Nishino et al., Icarus, 2015.
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Electrons on closed field lines of lunar crustal fields in the solar wind wake

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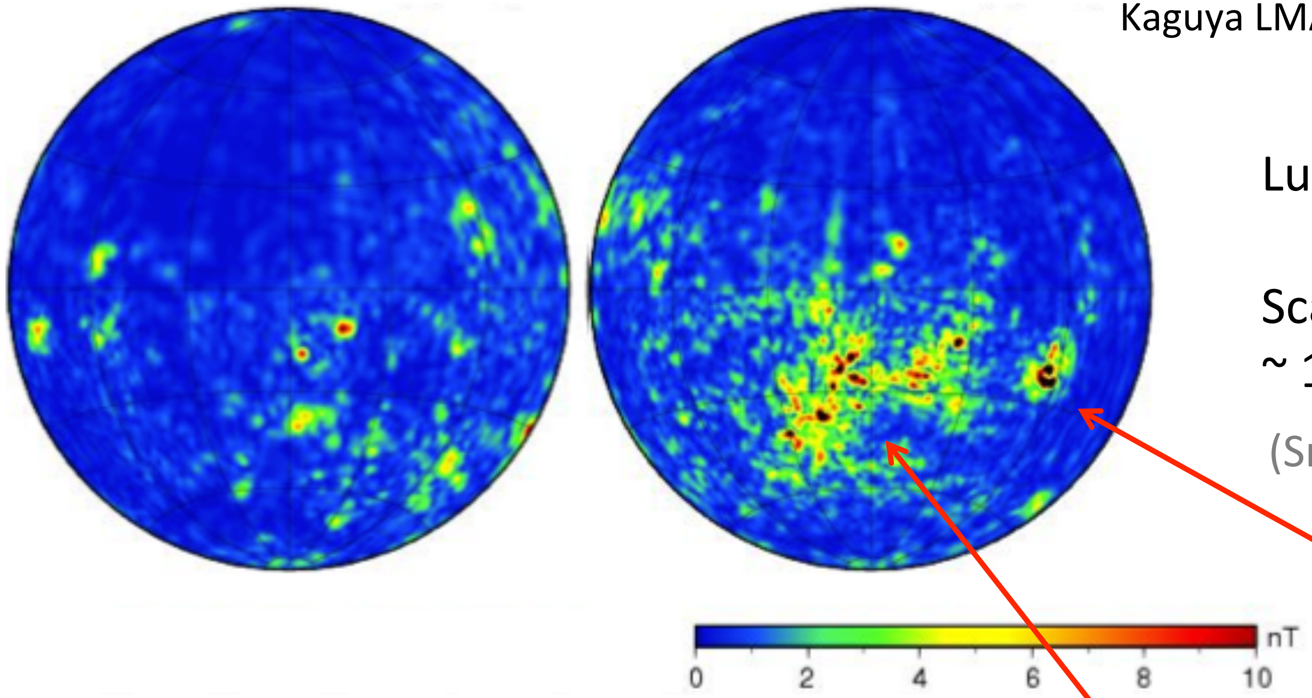
Masaki N. Nishino[1], Yoshifumi Saito[2], Hideo Tsunakawa[3], Futoshi Takahashi[4], Masaki Fujimoto[2], Yuki Harada[5], Shoichiro Yokota[2], Masaki Matsushima[3], Hidetoshi Shibuya[6], Hisayoshi Shimizu[7]

1 Nagoya Univ 2 JAXA 3 Tokyo TECH 4 Kyushu Univ 5 SSL/UCB 6 Kumamoto Univ 7 ERI, Univ Tokyo

Lunar crustal magnetic fields

nearside　　　　farside

Kaguya LMAG 30 km alt.



Lunar radius = 1738 km

Scale of magnetized area
~ 100-1000 km

(Smaller than Mars')

