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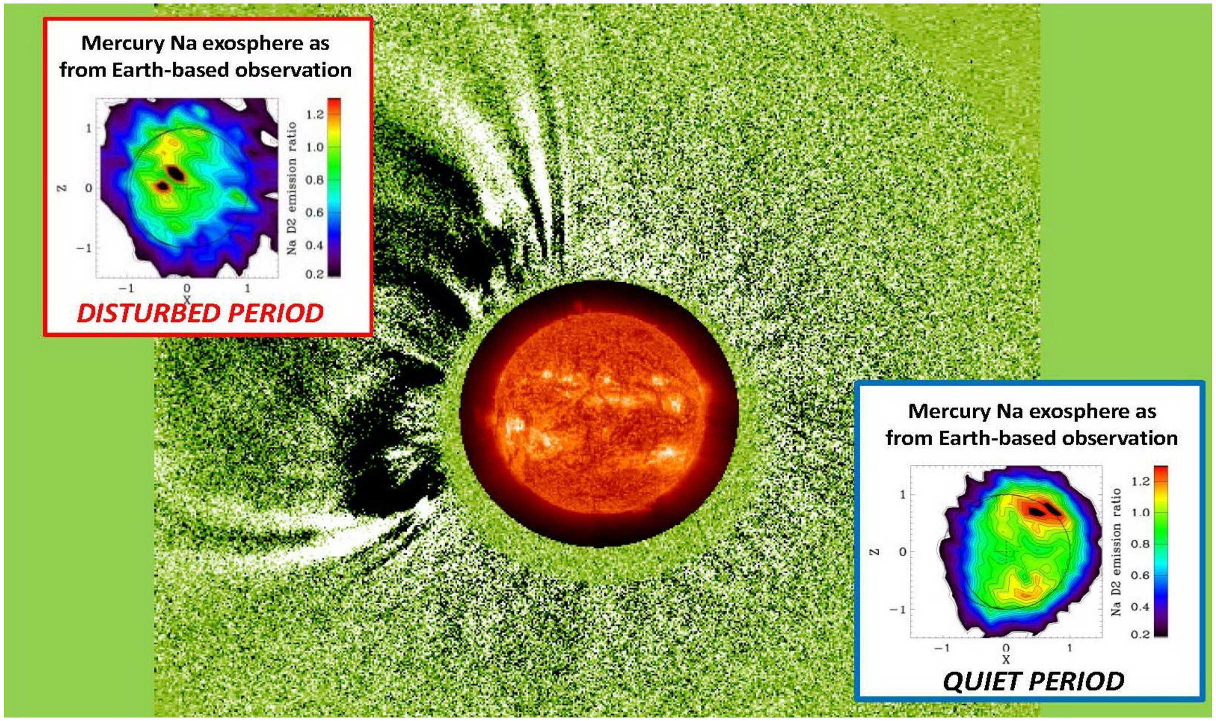

The exospheric Na high latitude emission, as observed from ground-based stations: a link to solar wind precipitation at Mercury

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Following previous studies from Mangano et al. (2013), Massetti et al. (2017), and Orsini et al (2018), this presentation is based on the analysis of exospheric Na emission at Mercury as monitored during a ***long campaign of ground-based observations from THEMIS solar telescope*** *in the Canary Islands, to investigate deeper the connection between the interplanetary magnetic feld near Mercury and the morphology of the planetary Na exosphere.*

In particular, our work focuses on the possible relationship between the Na emission location at high latitudes on the hermean dayside hemisphere with the interplanetary magnetic field, as measured 'in situ' by the magnetometer onboard MESSENGER.

MESSENGER IMF data are averaged over ~1 hour, the timing of each Na exospheric emission full scan. Our results are based on ~60 Na images from THEMIS database, in good seeing conditions, taken when the IMF data were also available (years 2011-2012-2013).

OUTLINE

- Following a work by Orsini et al., published in 2018, in this study we would like to face the possible relationship between exospheric Na distributions and Interplanetary magneric field with a more extensive database.
- As in the past study, we will check the Na data in correspondence with MESSENGER magnetic field detections.
- Hence, we analyze the whole clean 1-hour averaged Na emission images (about 60 cases) outcoming from the 2011 to 2013 THEMIS ground-based campaigns, when simultaneous IMF data from MESSENGER mission where available.
- The observed relationships between Na polar peaks location and IMF are here reported

The solar telescope: THEMIS

THEMIS is **90 cm f/16 Ritchey-Chretien telescope** with an alt-az mounting, a helium filled telescope tube, and a Stokes polarimeter located at the prime focus.

Since 2007 THEMIS is used also for observations of **Mercury's exosphere** (thanks to its characteristics, i.e. low diffuse light).

