SW17 Poster 1-090

Pickup Ion Distributions in the Inner Heliosphere (0.3 AU to 1 AU) as Observed by the Solar Orbiter SWA/Heavy Ion Sensor

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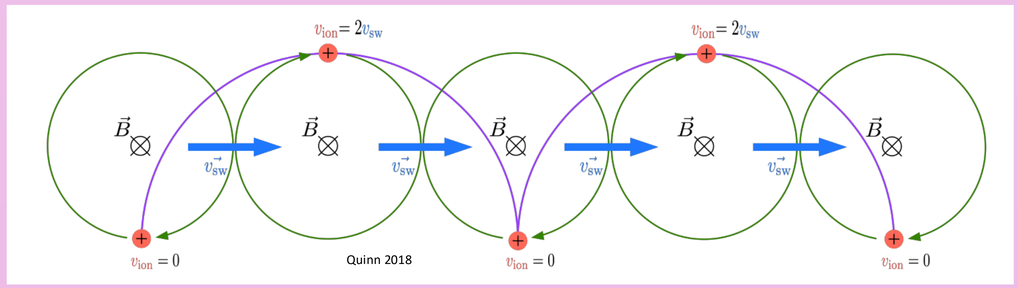
Introduction. Pickup ions (PUI) are generated when a neutral atom is ionized and then 'picked up' by the local magnetic field. For Z>1 ions, the single charge state of the PUI species is one distinguishing (although not always unique) characteristic used to separate the PUI from their highly ionized solar wind counterparts. Models for both interstellar He+ and for 'inner source' species predict an increase in intensity as heliocentric distance decreases, however interstellar PUIs also show intensity variation as a function of longitude – particularly the so-called gravitational focusing cone near 75° HAE Longitude for He^+. Interstellar PUIs are further distinguished by their distinctive velocity distribution function. Once a neutral is ionized, the freshly-made ion is "picked up" by the convecting magnetic field and begins gyrating around the magnetic field. This results in an abrupt 'cuts off' in intensity at twice the solar wind speed (spacecraft frame of reference). In this presentation we present PUI results from the Heavy Ion Sensor (HIS) on Solar Orbiter, that includes longitudinal and heliodistance (1 AU to 0.3 AU) measurements, with a concentration on observations of the cut off profile. The results indicate variations in the cutoff corresponding to solar wind bulk parameters but also a longitudinal variation in profile. We find these results are consistent with observations at 1AU by STEREO PLASTIC (Bower et al., 2019).

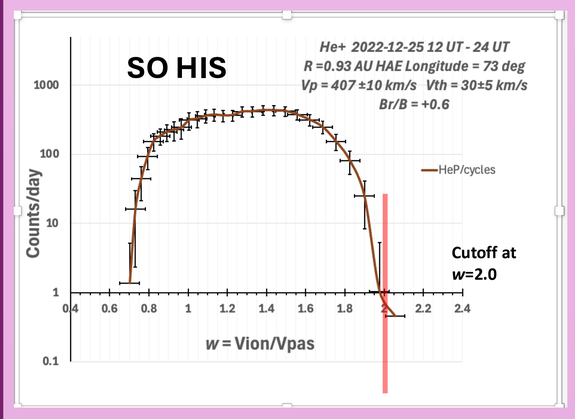


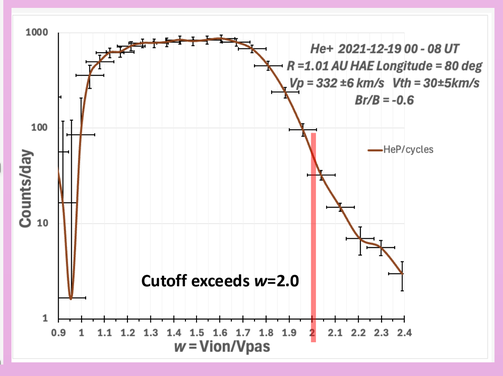
***1. W*-Profiles and Cut Offs.** Once a neutral is ionized, the freshly-made ion is "picked up" by the convecting IMF and begins gyrating around the magnetic field. PUI populations are often recognized by their velocity distribution function (e.g., Moebius et al., 1988), which *in the spacecraft frame 'cuts off' at twice the solar wind speed*

