Sodium on Mercury, Asteroids, and Comets

Shingo Kameda[1], M. Kagitani[2], S. Okano[2], H. Dairoku[1], A. Fusegawa[1],
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[1]Rikkyo University, [2]Tohoku University

The source process of Mercury's exospheric sodium has been discussed since its discovery in 1985. Sodium atoms released from the surface are photon-ionized in a few hours and some of them are lost to the interplanetary space. Past studies suggested that the source processes are solar photon-stimulated desorption, solar wind sputtering or diffusion, and micro-meteoroid vaporization and sodium atoms are continuously supplied to the exosphere still now. The volatility of sodium is relatively higher than other metal element. Kasuga et al. (2006) suggested that sodium is completely lost from the meteor stream if the effective temperature increased to 900 K. Mercury and the Moon experienced the high temperature in their accretion phase. On the other hand, comets have not experienced the high temperature. Because of this difference, the release rate of sodium from the surface of Mercury and the Moon ($\sim 10^{6\text{-}8}$ atoms/cm^2/s) is much lower than that of Comets ($\sim 10^{11}$ atoms/cm^2/s). This suggests that the sodium exospheric density is related with the heat history.

The Hayabusa 2 mission is ongoing targeting the launch in 2014. The goal of Hayabusa 2 is sampling the surface material of the C-type asteroid 1999JU3. This asteroid seems not to be heated so much according to the ground-based spectroscopy. Thus, it can be expected that the asteroid has some sodium in the exosphere. The Optical Navigation Camera (ONC) onboard Hayabusa 2 spacecraft has a sodium filter in the filter wheel. Even if the release rate of sodium from the asteroid is as low as that from Mercury and the Moon, the ONC can detect the asteroid's exospheric sodium emission.

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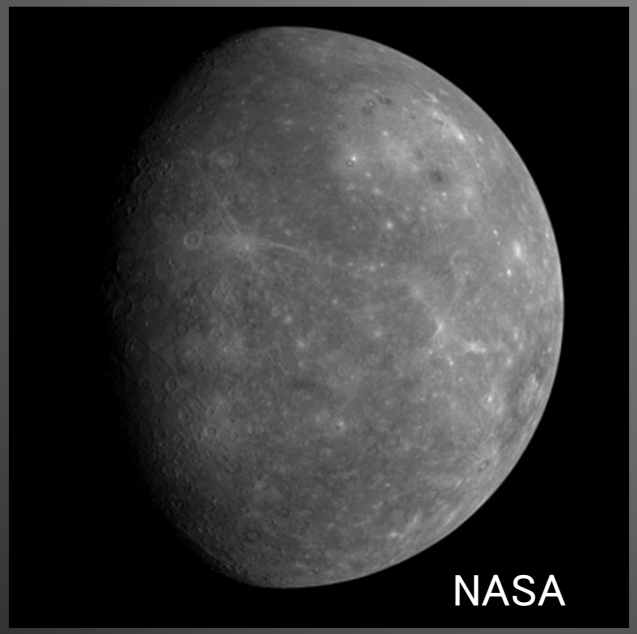
Mercury

--Just 3 Flyby by Mariner 10 in 1973-1974.

No observation by any orbiter

until March 18, 2011 (MESSENGER)

--Like Moon?



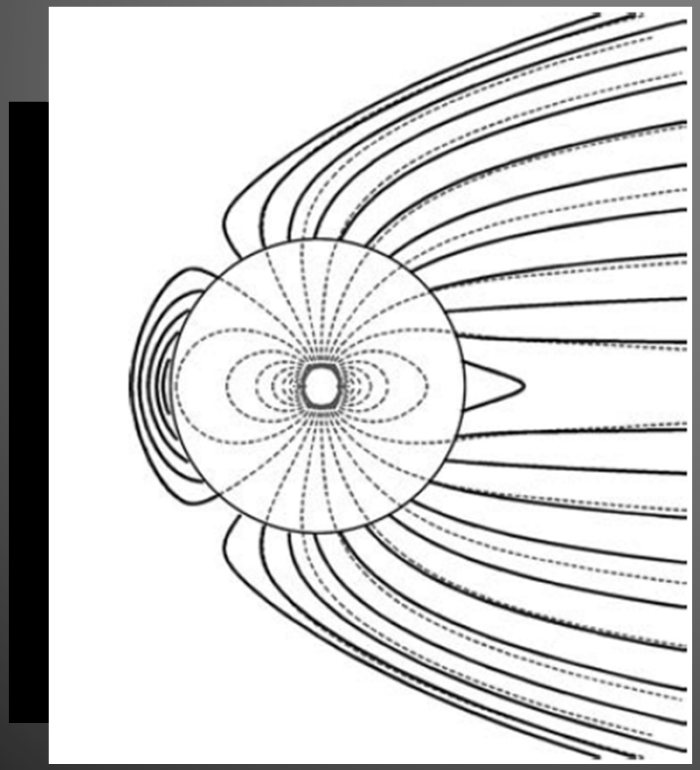
http://blogs.yahoo.co.jp/p2k5_net/38818872.html

Mercury

--Like Moon? → Several differences.

1, Intrinsic magnetic field

Found in 1973 and is still under discussion why it has.