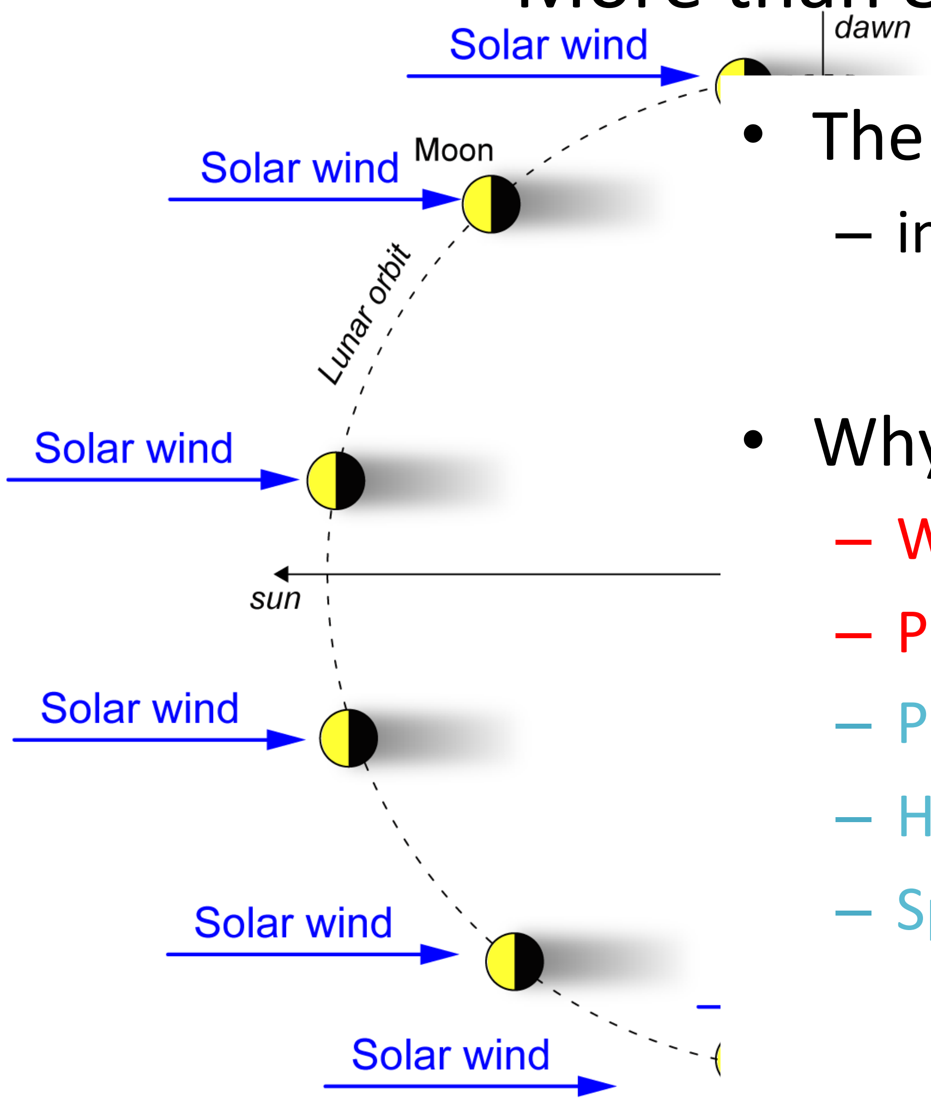
Crisium Antipode

SPA (South Pole - Aitken) basin

Alt.	effect
100 km	1-2 nT
30 km	~20 nT
surface	~300 nT

Cf. Interplanetary magnetic field at 1 AU ~ several nT

More than 80 % of time ...

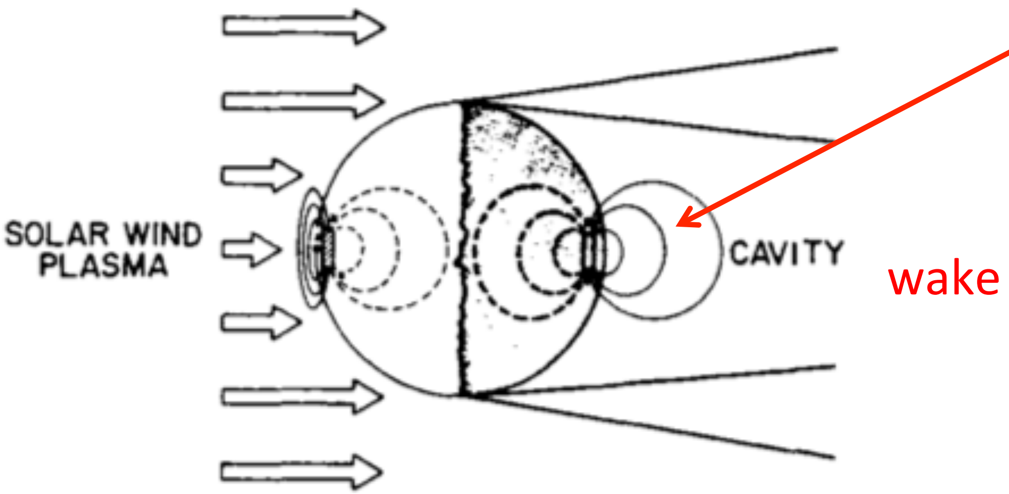


- The moon stays in the solar wind
  - interaction btwn SW and the Moon
- Why important ?
  - Wake formation behind the moon
  - Plasma refilling into the wake
  - Particle/dust acceleration
  - Hazardous in future missions
  - Space plasma and planetary surface
    - no thick atmosphere
    - no intrinsic magnetic field

What happens in the solar wind wake ?

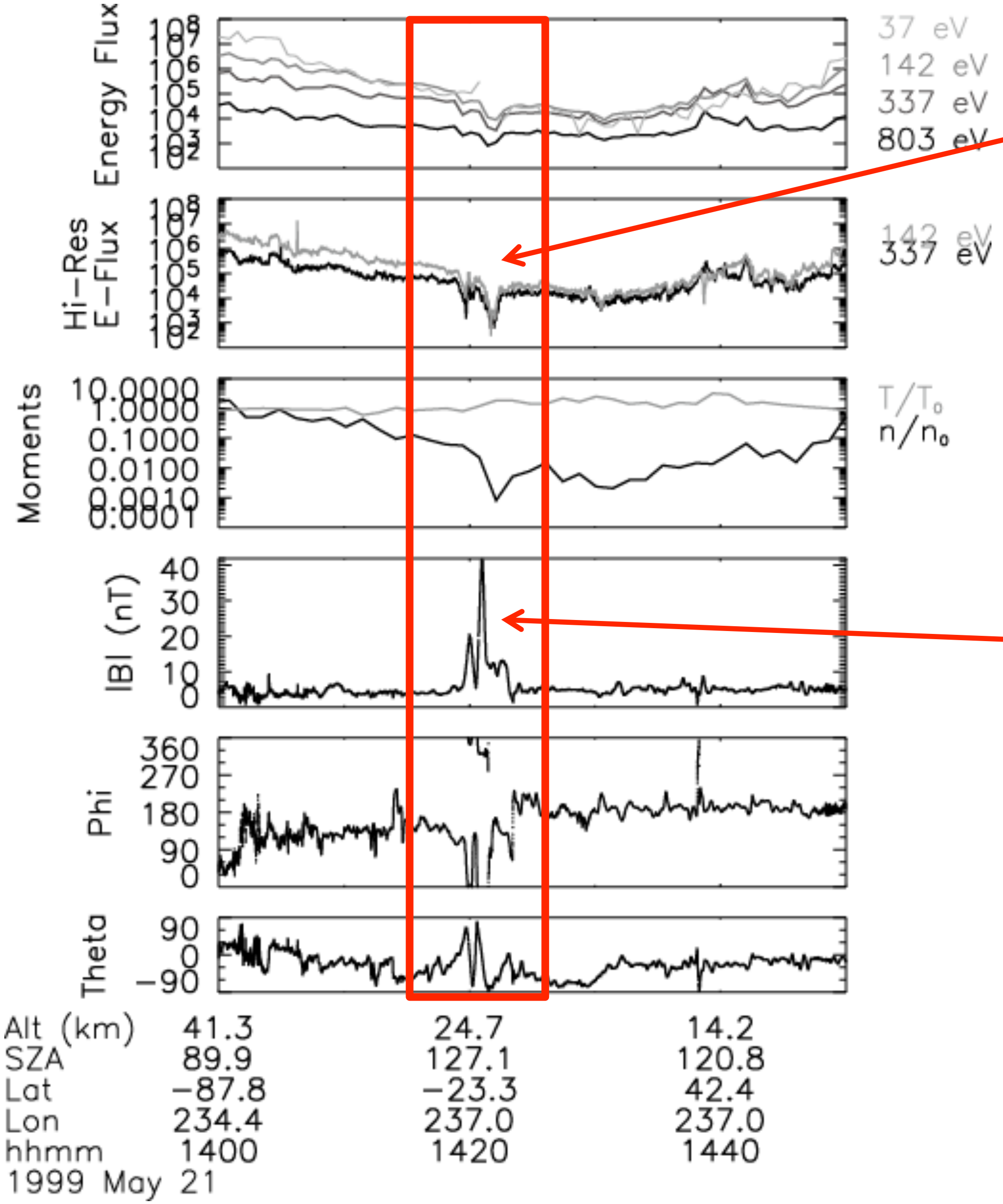
- Plasma cavity? (Cavity in the plasma void?)
- Mini-magnetosphere filled with plasma?

