Remote sensing of the electric potential on the lunar surface

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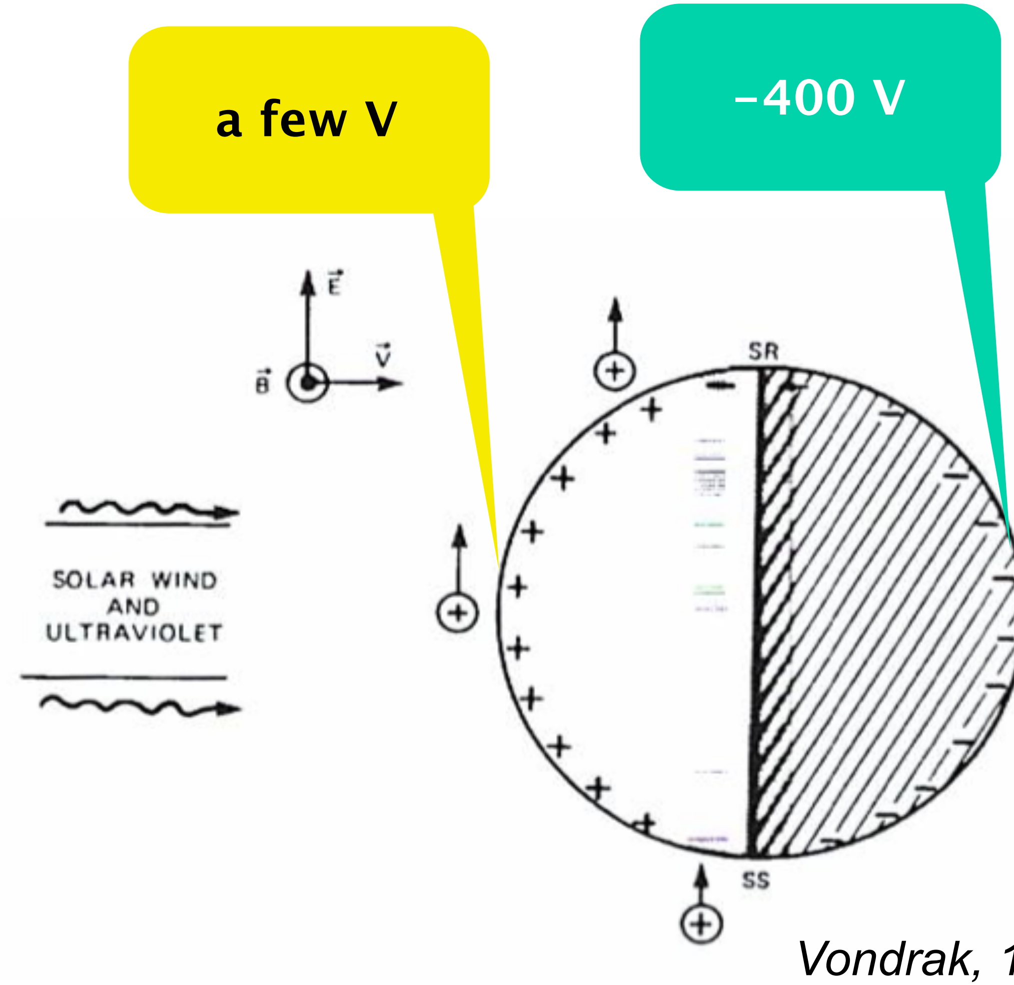
Potential of the lunar surface

- Measurements of the lunar surface potential are required both for understanding plasma and dust dynamics in the Moon environment and coming human surface exploration

- The high surface potentials may be hazardous for space systems

- Nominally, a few V on the dayside but may reach -400V on the night side.



Vondrak, 1983

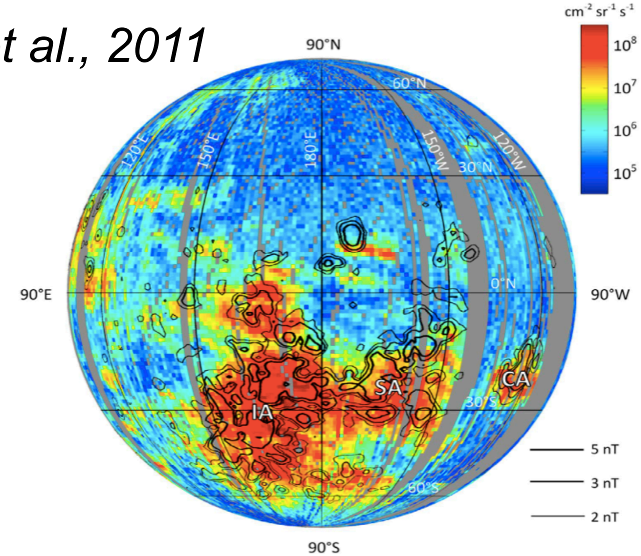
Magnetic Anomalies

- How do anomalies affect the surface potential? Any relations to the albedo variation in swirls?