$$w = V_{ion}/V_{sw}$$

S/C Frame of reference: 2*V_{sw} cutoff

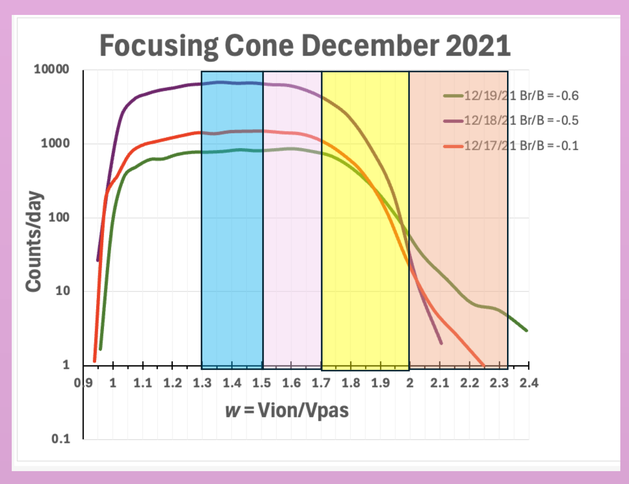
The *w=2.0* cutoff is applicable to a zero injection-speed and non-varying solar wind conditions. Moebius et al. (2015) studied the longitudinal injection speed dependence of the cutoff for He^+ , and others have looked at the effect on the profile due to compression and rarefaction regions (Saul et al., 2004; Taut et al., 2018; Bower et al., 2019). Epoch analysis, covering many months or years of STEREO PLASTIC data, were used in some of these cited studies. For HIS we have surveyed the cutoff variations by various parameters utilizing much shorter timescales.





2. SO HIS Survey. We created a data set for ions that meet M/Q and Mass criteria for He^+. The He^+ events were accumulated for 30 minutes (i.e., 60 HIS instrument 30-sec cycles). The data set covers the period November 2021 to early April 2023. Total number of samples: 16,430.

The overall counting trend suggests a temporal detector efficiency degradation causing a general downward shift in intensity. To nullify this effect, ratios of w-bands were used.



The ratio of w=2.0-2.3 to w=1.5-2.0 was used to examine the incidence of cutoffs exceeding w=2.0

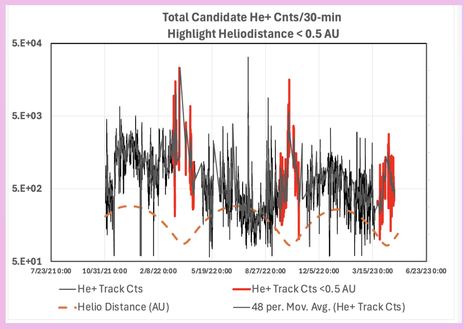
The He^+ events were subdivided into different *w*-bands, where the w for each ion is individually calculated using the V_{sw} from solar wind protons (SWA/PAS) and the He^+ speed (SWA/HIS).

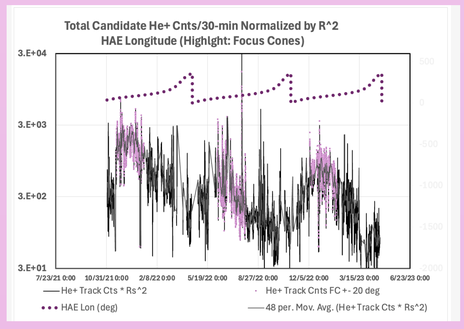
He^+ total = w >0.8

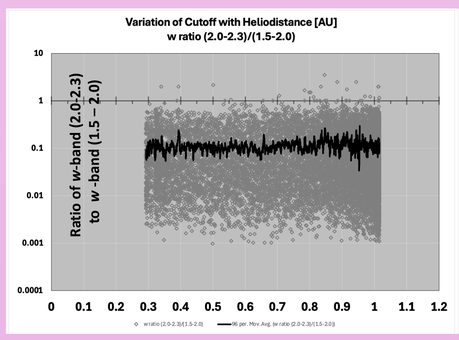
He^+ *w*-bands
- w 1.3 – 1.5
- w 1.5 – 1.7
- w 1.7 – 2.0
- w 2.0 – 2.3