What happens here?
Cavity or mini-magnetosphere?



Dyal et al. Nature 1972

Previous observations (Lunar Prospector)



Decrease in the electron flux in the vicinity of the CA anomaly

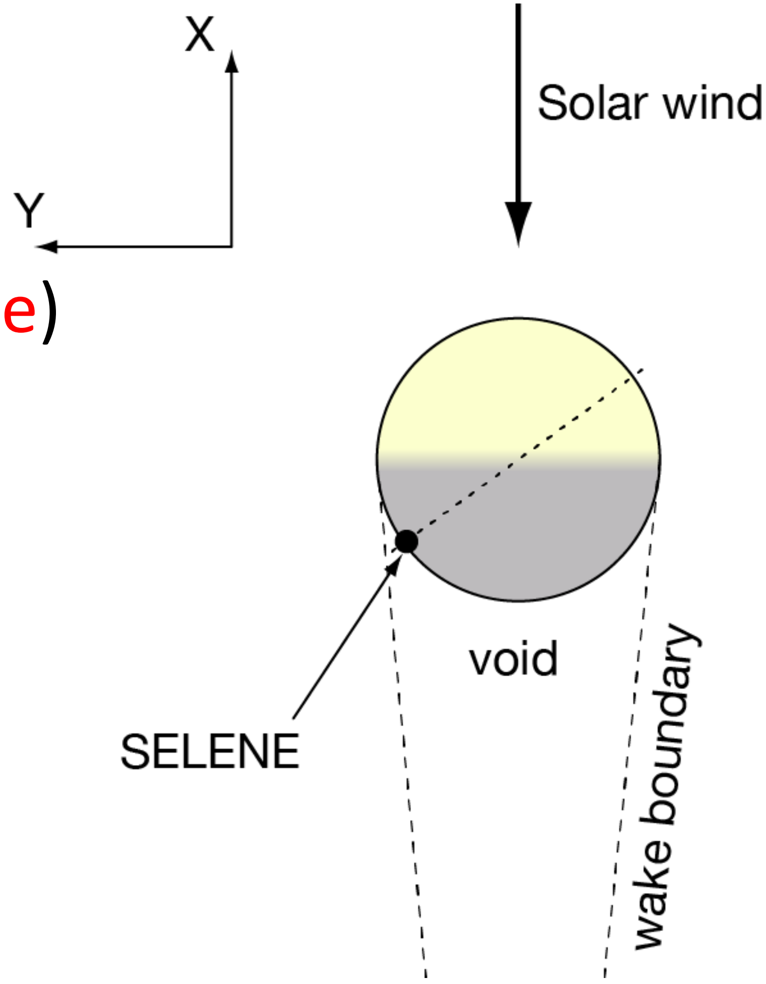
An enhancement in the magnetic field magnitude over the CA anomaly

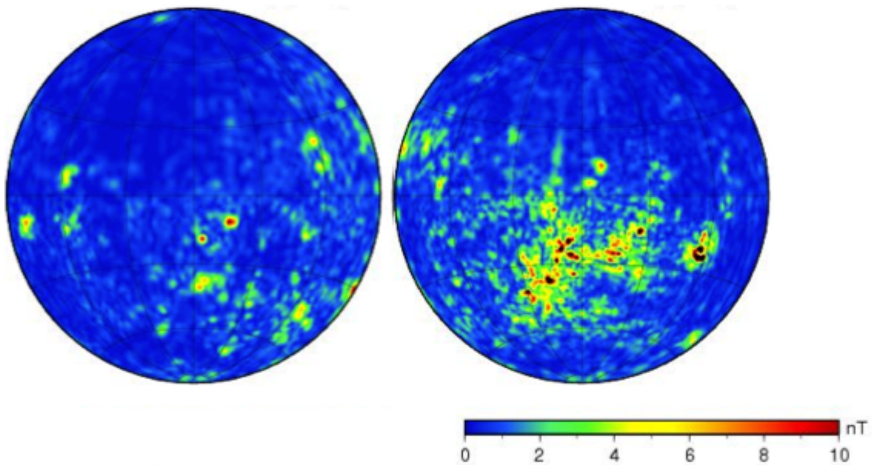
(Halekas+2008 PSS)

