Dynamics of solar wind protons reflected by the Moon

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Overview

- Observations of proton fluxes near the Moon by
  - Apollo SIDE
  - Nozomi
  - Kaguya (Selene)
  - Chandrayaan-1
- Modeling of reflected solar wind protons
Apollo SIDE observations

Energetic Ion Bursts on the Nightside of the Moon,
J.W. Freeman, Jr.,
JGR, v. 77, n. 1, 1972

Fig. 1. Location of the moon in its orbit at the onset of the December series of ion bursts.

Fig. 4. Number of differential energy spectra whose maximum fluxes are found at the various energies. Data collected from 14h 40m 28s UT December 13 to 14h 00min 34s UT December 15, 1969.
Reflected solar wind protons

Kaguya. Nishino et al., GRL 2009
Chandrayaan-1 observations

SWIM energy spectrum

Observation geometry

Approx. ecliptic plane

- Reflected from 15 deg below horizon
- Reflected at horizon
- Solar wind 35 deg above horizon
- Solar wind 45 deg above horizon

Integrated start rate [total counts/eV]

E/q [eV/e]
Gyro motion of reflected protons
Proton fluxes in the wake

Wake entry possible for reflected protons

Depending on IMF

(Nishino et al., GRL 2009, Type-II entry)
Reflection models

- Specular
- Perpendicular
- $\cos^2$ Perpendicular
- $\cos^2$ Specular
Test particle model of reflected protons
Hybrid model results

Similar results (away from wake) as a test particle model (constant IMF)
=> test particles can be used
Comparison with Nozomi observations

Test particle model

Model IMF similar to IMF during Nozomi observations
Gray = solar wind protons, Black = reflected protons
cos2specular reflections gave best fit (shown above)

Observations

1 0734:31 UT

2 0801:49 UT

B

B

B

B

Sw

Sw

Sw

Sw
Velocity spectrum of (all) reflected protons

Solar wind
Changing solar wind conditions
Summary

- Solar wind protons reflected by the Moon can explain
  - Nozomi observations
  - Kaguya observations
  - Chandrayaan-1 observations
  - Apollo SIDE observations (maybe)
- A local process that affects the global solar wind interaction
- A universal process that occurs at all bodies without a significant atmosphere. See the poster P43B-1431, *Strong interaction between Phobos and the solar wind*, Futaana et al., Thursday, December 17, 1:40 PM
- This study will appear in JGR