Geophysical Research Abstracts
Vol. 19, EGU2017-7322, 2017
EGU General Assembly 2017


# Non-linear wave particle interaction: implications for newborn planetary and backstreaming proton velocity distribution functions

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Seen from the solar wind (SW) reference frame, the presence of newborn planetary protons upstream from the Martian and Venusian bow shocks as well as SW protons reflected on each of them constitute two sources of nonthermal proton populations. That is, the proton velocity distribution function at these locations is composed by a core of SW particles and a secondary (less dense and more energetic) population of planetary and/or backstreaming ions. In both cases, the resulting particle velocity distribution function is highly unstable and capable of giving rise in particular to ultralow-frequency quasi-monochromatic electromagnetic plasma waves. Once these instabilities take place, the resulting waves are convected downstream by the SW and interact with nonthermal protons located downstream from the wave generation region, playing a predominant role in the dynamics of such planetary or backstreaming ions.

In order to contribute to the current understanding of this coupling, we analytically and numerically study the interaction between a charged particle and a large amplitude monochromatic circularly-polarized electromagnetic wave propagating parallel to a background magnetic field, from first principles. The selected wave properties (a first-order approximation) are chosen taking into account magnetic field measurements analyzed and reported in previous studies. In particular, we derive the trajectory of a charged particle in the pitch angle-gyrophase velocity plane for different initial conditions and relative wave amplitudes. We also determine the mean pitch angle and mean gyrophase associated with particles with the same kinetic energy (in the wave reference frame), and the relationship with the relative amplitude of the wave interacting with them. Finally, we perform estimations for the mean value of both angular variables for nominal conditions for newborn planetary protons in the upstream regions of Venus and Mars. The latter calculations are particularly useful to interpret magnetometer and ion measurements provided by the Mars Atmosphere and Volatile Evolution Mission (MAVEN) during time intervals with low frequency waves. Indeed, they constitute a mean to evaluate if observed nonthermal proton velocity distribution functions display signatures that can be understood in terms of non linear wave-particle processes.