

THE EFFECT OF BACKSCATTERED SOLAR WIND PROTONS ON THE CURRENT MEASUREMENT OF THE LUNAR DUST EXPERIMENT. Lianghai Xie¹, Xiaoping Zhang¹, Yongchun Zheng^{1, 2}, Dawei Gu^{1, 1} Lunar and Planetary Science Laboratory, Macau University of Science and Technology, Macau, China, ² National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China.

Introduction: Lunar horizon glows (LHG) are attributed to forward scattering of sunlight by lofted dust grains. The dust density calculated from the Apollo data is on the order of 10^4 m^{-3} [1], but observations from Clementine and Lunar Reconnaissance Orbiter (LRO) show the density is only about 1 m^{-3} [2], [3]. Recently, in-situ measurements of lunar exospheric dust have been done by the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft, with the upper limit of dust density less than 10^2 m^{-3} [4]. Nevertheless, the density lacks an altitude dependence, implying the lofted particles may come from other sources.

In fact, Lunar Dust Experiment (LDEX) on board LADEE is an impact ionization dust detector and ions with energy less than 30 eV can also contribute to the measured current. Here we present some positive evidences for the current caused by the backscattered solar wind (SW) protons, focusing on the dependences on SW parameters and solar zenith angles (SZA). It is proved that the so-called current associated with lofted lunar dust is actually dominated by the backscattered SW protons.

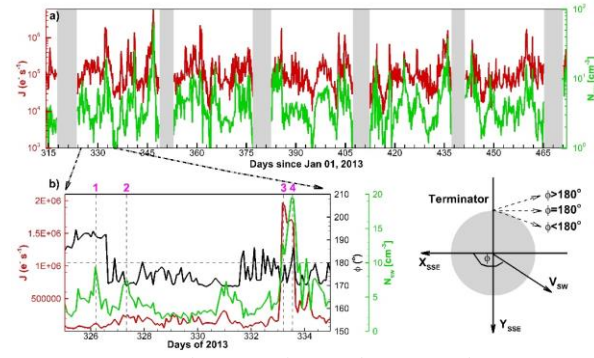


Figure 1. (a) The correlation between the measured current J (red line) and SW number density N_{sw} (green line). The gray bars indicate the times when LADEE is in Earth's magnetotail, where the data have been excluded. (b) The observations from Day 325 to Day 334 of 2013. The black line represents the SW direction, where ϕ is the SSE longitude as shown in the right bottom panel.

SW dependence: Here we use the average current measured from 5:30 LT to 6:30 LT to represent the current near the terminator. As shown in Figure 1a, a good correlation between the current and the SW density can be obtained, with the correlation coefficient of

0.75, suggesting the current should be mainly caused by the backscattered SW. In addition, a smaller ϕ can result in a larger J , as it corresponds to a smaller incident angle of SW, which then cause a larger incident flux at the surface and finally bring a larger proton-scattering flux into LDEX. As shown in Figure 1b, though with a smaller N_{sw} , Day 327 (marked by number 2) still has a larger J than Day 326 (marked by number 1). The reason should be the smaller ϕ of Day 327. Similar features can be also found between the measurements marked by number 3 and number 4.

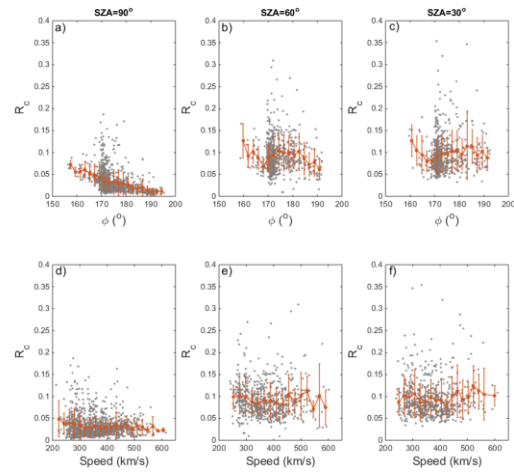


Figure 2. The ϕ and SW speed dependences of R_c for $SZA=90^\circ$ (a) and (d), $SZA=60^\circ$ (b) and (e) and $SZA=30^\circ$ (c) and (f). The gray dots indicate all the LDEX's measurements at each SZA and the red dots show the average ϕ and speed in the increments of 2° and 20 km/s, respectively.

SZA dependence: To discuss the affecting factors besides N_{sw} , we define a new variable, R_c , by normalizing the current with SW density: $R_c = J/(N_{sw} \times 10^6)$. As shown in Figure 2a, R_c basically decreases with ϕ as expected. Besides, the current favors a smaller SW speed as shown in Figure 2d, since smaller-speed protons can turn into low-energy ions more easily. However, the situation can be different at lower SZAs resulting from the picked-up ions from lunar ionosphere^[5] and the SZA dependence of scattering function^[6].

picked-up ions can bring large current when the convection electric field is pointing to LDEX, but fail

to affect the current when the electric field is back to LDEX. With all the measurements taken at $\text{SZA}=30^\circ$ and $\text{SZA}=60^\circ$, we find the current actually shows a better correlation with N_{sw} than the convection electric field. It can be concluded that the backscattered SW protons dominate the measured current at least when $\text{SZA} \geq 30^\circ$.

We use the measurements when the convection electric field is back to LDEX to discuss the ϕ and SW speed V dependences on the dayside. As shown in Figure 2, differing from monotonic decreases with both ϕ and V for $\text{SZA}=90^\circ$, there are a peak with ϕ and a raised tail with V at lower SZAs. The peak should be caused by the asymmetry in scattering angular distribution. SW ions are mainly reflected in the anti-SW direction for a moderate SZA. We call this direction as prevailing direction and the angle between the prevailing direction and the surface normal as exit angle. When ϕ increasing, the total scattered SW should decrease. But on the other hand, the LDEX boresight is closer to the prevailing direction and the relative influx of proton get larger. Then a peak R_C appears as shown in Figure 2b and 2c, where the R_C first decreases with ϕ , then increases up to a peak and finally decreases again. However, the ϕ where R_C peaks for $\text{SZA}=30^\circ$ is about 10° larger than the value for $\text{SZA}=60^\circ$, as a larger ϕ is required for $\text{SZA}=30^\circ$ to make the LDEX boresight closer to the prevailing direction.

Besides, Chandrayaan-1 observations taken near the subsolar point show proton-backscattering efficiency can increase with SW speed^[7], which results in the smoothed heads and raised tails in Figure 2e and 2f. Nevertheless, the V dependence of proton-backscattering efficiency gets weaker as SZA increases and the incident angle should be important for proton-surface scattering.

Discussion: Since the current is mainly caused by backscattered SW protons, the dust density should be further smaller than the value of 10^2 m^{-3} estimated by Szalay et al. and closer to the recent measurements from Clementine and LRO. This result provides a positive evidence for impact-generated dust exosphere.

It seems the backscattered protons have a similar scattering function to ENA at low altitude, and the protons are mainly reflected in the anti-SW direction especially when $\text{SZA}=50^\circ$. In addition, the proton-backscattering efficiency depends on both the SW speed and SZA. These results should be very useful for proton-surface scattering study. In the future, we will use the observations from KAGUYA to verify the results. Also, some experiments and numerical simulations should be done for further analysis.

References:

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