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Spectroscopic Measurements of the Ion Velocity Distribution at the Base of the Fast Solar Wind

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In situ measurements of the fast solar wind reveal non-thermal distributions of electrons, protons and, minor ions extending from 0.3 AU to the heliopause. The physical mechanisms responsible for these non-thermal properties and the location where these properties originate remain open questions. Here we present spectroscopic evidence, from extreme ultraviolet spectroscopy, that the velocity distribution functions (VDFs) of minor ions are already non-Gaussian at the base of the fast solar wind in a coronal hole, at altitudes of $< 1.1 R_{\odot}$. Analysis of Fe, Si, and Mg spectral lines reveal a peaked line-shape core and broad wings that can be characteristed by a kappa VDF. A kappa distribution fit gives very small kappa indices off-limb of $\kappa \approx 1.9 - 2.5$, indicating either (a) ion populations far from thermal equilibrium, (b) fluid motions such as non-Gaussian turbulent fluctuations or non-uniform wave motions, or (c) some combination of both. These observations provide important empirical constraints for the source region of the fast solar wind and for the theoretical models of the different acceleration, heating, and energy deposition processes therein. To the best of our knowledge, this is the first time that the ion VDF in the fast solar wind has been probed so close to its source region. The findings are also a timely precursor to the upcoming 2018 launch of the *Parker Solar Probe*, which will provide the closest in situ measurements of the solar wind at approximately 0.04 AU (8.5 solar radii).