The observation campaign

8 Years(fm 2007 to 2014) → >150 days

'MTR mode' multiline pectropolarimetry
Spectral range: 400 - 1000 nm

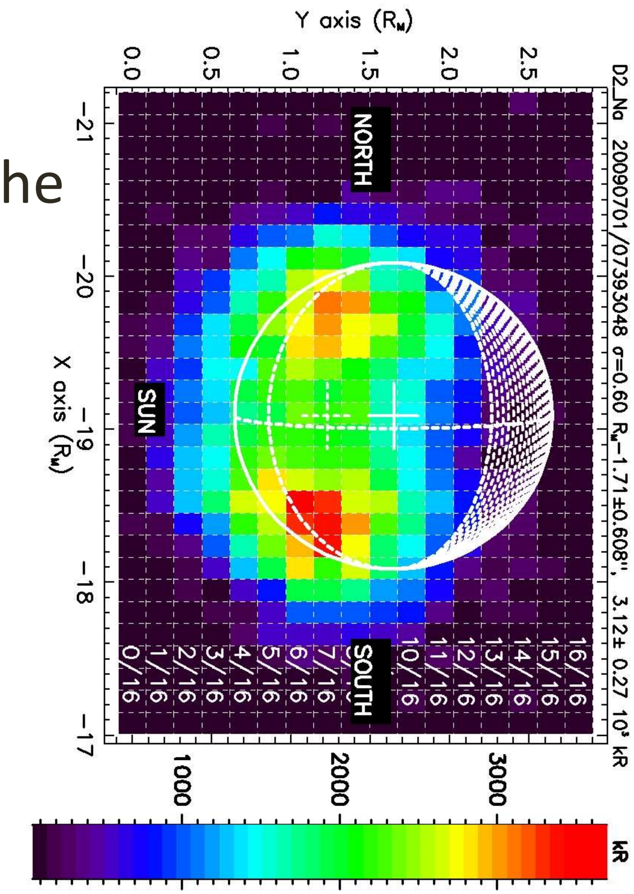
Two independent cameras observing at the same time:
D1 Na at 5896 Å **D2 Na at 5889 Å**

Two possible spatial resolutions:
R ~ 220,000 with slit: 0.5" & 120 "
R ~ 400,000 with slit: 0.25" & 70 "

Spectral resolution 0.027 Å to 0.016 Å
Spectral dimension 10.2 to 6 mÅ

Time needed for 1 scan: 40 ÷ 120 min

→ <u>**Observation time window: all the day!**</u>



MERCURY Na GROUND-BASED OBSERVATIONS FROM THEMIS
"CLEAN SKY" - Seeing degradation < 2"   (2011-2012-2013 campaigns)

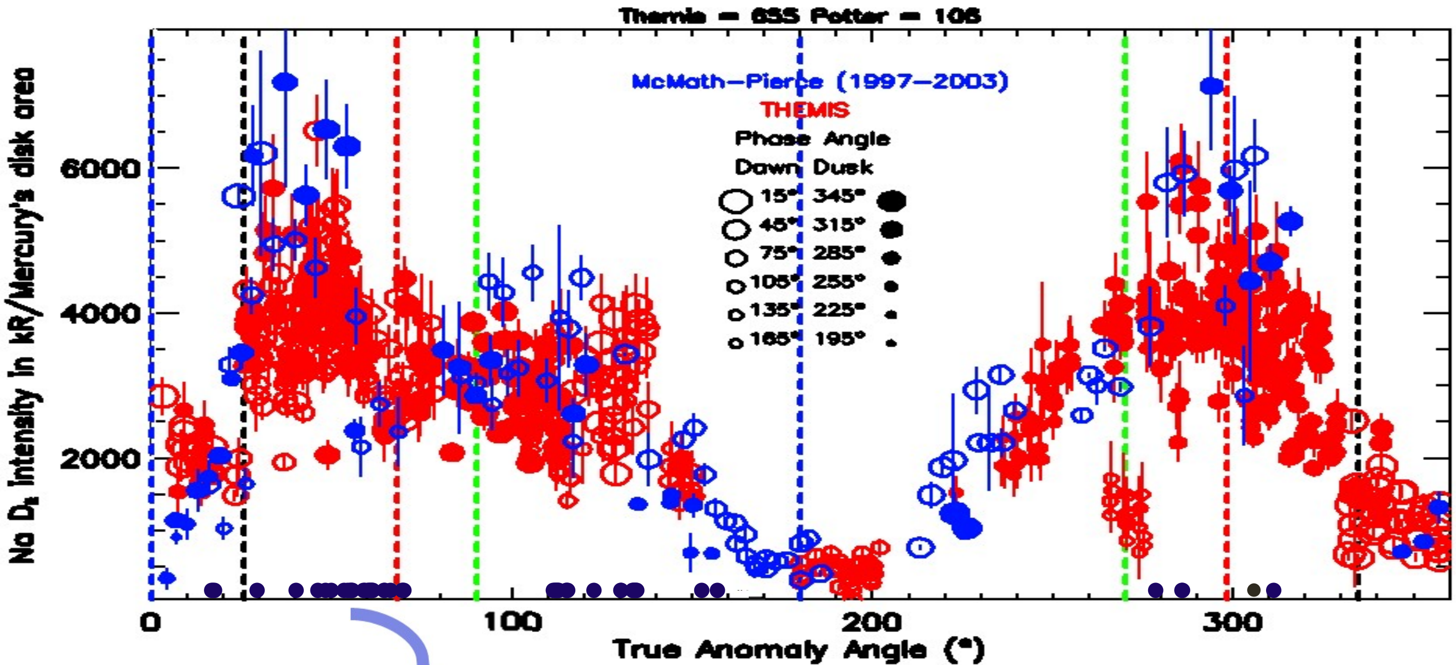
start time (dt=1hour)

2011-05-26 08:29:00 UT
2011-05-28 08:23:00 UT
2011-05-28 09:29:00 UT
2011-06-01 08:35:00 UT
2011-06-02 08:19:00 UT
2011-07-13 11:48:00 UT
2011-07-14 10:42:00 UT
2011-07-15 18:55:00 UT
2011-09-14 07:01:00 UT
2011-09-15 07:01:00 UT
2012-06-0513:20:00 UT
2012-06-0614:41:00 UT
2012-06-0617:58:00 UT
2012-06-0618:57:00 UT
2012-06-0709:42:00 UT
2012-06-0710:53:00 UT
2012-06-0715:19:00 UT
2012-06-0718:02:00 UT
2012-06-0719:03:00 UT
2012-06-0810:06:00 UT
2012-06-0811:16:00 UT
2012-06-0818:18:00 UT