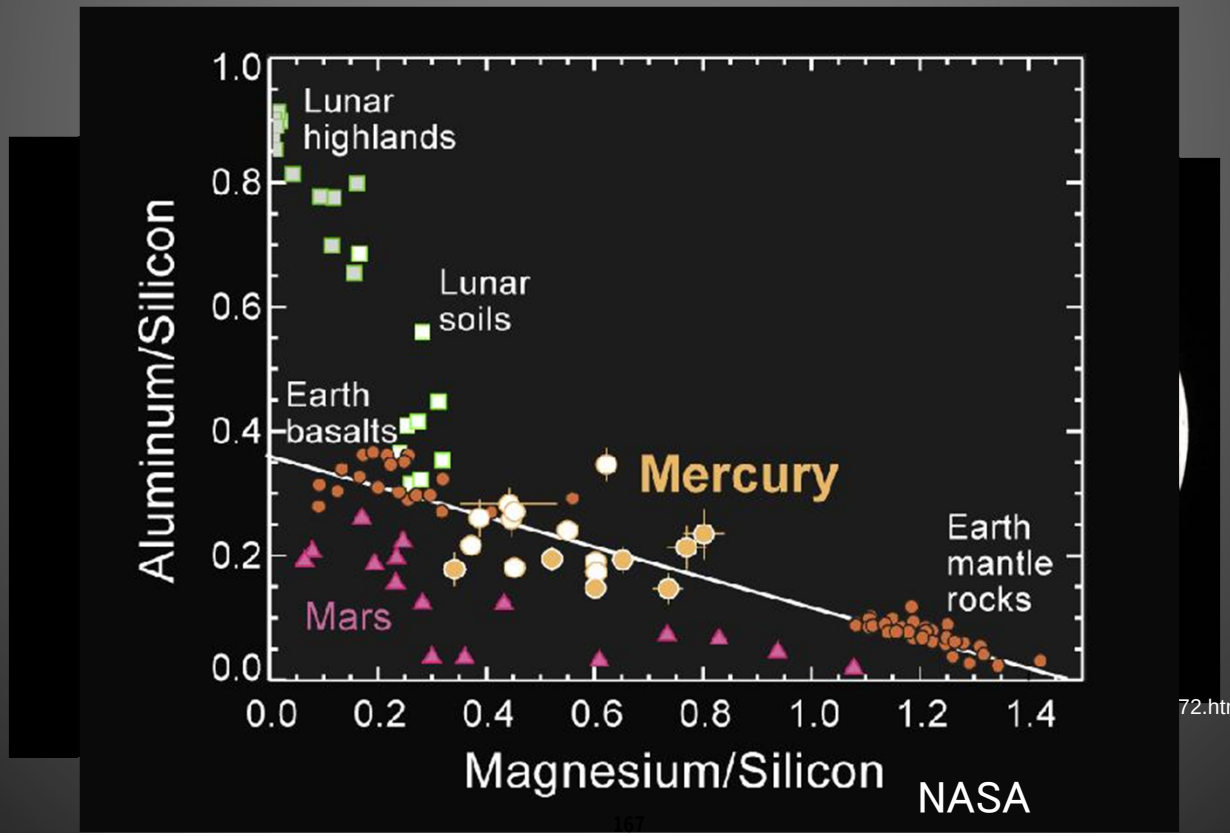


http://blogs.yahoo.co.jp/p2k5_net/38818872.html

Mercury

--Like Moon? → Several differences.

2, Composition (Observed by MESSENGER)



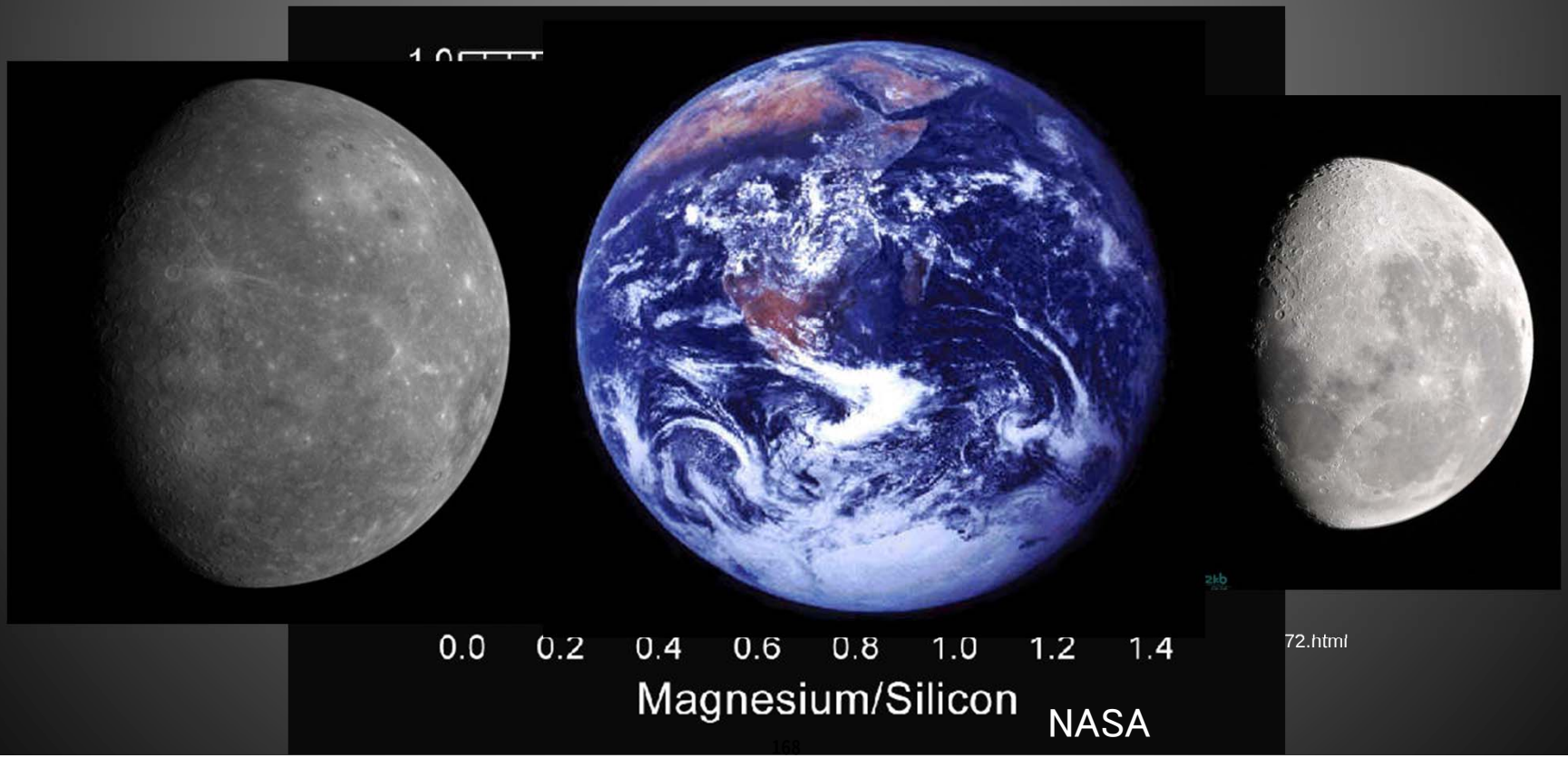
72.html

Mercury

--Like Moon? → Several differences.

2, Composition

Like Earth and Mars rather than Moon?

