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Ion cyclotron waves and acoustic waves driven by electron beam in Lunar wake plasma

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When the solar wind plasma hits the surface of the moon, it creates a plasma-depleted region in the dark side of moon. This region is called as lunar wake region. Even after the discovery of this region in APOLLO era, this region evokes large interest due to various exploratory missions such as Chandrayaan. ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with Sun) mission has revealed the presence of a variety of linear and nonlinear plasma waves in the lunar wake. Here, we present a linear study of propagation of electrostatic ion cyclotron waves and ion acoustic waves in four-component magnetized plasma comprising of fluid protons, doubly charged fluid Helium ions, beam electron streaming along ambient magnetic field and electron in kappa distribution. The analytical and numerical analysis indicates the presence of electron, proton and Helium cyclotron modes and slow, fast and electron acoustic modes. All these modes have positive and negative phase speeds. For parallel propagation and with the increase in the beam velocity, the electron acoustic mode with the negative phase speed turns to positive. Further increase in the beam velocity, the electron acoustic mode, whose phase speed now became positive, merges with the slow ion acoustic to form beam-driven slow ion acoustic wave in the lower wavenumber regime and merges with fast ion acoustic wave to form beam-driven fast ion acoustic wave in the higher wave number regime. This merging makes the modes unstable with finite growth rate. When the dispersion relation is analyzed for non- parallel propagation with no beam velocity, the coupling between various modes are seen, with no merging of modes and with no unstable region: electron acoustic mode couples with Helium cyclotron mode and proton cyclotron mode; fast ion-acoustic mode couples with Helium cyclotron mode and proton cyclotron mode; slow ion-acoustic mode couples with Helium cyclotron mode and proton cyclotron mode. With a finite beam and a non-parallel propagation introduced into the system, the coupling and merging of various modes takes place. A detailed analysis of analytical variations that has been carried out and it's implication in the Lunar wake/solar wind plasma will be discussed.