2012-06-0908:47:00 UT
2012-06-0909:50:00 UT
2012-06-0910:56:00 UT
2012-06-0914:41:00 UT
2012-06-0915:51:00 UT
2012-06-0918:00:00 UT
2012-06-0919:05:00 UT
2012-06-1811:39:00 UT
2012-06-1813:56:00 UT
2012-06-1815:05:00 UT
2012-06-1816:11:00 UT
2012-06-1817:25:00 UT
2012-06-1818:30:00 UT
2012-06-1819:33:00 UT
2012-06-1820:34:00 UT
2012-06-1909:44:00 UT
2012-06-1910:56:00 UT
2012-06-1911:56:00 UT
2012-09-1709:34:00 UT
2012-09-1910:55:00 UT
2012-09-1913:01:00 UT
2012-09-2010:17:00 UT
2012-09-2011:21:00 UT
2012-09-2012:25:00 UT

2012-09-2013:30:00 UT
2012-09-2014:35:00 UT
2012-09-2015:38:00 UT
2012-09-2016:43:00 UT
2012-09-2017:46:00 UT
2013-05-0210:04:00 UT
2013-05-0217:52:00 UT
2013-05-0313:00:00 UT
2013-05-0409:06:00 UT
2013-05-0411:42:00 UT
2013-05-1808:04:00 UT
2013-05-1809:11:00 UT
2013-05-1811:21:00 UT
2013-05-2007:59:00 UT
2013-05-2317:08:00 UT
2013-05-2407:33:00 UT
2013-05-2416:28:00 UT
2013-05-2417:33:00 UT
2013-05-2512:22:00 UT
2013-05-2514:34:00 UT
2013-05-2515:39:00 UT
2013-05-2516:45:00 UT
2013-05-2517:53:00 UT

True Anomaly Angle Na emission dependance



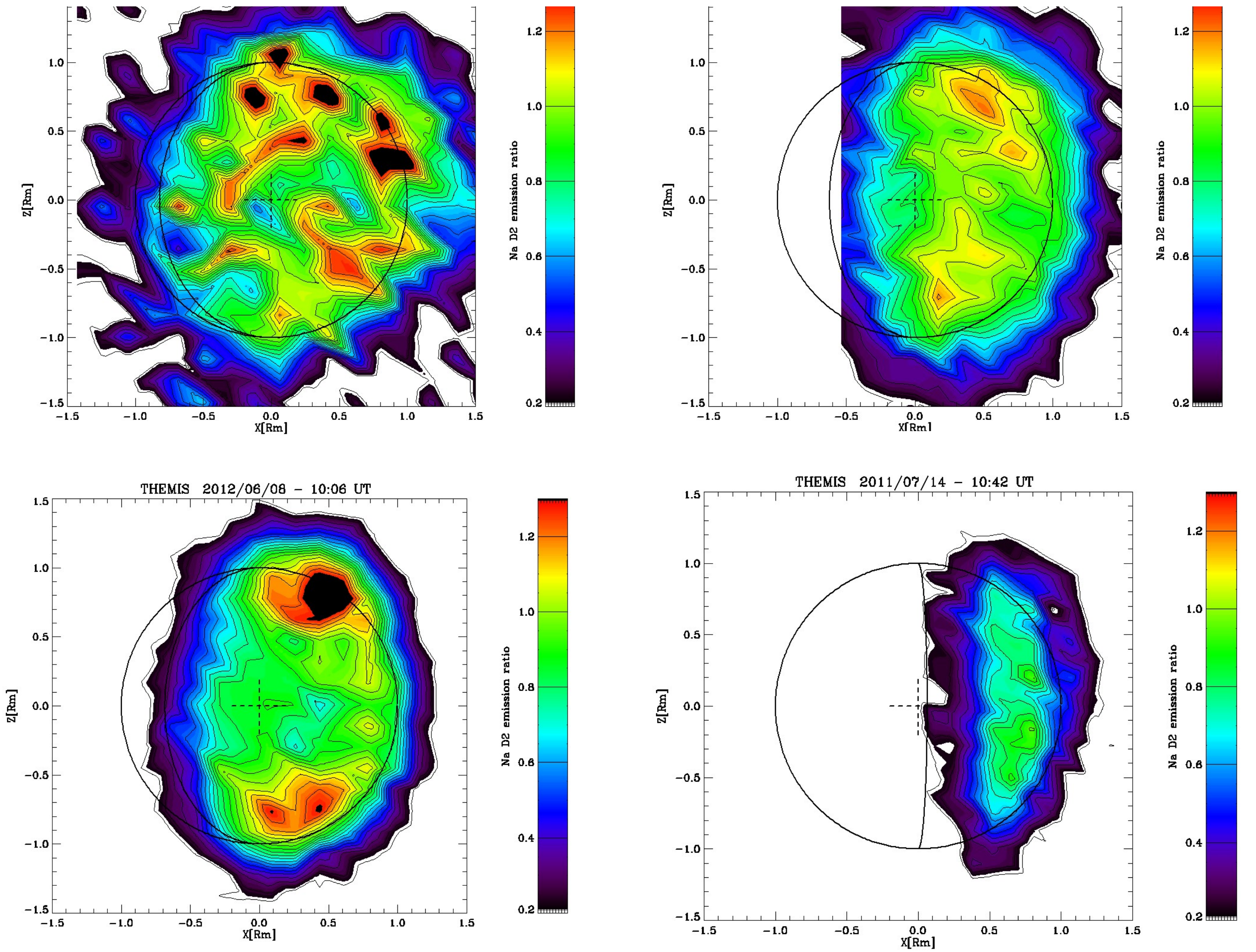
Selected Data - TAA ranges

This plot is the outcome of several Na observation campaigns from two ground-based stations (Themis in red and McMath-Pierce in blue, F. Leblanc, private communication).

