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Magnetosonic Waves Driven by Maxwellian Ring Beam Protons in The Martian Ionosphere

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Magnetosonic (MS) waves are low-frequency electromagnetic compressional oscillations typically found in Earth's inner magnetosphere, propagating almost perpendicular to the ambient magnetic field. These waves have frequencies ranging from the local proton gyrofrequency (Ω_{H^+}) to the local lower hybrid frequency and exhibit linear polarization. Concurrent wave and particle data from various satellite missions from the Earth's magnetosphere indicate that these waves are generated from the ring-like velocity distribution of energetic protons with a positive perpendicular slope [1]. Recent wave and particle observations from the MAVEN satellite suggest that MS waves with frequencies closer to local proton gyrofrequencies can be locally generated by the ring-beam [2] or ring distributed [3] hot protons in the Martian upper ionosphere. In the Earth's inner magnetosphere, the ring distributions are formed due to the perpendicular drift of energetic protons around the planet near the magnetic equatorial region. In contrast, unmagnetized planets like Mars lack a global magnetic field, so protons cannot drift around the planet. The ring/ring-beam distributions are formed due to the penetration of hot protons from the Martian magnetosheath into the cold ionosphere rich in heavier ions (O^+ and O_2^+) [2,3].

A comprehensive theoretical model of a homogeneous four-component plasma system developed through kinetic theory is used for the linear instability analysis of MS waves in the Martian Ionosphere. The model consists of tenuous Maxwellian ring beam distributed hot protons in the background of cold protons, atomic (O^+), and molecular oxygen (O_2^+) ions, which very well represent the Martian plasma environment. Using the plasma parameters observed in the Martian ionosphere, the excitation of MS waves is investigated. Effectiveness of ring and ring-beam hot proton distributions as a free energy source of MS wave generation is studied. The role of perpendicular and parallel spread of the hot proton velocity distribution on the wave growth is studied.

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