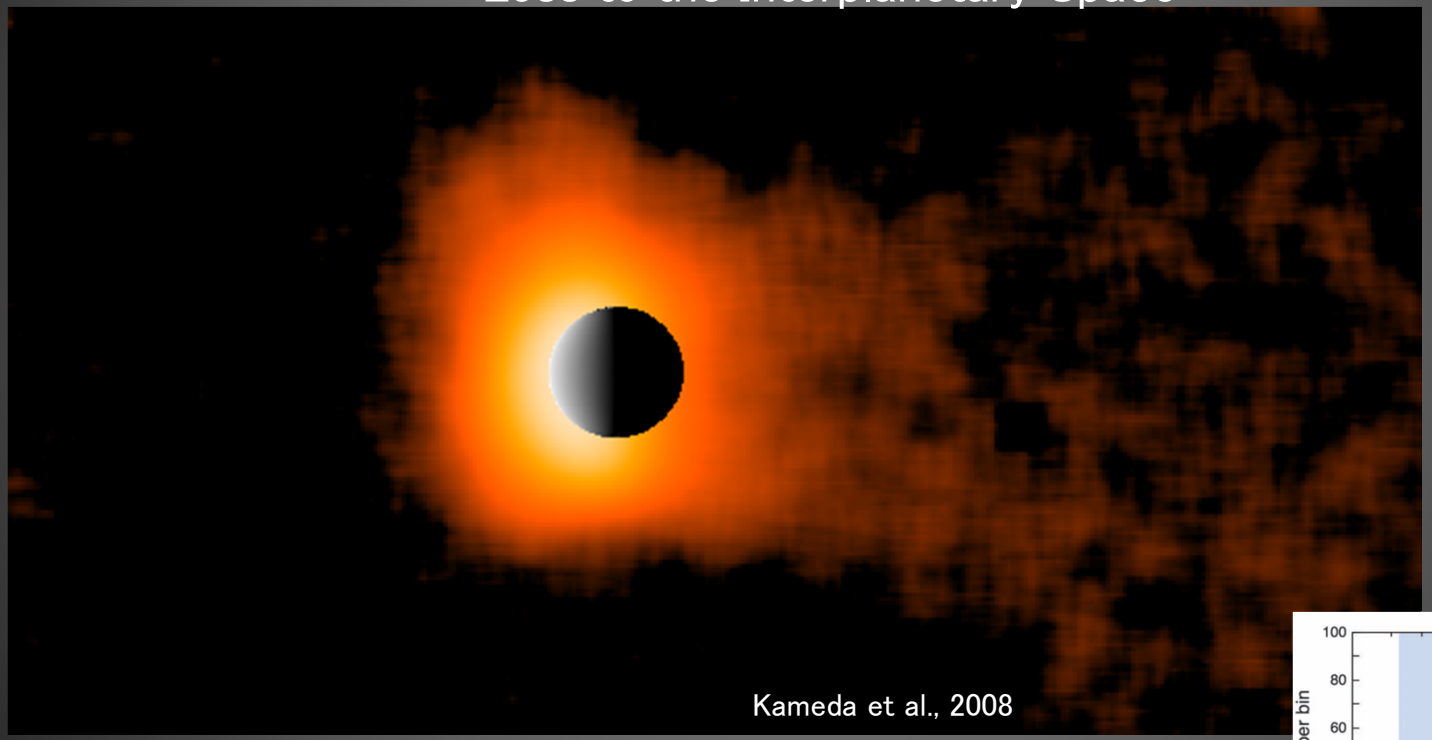


Mercury's atmosphere

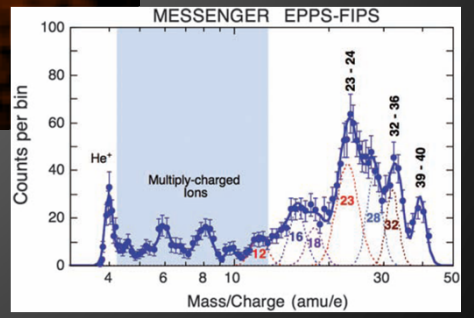
Collisionless atmosphere P~10^{-12} atm

Released from the surface ・Impact to the surface (SP, SW, IPD)

・Loss to the Interplanetary Space



Kameda et al., 2008



Zurbuchen et al., 2008

Remote Sensing: H,He,O,Na,K,Ca,Mg,Ca+,Al?,Fe?

In Situ : H^+,He^+,Na^+(Mg^+),O_2^+,K^+(Ca^+,Ar^+), etc.

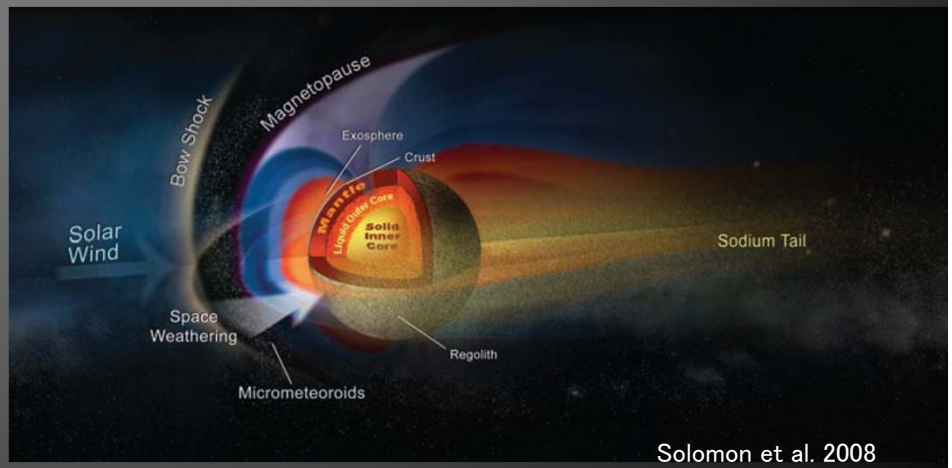
Mercury's Atmosphere

- **Interaction between the solid surface and Mercury's environment**

--Solar photon-stimulated desorption

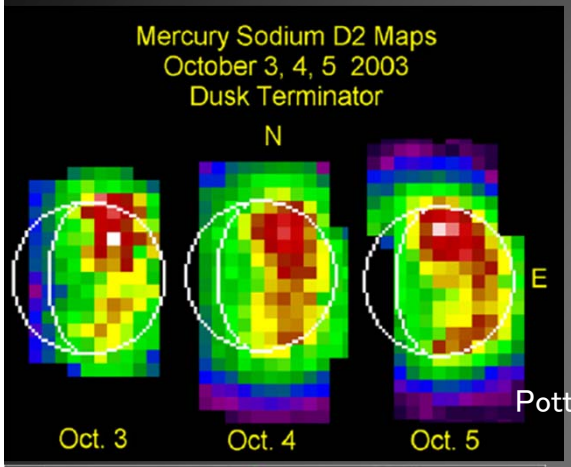
--Solar wind sputtering (or diffusion)

--Micrometeoroid vaporization

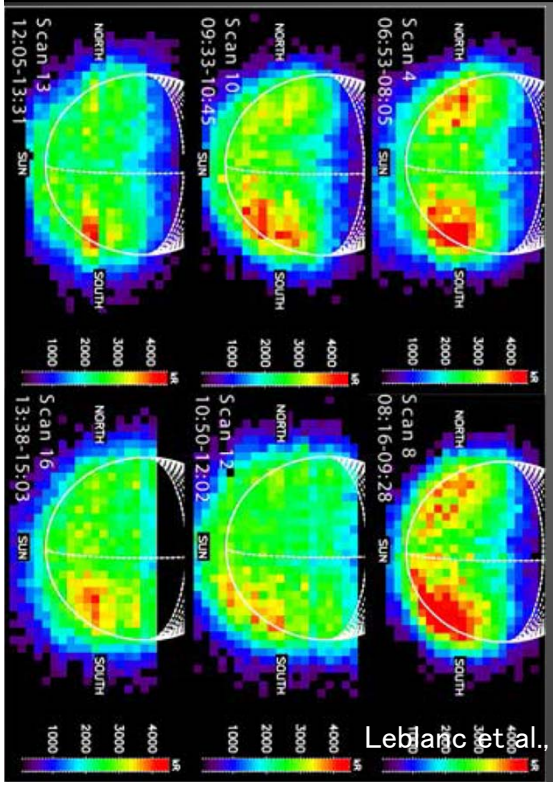


Solomon et al. 2008

Source process of Mercury's exosphere?