Our data

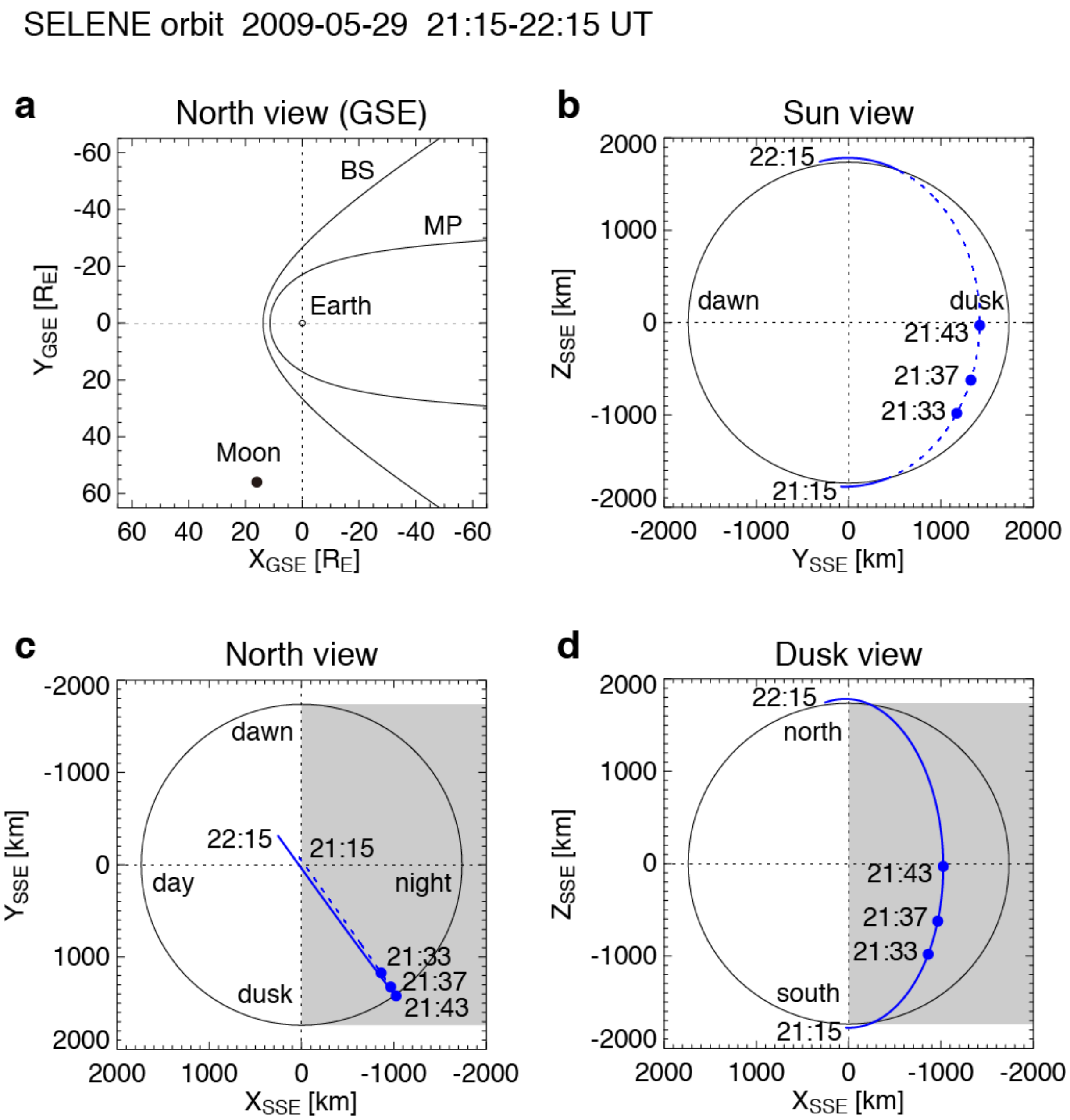
- Kaguya (SELENE) observations
- PACE+LMAG
- 14-15 km over Crisium Antipode
- Longitude = 126° in SSE (night side)