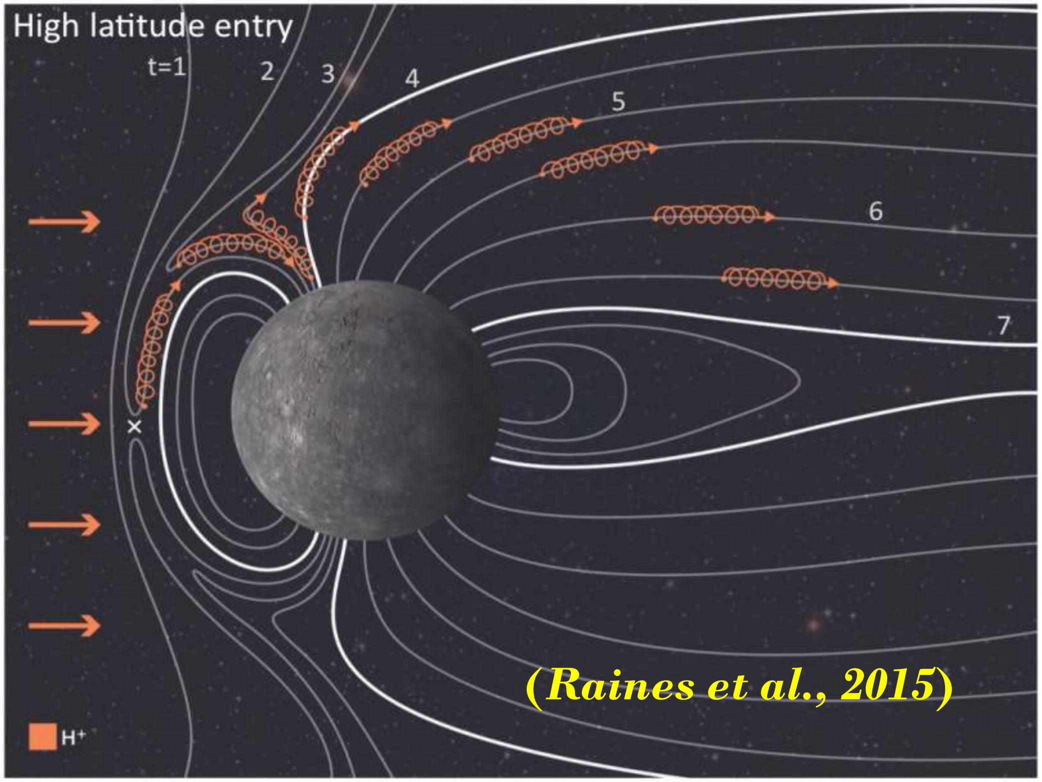
Before interpreting the signal significance, any Na intensity detection should be considered with respect to this experimental profile.

In fact, the selected data (black points at the plot bottom) stay where the observed intensity is not too low.

Na intensity map examples. North-south double peaks are observed, with different intensity. In few occasions (top left) they show sharp drifts during the one-hour accumulation time. Sometimes, they are instead faint (bottom right) and much closer one to each other.