Potter et al., 2008

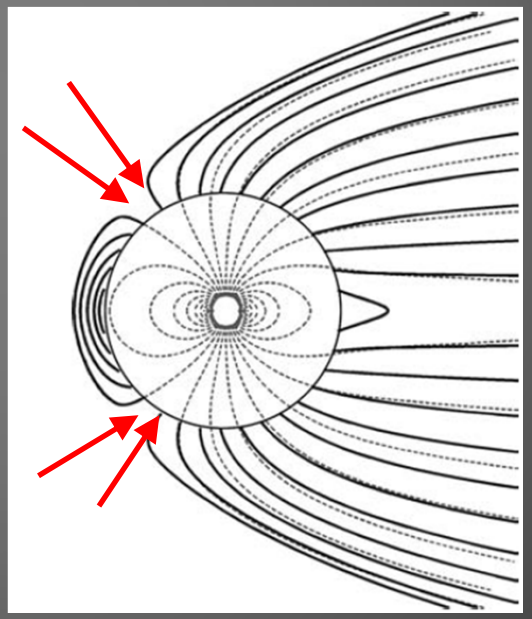


Leblanc et al., 2009

Concentration at High latitudes and

Temporal variability

→ Effect of Solar wind impact??



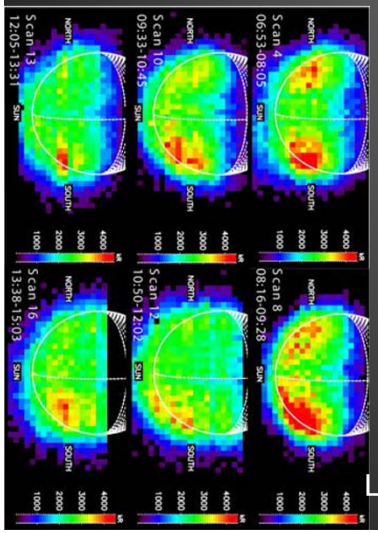
Source process of Mercury's exosphere?

Recent study

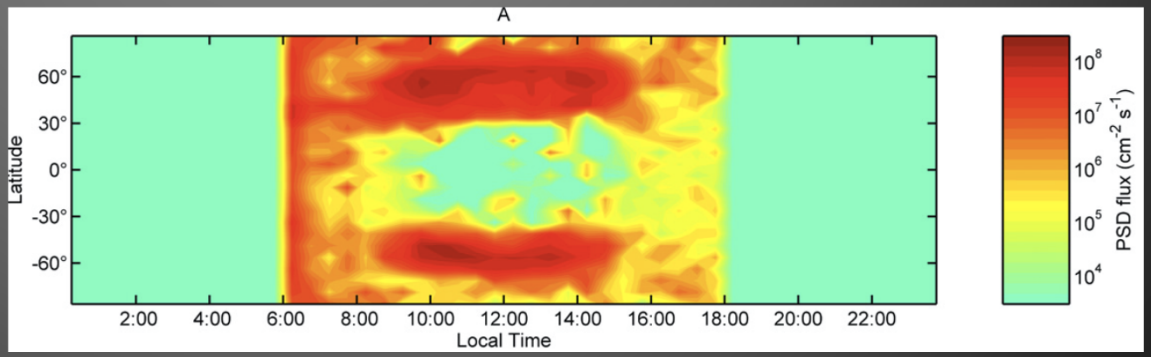
Only photon-stimulated desorption can explain the observed density of Na exosphere.

However, UV photon can desorb Na atoms in the few monolayers on the surface

→ Thermal or ion-induced diffusion supply Na to the surface from inside.



Leblanc et al., 2009



Mura et al., 2008

1999JU3: Target of Hayabusa2

- 700nm absorption band of hydrous material
  → non-heated → Organics

The only asteroid which has this absorption and we can go to.

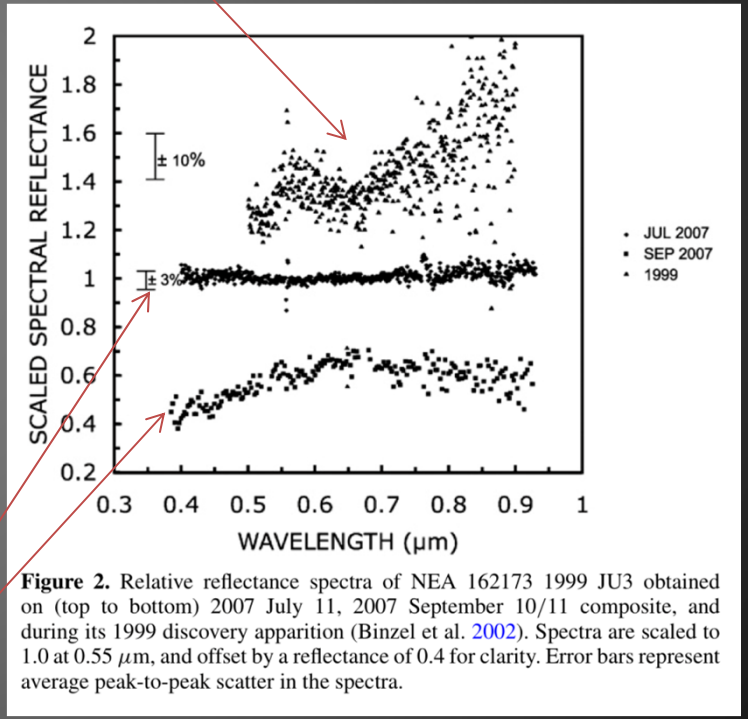


Figure 2. Relative reflectance spectra of NEA 162173 1999 JU3 obtained on (top to bottom) 2007 July 11, 2007 September 10/11 composite, and during its 1999 discovery apparition (Binzel et al. 2002). Spectra are scaled to 1.0 at 0.55 μm, and offset by a reflectance of 0.4 for clarity. Error bars represent average peak-to-peak scatter in the spectra.

- Non uniformity

Vilas, 2008

1999JU3: Target of Hayabusa2

- Possibility: much-heated regolith on the most part of the surface.
- Just in case that we cannot touch down to the place where the 700nm absorption is strong…

- Sodium can be diffused from inside.

