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The effect of the condensation of ice components on the theoretical estimate of the thermal evolution of ice giants

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Though Uranus and Neptune are similar in mass and radius, the former is significantly fainter than the latter. Most of previous theoretical studies of thermal evolution of ice giants assumed three-layer models composed of a hydrogen-helium envelope, an ice mantle and a rocky core. According to them, the observed effective temperature of Uranus is lower than theoretically predicted (e.g., Fortney et al., 2011; Nettelmann et al., 2013). Previous studies did not consider the condensation of ice components in the atmosphere.

The difference between Uranus and Neptune might be whether they experienced a giant impact event or not. Uranus is believed to have experienced a giant impact, since the axis of rotation of Uranus is tilted to the orbital plane (Slattery et al., 1992). The giant impact may have mixed Uranus's hydrogen and helium in the envelope with ice components and the planet has a significant amount of ice components in its atmosphere. If this is true, the initial compositional distribution is expected to be different between Uranus and Neptune. Especially, the effect of condensation is not negligible for Uranus.

In this study, we consider the thermal evolution of ice giants considering the condensation of ice components in the atmosphere. During the thermal cooling of the planet, the ice components in the atmosphere condense and then moist convection occurs. Then, the cooling of the planet is controlled by the radiation limit. The radiation limit appears when the optical depth and temperature structure of the entire atmosphere approach a fixed profile. Consequently, the effect of the condensation makes short the timescale of the thermal evolution of the planet. That effect is important to understand the difference of the thermal evolution between Uranus and Neptune.

Keywords: ice giants, thermal evolution