IMF and magnetosphere

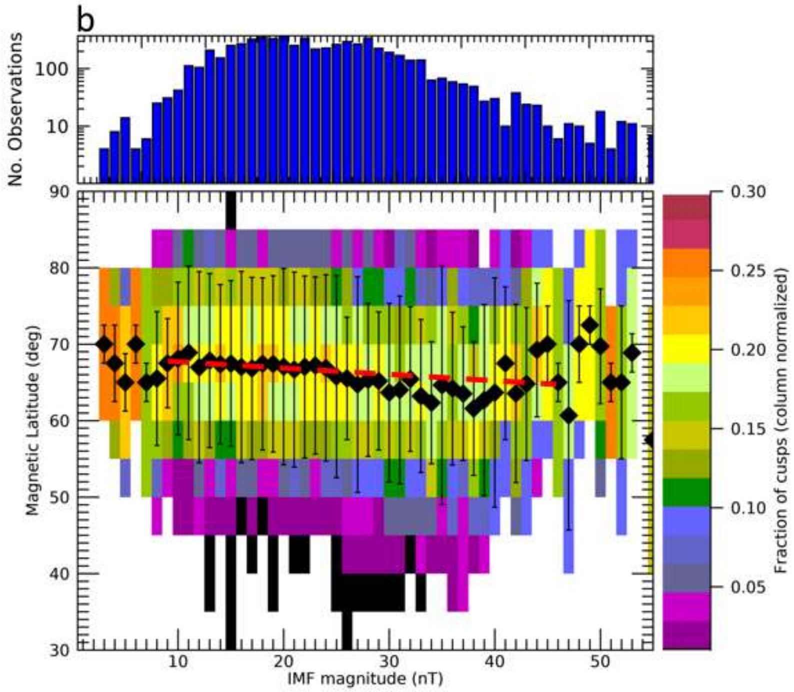


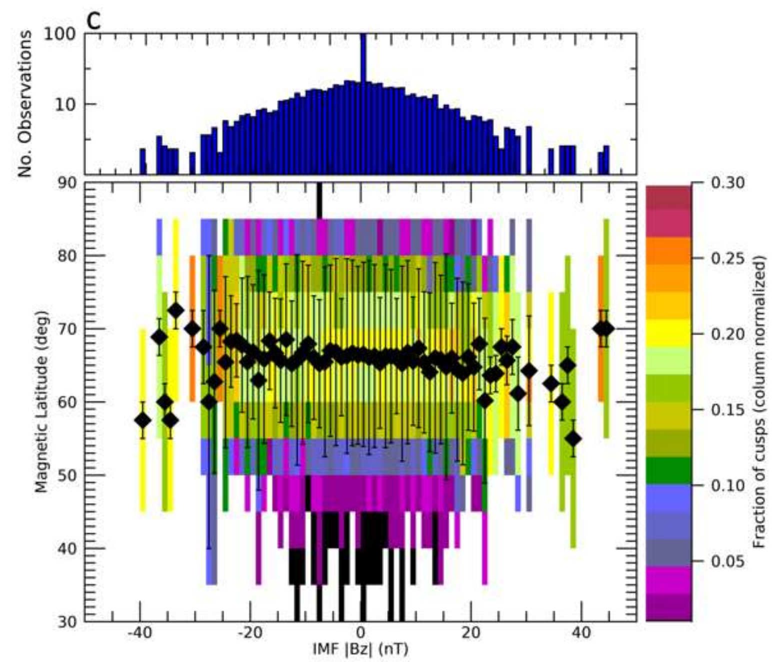
- Reconnection is linked to low Alfvénic Mach number which induces a low plasma β in the magnetosheath.
- IMF ~> 25 nT is likely to be associated to a low MA (< 5) upstream.
- This condition causes higher reconnection rate at Mercury, almost regardless of the IMF orientation.

Raines et al, in prep

NORTHERN MAGNETOSPHERIC CUSP - DEPENDENCE ON IMF

We identified the northern cusp in 2808 of 4106 MESSENGER orbits. The cusp appears to be a broad, elongated region which moves to lower latitude with increasing IMF strength.





A dependence on IMF magnitude is observed, falling 1.5 deg for each 10 nT increase in magnitude in the range 10 to 45 nT).

A weak dependence of the mean magnetic latitude of the cusp on the IMF Bz is observed, moving 1-2 deg lower as the component ranges -20 to 20 nT

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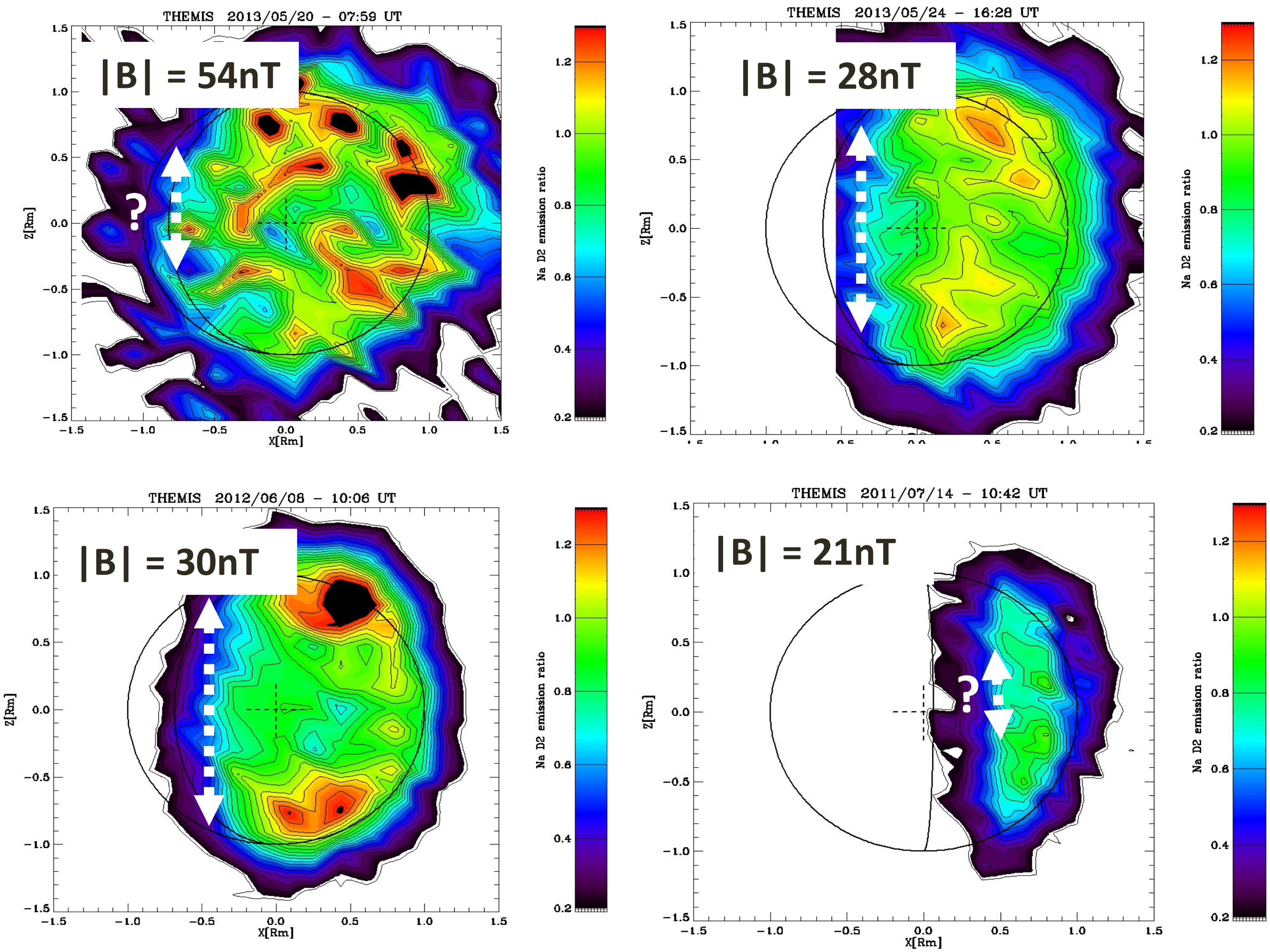
Na intensity map examples with given IMF. At high IMF (top left), the distance between the two peaks is not well discernible, and the Na signal is stronger and more fluctuating within the 1-hour acquisition time. At low IMF (bottom right) it is not discernible as well, but the signal is faint.