→If any ununiformity

→Unheated place

Sodium on Mercury, Asteroids, and Comets

Source rate

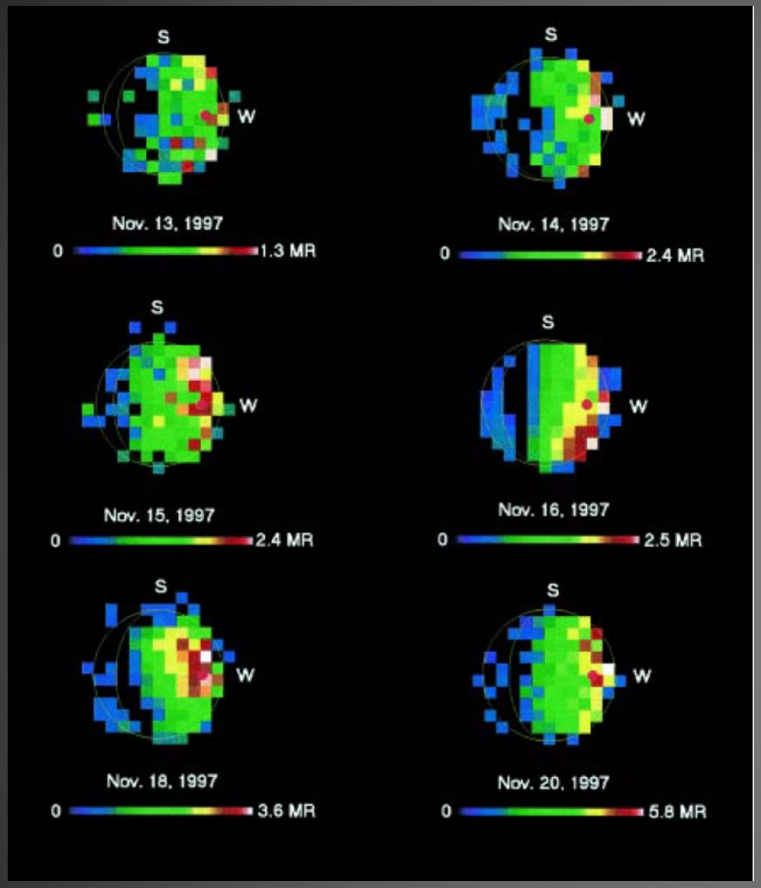
- Mercury & Moon ~10^{6-8} atoms/cm^2/s
- Asteroids ????
- Comets ~10^{11} atoms/cm^2/s

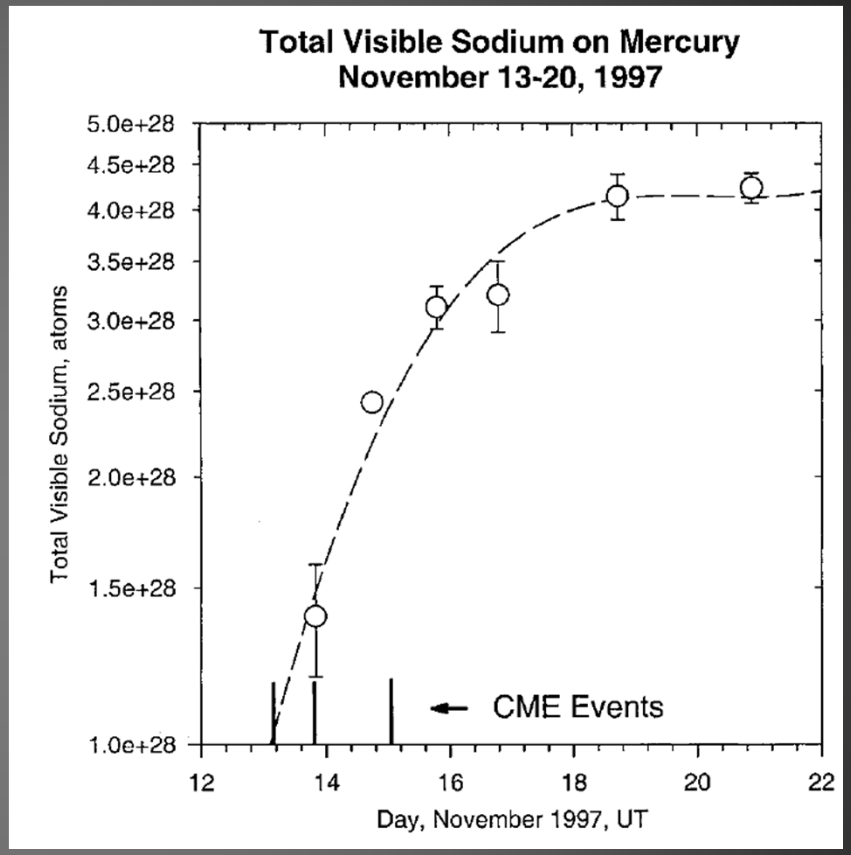
(Hale Bopp)[Cremonese et al., 1997]

The diameter of 1999JU3 is ~900m.

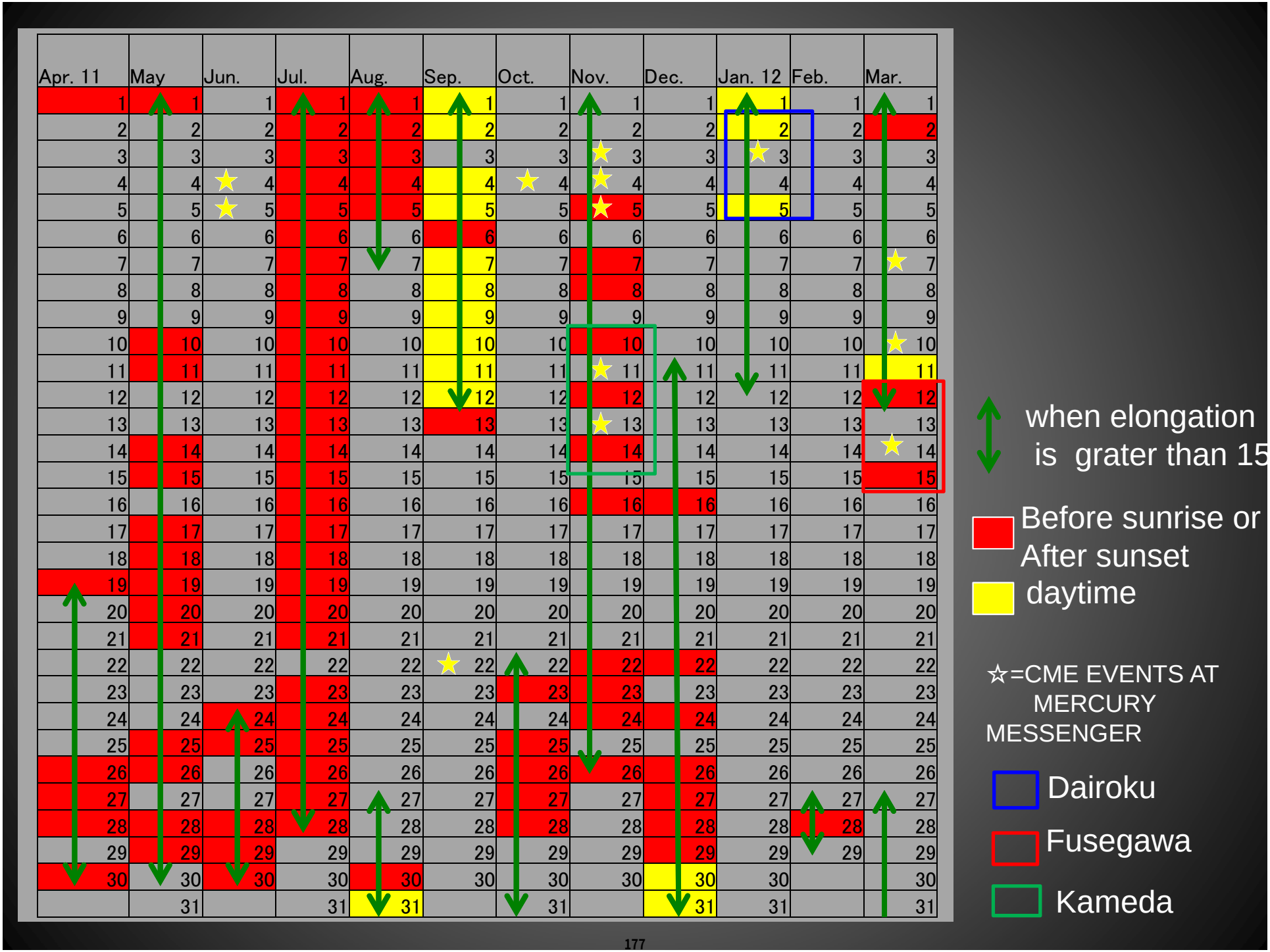
→Na emission is 1-100R (M&M),or100kR(C)

