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Dynamical evolution of sodium anisotropies in the exosphere of Mercury

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Abstract

The exosphere of Mercury is the still poorly known tenuous atmosphere surrounding this planet. It is the result of the diverse interactions among the surface, the interplanetary medium (Solar wind, photons and meteoroids), the planetary and the interplanetary magnetic fields. Ground-based observations detected intense and variable sodium emissions at global and local spatial scales, the latter being mostly concentrated in the mid-to-high latitude regions. In the present work we analyze the variability of the sodium exosphere on time-scale of 1 hour as obtained from high resolution Na observations. In addition, with the help of a devoted procedure to allow comparisons among data, and the help of both exospheric and magnetospheric models, we investigate the possible mechanisms that could explain the exospheric sodium emission distribution and its dynamics.

1. Introduction

The exosphere of Mercury is a complex object whose composition and dynamics are the result of the diverse interactions that occur between the Hermean surface and magnetic field on one side, and the interplanetary medium on the other. In fact, solar wind particles and photons, meteoritic impacts and interplanetary magnetic field have a role on the morphology, content and time evolution of this thin gaseous envelope. Since the discovery of the sodium component in the Hermean exosphere in 1985, many observations evidenced a significant temporal variability of the average sodium intensity and of localized peaks of emissions. Such peaks may appear at mid to high latitudes in both hemispheres, or be localized only in one hemisphere, or may display a maximum intensity close to the equator. To explain such behavior, a correlation with the IMF has been widely supposed, since its orientation is expected to allow preferential precipitation of solar wind protons into one cusp region or both, by driving the topology of the magnetic reconnection with the internal magnetic field. Good quality images of the Mercury sodium exosphere can be obtained by using a long slit scanning and tip-tilt corrections at ~ 1 kHz which allow to decrease the image distortions induced by atmospheric aberrations.

2. Observations

THEMIS is a solar telescope with a 0.9 m primary mirror and a 15 m focal length, and is located at 2400 meters a.s.l. on the Teide volcano in Tenerife (Canary Islands). Since 2007, THEMIS is used for a long term campaign of observations of the Mercury Na exosphere [1][2][3] and a wide data base is now available. The use of a solar telescope allows day-long observations and high resolution imaging with a spectral resolving power of at least $\lambda/\Delta\lambda$ = 220000. On July 13th 2008, very clear sky condition allowed the collection of a series of high resolution data (except the last two acquisitions, collected at low resolution). The seeing was very stable all day long; in fact, by applying an upper limit for the seeing of 2 arcsecs, we still retain six scans covering a time range of more than ten hours (Table 1).

Table 1: Details of the scan sequence on July 13th, 2008. Scan nr. 21 is the only one in low resolution.

Scan nr.	Time (UT)	Seeing (”)
4	06:52-08:05	1.61±0.69
8	08:16-09:28	1.33±0.61
10	09:33-10:45	1.45±0.60
12	10:50-12:02	1.77±0.59
16	13:38-15:03	1.70±0.59
21	16:55-17:38	1.55±1.15

To focus on the intrinsic temporal variability of the Na emission, we remove the TAA dependence. Then, to take into account possible effects caused seeing variability, we degrade all the images to match the worse seeing value of 1.77” (scan 12, Table 1). The resulting final six scans show two peaks at mid-latitudes (the southern more intense) along the whole time-sequence.

3. Analysis and Discussion

In order to detail the spatial distribution of the emission, we divide the disk of Mercury into 0.1 R_M-thick slices in latitude (i.e., perpendicular to the Z axis of Figure 1). The resulting intensity profiles are plotted in Figure 2. In the upper panel, a uniform exospheric bulk emission is superposed (solid black line) taken from the exospheric model.

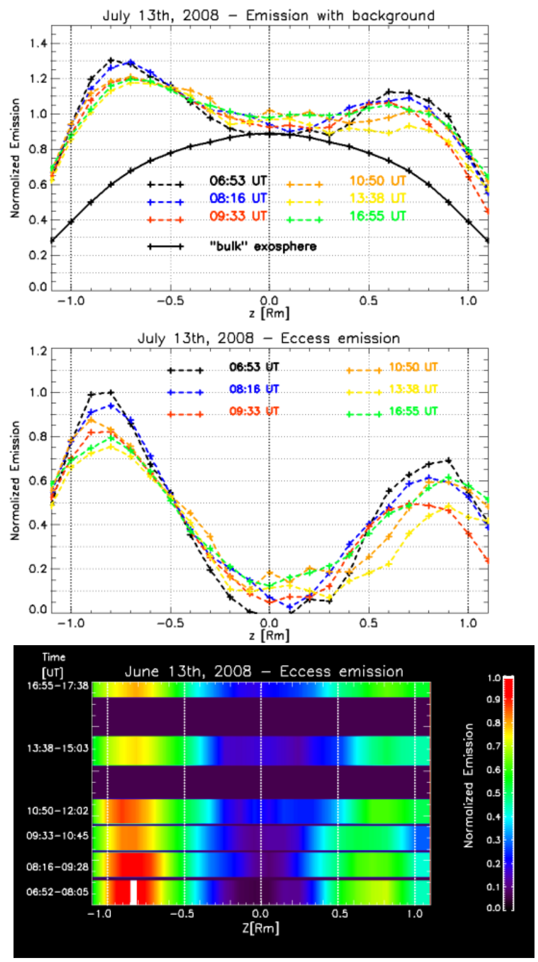

Figure 2: The resulting intensity profile after the disk of Mercury is divided into 0.1 RM-thick slices in latitude (i.e., perpendicular to the Z axis of Figure 1).

This will give an estimation of the net exospheric emission related to the mid/high latitude enhancements. In the middle and bottom panels the resulting emission profiles for the six selected scans are shown (time increases from bottom to top). This technique allow us to study in detail the emission intensity and evolution of the peaks alone. Both peaks in the northern and southern regions of the first three observations gradually decrease with time. Then, these peaks seem to invert their decreasing trend during the fourth scan (10:50-12:02 UT), and they also seem to slightly move poleward (see the right shift of the northern peak), while the equatorial region intensity continues to slightly increase until the end of our observations. We try to interpret the data in the frame of two different possible magnetic reconnection regimes: pulsed magnetic reconnection (i.e. per-event based) and (quasi-) steady reconnection. Both regimes have been observed to take place on the dayside magnetopause of the Earth's magnetosphere and they may be expected to occur at Mercury as well. A first precipitation event could have occurred at the beginning of the observations or even before, and then, at least, a second one (of lower intensity effects) could have occurred during the fourth scan (Figures 1a and 1d, respectively). This second event seems to be associated with a pole-ward movement of the peak position in the northern hemisphere, even if the seeing uncertainty does not allow to state it without any doubt and could be interpreted as the signature of variation in the IMF conditions. Finally, the exospheric model and magnetospheric model can help us stating some characteristics of the event and give insight about what really occurred at Mercury on July 13th, 2008. Details will be shown on that too.

References

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