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Observation and Modeling of Mercury's exosphere

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Abstract. An Italian long term campaign of observation of the sodium exosphere of Mercury has begun in 2002 by using the high resolution spectroscopic facility (SARG) at the Telescopio Nazionale Galileo (TNG) located on La Palma, Canary Islands. This effort is now part of an international campaign involving several observers and institutions in the world. This program is meant to investigate the variations of the sodium exosphere under different conditions of observation, namely: Mercury's position along its orbit, different solar flux, solar wind, IMF and micro-meteorites supply. The analysis of the exosphere at terminator and limb is expected to give us information on the altitude profile of the exosphere, and on its dynamics both on the dayside and nightside. Moreover, in the frame of the present and next future space missions to Mercury MESSENGER and BepiColombo, the database of collected data will be an useful tool to address a correct investigation of the Hermean exosphere. The intensity of the sodium emission has been extracted from the spectra by a dedicated procedure based on the Hapke rough reflectance model; it provides a versatile and coherent method to analyze all the data-sets already taken, and those to be taken during this long-term plan. Here we present the analysis of the data recorded in June-July 2005, and discuss preliminary results for one night.

Key words. Mercury – exosphere – sodium observations – TNG

1. Introduction

Starting from the first detection of sodium in the exosphere of Mercury (Potter and Morgan 1985), the strong doublet emission at 5890 –

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5896 Å (caused by sunlight resonant scattering) has made sodium detection the preferred way to map from ground-based observatories the exosphere of the planet, and to investigate its morphology and dynamics. In spite of that, several aspects of these topics are still unclear, and further studies are needed, also in the frame of the present and next future space missions devoted to Mercury's investigation: MESSENGER and BepiColombo.

An international long term campaign of observations of the sodium exosphere of Mercury has started this year, joining the italian contribution and its experience since 2002. For the Italian part, observations are performed with the TNG (Telescopio Nazionale Galileo), the 3.58 *m* Italian Alt-Az telescope located on the island of La Palma, Canaries. It is equipped with an active optics system, and its two Nasmyth foci host five instruments permanently mounted. Among these instruments there is SARG, an high efficiency spectrograph with an echelle grating designed for the spectral range from 370 *nm* up to 900 *nm*, for a resolution from R=29000 to R=164000. In our observations, we used a resolution of 115000 and equipped SARG with a specifically designed 60-Å wide Na filter that, together with a long slit (26.7x0.4 *arcsec*), allows contemporary observation of the planet and the sky, removes order overlapping, and permits an accurate subtraction of the night sky continuum.

In 2005 there have been performed 3 nights of observation: June 29th and 30th, and July 1st. At that time the planet diameter was 6.7-7.0 *arcsec*, the illuminated fraction decreasing from 57 to 53 % the heliocentric distance and the true anomaly angle increasing from 0.42 to 0.43 AU, and from 124 to 130 degrees respectively. The elongation was in the range 23.9-24.7 degrees East, hence Mercury was visible at sunset, and the observations have been performed at around 19:00 UT, for 1-1.5 hour/night.

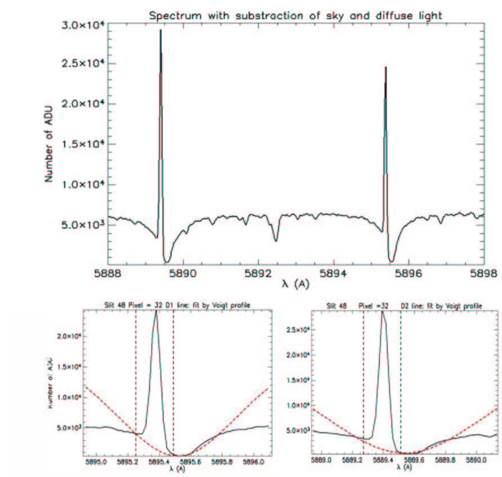

Fig. 1. Upper panel: spectrum showing the two Fraunhofer absorption lines and the corresponding Na emission lines. Bottom panel: zoom of the two exospheric D lines (D2 left, D1 right), and the Voigt profile superimposed (dashed line) used to fit the absorption lines.

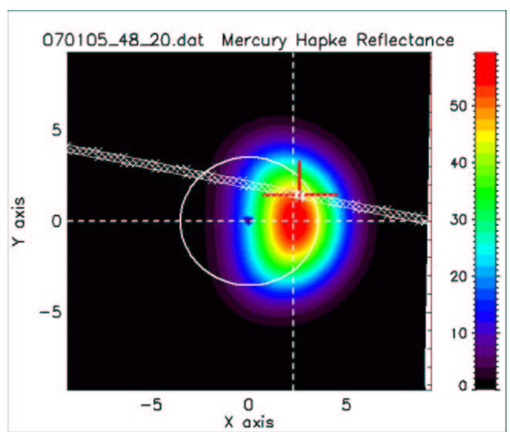

Fig. 2. Hapke reflectance model of Mercury's disk, with the slit superimposed. The cross inside the slit represents the position of maximum for the reflectance values.

