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Variation of the amplitude of pickup protons generated LF waves inside the Martian electron foreshock

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Using MAVEN observations, we report variations of the amplitude of electromagnetic waves observed at the local proton cyclotron frequency upstream from the bow shock on short (plasma) time/length-scales: 1) a sharp sudden increase of the amplitude when crossing the electron foreshock boundary and 2) a decrease of this amplitude clearly correlated with the increasing distance from the shock along the magnetic field inside the foreshock, without any simple relation to the planetary radial distance. Such waves have been widely reported and studied in the environment of Mars (and Venus). As for comets, their free energy source comes from the initial highly unstable ring-beam velocity distribution of the newly created protons (by ionization of the exospheric hydrogen atoms). The amplitude of these waves is generally expected to depend only on different drivers including the observed large seasonality of the hydrogen exosphere, the EUV solar flux, the solar wind density and velocity or the IMF cone angle at different levels of importance. These waves surprisingly also display the two same aforementioned properties as the foreshock electrons fluxes at Mars though the wave origin is related to the ions only. Also, the drivers mentioned above should not (and do not) show any noticeable change when crossing the electron foreshock boundary and inside the pure electron foreshock. We investigate the possibility that the extra free energy necessary to increase the wave amplitude could be due to supplementary ionization of hydrogen atoms by electron impact ionization inside the foreshock. Higher frequency (so called '1-Hz waves') which are usually observed on field lines connected to the bow shock and used as a signature of a location inside the foreshock can be observed simultaneously. Therefore, the electron foreshock also plays a role in the production of pickup protons from high altitude.