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# Oxygen foreshock of Mars and its implication on ion acceleration in the bow shock

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Ion acceleration inside the bow shock is one of the poorly understood phenomena that has been observed for more than 30 years as the foreshock phenomena. While the Fermi-acceleration mechanism explains the diffuse component of foreshock ions, we still do not know the detailed mechanism that produces the discrete intense ions flowing along the local magnetic field direction (with and without gyration). One of the reasons for such difficulty is that majority of the bow shock study was performed for the Earth's case where Oxygen ions cannot be used to understand the acceleration mechanisms. The planetary oxygen ions that reach the Earth's bow shock have already been significantly accelerated, and are not adequate for such a study.

In this sense the Martian bow shock is an ideal place to study the acceleration mechanisms leading to foreshock ions, although the nature of the bow shock is slightly different between the Earth and Mars (Yamauchi et al., 2011). On 21 September 2008, the Mars Express (MEX) Ion Mass Analyser (IMA) detected foreshock-like discrete distributions of oxygen ions at around 1 keV in the solar wind attached to the bow shock. This was the first time that a substantial amount of planetary oxygen was observed upstream of the bow shock. The oxygen energy increased from low energy (< 300 keV) inside the magnetosheath (or it should be called an extended bow shock) to nearly 2 keV at more than 2000 km from the bow shock. Foreshock-like protons are also observed but at a shifted location from the oxygen by about 1000 km, at a slightly higher energy, and flowing in a slightly different direction than the oxygen ions. Both protons and oxygen ions are flowing anti-sunward at different angles with respect to the solar wind direction. The observation is consistent with an electric potential barrier at the bow shock that simultaneously accelerates the planetary oxygen ions outward (to form the foreshock oxygen ions) and reflects a portion of the solar wind (to form the foreshock protons).

Yamauchi, M., et al. (2011): Comparison of accelerated ion populations observed upstream of the bow shocks at Venus and Mars, Ann. Geophys., 29(3), 511-528, doi:10.5194/angeo-29-511-2011.

Yamauchi, M., et al. (2015): Oxygen foreshock of Mars, Planet. Space Sci., 119, 48-53, doi:10.1016/j.pss.2015.08.003.