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The Mars aurora: UV detections and in situ electron flux measurements

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Abstract

A detailed search through the database of the SPICAM instrument on board Mars Express made it possible to identify 16 signatures of the CO Cameron and CO_2^+ doublet auroral emissions. These auroral UV signatures are all located in the southern hemisphere in the vicinity of the statistical boundary between open and closed field lines. The energy spectrum of the energetic electrons was simultaneously measured by ASPERA-3/ELS at higher altitude. The UV aurora is generally shifted from the region of enhanced downward electron energy flux by a few to several tens of degrees of latitude, suggesting that precipitation occurs in magnetic cusp like structures along inclined magnetic field lines. The ultraviolet brightness shows no proportionality with the electron flux measured at the spacecraft altitude. The Mars aurora appears as a sporadic short-lived feature. Results of Monte Carlo simulations will be compared with the observed brightness of the Cameron and CO_2^+ bands.

1. Introduction

The presence of an auroral emission in the Mars nightside atmosphere was first detected during a limb observation performed on 11 August 2004 with the Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars (SPICAM) UV spectrograph on board Mars Express by Bertaux et al. (2005). The auroral spectra showed the CO Cameron bands and the CO_2^+ doublet at 288.3 and 289.6 nm.

Energetic electron spike events have previously been detected in regions of maximal crustal magnetic field radial component by Mitchell et al. (2001) who interpreted these measurements as evidence of past or present reconnection of the residual magnetic field lines to the interplanetary magnetic field lines. Peaked electron distributions have been measured with MAG/ER on board the Mars Global Surveyor (MGS) satellite (Brain et al., 2006) and by the ASPERA-3 set of plasma instruments on Mars Express (Lundin et al., 2006a, 2006b). These peaked electron distributions are considered as signatures of acceleration by electric fields along magnetic field lines. Lundin et al.'s (2006b) observations suggested that open magnetic field regions analogous to Earth's polar cusps are present near strong and moderate crustal fields on the Martian nightside. Halekas et al. (2008) identified localized events detected in strong magnetic cusp regions and sometimes associated with signatures of field-aligned currents, similar in several aspects to terrestrial cusp aurora.

2. Observations

The duration of the auroral detection by SPICAM may be used to estimate the latitudinal width of the aurora. We assume that the aurora is located at an altitude Z_{aur} ~130 km, in agreement with the limb observations by Bertaux et al. (2005a) and a recent study of three auroral detected made at the limb with SPICAM by Soret et al. (this session). The estimated latitudinal size of the region of precipitation is thus small, ranging from 21 km to 125 km, with most values less than 60 km. These widths are comparable to or less than those derived from localized electron flux measurements by MGS and ASPERA-3.

All UV auroral detections are located in the southern hemisphere between 17.3° and 64.1° S and in a restricted longitude sector extending from 158° to 214°, a region where the crustal magnetic field is relatively large. More specifically, the UV aurora is observed in boundary regions between closed and open field lines as shown in Figure 1. It shows the position of the UV aurora (white dots) and the ground track of the corresponding Mars Express orbits overlaid on a map of the probability to find a closed magnetic field line derived from the

magnetometer/electron reflectometer measurements on board MGS.

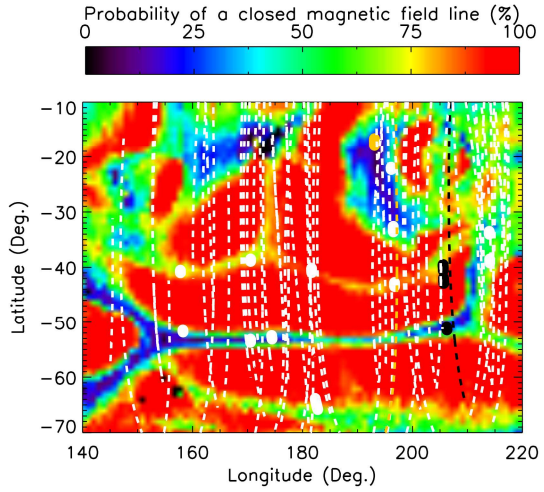

Figure 1: Ground tracks of Mars Express orbits (white dashed line) passing within 5 degrees of longitude of detections of UV aurora (white dots) overlaid on a map of the probability to find a closed magnetic field line at ~400 km. The light brown and the black circles indicate detections for which the SPICAM slit projection passed nearby within two days from the auroral events during other orbits (dashed lines, same colors as circles).

3. Discussion and Conclusions

Some of the characteristics of the auroral UV aurora and their relation to in situ electron precipitation measurements at higher altitude clearly appear:

- the Mars aurora is a spatially localized phenomenon located near the open-closed magnetic field line boundary in cusp-like structures
- the observed nadir brightness occasionally reaches as much as ~2.0 kR in the CO Cameron bands
- a majority of the passes over the “auroral” regions at different times and dates shows no evidence of UV auroral events. This suggests an infrequent phenomenon, but can also result from a combination of the SPICAM sensitivity, and the spatial-temporal variability of the phenomena.
- no clear correlation is observed with the down going electron energy flux measured at higher altitude with ASPERA-ELS
- the location of the footprint of the magnetic field line threading the peak in the electron flux may be shifted by several degrees from the sub-satellite latitude, indicating that the local field lines are tilted from the vertical.

The lack of proportionality between the auroral brightness and the downward energy flux is somewhat measured by ASPERA is unexpected. If, as suggested by ASPERA measurements of upward moving ions, a quasi static potential totally or partly located below the spacecraft accelerates the electrons downward, the electron energy flux reaching the denser atmosphere can be drastically higher than the *in situ* measurement. In this case, the ultraviolet aurora will be more intense than expected from the energy flux measured at higher altitude. The geometry of nadir observations of field-aligned auroral emissions may also explain lower brightness than expected from a nadir observation.

The inclination angles derived from MGS MAG/ER measurements during localized events vary from 83.2° (B field pointing downward nearly vertically) to 0.2° (quasi horizontal). Translating the time delays between the SPICAM and the ASPERA auroral peaks in terms of orientation of the local B-field, the tilt angles from nadir vary from ~3° (quasi vertical) to ~55°. We also note that the lack of auroral persistency observed with SPICAM (see Figure 1) raises questions about the global versus local context of aurora at Mars. Aurora may be more frequent on a global scale, like the terrestrial aurora, but less frequent on a local scale, in view of the difference between a global dipole magnetic field and the complexity of the Martian crustal magnetic field. All together, it appears that the UV aurora is most likely associated with the localized and/or temporarily variable phenomena.

A likely scenario is that the aurora is produced by electron acceleration in parallel electric fields associated with upward field aligned currents generating peaked electron distributions. They can arise on the boundary between closed and open residual field lines as a consequence of the shears of the flow velocity of the magnetosheath or magnetospheric plasmas.

Acknowledgements

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