Orsini ,Mangano, Mura, Milillo,

MexAG Conference, February 3-5, 2021

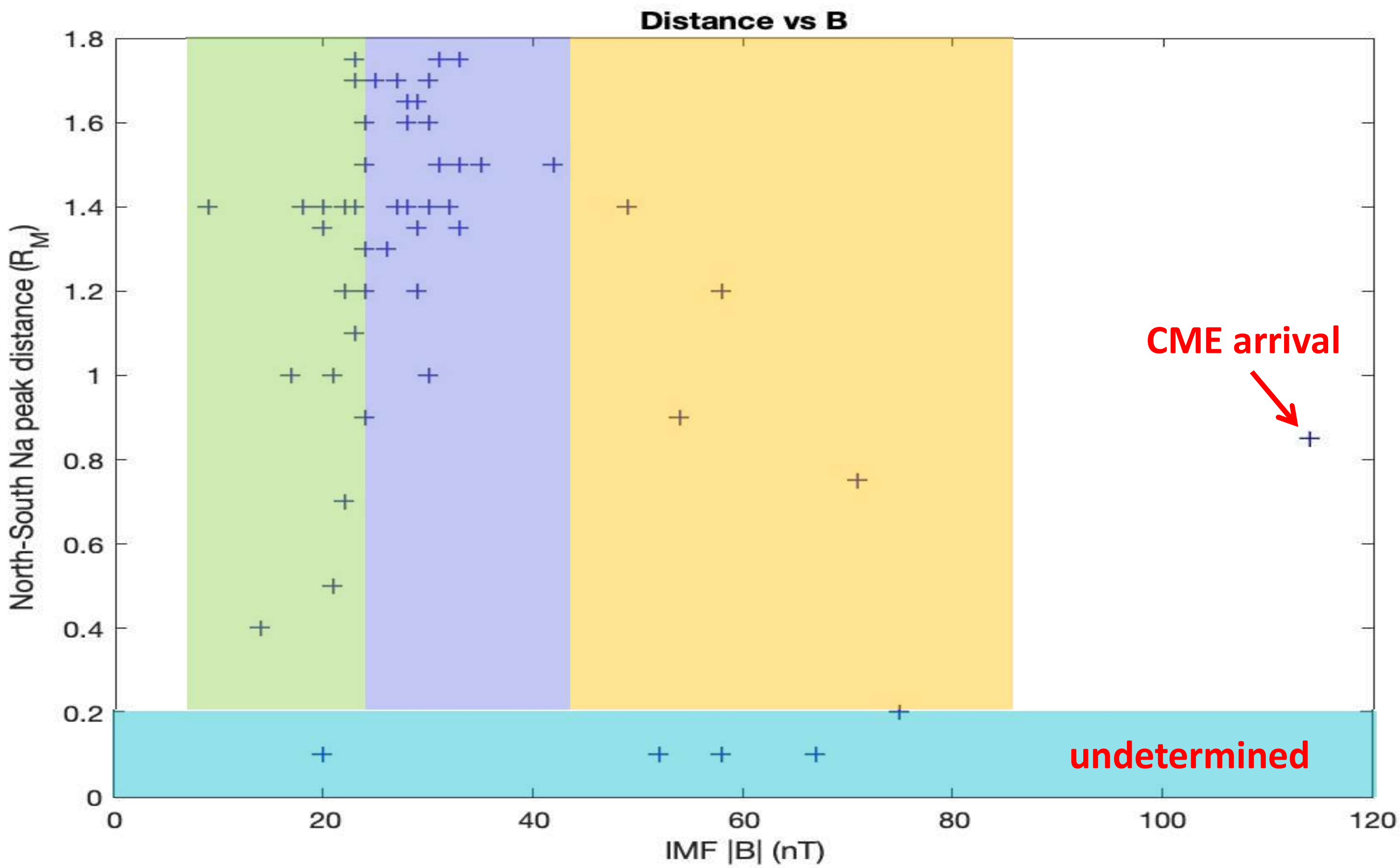
1st QUESTION

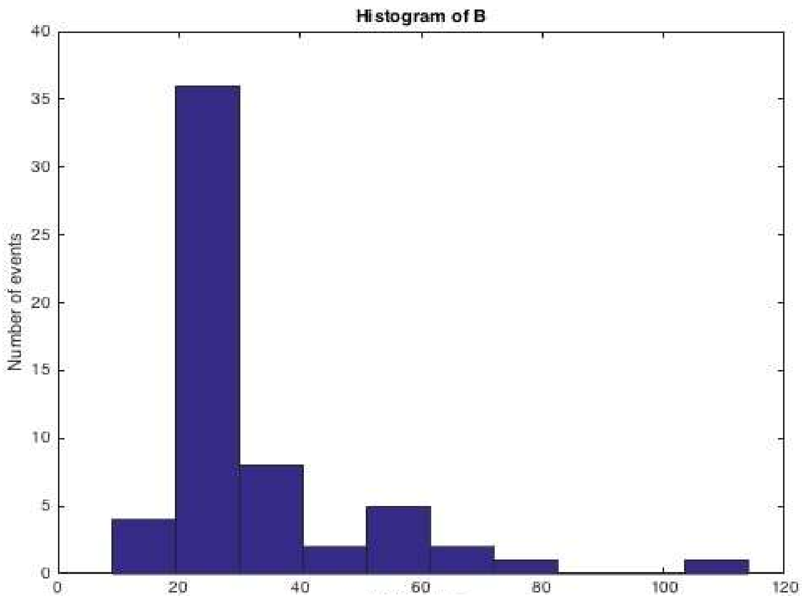
Are the Na two-peak latitudinal locations dependent on the IMF magnitude, as it happens for the cusps?

