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Properties of reflected Solar Wind protons on the Martian Bow Shock: investigations by means of 3-dimensional simulations

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The reflection of a part of the incident ions at a Bow Shock (BS) is a phenomenon familiar to the Solar System and is one of the main dissipation mechanisms for supercritical collisionless shocks in space plasmas.
The first evidence of reflected ions on the Martian BS was provided by the ASPERA instrument on-board the Phobos 2 spacecraft (Dubinin et al., 1993). Yamauchi et al. (2010) recently brought some supplementary properties of reflected ions observed by the instrument ASPERA 3 of Mars-Express mission.
In this study, the Martian ion foreshock is investigated and particularly the properties of the reflected Solar Wind protons. A numerical approach is used to study the reflection of Solar Wind protons on the Martian BS. A two steps approach is adopted to provide a complete analysis of the reflected protons population.
First, we used the 3-dimensional hybrid model of Modolo et al. (2005) to compute a stationary state of the interaction between Mars and the Solar Wind. This model describes in particular the spatial variations of the electric and magnetic fields and the 3-dimensional structure of the Martian BS.
Second, we followed particles' motion in the electromagnetic field computed by the hybrid simulation by means of a 3-dimensional test-particle model, and we defined detection criteria in order to identify reflected protons. In practice, a particle is recorded as a reflected particle if it encounters the shock and leaves the simulation domain outside the Bow Shock. The reflection has to occur before a given abscissa downstream of the plane of the terminator of the planet.
Such approach provides a complete description of the properties of this population with a good statistical set of particles.
Our simulation study allows us to get some significant information concerning the reflected Solar Wind protons, especially in order to set back the in situ observations in a global context or make predictions for future observations. This study emphasizes that reflected protons enter the acceleration zone in a region located between the quasi-parallel and quasi-perpendicular shock and they exit by the quasi-parallel shock region. We also investigated some local properties: the ratio of reflected particles varies from about a few percent depending on the spatial location. The global energy spectrum of the reflected protons extends from a few 100eV to 10keV and the local spectra demonstrate an energy gradient in the direction of the convection electric field.
A description of the properties of pickup protons, ions originated from the hydrogen exosphere, will complete this investigation of the Martian ions foreshock following the work of Dubinin et al (1995).