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Anisotropy of the He+, C+, N+, O+, and Ne+ Pickup Ion Velocity Distribution Function

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Interstellar and inner-source PickUp Ions (PUIs) are produced by the ionization of neutral atoms that originate either outside or inside the heliosphere. Just after the ionization, the singly charged ions are picked up by the magnetized solar wind plasma and develop strong anisotropic toroidal features in their Velocity Distribution Functions (VDF). As the plasma parcel moves outward with the solar wind, the pickup-ion VDF gets more and more affected by resonant wave-particle interactions, changing heliospheric conditions, and plasma drifts, which lead to a gradual isotropization of the pickup ion VDF. Past investigations of the pickup ion torus distribution were limited to He^+ pickup ions at 1 Astronomical Unit (AU).

The aim of this study is to quantify the state of anisotropy of the He^+, C^+, N^+, O^+, and Ne^+ pickup ion VDF at 1 AU. Changes between the state of anisotropy between PUIs of different mass-per charges can be used to estimate the significance of resonant wave particle interactions for the isotropization of their VDF, and to investigate the numerous simplifications that are generally made for the description of the phase space transport of PUIs.

Pulse height analysis data by the PLAsma and SupraThermal Ion Composition instrument (PLASTIC) on board the Solar Terrestrial RElations Observatory Ahead (STEREO A) is used to obtain velocity spectra of He^+, C^+, N^+, O^+, and Ne^+ relative to the solar wind, $f(w_{sw})$. The w_{sw}-spectra are sorted by two different configurations of the local magnetic field - one in which the torus distribution lies within the instrument's aperture, $\phi_\perp$, and one in which the torus distribution lies exclusively outside the instrument's field of view, $\phi_{||}$. The ratio of the PUI spectra between $\phi_\perp$ and $\phi_{||}$ is used to determine the degree of anisotropy of the PUI VDF.

The data shows that the formation of a torus distribution at 1 AU is significantly more prominent for O^+ (and N^+) than for He^+ (and Ne^+). This cannot be explained by resonant wave-particle interactions as the sole mechanism for the isotropization of the PUI VDF. The anisotropy of the O^+ VDF compared to He^+ is highly fluctuating but consistently higher over an observation period of 6 years and therefore unlikely to be related to either specific heliospheric conditions or solar activity variations. To our surprise, we also found a clear signature of a C^+ torus distribution at 1 AU very similar to the one of He^+, although as an inner-source PUI, C^+ should have a considerably different spectral and spatial injection pattern than interstellar PUIs.