Ultraviolet Radiation

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Definition

The lunar surface has a complex plasma environment due to incoming solar wind flux and charged micron-sized dust particles and the presence of solar ultraviolet (UV) radiation. UV resonance fluorescence of solar radiation provides a sensitive detection of major elemental constituents, such as H, H_2, O, C, N, and noble gases in the tenuous daytime lunar atmosphere. Photoemission due to the solar UV radiation is the dominating process in the charging environment, creating a photoelectron "sheath." Such detections were observed by LADEE UV spectrometer and the Apollo 17 UV spectrometer.

Lunar Dusty Plasma

On the sunlit side of the lunar surface in the solar wind, photoelectric charging due to UV radiation and the consistent collection of solar ions and electrons dominate the lunar plasma environment (Poppe and Horanyi 2010; Örger et al. 2017). This sunlit side is expected to charge positively. Since the photoelectron current dictates the charging process of the sunlit lunar side, it is interesting to note that the photoemission properties of the lunar soil are diverse (Lisin et al. 2015). The sources can also be used to determine the surface potential and electric field, which can also vary as the current sources alter with time. Örger et al. (2017) suggests that the lunar horizon glow is produced by scattering of the sunlight by electrically charged dust grains, though the physical mechanism of this process is still under investigation.

UV charging of the grains may be caused by several processes (Abbas et al. 2007), which include: (i) ion or electron collisions on the nightside, leading to negatively charged grains with < 100 eV electrons; (ii) triboelectric charging of dust grains by contact-charging from a solid material with high work-function (WF) to one with a lower WF; or (iii) photoelectric emissions by photons higher than the grain material's WF. On the Moon, the dayside is hypothesized to have UV radiation at < 200 nm wavelengths with photon energies higher than the lunar regolith WF, making this the dominant charging process, though the interaction of the solar wind charges the grains negatively on the nightside (Halekas et al. 2002; Abbas et al. 2007).

Even without major physical activity, such as impacting, dust grains are levitated by electrostatic fields and transported from the surface in the near-vacuum lunar environment (Abbas et al. 2007). However, the dominant process for charging the lunar surface is the photoelectric emission induced by the solar UV radiation. Evaluating this process requires measurements of the photoelectric yields to determine the charging potential of individual grains (Abbas et al. 2007).

Fine micron to sub-micron sized dust grains cover the lunar surface formed by meteoritic impacts over billions of years. A photoelectron covering (sheath) develops near the lunar surface, while electrons accelerate towards the Moon and ions are slowed. These dust grains are transported, and thus levitate, on the lunar surface, as observed by transient dust clouds and horizon glows recorded by the Apollo 17 mission (Lunar Ejecta and Meteorite Experiment) and Lunar Surveyor spacecraft (Criswell 1973;

Pelizzari and Criswell 1978). The Clementine spacecraft later recorded a high-altitude horizon glow (Zook et al. 1995).

Apollo 17 UVS

The Apollo 17 far-UV spectrometer (UVS) primary objective was to measure the composition and density of the lunar atmosphere based on the fluorescence and scattering of solar far-UV radiation (Fastie et al. 1973). The Apollo UVS can provide density measurements from $10^1 – 10^4$ cm^{-3} for several elements and compounds, such as H_2, O, C, N, CO, Kr, and Xe (Fastie et al. 1973). Interestingly, this instrument revealed that the surface concentration of H is < 10 cm^{-3} and the concentration of H_2 is < 1.2 x 10^4 cm^{-3}. While these numbers are much lower compared to predicted models, this suggests that the solar wind protons are converted into H_2 at the lunar surface (Fastie et al. 1973). This experiment by Apollo 17 led to more refined estimates on the atomic oxygen density and allowed for comparable O/Na ratios in the atmosphere of the Moon to Mercury (Feldman and Morrison 1991).

The examination of the Apollo 17 UVS data have brought many questions and hypotheses regarding the atomic abundances and molecular fluorescence of lunar materials. From Feldman and Morrison (1991), the discovery of sodium and potassium in the lunar atmosphere have raised the question of the absence of atomic oxygen.

LADEE UVS

The Lunar Atmosphere and Dust Environment Explorer (LADEE) included an Ultraviolet-Visible Spectrometer (UVS) instrument onboard, one of three instruments to characterize the lunar exosphere. The UVS operated between 230 – 810 nm and used two optical apertures to make observations of the exosphere at a range of altitudes and times (Colaprete et al. 2015). The UVS instrument supported the goals of LADEE by observing emission by exospheric gases and extinction (or optical scattering) by dust. The UVS requirements were: (i) detecting resonance scattering emissions of K and Na in the lunar atmosphere with a spatial coverage of ±20° of the lunar terminator; (ii) establish new limits or detections of Mg, Al, Si, Ti, Fe, and Ca (Table 1); (iii) search for as-yet undetected species; (iv) perform solar occultations to detect suspended particles over an altitude range of 1.5 – 50 km; and (v) detect scattered sunlight by suspended dust particles (Colaprete et al. 2015).

Cross References

Lunar Ionosphere

Plasma environment of the Moon

Cosmic Rays in the Lunar Environment

LADEE

References

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Figures and Tables

Table 1: The known lunar exospheric species that the LADEE instrument investigated, and verified observations made by ground-based spectrometry and the Apollo 17 experiments. The g-factor [photons/second] identifies the atomic and molecular fluorescence efficiencies. Table adapted from Colaprete et al. (2015).

Species	**g-factor (photons sec^{-1})**
Al	0.0364
Ca	0.4900
Fe	0.0077
K	1.9400
Na	0.5250
Si	0.0021
Ti	0.0873
Mg	0.0320
O^2	0.0200