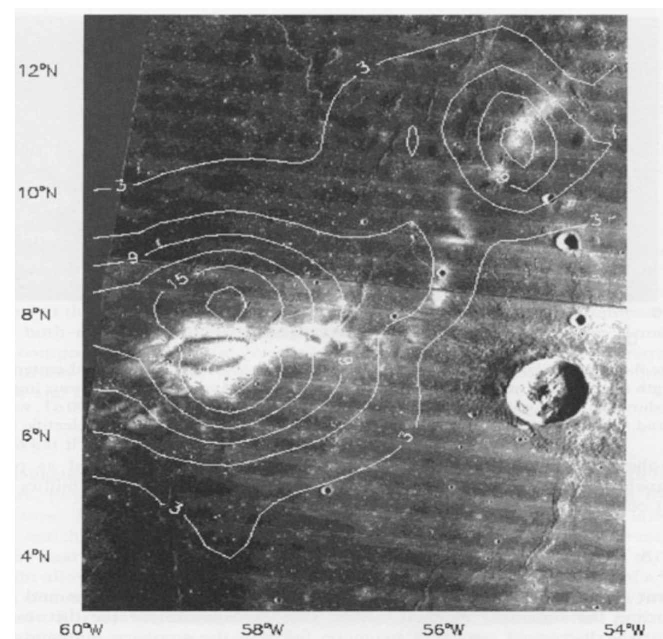
- The lunar crust exhibits the regions of strong magnetization (lunar magnetic anomalies)
  - Maximum strength is ~300 nT at the surface

- Strong influences on the local plasma and dust environments. The solar wind flow is strongly affected

