Title: Constraining the Depth of Winds in Uranus and Neptune

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Abstract: Determining the depth of the atmospheric winds in the outer planets of the solar system is a key topic in planetary science. It is still unknown whether the winds are deep-seated or shallow. In our research we aim to constrain the depth of the winds on the ice giants Uranus and Neptune. This is done by determining the total Ohmic dissipation of induced electrical currents due to the interaction between the planetary magnetic field and the winds. According to entropy balance, the Ohmic dissipation associated with this electrical current cannot exceed a certain multiple of the planetary net luminosity, determined by temperature ratios in the planetary interior.

Recently, the depths of the winds in Jupiter and Saturn were constrained from Juno and Cassini gravity data (Kaspi et al. 2018, (Nature, 196); 2019 (arxiv:1908.09613)), and were found to be consistent with the Ohmic constraint (Liu et al. 2008, (Icarus, 196)).

In this work we investigate whether the same mechanism applies to Uranus and Neptune. The formulation is more challenging for the ice giants due to the non-axisymmetric, multipolar nature of their magnetic fields, and ambiguities in their internal structures and bulk compositions. We therefore consider various interior structure models and compositions, and use results from *ab initio* simulations to determine the electrical conductivity profiles of H_2:H_2O mixtures under the planetary conditions.

We find that although the Ohmic dissipation limit depends on the assumed interior structure, most of the models agree with a penetration depth of ~1000–1500 km for both Uranus and Neptune. This result is consistent with the limits inferred from using the planets' gravity data (Kaspi et al. 2013, (Nature, 497)). We conclude that deep-seated winds on the ice giants are not probable and are confined to the outer ~10% of the planetary radius in both planets.

Key words: Magnetism, Sun and Solar System