- 80 nT, 0.1 keV → r_{e_gyro} = 0.42 km





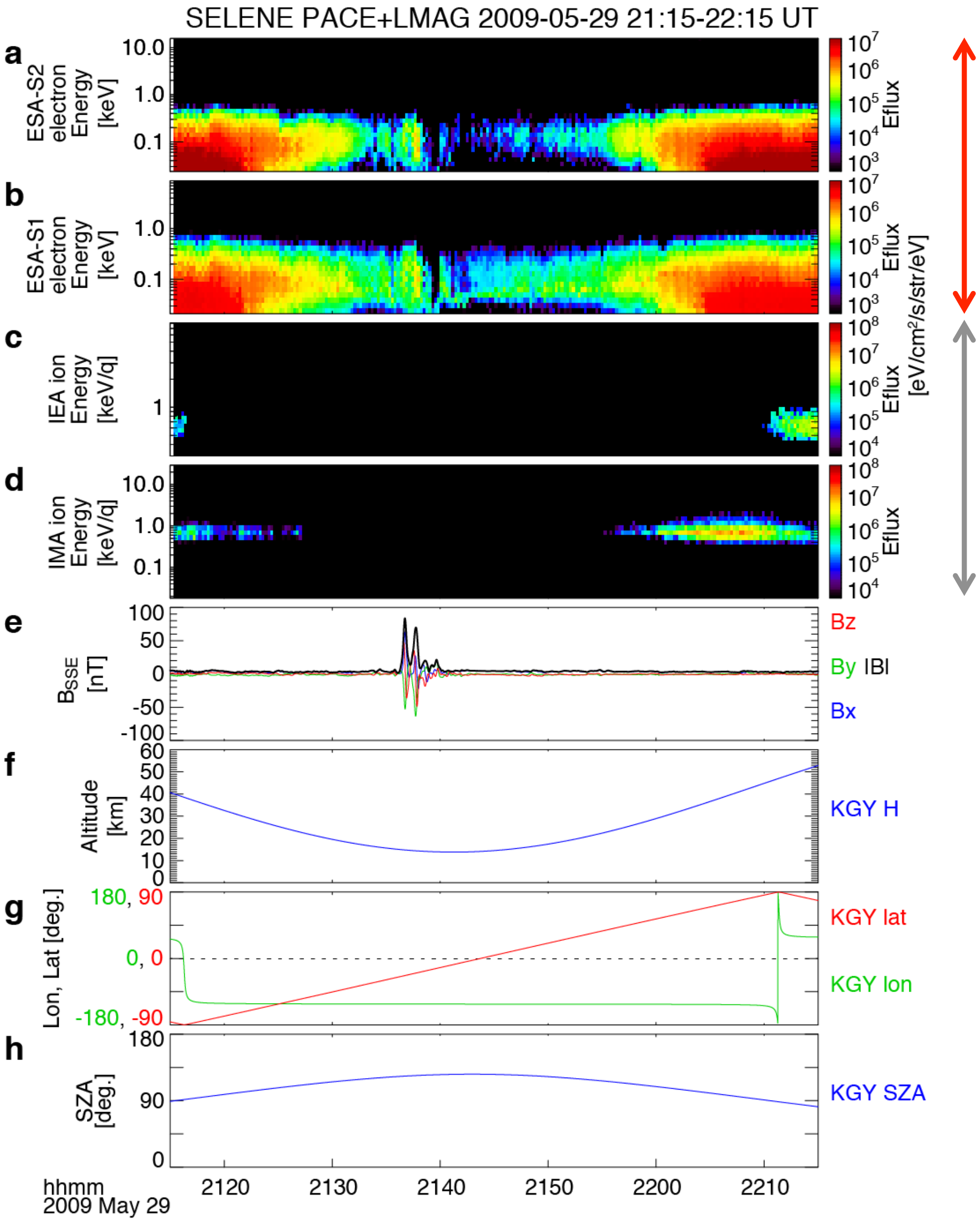
SELENE orbit (1h)