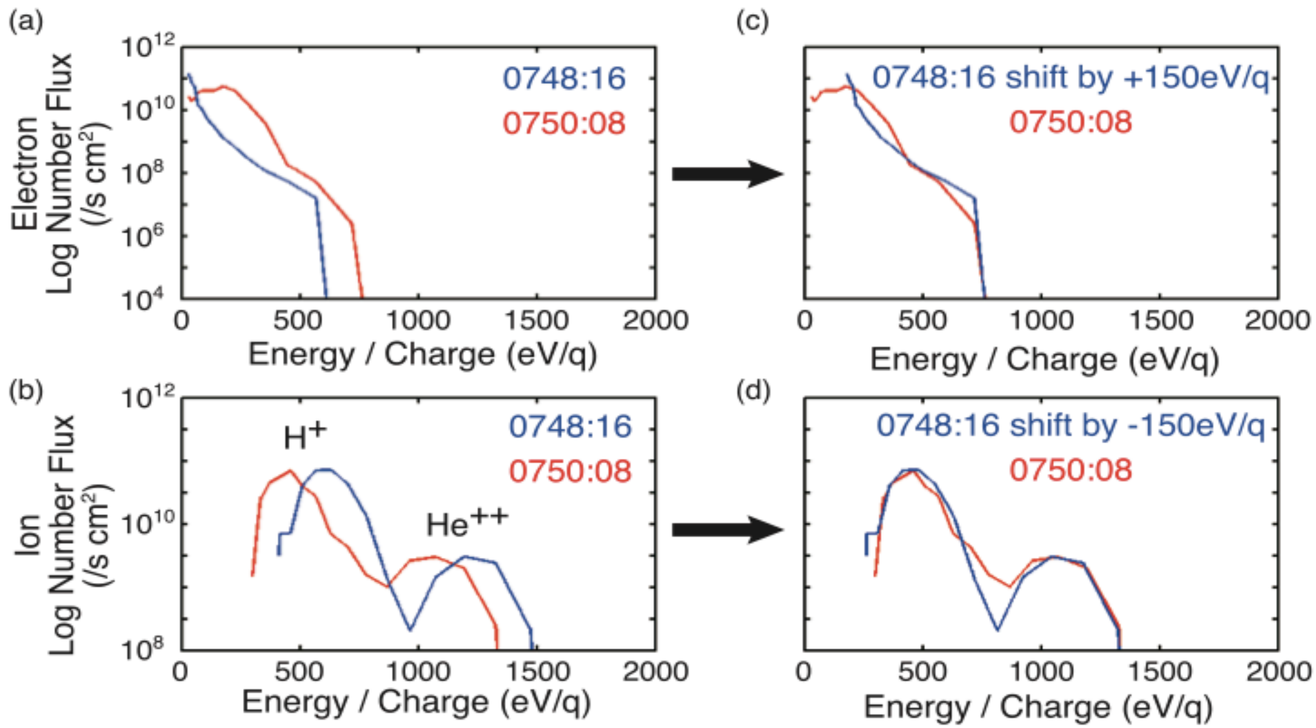
Lue et al., 2011



Hood et al., 2001



Surface potential inside an anomaly

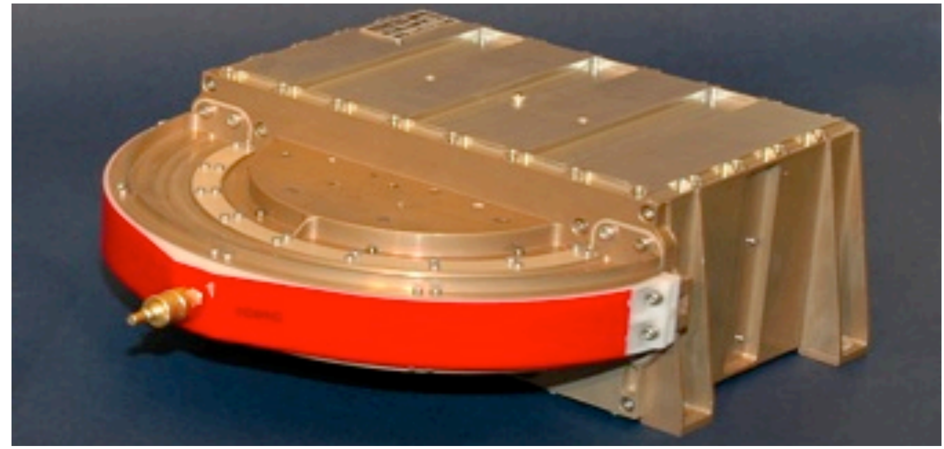


Saito et al., 2012

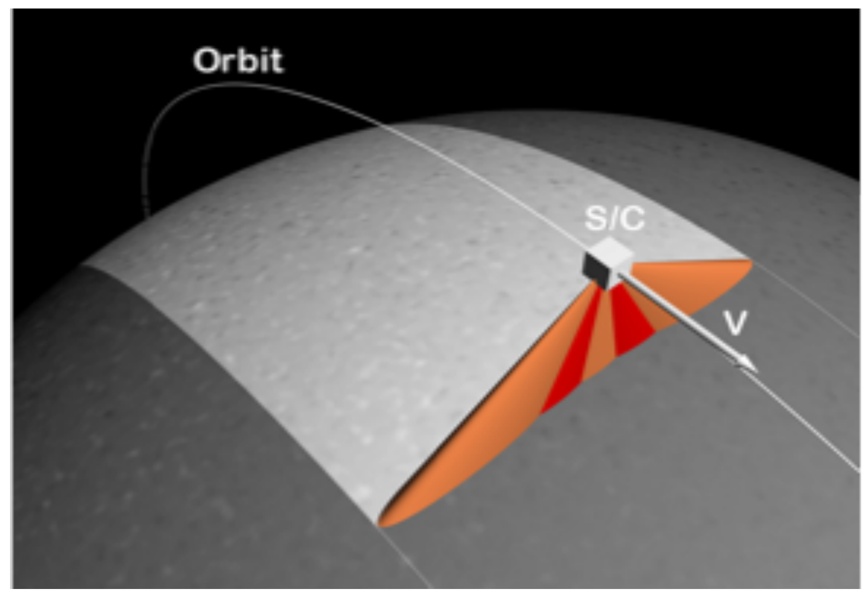
- *Saito et al., 2012* suggested electrostatic potential +150 V/q from the difference of ion and electron energy spectra inside and outside of an anomaly.
