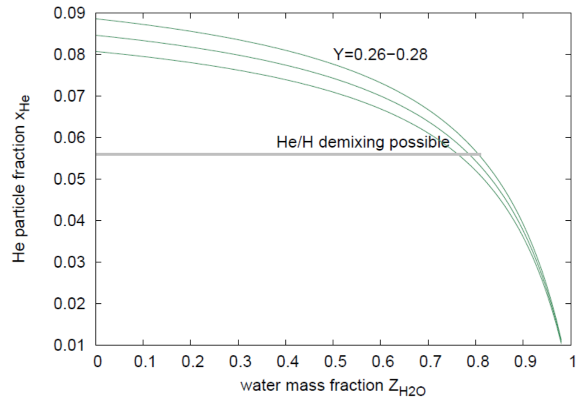
Background: Some fundamental properties of the interiors of the Ice giants Uranus and Neptune are far from being understood. Structure models guided by the observed gravitational harmonics J_2 and J_4 suggest a H/He-rich envelope atop an ice-rock interior. However, formation explain their current structure only if they invoke specialized conditions, which themselves call for explanations [1].

Recently, the separation of water from molecular hydrogen in the evolved and cooled mature planets Uranus and Neptune has been proposed as a mechanism to explain their inferred current structure [2]. On the other hand, evolution models guided by the observed luminosities suggest that primordial heat is trapped in their interiors due to the compositional barrier and slowly released at present. Surpringly, this mechanism can explain both the faintness of Uranus and the brightness of Neptune with only moderate differences in their assumed structures [3]. However, additional processes such as from phase separation [2] or condensation in their atmospheres could influence their evolution significantly.

In this work, we discuss two controversial structures for Uranus. First, we show that interior models adjusted to the luminosity [3] are too hot for H_2O/H-separation to occur; those would predict a protosolar atmospheric helium abundance. Second, we adopt the assumption of an initially more homogenous interior that cooled sufficiently to allow for demixing [2]. We find that much earlier in the evolution, interior conditions can become favorable to the demixing of helium from hydrogen in the deep interior, as He/H phase separation occurs at higher temperatures [4].



In Figure 1, we plot the He particle fraction $x_{He}=N_{He}/(N_{He}+N_H)$ as a function of the assumed water mass fraction in the deep interior assuming full dissociation of water and hydrogen. In a highly ice-rich interior (Z_{H2O} larger than 0.83), the He/H ratio becomes too low for He/H phase sepration to take place. At lower water content, we find that H/He-phase separation can occur at pressure levels around 1.5-4 Mbar according to the H/He phase diagram of [4]. This work aims to predict the atmospheric helium abundance of Uranus from this process, which can be probed by in-situ measurements.

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References:

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