

ENERGETIC NEUTRAL ATOMS DISTRIBUTION ON THE LUNAR SURFACE AND ITS RELATIONSHIP WITH SOLAR WIND CONDITION. Huizi Wang¹, Chao Xiao¹, Jiang Zhang¹, Quanqi Shi^{1*}(sqq@sdu.edu.cn), Ruilong Guo¹, Chao Yue², Ji Liu¹, Anmin Tian¹, Wensai Shang¹, Jian Chen¹, ¹Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, Weihai, Shandong, 264209, China; ²School of Earth and Space Sciences, Peking University, Beijing, China.

Introduction: The lunar surface is exposed to solar wind (SW) proton due to lack of a global magnetic field or dense atmosphere. The interactions between the solar wind and lunar surface have been investigated for several decades. The in-situ observations from Chang'E, Kaguya, Chandrayaan-1, and Interstellar Boundary Explorer (IBEX) missions reveal that 0.1-1% of SW protons are backscattered from the lunar surface [1-2], while 10-20% of SW protons converted to energetic neutral atoms (ENA) [3-4], and the remaining part implanted into the lunar regolith that would produce OH/H₂O [5] as for the non-magnetized regions of the surface. Among these processes, imaging of sputtered ENA is considered to be an eligible technique to give us useful information on the interactions between the SW proton and lunar surface regolith [6].

The ENA are mainly generated by photon-stimulated desorption, micrometeorite vaporization, and sputtering by solar wind protons [6]. The observed energy spectra of the ENA depend on various solar wind parameters such as incident angle, flux intensity, proton energy, and the lunar local magnetic field [3]. These observations promote an understanding of the interactions between the solar wind proton and the lunar surface based on orbital measurements. However, studies of ENA based on in situ observations on the lunar surface have never been conducted yet. The Advanced Small Analyzer for Neutrals (ASAN) onboard the Chang'E-4 Yutu-2 rover is the first time to observe the ENA on the lunar farside surface. Zhang et al. show the first result of ASAN and find that the reflection ratio derived from ASAN data has a good agreement with previous works from the Chandrayaan-1 and IBEX missions. However, the previous results of the relationship between the solar wind parameters and ENA remain unclear. In this study, we intend to study the ENA distribution (along with the solar elevation angle, solar azimuth angle, solar azimuth rover) and the relationship between the ENA differential flux and solar wind parameters such as density, velocity, and dynamic pressure.

Instrumentations: (1) ASAN, is designed at a unique observation geometry on the Yutu-2 rover, which let us study the ENA variation on the lunar surface. The Chang'E-4 landed on the lunar farside

surface at 177.6 ° E, 45.5 ° S. The ASAN was operated irregularly at the lunar local time from 7 a.m. to 9 a.m. and from 2 p.m. to 4 p.m., during which the Moon was in the solar wind and the geometry of the ASAN varied with time (Figure 1). (2) We use the ARTEMIS data to study the variation of the lunar plasma environment during the simultaneous observation time with the Chang'E4 mission from January 11, 2019 to April 28, 2020.

Results: (1) *Overview of ENA spectra distribution in 17 lunar days.* We show the hydrogen ENA energy spectra measured by the ASAN on every lunar day from 2019/01 to 2020/04. As we mentioned in the previous sections, the ASAN was operated irregularly, which causes that not all of the observations both have dawn side and dusk side measurements in each lunar day. However, during 14 lunar days (except 1, 9, 15), we can find most of the observations shows the ENA flux is higher on the dawn side than on the dusk side (Figure3). (2) *The integration of ENA differential flux with solar wind flux/density/velocity/pressure.* To show the relationship between the solar wind and the ENA flux distribution, we first integrate over all of the energy and over energy from 200 to 600 eV to obtain the directional flux of ENA, at which the ASAN carried out the observations. In Figure 4, we find that the directional flux of ENA is controlled by the solar wind parameters. More work needs to be done on the relationship between the ENA reflection ratio with the solar wind parameters and the observation geometry.

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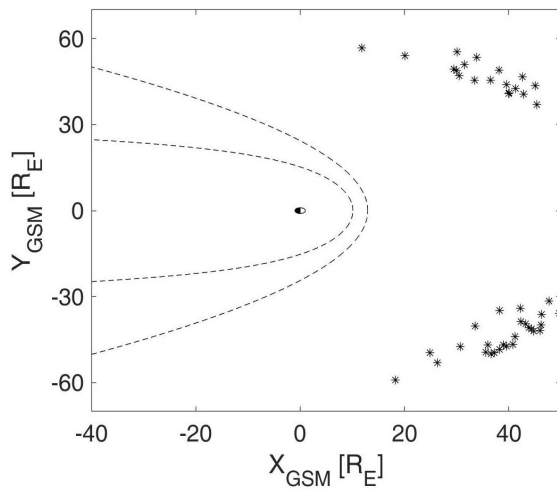


Figure 1 The position distribution of the Moon in GSE coordinate system when the Chang'E 4 ASAN operates.