2. IDL Analysis Procedure

An IDL procedure has been developed by F. Leblanc to work on raw data and to provide us with a unique tool to derive sodium exospheric emission from Mercury spectra in a coherent way and to make easier comparisons among different data-sets along our long-term observation program. This code incorporates all the steps needed to extract the D sodium lines from raw spectra. A further step will be the final con-

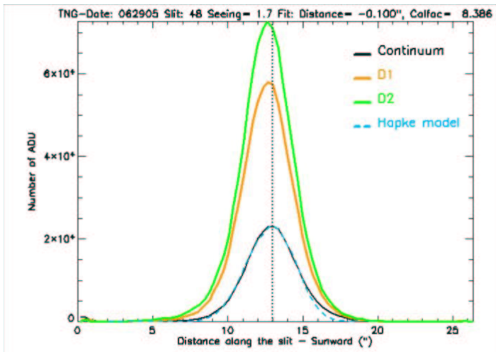

Fig. 3. Plot of the extracted D1 and D2 lines (in ADU) as they increase and decrease along the slit positioned on the planet's disk. Also shown is the comparison between the continuum (dark line) and the Hapke model along the same slit (dashed line).

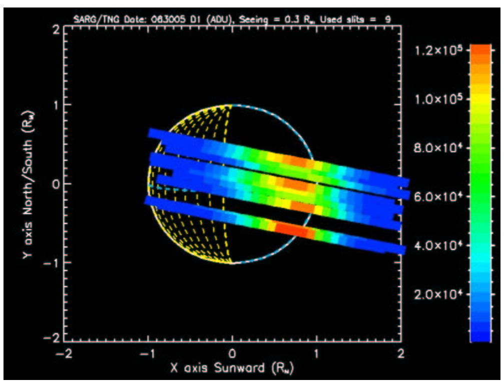

Fig. 4. 2D plot for D1 line (ADU) for the night of June 30th, 2005. The illuminated part of the planet is on the right side.

version to column density.
The analysis procedure can be summarized as follows:

1. the diffuse light and sky background are subtracted.
2. the fitting of the D1 and D2 Fraunhofer solar absorption lines is performed by using a Voigt profile (Hummer 1962). In fact, the emission line lies inside the absorption feature, and for a correct extraction of the exospheric emission, a good fit of the Fraunhofer lines is needed.
3. extraction is done via subtraction of the Voigt profile from the spectra in the region of interest.

An important step in this procedure is the determination of the surface rough-reflectance at Mercury's surface. It is calculated from the Hapke model (Hapke 1986) at each location in the surface grid, taking into account the particular geometry and seeing of each observation. By comparing the Hapke model and the continuum value, as estimated close to the D1 and D2 emission lines, the seeing value for each slit position is determined.
Even more important, the Hapke reflectance value can be used to absolutely calibrate the data, by using the measured continuum in a wavelength range close to the sodium D lines. The correspondence between the peak in ADU counts (Analog to Digital Unit) along the slit, on the planet disk, and the maximum of the Hapke reflectance model, gives the calibration factor to pass from ADU to intensity (Rayleigh). In fact, this maximum corresponds theoretically to the maximum value of the measured continuum along the slit. Using a typical value for the solar flux around the D1 and D2 lines, it is then possible to associate the number of ADU of the maximum value of the measured continuum to the flux of photons reflected at Mercury's surface towards the observer (according to Hapke's model), and derive the calibration factor.
This conversion of non-calibrated data to Rayleigh emission is performed with a method due to Sprague et al. (1997).

In the following figures the main steps of the code are shown. In Figure 1 the spectrum after subtraction of the sky background and diffuse light is shown (upper panel). In the bottom panel the Voigt profile to fit the Fraunhofer lines is in dashed line. In Figure 2 it can be seen the Hapke reflectance model of Mercury disk, with the slit superimposed. The big cross inside the slit represents the position of maximum for the reflectance values. In Figure 3 are shown the extracted D2 and D1 lines (in ADU) as they increase and decrease along the slit positioned on the planet's disk. Also shown is the comparison between the continuum and the Hapke model along the same slit.

3. Conclusions

The application of this procedure to all the spectra recorded during every night, permits a 2D view of the sodium exosphere at that moment. As an example, in Figure 4 it is shown the situation for the night of June 30th, 2005. Intensities are given for D1 line. Apart from the uncertainty in the position caused by the rapidly changing seeing at sunset (here ranging from 1.5 to 2.2 *arcsec*), this 2D view covers a wide equatorial band and shows an almost homogeneous signal coming form the region. An evident enhancement appears in the southern hemisphere, close to sub-solar longitudes. The reason for this peak could be due to several causes and will be investigated in a further step. For example, the peak could be caused by the occurrence on the surface of a region particularly Na-rich and/or a particular configuration of the Interplanetary Magnetic Field (Bx < 0) allowing a higher ion precipitation in the southern hemisphere with respect to the northern one, hence an higher sodium production via sputtering.

Interpretations and refinements of the data will be done in the next future.

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