14-15 km over Crisium Antipode

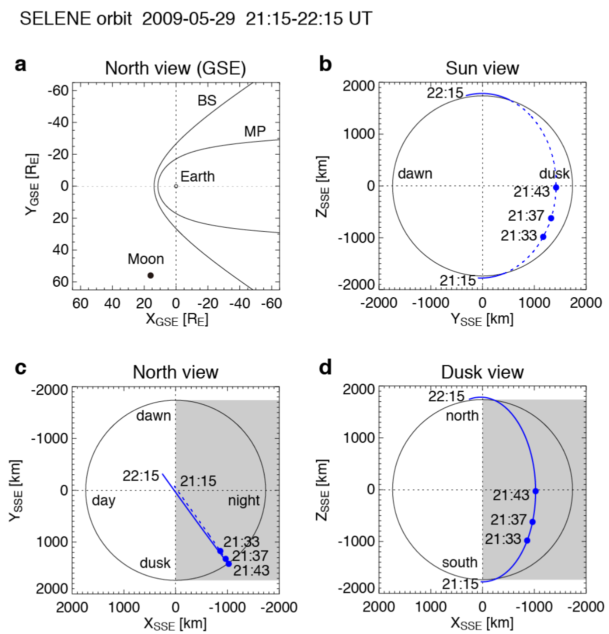
Longitude = 126° in SSE

Plasma and magnetic field over CA

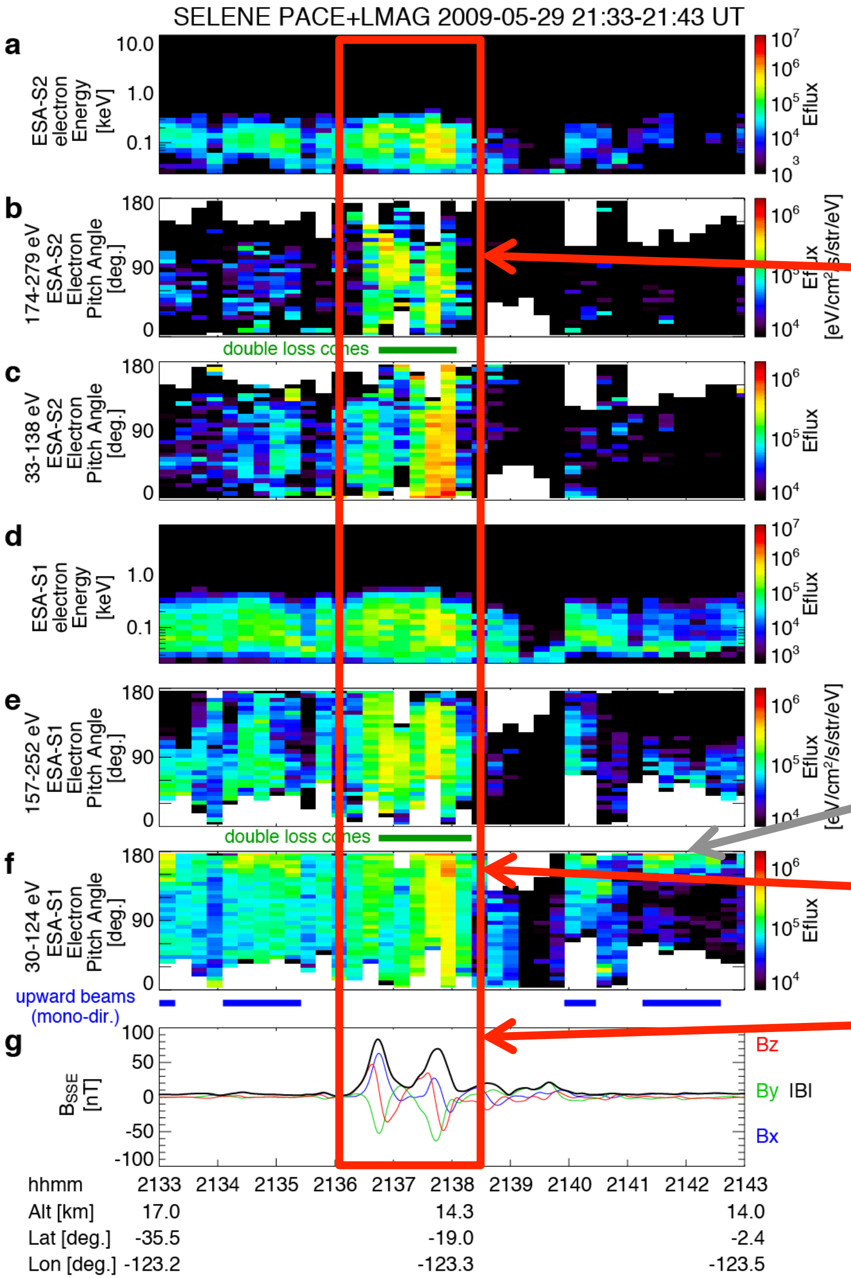


Alt: 14-15 km over CA

- High electron flux
- Large variation in B



Enhancement of electron flux (21:37 UT)



Magnetic field and electron flux enhance.

ESA-S2
(incl. downward-going e-)

double loss cones
in the medium energy range
→ closed magnetic fields

ESA-S1
(incl. upward-going e-)

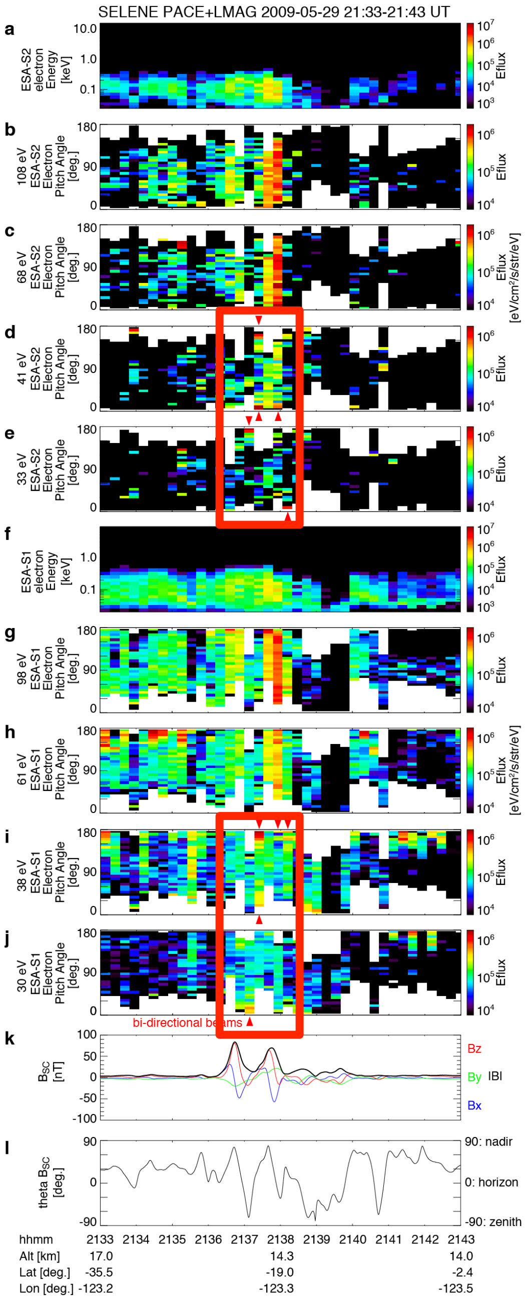
typical upward beams in the wake

field-aligned beams
in the low energy range

15 km alt. over
CA in the wake

Large variation in magnetic field direction along the orbit
➔ Need to investigate high-resolution data

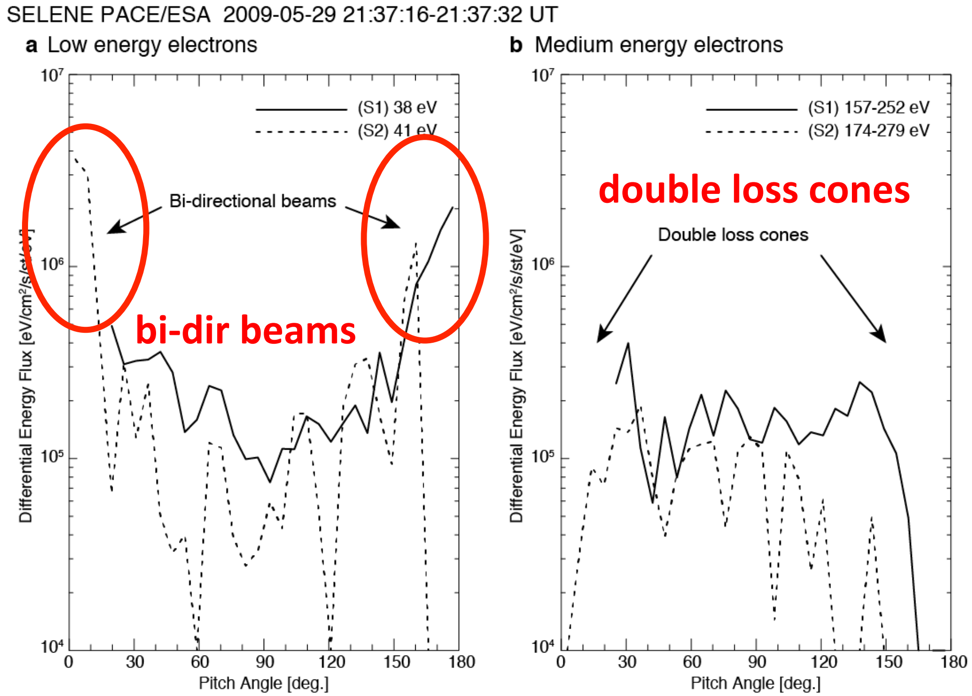
Bi-directional low-energy beams



ESA-S2
(incl. downward-going e-)

