Internally generated ULF waves in the Martian magnetosphere

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In contrast to relatively well studied upstream waves generated externally to the bow shock of Mars, the presence, sources, and consequences of internally generated ULF waves in the Martian magentosphere are yet to be properly identified. Here we investigate ULF waves driven by local proton instabilities in the Martian magnetosphere by utilizing magnetic field and plasma data obtained by MAVEN. In the dayside upper ionosphere and nightside magnetotail of Mars, MAVEN detected narrowband emissions in the predominantly compressional component near the local proton cyclotron frequency and its harmonics. The dayside waves are typically accompanied by ring/shell-like proton velocity distribution functions formed by injected hot protons of magnetosheath origin, and these waves are observed preferentially in the presence of dense ionospheric protons under high solar extreme ultraviolet (EUV) conditions. Meanwhile, the nightside waves tend to be observed when both of the solar wind dynamic pressure and solar EUV flux are high, leading to simultaneous enhancement of warm and cold protons in the magnetotail. The wave properties and their dependence on local and upstream conditions can be mostly explained by a proton Bernstein mode instability driven by a positive perpendicular slope in proton velocity distribution functions. We discuss potential implications of these waves for energization of ionospheric protons.