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Plasma Waves near the Moon

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The Moon has a thin surface bound exosphere consisting mainly inert gases helium, neon and argon. Apart from the ionosphere being generated due to the ionization of the neutral lunar atmosphere by the impinging solar UV radiation, the Moon is engulfed by some ion concentration sheaths which are associated with the lunar surface charge regions having symmetric locations. The plasma environment of Moon is not static and constantly changes when it traverses around Earth. About one-fourth of lunar orbit is not in the solar wind path when it is in the Earth's shadow, where it encounters either the tenuous plasma of the magnetospheric tail lobes or the energetic plasmas of magnetosheath and geomagnetic plasma sheet. Moon, does not possess a magnetosphere or fully developed ionosphere but has an exosphere where tenuous plasma is present to generate several plasma waves in the presence of solar wind.

Plasma waves observed in the lunar wake are the high frequency electromagnetic waves at 18 kHz and 36 kHz. In lunar wake, Langmuir waves with frequency 4 kHz were also observed which got frequency and amplitude modulated at 19 kHz also with a period of 40 s. Whistler wave signals in the frequency range of 50-100 Hz were observed. During the passage through lunar wake, WIND observed that the broadband electrostatic noise (BEN) having frequency $\leq$ 6 kHz and a wave amplitude of 10 mV/m there. The WAVES onboard WIND also observed the reduction in electron plasma frequency consistent with the lack of electrons in lunar wake [1].

Apart from these plasma wave detections, the magnetometer onboard WIND also observed anomalous ultra-low frequency (ULF) magnetic wave activity outside the lunar wake in frequency range 0.021-5.43 Hz [2]. GEOTAIL observed left-handed, circular polarized ULF waves propagating parallel to the background magnetic field having frequency 0.3-1.2 Hz at 27 R_L (Lunar radius) upstream of the Moon in lunar wake [3].

The magnetometer onboard Lunar Prospector (LP-MAG) observed monochromatic circularly polarized low frequency waves in frequency range 0.4-4 Hz in lunar vicinity and likely to be either upstream whistler waves produced at shock surfaces above lunar crustal magnetic sources or phase-standing whistlers generated by direct solar wind interaction with lunar crustal magnetic fields. It can be observed in the figure that the largest wave powers are associated with the strongest crustal fields on the lunar surface. However, it is to be noted that the waves are observed only in the solar wind indicating that the wave generation mechanism is related with the solar wind-lunar crustal magnetic field interaction [4].

Similarly, whistler waves in the frequency range 0.03-10 Hz were observed by Kaguya in the sunlit side of Moon irrespective of the local lunar magnetic anomalies at an altitude of 100 km above the lunar surface [5].

Kaguya observed three types of electrostatic solitary waves near the Moon - type A at the wake boundaries, type B above magnetic anomalies and type C above the lunar surface without magnetic anomalies but in the solar wind. Langmuir waves in frequency range 10-20 kHz were also observed few times by instruments onboard SELENE (Kaguya) near lunar wake boundary. These waves, enhanced at local plasma frequency, were normally observed in the sunlit region and boundaries facing the Sun and in the lunar wake when the Moon is immersed in the solar wind [6].

Low frequency ion cyclotron waves, arising due to ion temperature anisotropy, in frequency range 0.04-0.17 Hz were observed at lunar surface by the lunar surface magnetometers by Apollo 15 & 16 when the Moon was in the earth's magnetotail. The anisotropy in the ion temperature occurring near the Moon was proposed to be the reason behind the generation of these waves [7].

In this paper, plasma waves in and around the moon are discussed along with some unresolved issues.

References

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