ESA-S1
(incl. upward-going e-)

Electron data at each energy are obtained for 0.5 sec



	beam energy	data period
S1	38 eV	21:37:18.0-21:37:18.5
S2	41 eV	21:37:17.5-21:37:18.0

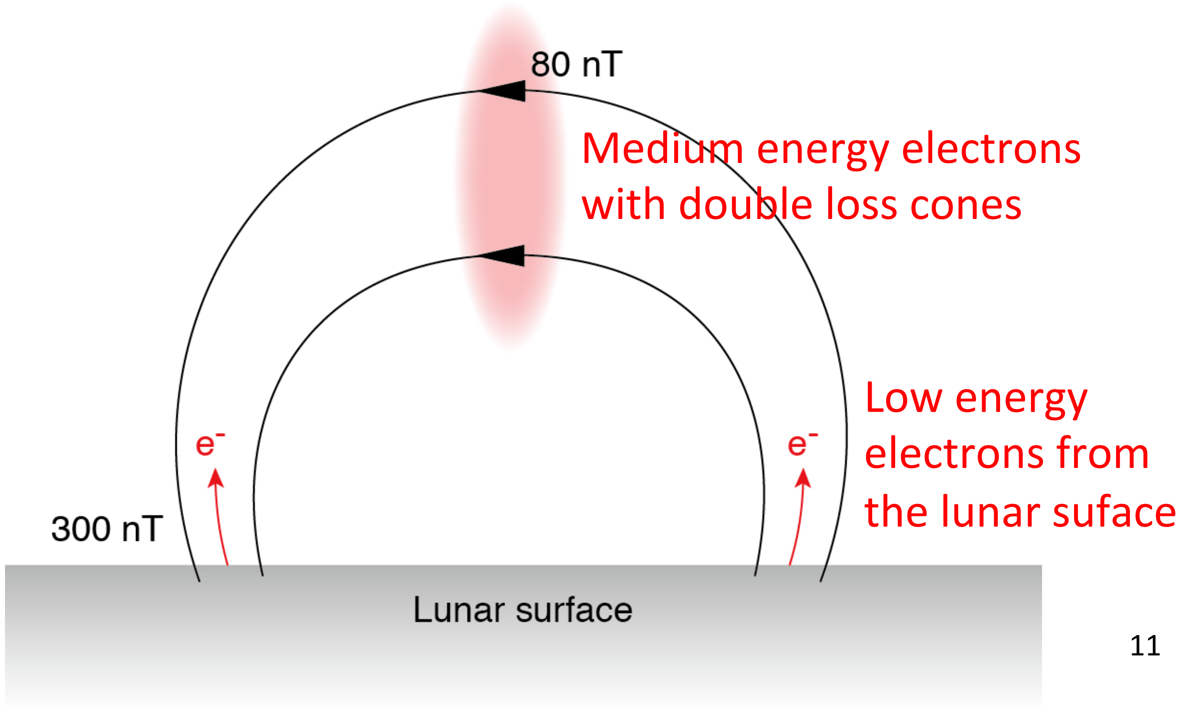
Closed magnetic field

Loss cone angle

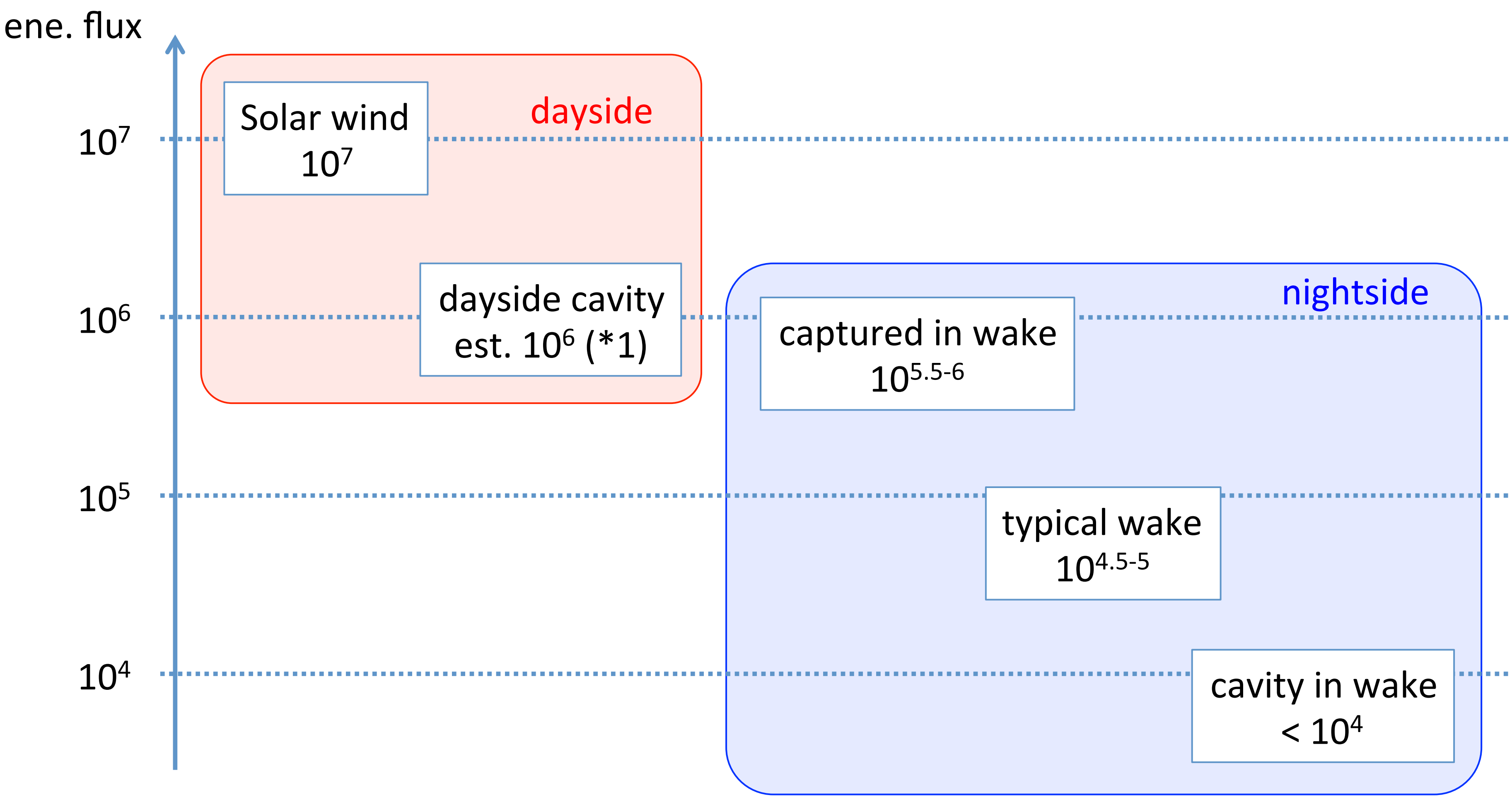
- 300 nT at the footprints, 80 nT at 15 km altitude
- Loss-cone angle (at 15 km alt.) = 31 degrees
- Double loss-cone in the middle energy range
- Electron beams in the loss-cone angle are fresh electrons from the lunar night side surface

