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Sodium exosphere of Mercury: a call for new Earth-based telescopes and observers

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Abstract

The present poster is meant to inform the community of the necessity to organize a wider group of Earth-based observers of Mercury exosphere, and to call new scientists to this goal. Basic scientific rationale of this kind of observations is given, as well as references and basic requirements for the instrumentation to be used for this purpose.

1. Introduction

Mercury's tenuous neutral atmosphere (called 'exosphere') is the complex result of the many interactions among the interplanetary medium on one side (including the interplanetary magnetic field, solar plasma and radiation, and interplanetary dust and meteoroids) and the planetary surface and magnetic field on the other. The exosphere was detected for the first time from the Mariner 10 spacecraft in 1974 with the detection of H, He and O. Subsequently, exospheric Na, K and Ca were identified via Earth-based observations in the 80's, and more recently, Al and Fe were detected by ground-based observations. The NASA spacecraft MESSENGER also detected new species including Al, Mg, Mn and Ca^{+}, and other emissions that were interpreted as traces of CO^{2}, H_2O, N_2 and other noble gases. Ions of the He^{+}, Na^{+} and O^{+} groups were also identified in-situ (Raines et al., 2015). On October 2018 BepiColombo, the new joint ESA/JAXA mission to Mercury was launched to be inserted into Mercury's orbit in 2025, after a series of 6 flybys at the planet starting from 2021.

2. Why sodium?

In almost all Earth-based observations up to now, sodium was the species of election to trace the exosphere, since its doublet at 589 nm (D line) is very strong and free of telluric lines. Earth-based observations over the last 3 decades have found that abundances of Na and K undergo strong changes by several orders of magnitude. Their unexpected dynamism is strictly related to the existence of the intrinsic planetary magnetic field that causes exchanges between neutral and ion populations and which allows the penetration of the solar wind particles down to the surface through the magnetic cusps. In fact, the process of high energy ions implanting onto the surface seems to be the responsible of the release of superficial atoms into the exosphere, causing peaks of emission localized in the regions of the magnetic cusp footprints. Those peaks show also strong dynamism, and may be present for a long time, or vanish and reappear in a few hours, or even migrate toward the poles or the equatorial region up to merging into a single sub-solar peak (Figure 1).

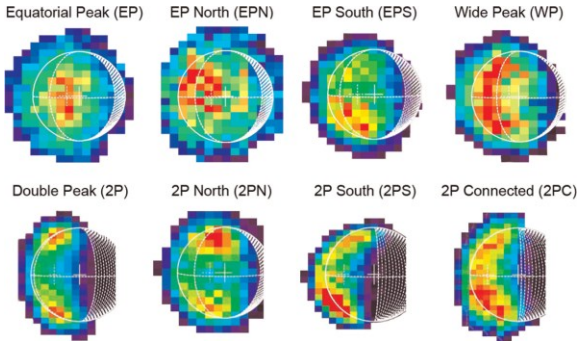

Figure 1: Examples of the 8 recurrent Na emission patterns identified in the Hermean exosphere [1].

The long and short term variability of Mercury sodium is therefore a mean to better understand what drives the complex dynamics of Mercury's exosphere and its interactions with the surface on one direction, and with the magnetosphere and interplanetary medium on the other.

3. Why Earth-based observations?

MESSENGER observed the tail variability during flybys and the seasonal variability during its orbiting phase in 2011-2015. Nevertheless, in-situ spacecraft like MESSENGER or BepiColombo will not be able to image all the exospheric morphology at a glance, nor to monitor its global morphological variability, as it is instead possible from a more distant point of view (as from the Earth). For this reason, it is still imperative to perform Mercury observations from Earth-based telescopes, and plan a long term campaign to monitor Mercury exosphere (its morphology, variability and reactions to external forcing) while waiting for BepiColombo to reach Mercury, and to be ready to support the forthcoming in-situ measurements.

4. Coordinated observation plan and call for new observers

A long series of Earth-based observations of Mercury exosphere were performed by R. Killen, T. Morgan and A. Potter starting from the 80's, and a large database was collected by using the National Solar Telescope McMath-Pierce in Kitt Peak, Arizona. Observations are performed in the US and in Hawaii also by using various telescopes and coronagraphs to image both the disk and the tail by C. Schmidt, M. Mendillo, J. Baumgardner (Boston University), and from the Japanese team lead by S. Kameda (Rikkyo University).A French-Italian campaign is performed starting from 2003 with the 3.5m TNG and 0.9m THEMIS telescopes in the Canary Islands by V. Mangano, F. Leblanc, C. Barbieri.

Alhough the campaign is still ongoing, we need to organize a wider group of Earth-based observers of Mercury's exosphere, and to call new scientists to this goal.

A new generation of telescopes is needed to substitute the old ones that are going to be dismissed (in Table 1 a list of requirements for this kind of observations).

New telescopes well suited for this purpose need to be identified and contacted, hopefully positioned also in new geographic sites (with the aim to reach full coverage of observations for 24 hours/day during coordinated campaigns).

Finally, we need and aim to prepare the basis of a long term plan of coordinated observations to start from now until the end of BepiColombo mission in late 20's.

	Requirement	Goal
Obs. Wavelengths	Na I 589.0 nm + 589.6 nm (0.5 nm wide)	+K I 769.90 nm
Spectral resolution	2 pm	<1 pm
FOV	20" × 20"	As large as possible
Spatial resolution	1"-0.5" (dep. on Mercury distance)	0.25"
SNR	10	100
Integration time/slit	3min	30s
Cadence (full FOV)	1h	as fast as possible
Stray Light	10-4 @10" off Solar-disk	as low as possible
Obs. Wavelengths	10-7 @5' off Solar-disk	+K I 769.90 nm
Spectral resolution	Na I 589.0 nm + 589.6 nm (0.5 nm wide)	<1 pm
FOV	2 pm	As large as possible

Table 1: Basic requirements to perform good Na (and K) measurements of Mercury exosphere.

References

[1] Mangano, V., Massetti, S., Milillo, A., Plainaki, C., Orsini, S., Rispoli, R., Leblanc, F.; THEMIS Na exosphere observations of Mercury and their correlation with in-situ magnetic field measurements by MESSENGER, Planet. Space Sci., 115, 102–109, doi:10.1016/j.pss.2015.04.001, 2015.