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Solar Wind control in Gas Giant Ionospheres

T. Stallard(1), H Melin(1), S. Miller (2), J. Blake (1) and J. O'Donoghue (1)
(1) University of Leicester, UK (tss@ion.le.ac.uk), (2) University College London

Abstract

The influences that the Solar Wind and Gas Giant magnetospheres have upon the upper atmospheres and ionospheres of these planets is largely controlled by currents closing along magnetic field lines into the polar regions. These currents in turn result in significant currents across the ionosphere that can be observed from ground-based observations. Here, we will present a discussion of the current understanding of how the Solar Wind controls the auroral regions of the Gas Giants, as has been measured in the past. We will also present new ion wind measurements from the past year, with observations from VLT of Jupiter, Saturn and Uranus.

1. Past measurements

Using past observations of the ion wind flows within the auroral regions of both Jupiter and Saturn, it has been possible to determine six main velocity regimes across both these planets [Stallard et al., 2012], as shown in Figure 1:

(a) Equatorial regions: away from any significant currents, in which ions co-rotate with the planet. **(b) Breakdown in co-rotation:** The initial breakdown in co-rotation poleward of equatorial co-rotating ions occurs. This region is directly associated with a continuous auroral oval of H_3^+ emission. **(c) Boundary sub-rotation:** sub-rotating ions poleward of the breakdown in co-rotation and equatorward of the region is associated with the solar wind but not associated with any significant auroral emission. **(d) Bright co-rotation:** near co-rotating ions, poleward from the initial breakdown in co-rotation and associated with significant auroral emission. **(e) Dim sub-rotation:** regions of strong sub-rotation or even zero rotation within the auroral polar regions, strongly associated with the solar wind. This region is either open to the solar wind, or is indirectly manipulated by solar wind effects.

(f) Polar co-rotation: co-rotation entirely enclosed by the surrounding sub-rotating ionosphere, close to the magnetic pole. In a region that should be open to the solar wind, this is highly unexpected, and may result from the twisting of magnetic field lines down into the tail.

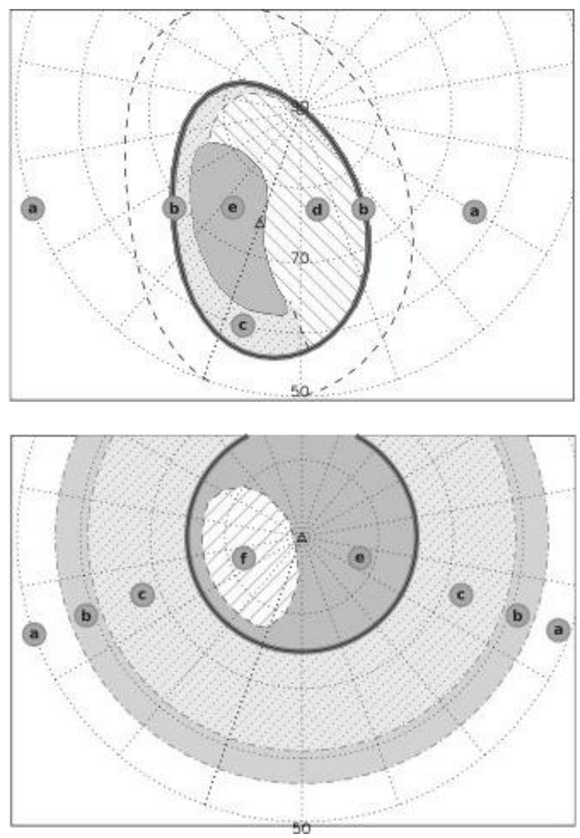

Figure 1: Maps of ion flow in the northern auroral regions of (top) Jupiter (at a central meridian longitude of 160) and (bottom) Saturn. The various flow regions are demarcated by patterned backgrounds and lettering, matching Figures 1, 3, and 4. In addition, the main (brightest) auroral oval for each planet is delineated (thick gray and black line), as well as the path of the magnetic mapping to

Io across Jupiter (dashed line) and the mid-latitude auroral oval at Saturn (the region within the dash-dotted lines).

2. Recent measurements

Our understanding of these flow regions comes from a number of different observations, all of which have been limited somewhat by the observational constraints of ground-based astronomy. We intend to update some of these conclusions using recently and yet to be acquired data from the CRIRES instrument on ESO's Very Large Telescope

The regions described at Jupiter come from a single observation. More recent observations have confirmed the result, but have not allowed a detailed analysis of the ion wind flows in the polar region . Recent observations at VLT have, as a result of the increased light gathering capabilities, allowed full spectral mapping of the entire auroral region. While our analysis of this data is still in the preliminary stages, we can clearly observe strong ion wind flows within the auroral region that have as strong a morphological diversity as the auroral emissions themselves (Figure 2).

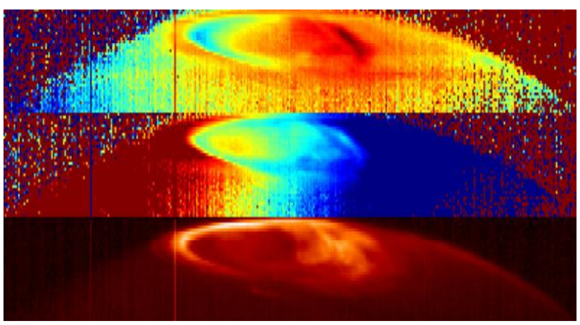

Figure 2: The ion wind flows across the auroral region in the planetary frame (top; with significant corrections still to be made), in the inertial frame (middle), compared with the measured auroral emission from Jupiter's H3+ aurora (bottom).

At Saturn, we are very strongly limited both by light gathering capabilities and by turbulence within the Earth's atmosphere smearing our observations of the ionosphere. Upcoming observations will attempt to counteract both these effects by observing the planet from VLT, using AO. This will potentially allow us to view the ion wind flows in a vastly improved spatial extent.

Ion winds have previously be sought at Uranus, but the weakness of the signal has prevented a detection from being made. Recent VLT observations of Uranus cutting through the regions where the aurorae are expected to occur have revealed tantalizing flows within the ionosphere that we believe may reveal the location of the aurora.