- In situ data only provide information along the spacecraft orbit and indirect way of measuring the potential.
- Here we propose a technique to remotely study and map the surface potential using energetic neutral atom (ENA) diagnostics

ENA imager CENA onboard Chandrayaan-1

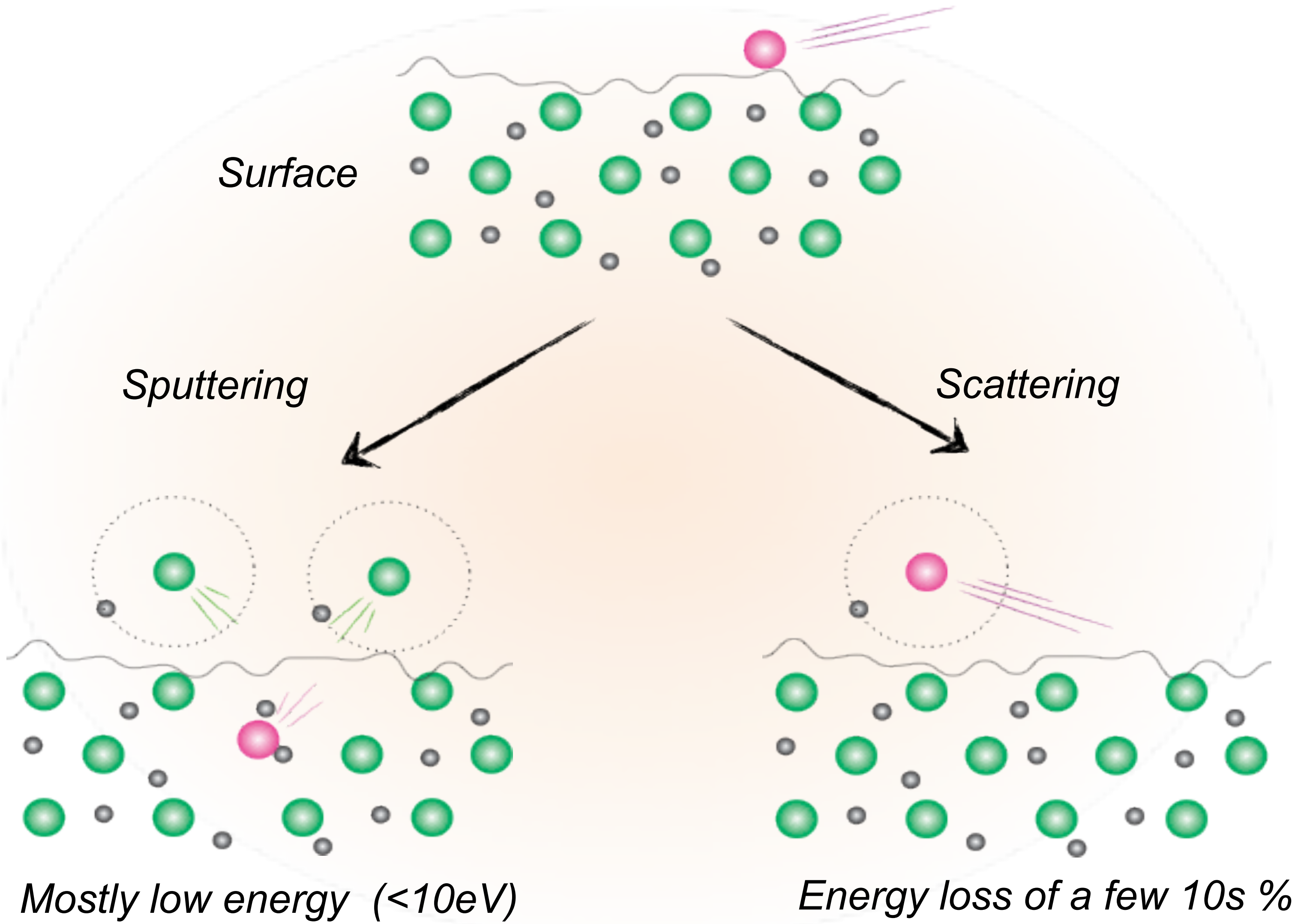
- Neutral atoms 10 eV – 3.3 keV
- 7 pixels of 9°x30° with 15°x160° FoV
- Scanning imaging from nadir pointing spacecraft
- Data for Jan-July 2009.