For checking this possible dependence, we have plotted the distances between the two-peak Na emissions (in Mercury radii), observed by THEMIS, versus the IMF magnitude (nT), as observed by MESSENGER.

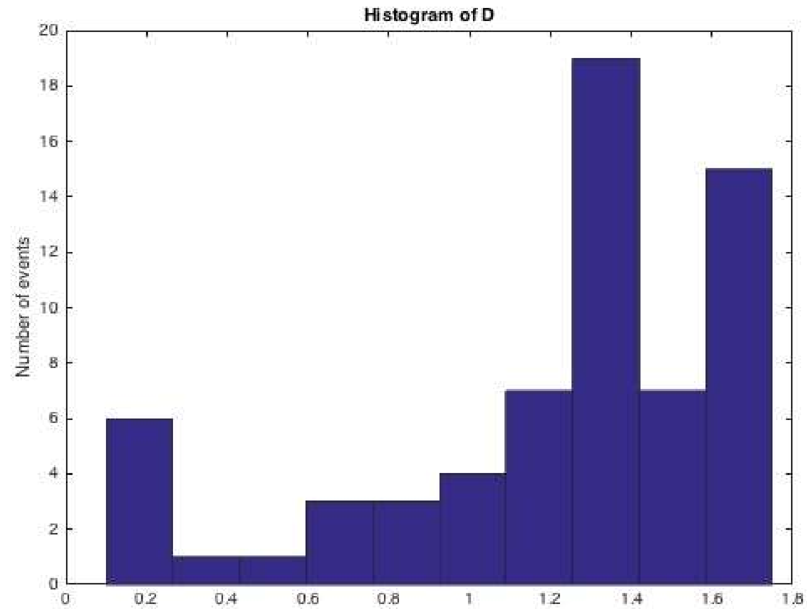
The two peak distances versus IMF magnitude profile exhibits three different regimes. The left one, at IMF<23nT, shows scattered data extending from low (sometimes difficult to discriminate) to high distances. The right one, at IMF>45nT shows a decreasing trend versus IMF. In the central area, most of the data are more concentrated at high distances/latitudes.

The above considerations suggest that **there is always a well-defined Na two-peak emission regime when IMF is nominal at Mercury.** Occasionally, with weaker or more intense IMF, the two peaks are less discernible and mostly localized at lower latitudes.





IMF magnitude, nT



Two peaks distance, Rm

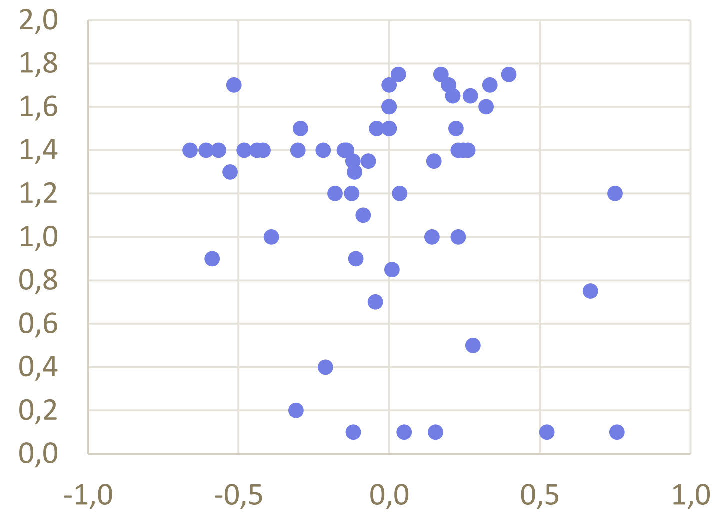
The histograms of occurrence of IMF magnitude and two peak distances confirm the idea that **the most frequent condition corresponds to IMF between 20 and 40 nT, as well as to two well-defined Na peaks at relative distances from 1.3 to 1.7 Rm** (Mercury radii)

Na two-peaks distance vs. IMFz,x,y/IMF (angle, radians)

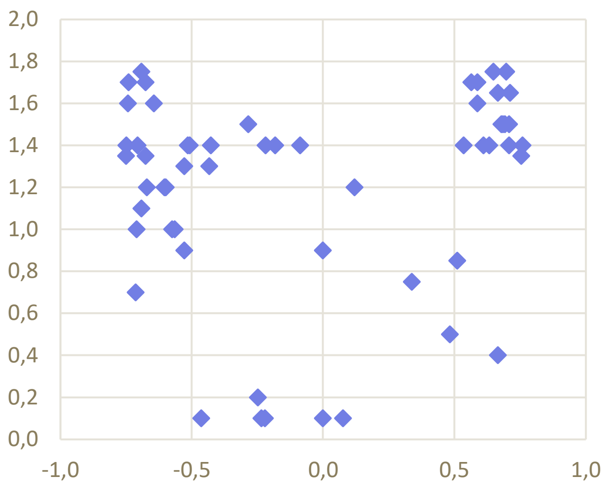
The two-peak distances versus IMFz,x,y/IMF angle (at any IMF) **do not exhibit any prticular trend**.

Hence, generally the **IMF strenght does cause reconnection by itself**, so that the standing two peak Na emissions result from this occurring reconnection, which causes particle precipitation at mid-high latitudes.