Rapid change observed in the past

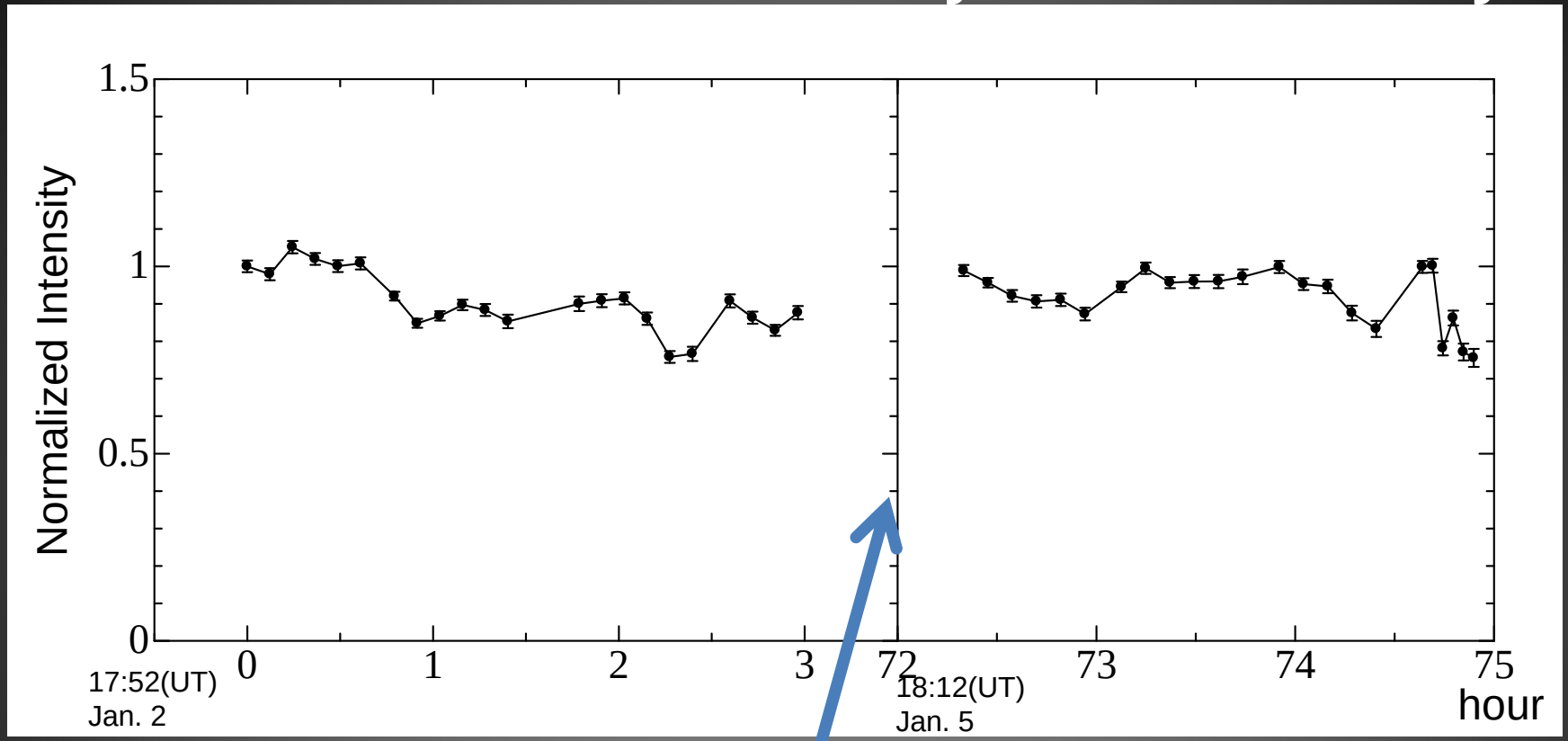




Potter et al., 1999 explained that the increase was possibly caused by CME. (and no other candidate)


Apr. 11
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan. 12
Feb.
Mar.
when elongation is grater than 15
Before sunrise or After sunset
daytime
☆=CME EVENTS AT MERCURY MESSENGER
Dairoku
Fusegawa
Kameda

