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Electron Flux Depressions, or ‘Holes’, in the Upper Atmosphere of Mars and the Subsequent Identification of Martian Plasma Boundaries

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Abstract

We report the observation of rapid depressions, or ‘holes’, in the electron flux measurements integrated over an energy range of 20-200eV, as measured by the ESA Mars Express spacecraft’s electron spectrometer instrument [1]. The period of study includes early 2012 in which we show that the holes are preferentially observed over regions of remnant crustal magnetic field, as given by the Cain et al. model [2], with increased clustering of events over denser field regions. The electron hole events are observed over a range of altitudes mostly in correspondence with the upper Martian atmosphere (350-1000km), with clear evidence towards being persistent features. With the absence of a magnetometer on-board Mars Express, we further demonstrate that with careful analysis of the variation in the integrated flux, it is possible to identify boundaries in plasma populations within the solar wind-Martian atmosphere system.

1. Introduction

Since Mars lacks an intrinsic global magnetic field, the interaction of its atmosphere with the solar wind (SW) can be thought to be mostly atmospheric (like Venus). Mars is however believed to have once had a strong magnetic field (similar to that of Earth) which has since subsided leaving a strong remnant field within the crust of the planet’s southern hemisphere. This remnant crustal field is thought to lead to unique interactions with atmospheric plasma only observable at Mars.

2. Electron Flux ‘holes’

The ESA Mars Express (MEX) spacecraft contains a suite of instruments ideal for studying plasmas, one of which is the electron spectrometer (ELS) which forms part of the ASPERA-3 package [1]. Observations of rapid and large depressions, or ‘holes’, in the ELS measurements of electron flux (over all energy ranges) were noted to occur in multiple orbits of a sample set from January to April 2012. These observations led to the creation of an automated process to detect such electron hole phenomena via the analysis of the electron flux integrated over an energy range of 20-200eV (see Panel (a) of Figure 1).

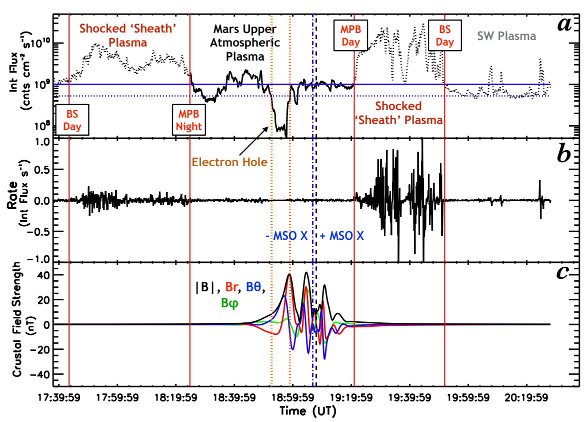

Figure 1: (a) Electron flux measurements by ELS on-board MEX integrated over an energy range of 20 - 200eV. (b) Integrated flux ‘rate’, normalised to range -1, 1. (c) Cain et al. [2] model crustal magnetic field strength in terms of magnitude (black) and spherical components, radial (red), azimuthal (green), and latitudinal (blue). Panel (a) labels multiple regions/boundaries noted in the text with their footprints extended into panels (b, c). The plots are centred around MEX periapse (dashed black vertical line) with the Martian terminator plane highlighted by dot-dashed blue vertical line of orbit 10392 (2012/02/27).

Of the sample period of 340 orbits, multiple electron hole events were located with occurrence either side of the Martian terminator plane, with ∼75% un-

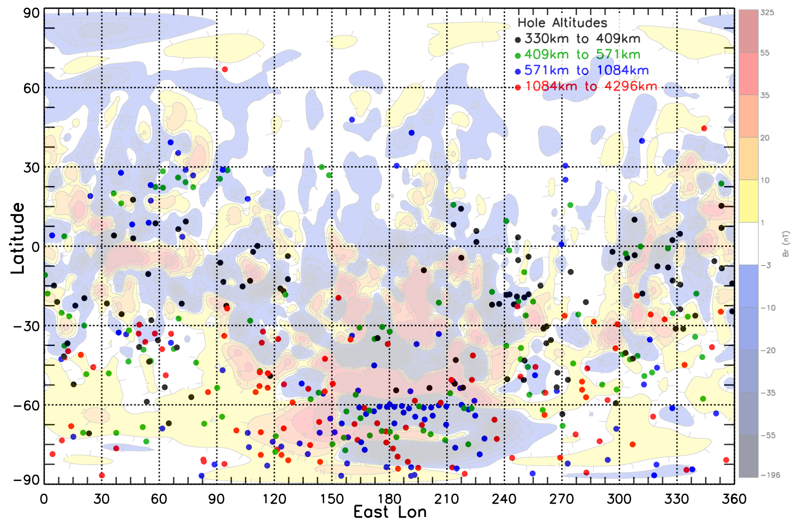

Figure 2: Map of located electron hole events colour coded into four quartiles of altitude at the central event point. Contours of model radial crustal field values (at a constant altitude of 300km) watermarked into background to show general relationship towards magnetic regions.

der 1000km altitude (see quartile ranges in Figure 2), thus corresponding to phenomena in the upper atmosphere. By comparing the event locations with respect to the Cain et al. [2] model crustal magnetic field values, it is evident there is a strong relationship between the two, as shown in magnetic map of Mars in Figure 2, with increased clustering of events over stronger crustal field regions.

Examination of the periodicity of events occurring in the same location resulted in a repeat pattern of seven orbits per identification. This corresponds well with MEX being approximately in the same location every seven orbits leading to the suggestion of the phenomena being persistent features.

3. Plasma Boundaries

To only study phenomena occurring in plasma of Martian origin, external sources such as that of the SW and interaction regions, i.e. 'sheath' plasma, were removed from the electron flux measurements. This was achieved through careful analysis and thresholding of the variation in flux with time (see panel (c) of Figure 1), also leading to the identification of boundaries believed to be the magnetic pile-up (MPB) and bow shock (BS) as shown throughout Figure 1.

4. Summary and Conclusions

Over a sample period of January to April 2012 multiple events coined the term 'electron holes' have been observed as sharp and deep depressions in integrated electron flux profiles. The identified events appear to show a strong correlation towards model crustal magnetic field regions and have been shown to be some form of persistent feature believed to be immune to external factors such as SW conditions. With the absence of an on-board magnetometer on MEX, a method was devised to identify plasma populations external to the Martian upper atmosphere by examining the variation in the integrated electron flux measurements. This has also allowed the identification of plasma boundaries in the Martian plasma system and thus the ability to look at the time variation of such boundaries.

Acknowledgements

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