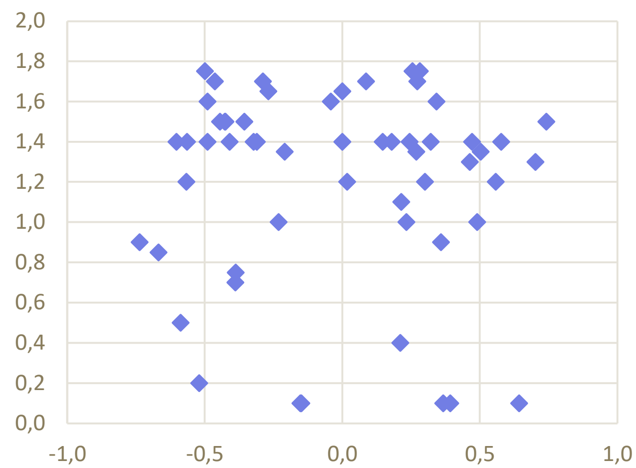
arctan(z/magnitude)



arctan(x/magnitude)



arctan(y/magnitude)



2nd QUESTION

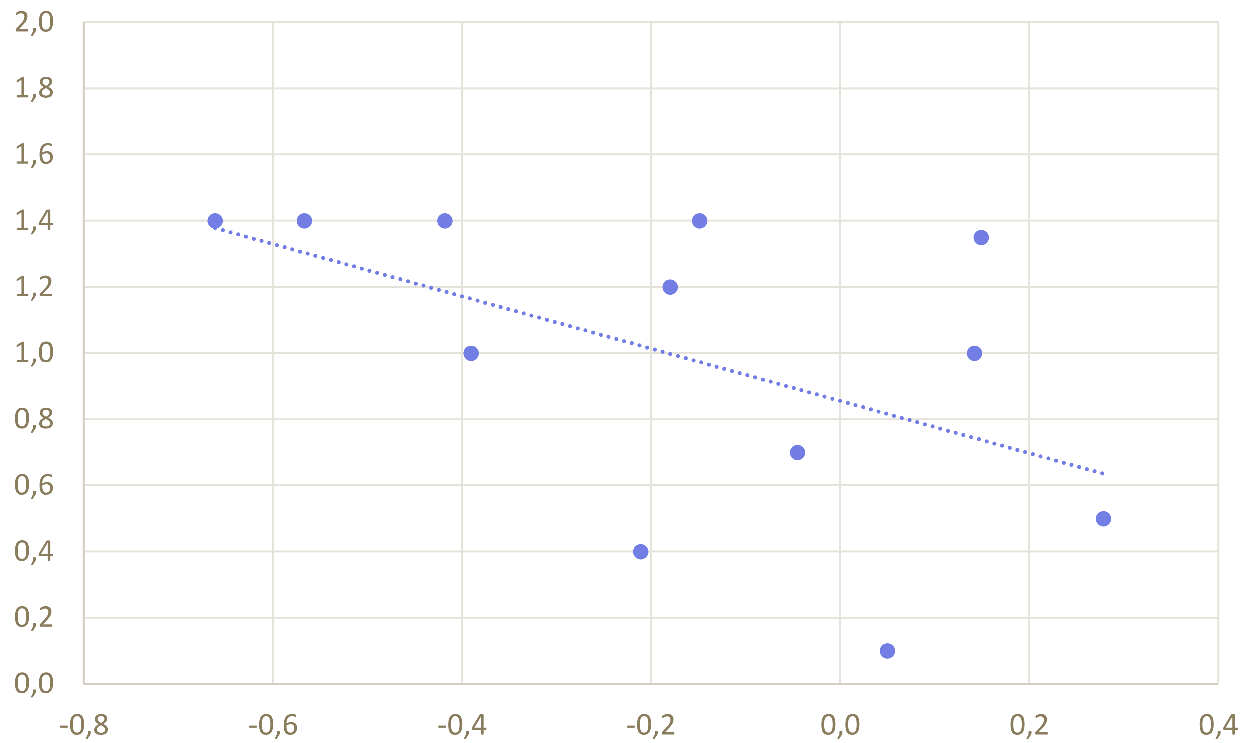
At Mercury, given the weak intrinsic magnetic field, the IMF magnitude is often sufficient by itself to generate reconnection regimes, and hence particle precipitation and Na emission in the mid-high latitude regions.

In condition of a very weak IMF (< 23 nT), can the IMFz (<0) be responsible for reconnection efficiency (as it happens at the Earth) and, hence, the driver of particle precipitation and effective Na emission at mid/high latitudes?

Na two-peak distance vs. IMFz/IMF angle, IMF<23 nT

When considering only weak IMF cases (<23 nT), **a dependence is observed in the plot vs the IMFz/IMF angle**, so that more stable Na peaks at high distances/latitudes are noticed when the angle is negative, whereas a more scattered condition occurs when such an angle is close to zero or positive.

Hence, it is reasonable to assume that only when occasionally IMF is weak, the reconnection could be controlled by IMFz, like it happens at the Earth with any IMF magnitude.



CONCLUSIONS

- A relationship between cusp particle precipitation and Na emission in Mercury's exosphere was previously shown by Orsini et al., 2018.
- Recent speculations by Raines et al., (in preparation) do relate the northern cusp magnetic latitude to the IMF intensity.
- In this presentation, we have shown that **the Na emission locations in Merury's exosphere seem to be also related to IMF intensity**. The Na two-peak distributions appear to be more discernible within a specific IMF range, from ~23 to ~ 45nT.
- If we select only cases **with IMF <23 nT, a dependance of the two-peak distances versus IMFz/IMF angle is noticed**, so that more stable Na peaks at high distances/latitudes are present when the angle is negative, whereas a more scattered condition occurs when such an angle is close to zero or positive. This could be the effect of reconnection process control by IMFz/IMF, like in Earth's case.
- Further investigations will be possible once the BepiColombo fleet will be operative around Mercury.
- During BC operations, simultaneous ground-based observation campaigns would be very useful for better understanding the dynamics of these processes.

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