Barabash et al. 2009

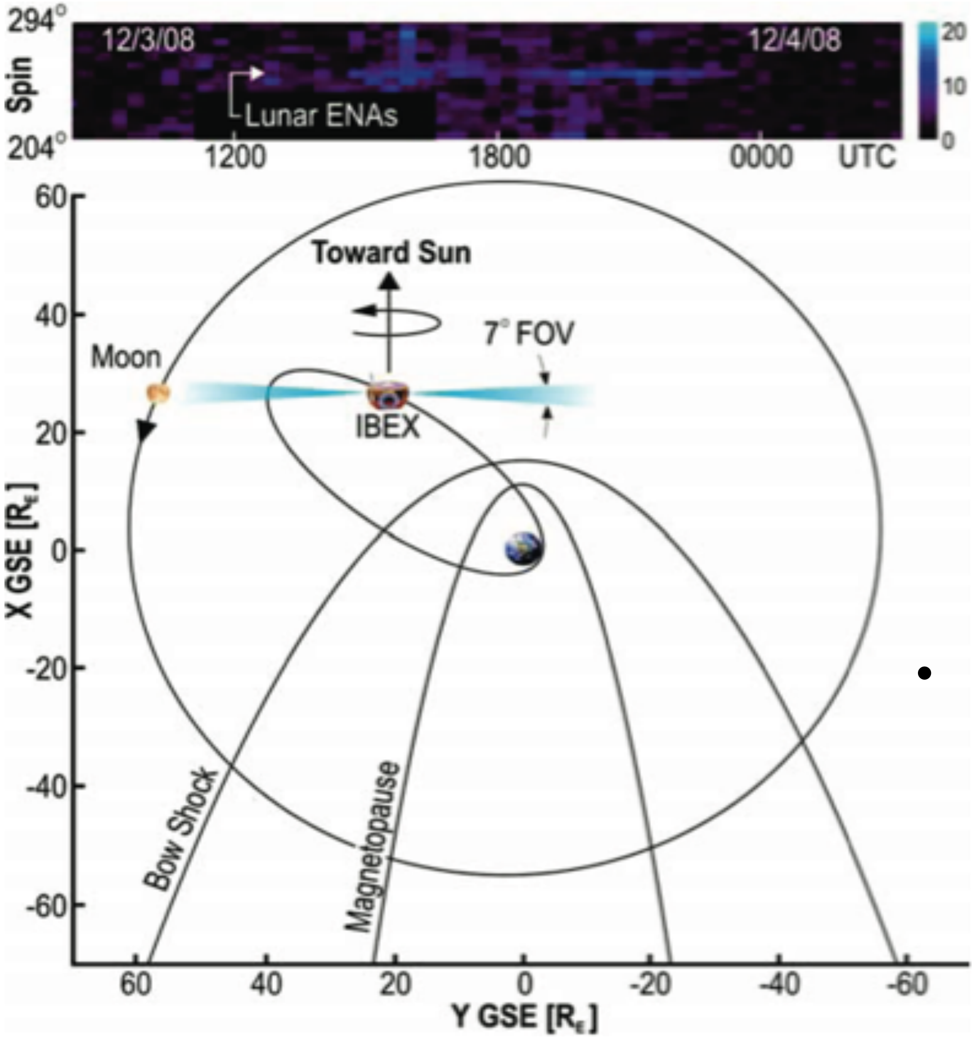


ENAs from the surface



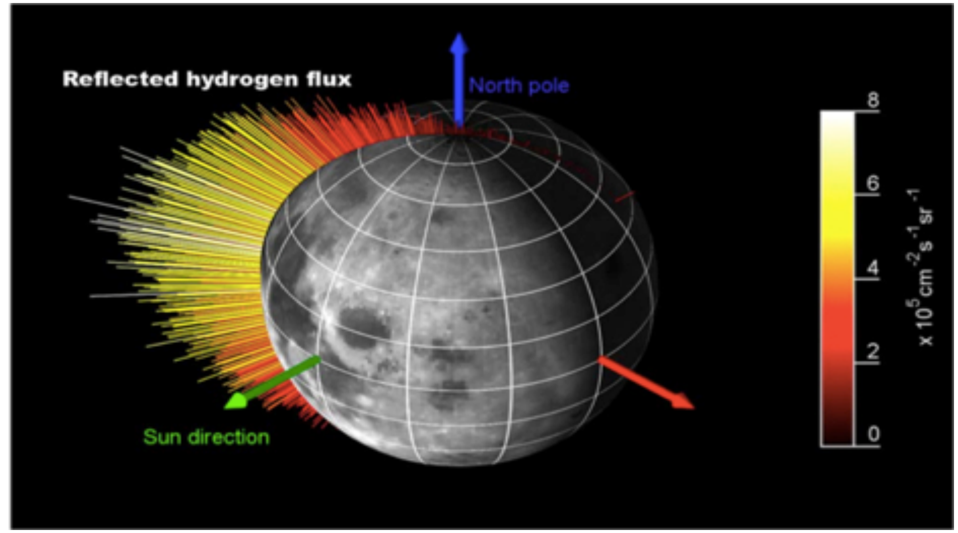
Discovery of backscattering ENAs

Lunar ENAs (IBEX)



McComas et al., 2009

Lunar ENAs (Chandrayaan-1/CENA)



Wieser et al., 2009

- Contrary expectations (>99% absorption), 10-20% of particles are scattered back from the porous regolith as neutrals, backscattered hydrogen.

Energy spectrum of backscattered ENAs

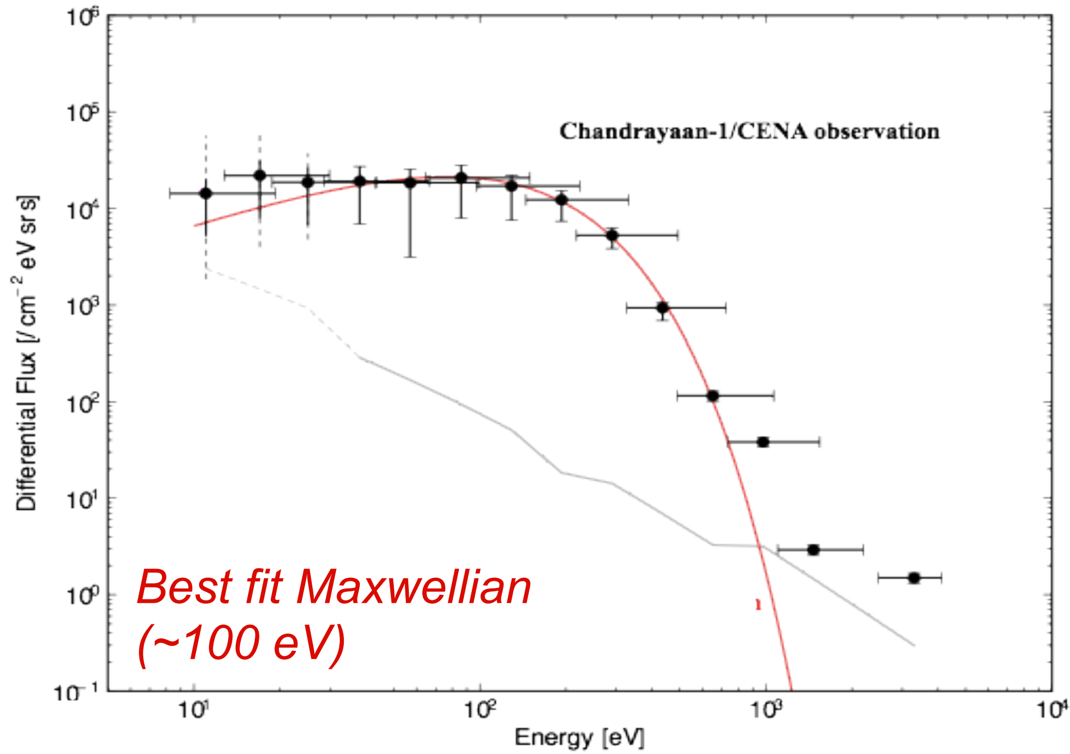
- Maxwellian spectrum with a temperature of ~60–140 eV

- Backscattering efficiency, r=0.19 (±0.03), independent of solar wind parameters

$$J(E) = \frac{rF_{\rm SW}}{2\pi} \frac{E}{(kT)^2} \exp\left(-\frac{E}{kT}\right)$$