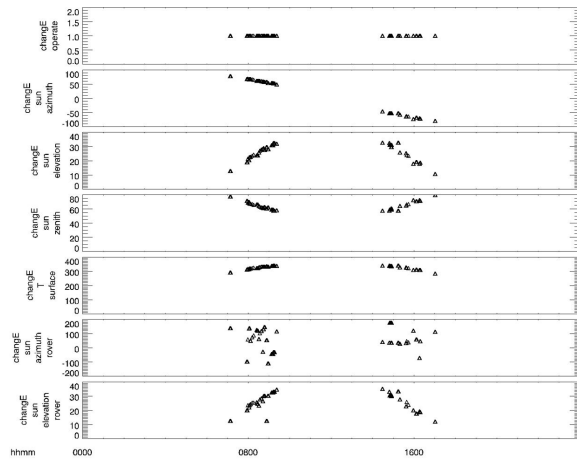


Figure 2 The data distribution of ASAN (sun azimuth angle, sun elevation angle, sun zenith angle, sun azimuth rover, sun elevation rover) along lunar local time from 2019/01-2020/04.

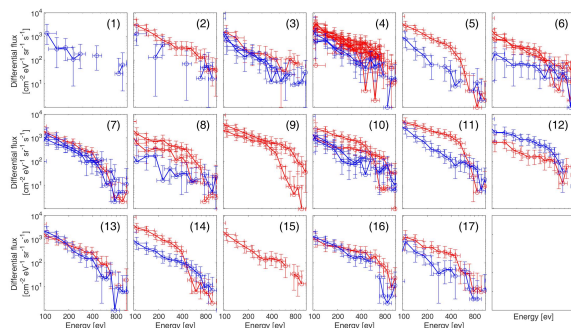


Figure 3 The hydrogen ENA energy spectrum observed by the ASAN on each lunar day from 2019/01-2020/04. The blue line shows the ASAN observation was in the afternoon of the lunar local

time and the red line shows the ASAN observation was in the morning of the lunar local time.

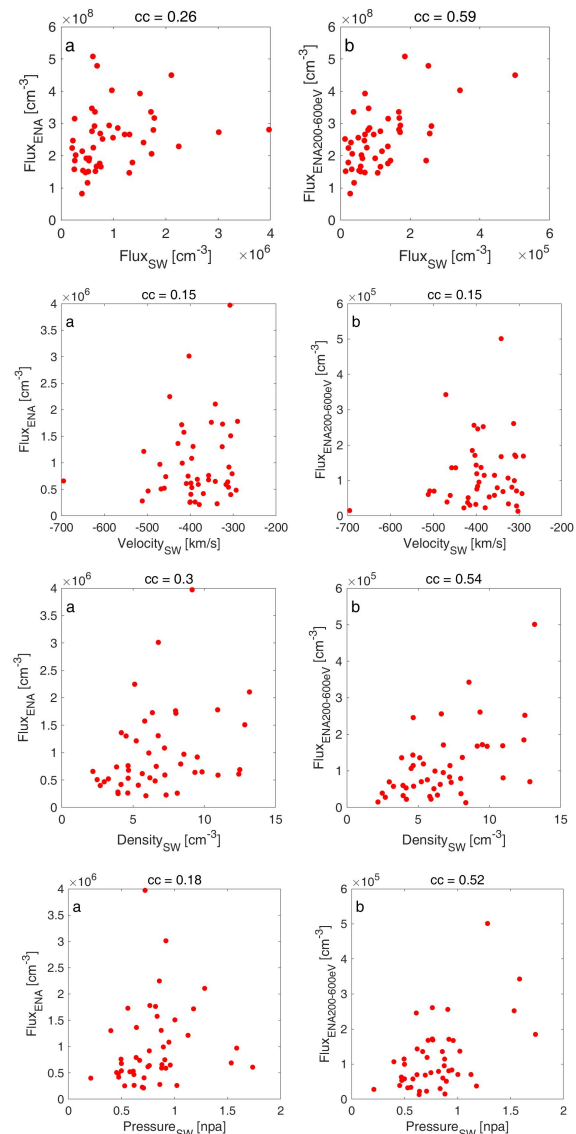


Figure 4 The relationship between the solar wind parameters (flux, velocity, density, pressure) and the integration of ENA differential flux and the integration of the ENA differential flux at energy 200- 600 eV.