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Streaming Beam-Plasma Instability Generation around Moon in Variable Lunar Plasma Environment

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Plasma instabilities are often observed in space plasma systems such as the Sun, planetary ionospheres, etc. Earth's natural satellite Moon has a very thin atmosphere and hence a feeble plasma ionosphere. However, this tenuous lunar plasma environment is a place of several non-linear plasma phenomena. The solar wind, which strikes the lunar surface unhindered due to the absence of global lunar magnetic field, is capable of triggering plasma instability in the lunar exosphere.

Two-stream instability (TSI) generation is studied analytically in the lunar plasma environment which gets triggered due to the interaction of solar wind plasma with the lunar electron plasma near the exosphere. In this interaction process, it is considered that only the lunar electrons constitute the plasma background due to the considerably low ion population in the plasma environment around Moon. In the analysis, the conditions for the TSI, to come into existence, are obtained and the growth of this instability with time the passage of time is estimated as shown in Figure 1.

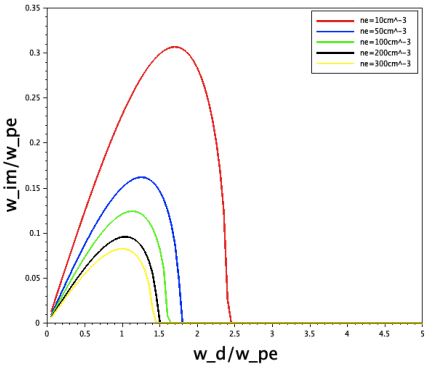

Figure 1: TSI growth factor with k for different n_e.

The TSI growth factor is found to be a function of the lunar electron number density (n_e), the solar wind electron number density ($n_{e,sw}$)and the solar wind electron thermal velocity (v_{the}). The lunar TSI can explain the observation and presence of high electron density in lunar ionosphere as it leads to the bunching of solar wind electrons which increases the electron number density of the lunar plasma environment. Particle-In-Cell (PIC) simulations are also carried out for the visual depiction of this plasma TSI evolution with time in phase space [1, 2]. This study is further extended in which, along with the non-energetic ('cold') electrons which are in the majority, a fraction of energetic electrons ('hot') of the total lunar electron population is also considered and this fraction of energetic electrons is taken as 1%, 2%, 5%, 10%, 20% and 25% of the total lunar electron population. The higher proportions of the energetic lunar electrons is assumed to be a result of a transient event taken place in the lunar plasma environment which is otherwise difficult to sustain. The inclusion of energetic electron proportion in the lunar plasma environment, available for interaction with the incoming solar wind, changes the scenario for the TSI to occur in the lunar ionosphere and the analysis shows that it modifies the TSI dispersion relation as shown in Figure 2.

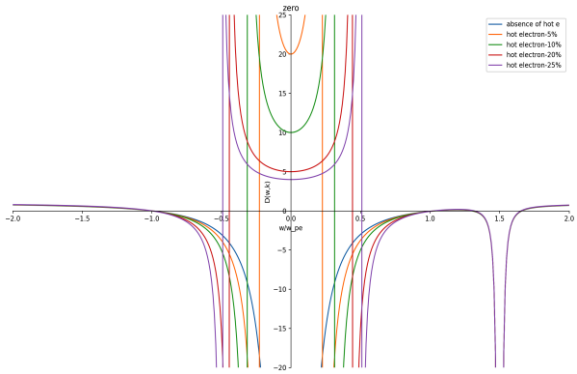

Figure 2: The modified dispersion relations with different fractions of energetic lunar electrons.

The PIC simulations suggest that the lower fractions (1%, 2% and 5%) of energetic electrons do not have much impact on the interaction but the presence of higher proportions of the energetic electrons such as 10%, 20% and 25% in the lunar plasma environment not only hastens the electron bunching during the interaction with the incoming solar wind electrons during the TSI but also support the mixing of solar wind electrons with the lunar electron population [3]. Moreover, the energetic electrons in the lunar plasma environment are capable of triggering non-linear phenomena such as the generation of lunar plasma waves.

References

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