r=0.19

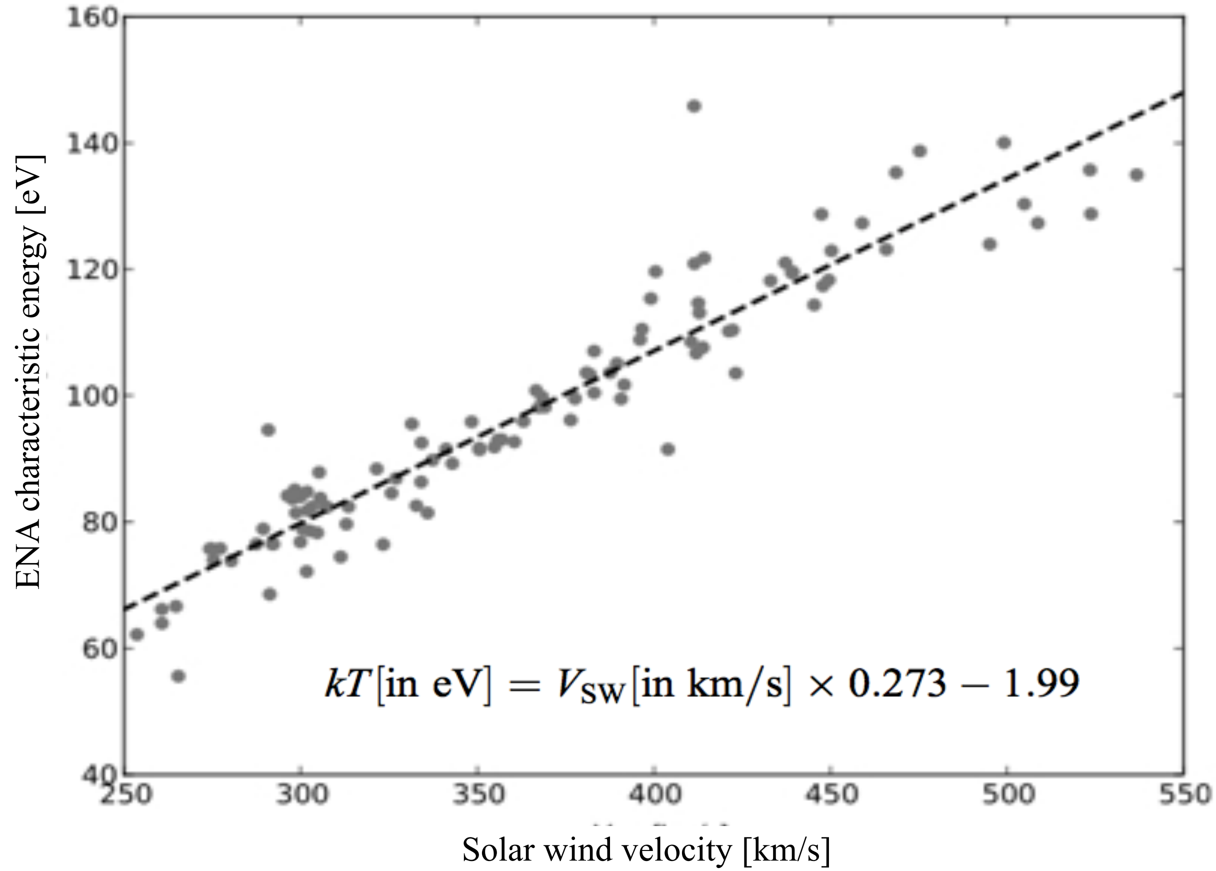
$$kT[\text{in eV}] = V_{\rm SW}[\text{in km/s}] \times 0.273 - 1.99$$



