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Non-auroral altitude profiles of H_3^+ density and temperature at Jupiter

L. Moore (1), J. O'Donoghue (2), H. Melin (3), and T. Stallard (3)

(1) Boston University, Center for Space Physics, Massachusetts, USA (moore@bu.edu) ; (2) Goddard Space Flight Center, Greenbelt, USA; (3) Department of Physics and Astronomy, University of Leicester, Leicester, UK

Abstract

Over the past few decades the H_3^+ ion has proven to be a tremendously valuable probe of giant planet upper atmospheres. Auroral H_3^+ emissions at Jupiter, Saturn, and Uranus have been regularly monitored by ground-based IR telescopes, and low-latitude H_3^+ emissions have also recently revealed intriguing ionospheric coupling processes from above (particle flow from Saturn's rings) and below (an upper-atmospheric hotspot above Jupiter's Great Red Spot).

High spectral resolution observations can be used to derive the density and temperature of the emitting H_3^+. The main remote diagnostic of planetary ionospheres, the technique of radio occultations, yields altitude profiles of electron density, yet only near the terminator of the giant planets. Therefore, direct measurements of the density of a major giant planet ion – potentially at anywhere on the sunlit hemisphere – is a valuable complementary constraint. Moreover, it is difficult to measure upper-atmospheric temperature remotely, and as H_3^+ is thought to be predominantly in local thermodynamic equilibrium with the neutral atmosphere, it can also provide insight into global giant planet energetics.

Despite the valuable scientific contributions from both space-based and ground-based observations of H_3^+, there is a fundamental ionospheric diagnostic missing: the variation with altitude. Aside from a few limited limb-viewing geometries, all historical H_3^+ observations sample only the column-integrated ionospheric H_3^+ density and temperature.

We present two new derivations of non-auroral H_3^+ altitude profiles at Jupiter based on recent Keck observations. These derivations are focused on 55N and 20S degrees planetocentric latitude. First, the spectral slit overhangs the planet's limb, and altitude structure is determined by inverting the density/temperature values derived by fitting a model spectrum to the data. This method requires an assumption of spherical symmetry, and application of a standard "onion-peeling" technique. Second, we combine a 1-D model of Jupiter's ionosphere with the H_3^+ observations in order to derive altitude profiles of density and temperature. This approach uses the model in order to fix the shape of the H_3^+ density profile, an assumption that is justified by the relatively simplistic nature of the photoionization and subsequent chemistry of the H_3^+ ion and validated by comparison to the altitude profile from the first approach. (Note, however, that it is currently only valid at non-auroral latitudes, as ionization due to particle precipitation introduces too many unknowns.)

As H_3^+ is predominantly in local thermodynamic equilibrium with the neutral atmosphere, this method can in principle be used to derive an estimate of the neutral temperature profile wherever H_3^+ can be detected. This further increases the value of H_3^+ observations as a probe of giant planet upper atmospheres, especially from the ground, as there will be a dearth of spacecraft at the giant planets between the end of the Cassini and Juno missions and the arrival of the JUICE and Europa Clipper missions.