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Uranus evolution models with simple thermal boundary layers

Nadine Nettelmann (1,2), Ronald Redmer (1), Jonathan J. Fortney (2), Sebastien Hamel (3), and Mandy Bethkenhagen (1)

(1) Institute for Physics, Rostock University, Rostock, Germany, (2) UCSC, Santa Cruz, USA, (3) LLNL, Livermore, USA

The strikingly low luminosity of Uranus imposes a long-standing challenge to our understanding of Ice Giant planets. Similar to the Earth, Uranus appears to evolve in equilibrium with the solar incident flux (Teq).
Here we present the first Uranus structure and evolution models that are constructed to agree with both the observed low luminosity and the gravity field data. Our models make use of modern ab initio equations of state at high pressures for the icy components water, methane, and ammonia.
We argue that the transition between the ice/rock-rich interior and the H/He-rich outer envelope should be stably stratified. Therefore, we introduce a simple thermal boundary layer (TBL) and adjust it to reproduce the luminosity. Due to this TBL, the deep interior of the Uranus models are up to a factor 3 warmer than adiabatic models, necessitating the presence of rocks there with a possible I:R of 1 x solar.
Furthermore, we also allow for an equilibrium evolution (Teff $\sim$ Teq) that begun prior to the present day, which would therefore no longer constitute a "special time" in Uranus' evolution. Once Teff $\sim$ Teq happens, a shallow, subadiabatic zone in the atmosphere begins to develop. Its depth is adjusted to meet the luminosity constraint. This work provides a simple foundation for future Ice Giant structure and evolution models, that can be improved by properly treating the heat and particle fluxes in the diffusive zones.