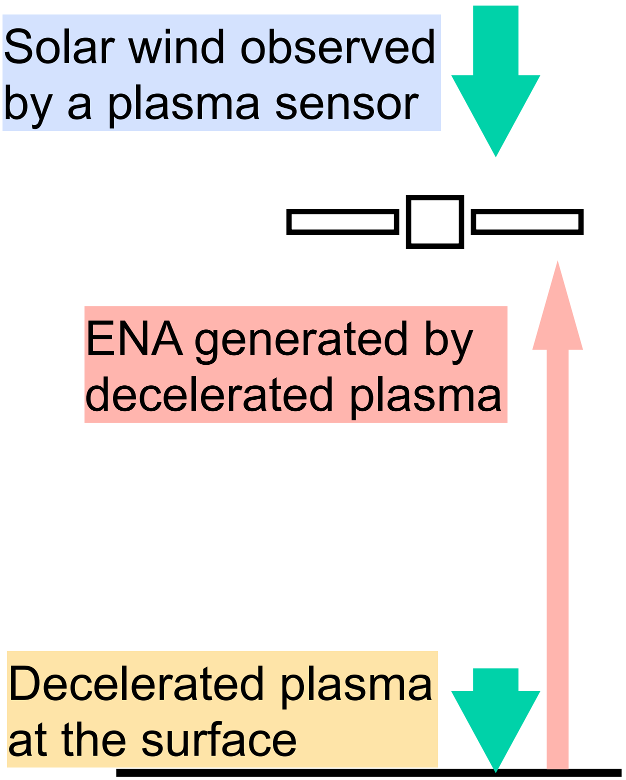
Futaana et al., 2012

Dependence on the impinging ion velocity

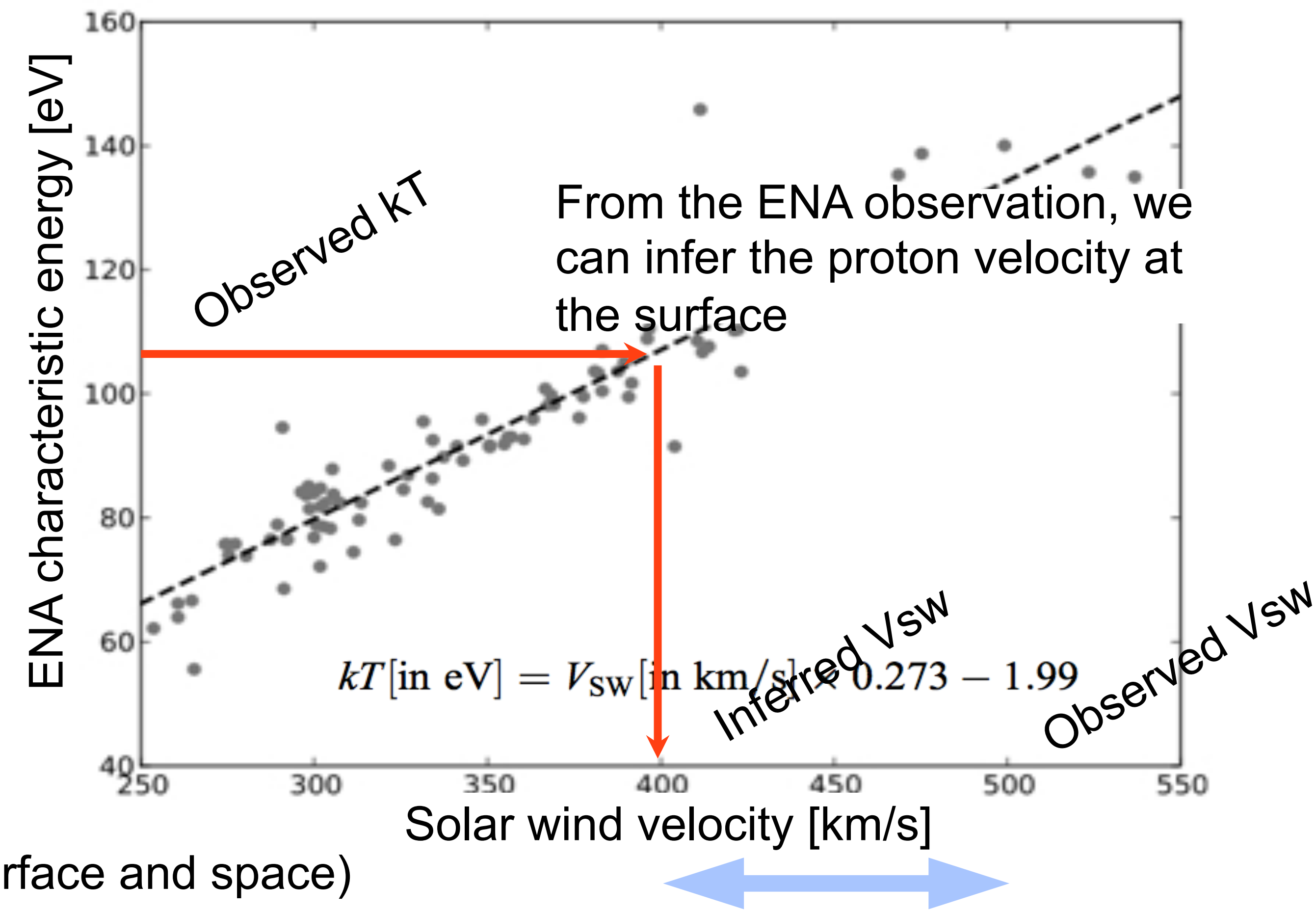
Observed linear relation between the ENA temperature and solar wind velocity