Loss cone angle

$$\frac{B_0}{B_M} = \sin^2\theta$$



Electron energy flux (about 100 eV)

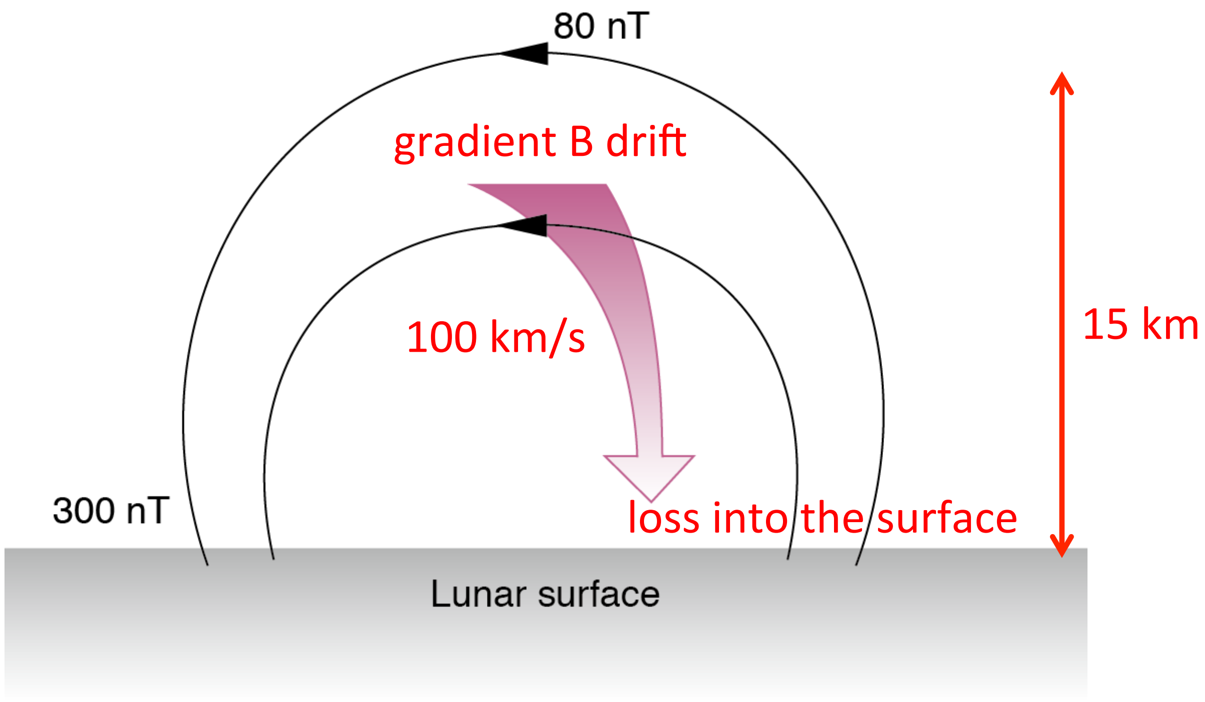


*1 An order-of-magnitude density drop near the terminator (SZA~81 deg) (Halekas+2008, PSS)

Gradient B drift

- grad B = 10 nT/km
- 100 eV electron
- Gradient drift speed of 100 km/s
- Quick loss into the lunar surface
- *How are electrons there? Supply??*

$$B(r) \propto r^{-3}$$



$$V_d = \left(\frac{\varepsilon_\perp}{qB^3}\right)\left(B \times \nabla B\right)$$

$$\varepsilon_\perp = \frac{1}{2} m v_\perp^2$$

Summary & Discussion

- Trapped electrons 15 km over CA anomaly in the wake
- Bi-directional low-energy electron beams (<100eV)
- Double loss cones (medium energy)

→ Closed magnetic fields

- Loss into lunar surface by grad B drift at 100 km/s
- How are hot electrons supplied to the closed field lines?
  - Do electrons move around the surface to come to CA?
  - Direct supply of SW electrons along Parker-spiral IMF?

- What can we see at different altitudes (e.g. 50 km) ?
- Comparison between observed and model fields