The Interaction between Ice Giant's Atmospheres, Ionospheres and Magnetospheres

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Abstract

Planetary atmospheres and ionospheres exchange energy and momentum with their surrounding space environment that have decisive effects on atmospheric evolution and significant impact on ionospheric structure and dynamics. While gravity and atmospheric temperature dictate thermal escape of the atmosphere, several different non-thermal escape processes provide energy well beyond the escape energy. With no, or very weak magnetic fields, Mars and Venus experience loss through pick-up and electric field polarization processes governed by direct solar wind interaction with the ionosphere resulting in total escape rates on the order of 1E25 particles per second. Although Earth has a significant intrinsic magnetic field that seemingly shields it from direct solar wind interaction, multiple magnetospheric processes efficiently funnel energy from the solar wind to the ionosphere resulting in outflowing atmospheric material well above escape velocities (11 km/s) primarily in the auroral zone and polar caps. The complexity of these escaping pathways results in a wide range of estimates of terrestrial atmospheric loss rates of 1E25- 1E27particles per second. Even the giant massive planets, Saturn and Jupiter see upward acceleration of atmospheric ions in the auroral zones to energies orders of magnitude higher than their escape energy of about 18 eV for hydrogen. The low temperatures and high gravity of the ice giants theoretically inhibit any thermal escape of even hydrogen to space. However, the presence of a substantial magnetosphere at the Ice Giants and its unusual orientation, leaves room for several atmospheric non-thermal escape mechanisms to overcome the escape energies of a few eV for hydrogen, and leaves the atmospheric loss rates completely unknown.

Measurements of the ionospheric and atmospheric composition and density structure from a descending Ice Giant's Probe, together with measurements of the escaping particle energy and composition from an orbiting platform are critical to understanding atmospheric loss at these unusual planets. Magnetospheric energy input in the form of particle precipitation and electrical currents may affect the upper atmospheric temperatures and scale heights, and are therefore also very important measurements.

Understanding how the evolution of atmospheres in our galaxy is impacted by the interactions with their space and solar environment, is critical for understanding habitability and the emergence of life. With the anticipated vast array of different exoplanetary magnetospheric configurations and stellar types, the unusual configurations of Uranus and Neptune represent dramatic knowledge gaps in our understanding of atmospheric loss through magnetospheric interactions.

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