Calculations of the surface potential

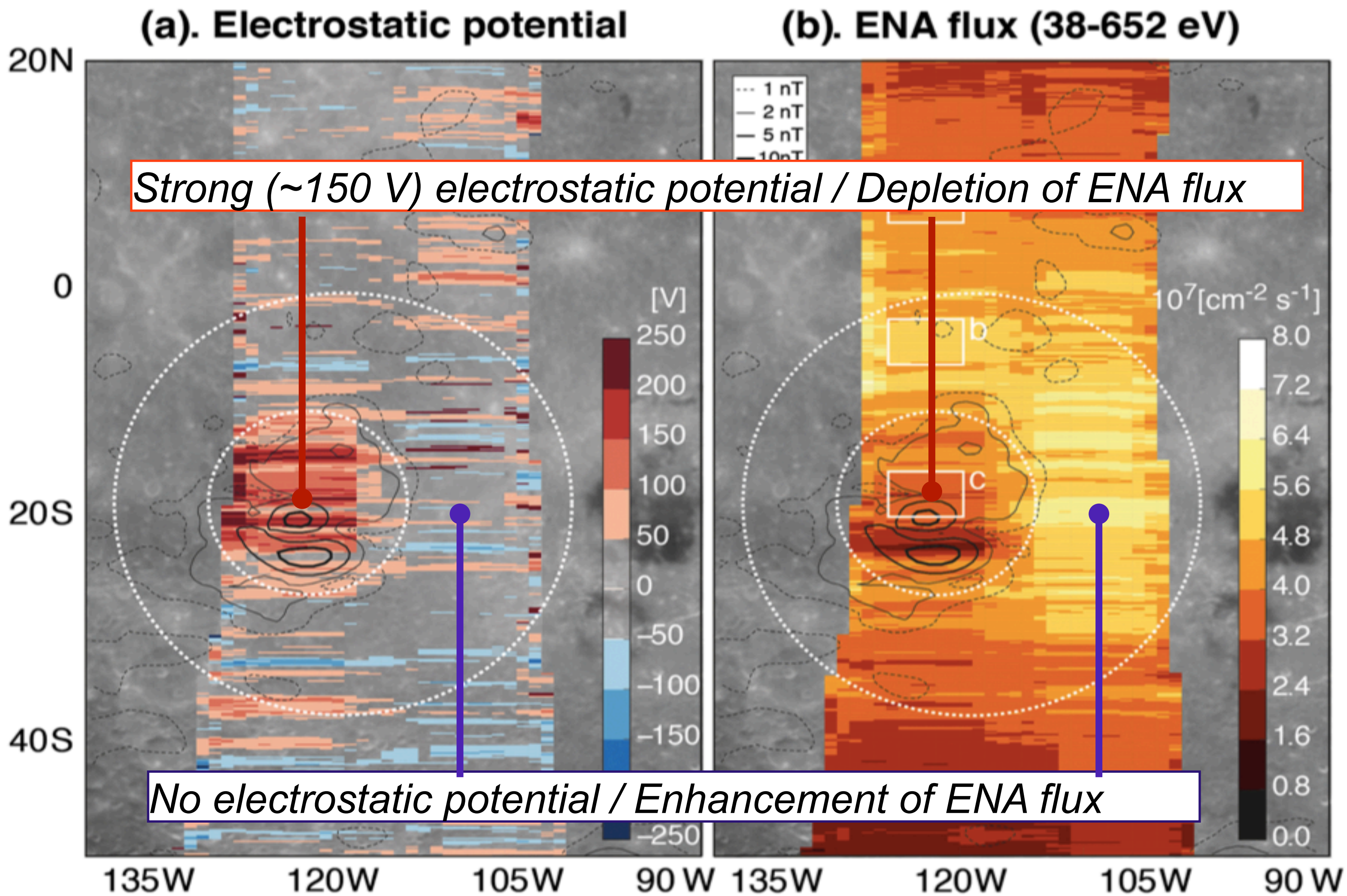


Surface potential
(Potential between the surface and space)

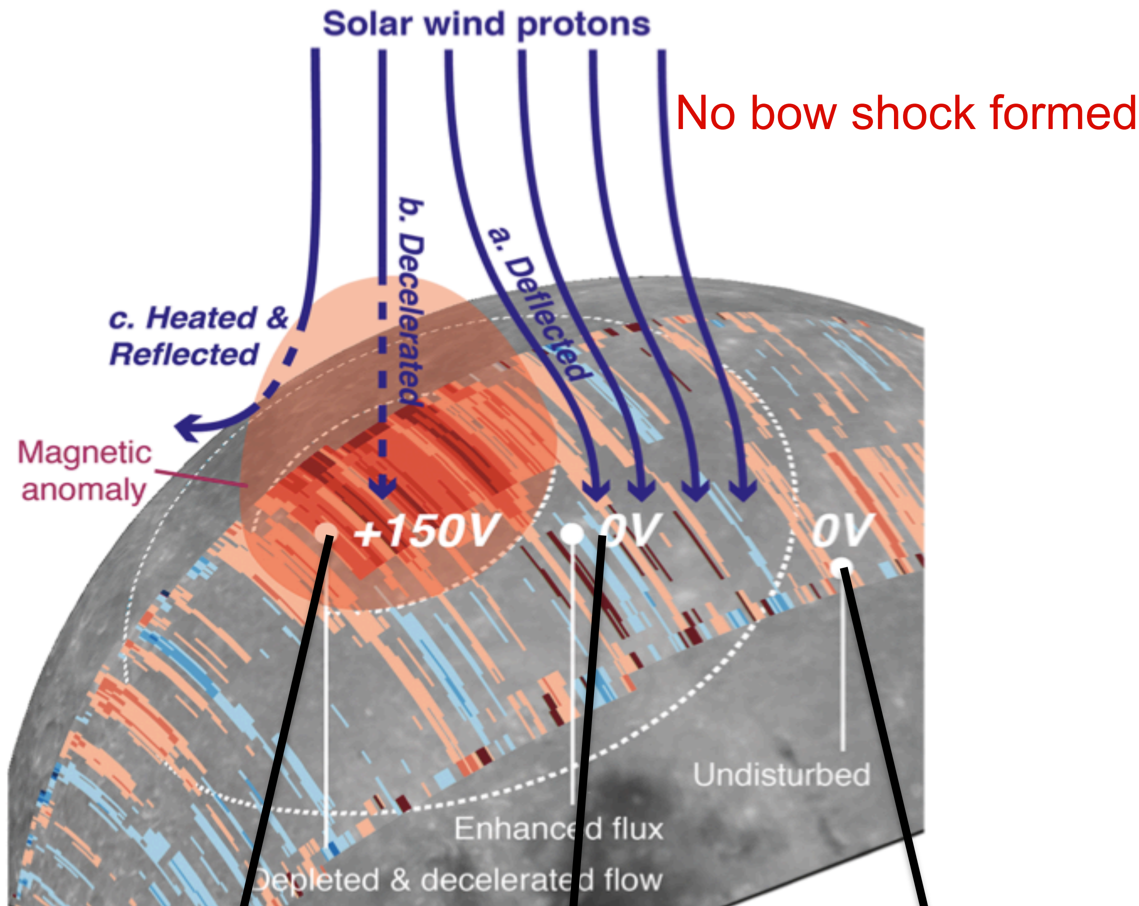


The difference of the inferred and observed solar wind velocities corresponds to the surface potential

Potential mapping



SW interaction with an anomaly



E~+150 V
B~100 nT
F~0.5 Fsw

E~0 V
B~0 nT
F~1.5 Fsw

E=0 V
B=0 nT
F=Fsw

Summary

- We develop a new technique to map surface potential on airless bodies using backscattered ENAs.

- Applying this technique to the Chandrayaan-1 CENA ENA data revealed the existence of >+100 V potential in the area of a magnetic anomaly (Gerasimovich crater). No significant potential was observed in the surrounding areas.

- The potential creates a field of ~1 mV/m (assuming 100 km spatial scale) and may influence the environment, particularly local plasma environment and charged dust.