Short-term variability of Na density



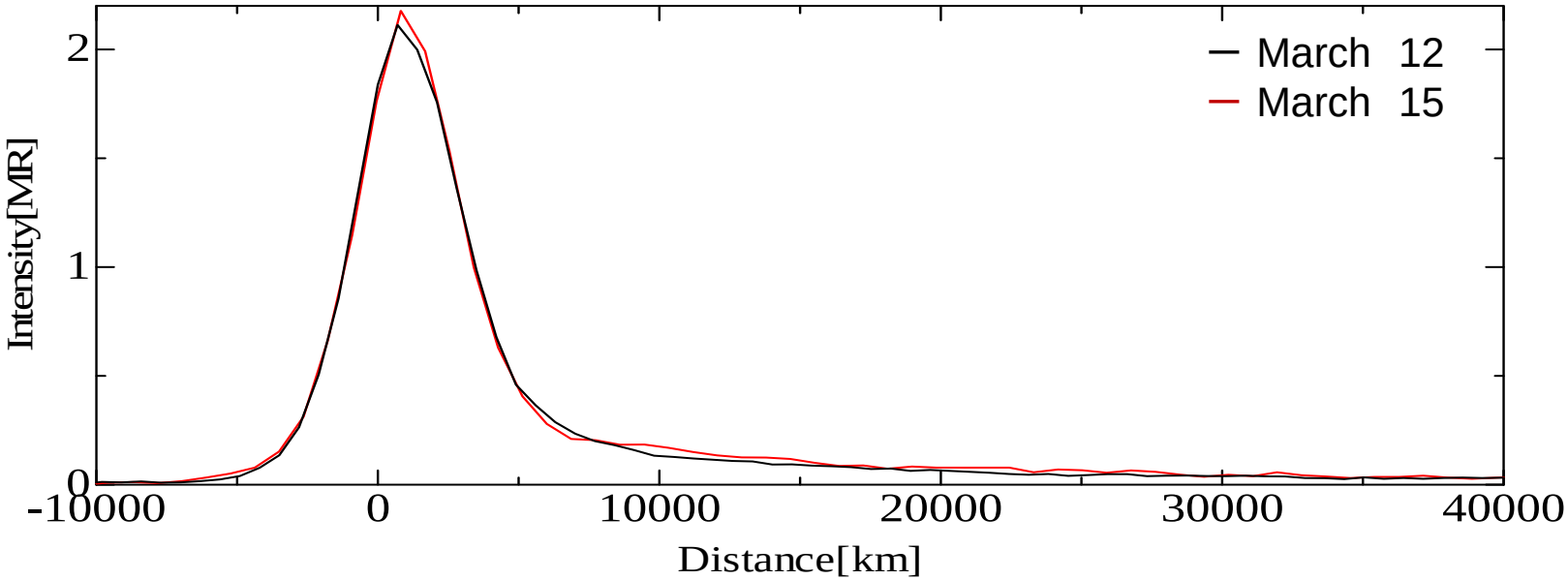
error＜～2.7%

	Jan. 2	Jan. 5
γ	0.37116	0.30123

CME EVENTS AT MERCURY MESSENGER

Dairoku et al.
Presented on Apr 3

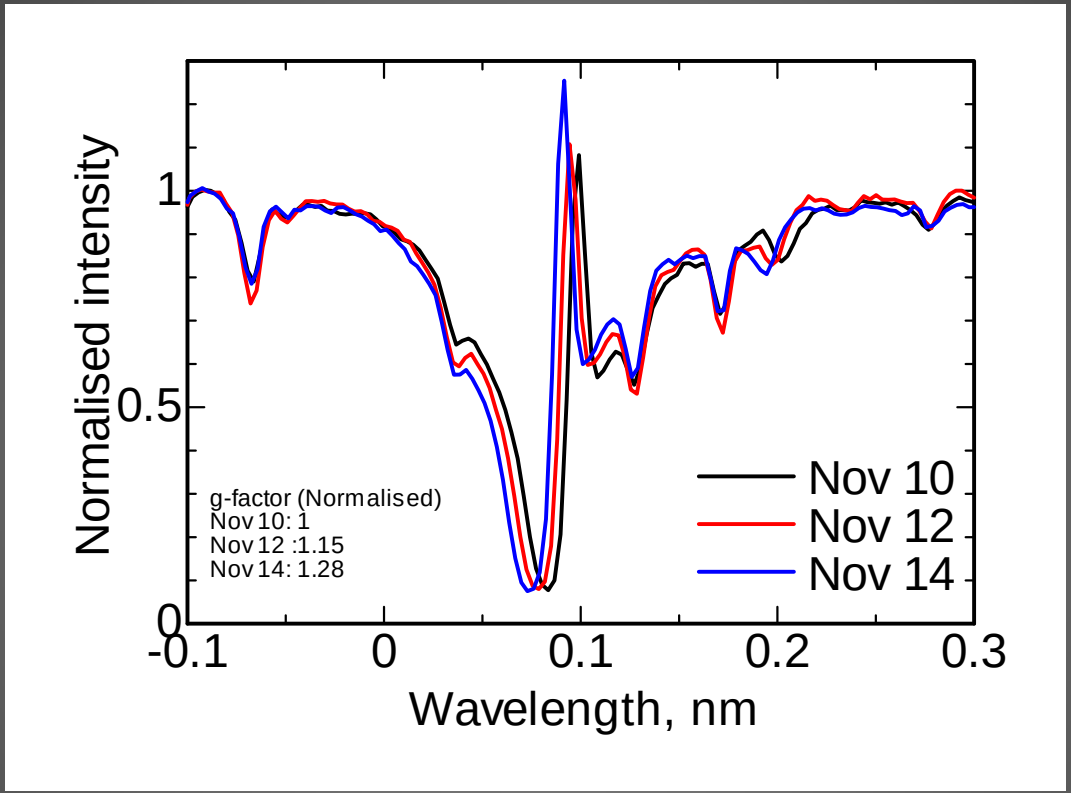
Jan. 3 02 hours +/- 7 1152 km/sec head on



- Based on preliminary heliospheric modeling carried out at NASA GSFC Space Weather Center, it is estimated that the CMEs reached Mercury at about March 14, 2012, 07:12 (plus minus 7 hours)

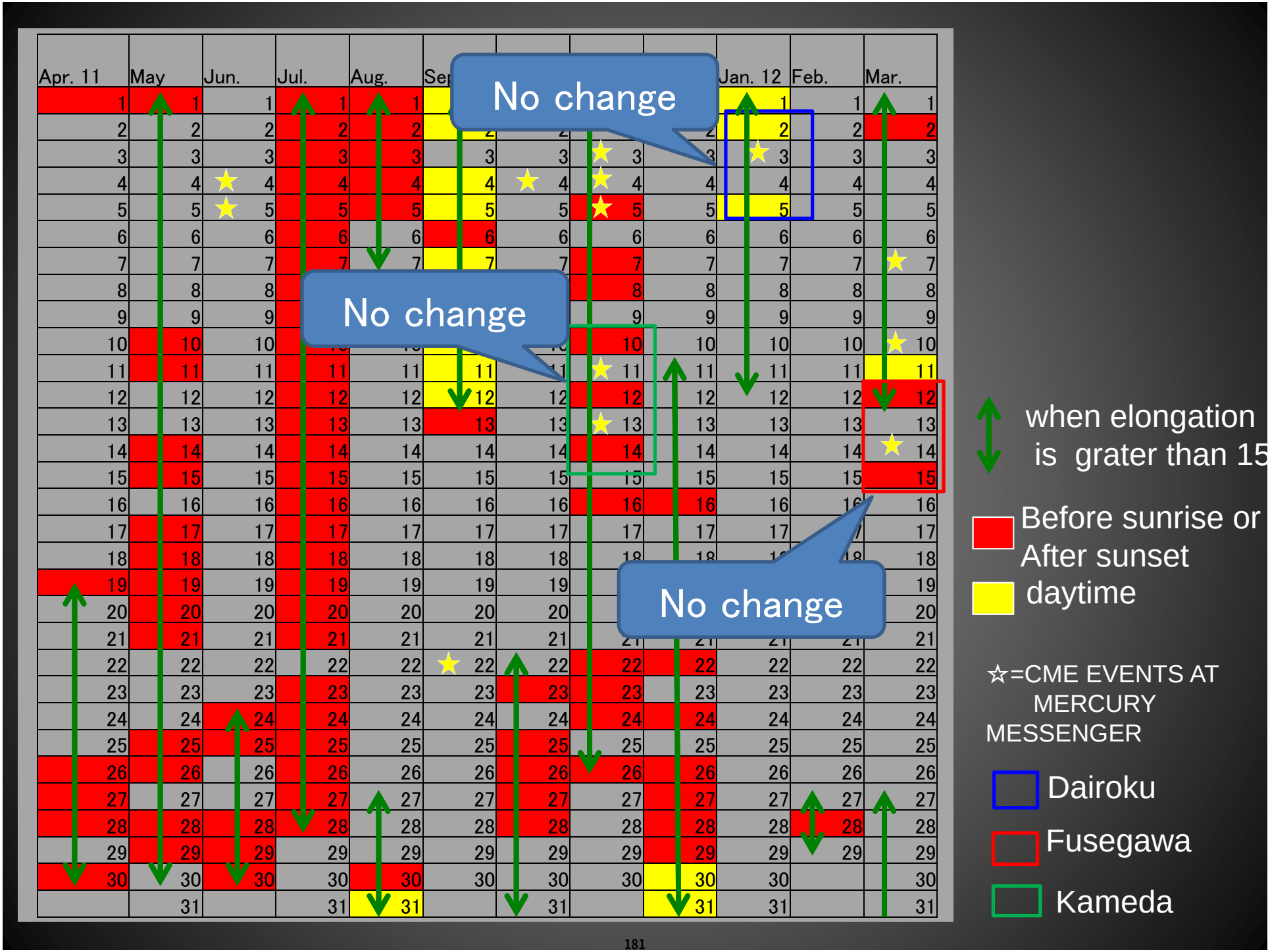
→ No significant change between March 12 and 15.

