

# Supplementary Material for ”Ultra-low Frequency Foreshock Waves and Ion Dynamics at Mars”

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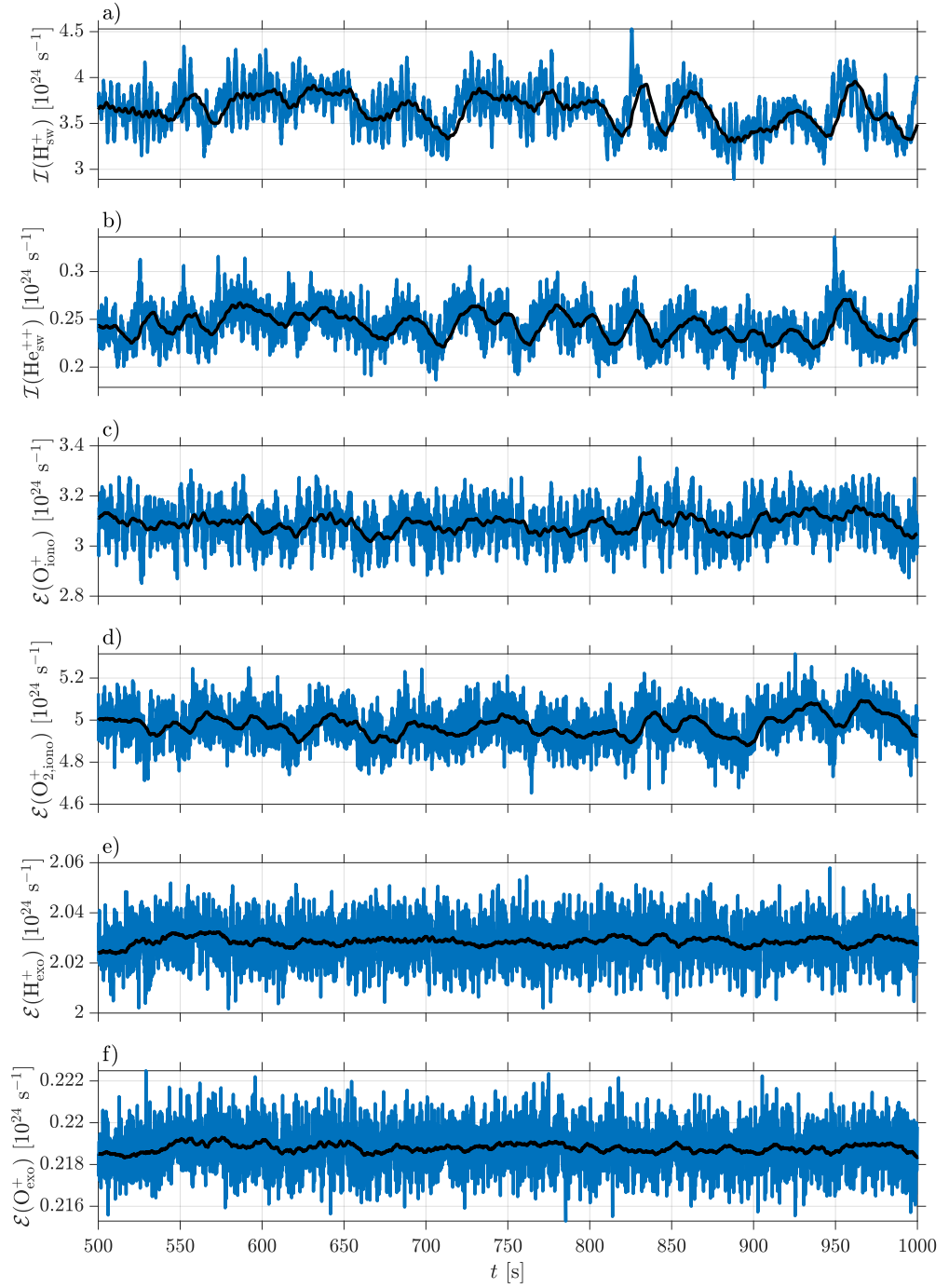
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**Movie S01.** Dynamics of the solar wind proton scalar, kinetic temperature (top panels) and the  $B_z$  component of the magnetic field (bottom panels) on the  $XY$  ( $z = 0$ ) plane in Run 1 (left panels) and Run 2 (right panels).

**Movie S02.** Dynamics of the oxygen ion ( $O^+$ ) density on three perpendicular planes in Run 1 (top panels) and Run 2 (right panels).

**Movie S03.** Dynamics of the oxygen ion (left:  $O^+$  and right:  $O_2^+$ ) densities on the  $yz$  plane in the heavy ion plume in Run 1. The white star shows the point P3 location.



**Figure S04.** Time series of global solar wind ion precipitation rates (a and b) and global planetary ion escape rates (c-f) in Run 2. The black line gives the running average over 10 s.