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Mercury's bow shock and foreshock waves observed by Messenger

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Abstract

The region upstream from a planetary bow shock is a natural plasma laboratory containing a variety of wave particle phenomena. The study of foreshocks other than the Earth's is important for extending our understanding of collisionless shocks and foreshock physics since the bow shock strength varies with heliocentric distance from the Sun, and the sizes of the bow shocks are different at different planets. Mercury's bow shock is unique in our solar system as it is produced by moderate Mach number and low plasma beta solar wind blowing over a small magnetized body with a predominately radial interplanetary magnetic field. We use Messenger high resolution (20 samples per second) magnetic field data to study Mercury's bow shock structure, and the characteristics of ultra low frequency waves observed at the foreshock. Bow shock profiles depend on the upstream Mach number, on shock geometry with respect to the upstream magnetic field, and on the plasma beta. Mercury's bow shock is weaker than Earth's with a Mach number $M_A \leq 3$, and is 10 times smaller. Thus, a more laminar shock is expected and a less complex foreshock may develop. A preliminary study has shown the existence of at least three types of waves: 1) whistler waves at frequencies near 2 Hz; 2) waves with frequencies ~ 0.1 Hz; 3) fluctuations with broad spectral peaks centered at ~ 0.6 Hz. Whistler waves propagate at angles up to 30 degrees, and lower frequency waves are more parallel propagating. We investigate wave properties such as polarization, ellipticity and compressibility. We also discuss wave origin and evolution. While whistler waves may be generated at the bow shock, the origin of lower frequency waves can be attributed to local generation by kinetic ion-ion instabilities. Due to the small scale size of Mercury's foreshock it is possible that waves suffer less steepening than at Earth.