Preliminary result



The spectrum on the equator of Mercury.

MESSENGER detected CME on Nov 11 and 13.
→No significant variation in sodium exosphere


Apr. 11
May
Jun.
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Jan. 12
Feb.
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No change
No change
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when elongation is grater than 15
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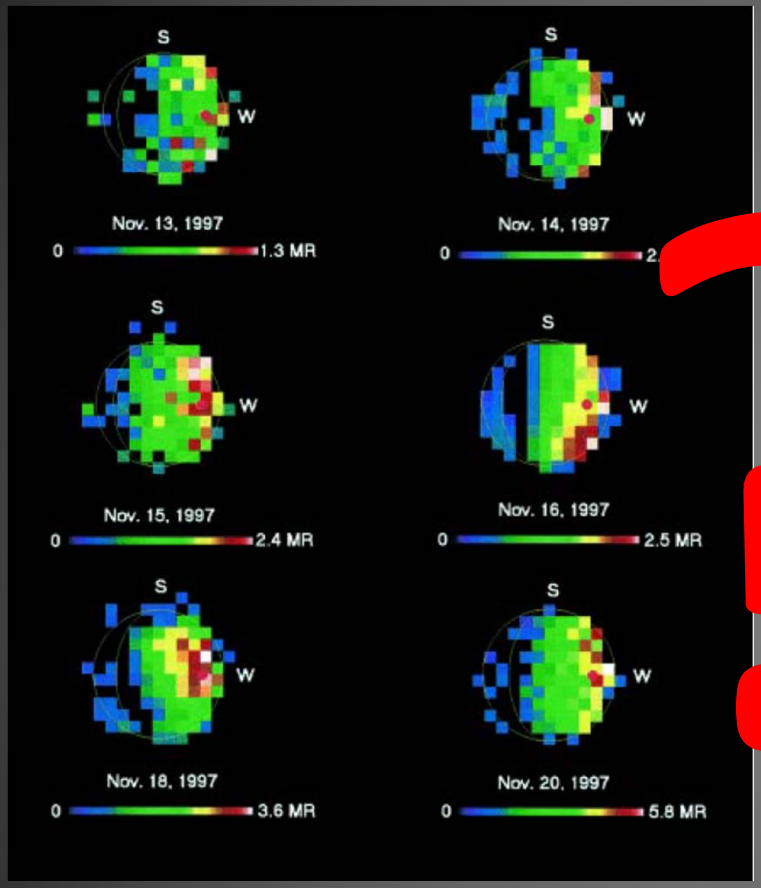
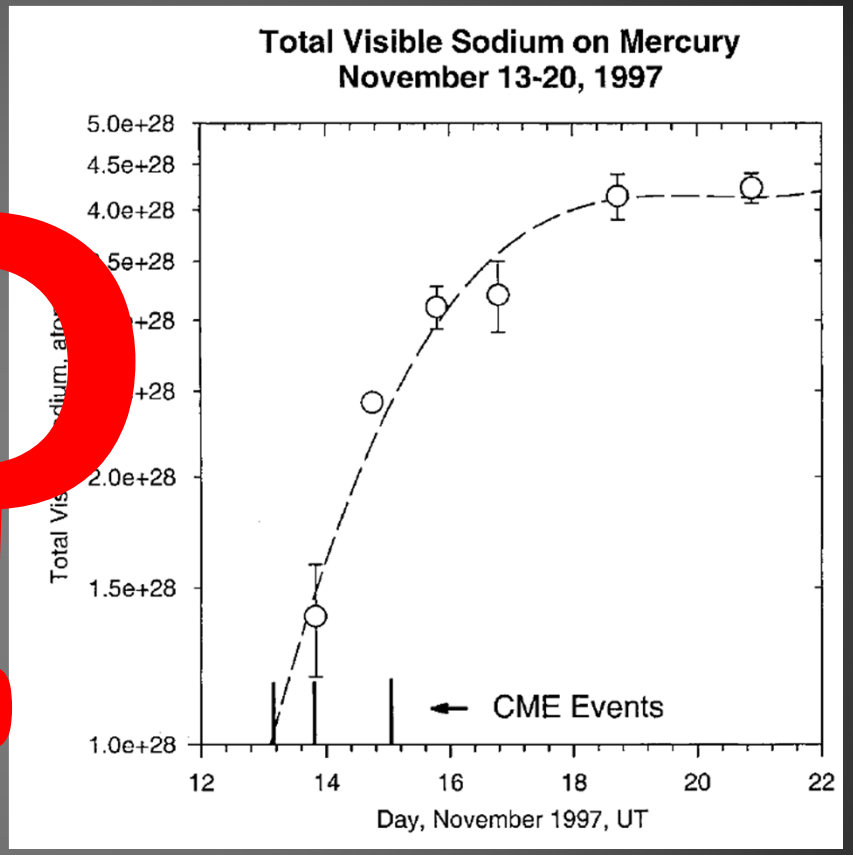
Rapid change in the past?





Potter et al., 1999 explained that the increase was possibly caused by CME. (and no other candidate)

The plan in FY2012

Apr. 12	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 13	Feb.	Mar.
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10
11	11	11	11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12	12	12	12
13	13	13	13	13	13	13	13	13	13	13	13
14	14	14	14	14	14	14	14	14	14	14	14
15	15	15	15	15	15	15	15	15	15	15	15
16	16	16	16	16	16	16	16	16	16	16	16
17	17	17	17	17	17	17	17	17	17	17	17
18	18	18	18	18	18	18	18	18	18	18	18
19	19	19	19	19	19	19	19	19	19	19	19
20	20	20	20	20	20	20	20	20	20	20	20
21	21	21	21	21	21	21	21	21	21	21	21
22	22	22	22	22	22	22	22	22	22	22	22
23	23	23	23	23	23	23	23	23	23	23	23
24	24	24	24	24	24	24	24	24	24	24	24
25	25	25	25	25	25	25	25	25	25	25	25
26	26	26	26	26	26	26	26	26	26	26	26
27	27	27	27	27	27	27	27	27	27	27	27
28	28	28	28	28	28	28	28	28	28	28	28
29	29	29	29	29	29	29	29	29	29	29	29
30	30	30	30	30	30	30	30	30	30		30
	31		31	31		31		31	31		31

↕ when elongation is grater than 15°

Before sunrise
After sunset

daytime

☆=CME EVENTS AT MERCURY MESSENGER