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Alfvèn wave acceleration and ion outflow from Mars

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Intense ULF wave activity characterizes the Martian plasma environment. The waves are generated in the shocked solar wind plasma (sheath), subsequently propagating into the Martian induced magnetosphere. ULF waves are omnipresent in the Martian magnetosphere. Even the ionosphere down to 300 km altitude (pericenter of Mars Express) is characterized by strong density modulations in the ULF frequency range. Coincident with density modulations is ion acceleration to relatively low velocities, the ion outflow near Mars having velocities typically less than 20 km/s. The ion acceleration may be velocity dependent, i.e. the energy peaks are proportional to the ion mass, but the more general feature is a mix between energy- and velocity-dependent energization. The combination of low-velocity outflow and the above mass dependent acceleration suggests a mass-loaded wave energization process.

Multi-species ion data from the ASPERA ion instrument on Mars Express is compared with the wave activity inferred from the ion and electron modulation in the ULF frequency range. Due to the lack of magnetometer data we are unable to determine the wave mode, but the coincident modulation of ions and electrons suggests MHD waves. Nevertheless, using ponderomotive force theory of the wave electric field in the induced magnetic field environment of Mars, the ion energization by MHD waves can be computed and compared with the observed ionospheric ion acceleration. Wave focussing onto the plasma sheet is also considered a means for further ion acceleration in the Martian tail.