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Hybrid simulation of the shock wave formation behind the Moon

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Abstract

A standing shock wave behind the Moon was predicted by *Michel* (1967) but never observed nor simulated. We use 1D hybrid code in order to simulate the collapse of the plasma-free cavity behind the Moon and for the first time to model the formation of this shock. Starting immediately downstream of the obstacle we consider the evolution of plasma expansion into the cavity in the frame of reference moving along with the solar wind. Well-known effects as electric charging of the cavity affecting the plasma flow and counter streaming ion beams in the wake are reproduced. Near the apex of the inner Mach cone where the plasma flows from the opposite sides of the obstacle meet, a shock wave arises. The shock is produced by the interaction of oppositely directed proton beams in the plane containing solar wind velocity and interplanetary magnetic field vectors. In the direction across the magnetic field and the solar wind velocity, the shock results from the interaction of the plasma flow with the region of the enhanced magnetic field inside the cavity that plays the role of the magnetic barrier. Simulations with lower electron temperatures (T_e~20eV) show weakened shock formation behind the moon at much greater distances. The shock disappears for typical solar wind conditions ($T_i \sim T_e$) Therefore, in order to observe the trailing shock, a satellite should have a trajectory passing very close to the wake axis during the period of hot solar wind streams. We expect the shock to be produced at periods of high electron temperature solar wind streams ($T_i \ll T_e$~100eV). The appearance of the standing shock wave is expected at the distance of ~ 7R_M downstream of the Moon.