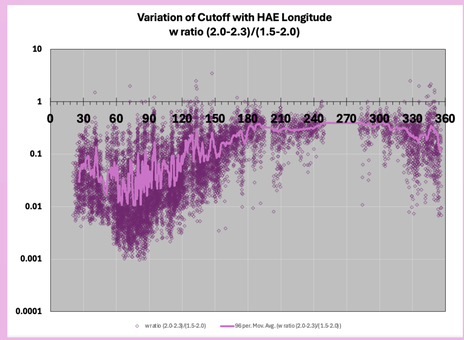
Acknowledgement

This study uses public access data provided by the Solar Orbiter SWA Proton Alpha Sensor (PAS, PI Louarn) and the Solar Orbiter Magnetometer (MAG, PI Horbury). The HIS analysis was funded under SWRI Solar Orbiter HIS contract to the University of New Hampshire, A99200MO and by internal UNH funds.







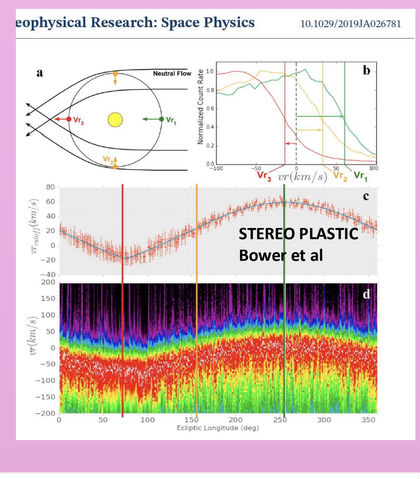


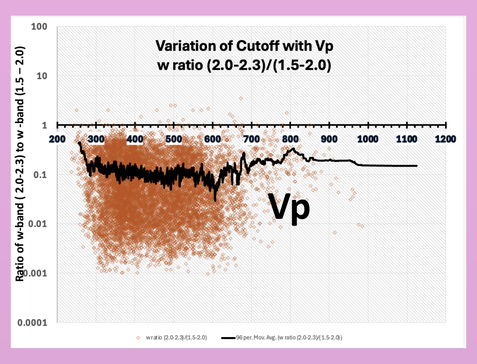
Heliodistance [AU] **HAE Longitude [deg]**

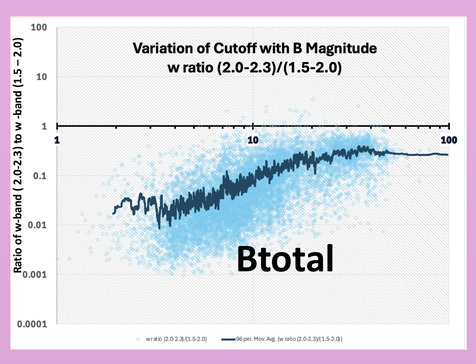
***3. Survey Results – Orbital Parameters*.** Total He^+ Counts (*w*>0.8) indicate increased He^+ PUI intensity as Solar Orbiter approaches perihelion, as predicted by models. No significant heliodistance dependence on cutoff is observed in the *w*-band ratio (2.0-2.3)/(1.5-2.0), although there is an increase in variance at larger distance.

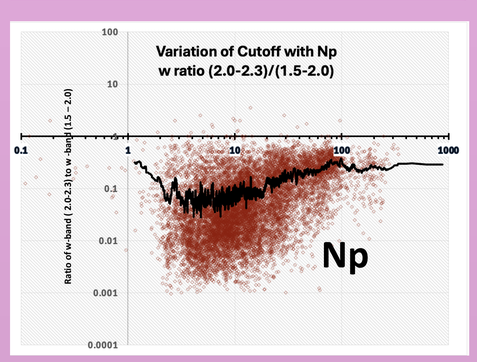
The He^+ PUI intensity increases within the gravitational focusing cone (FC) near 75° Longitude. There is also a clear longitudinal signature in the *w* cutoff ratio (2.0-2.3)/(1.5-2.0).

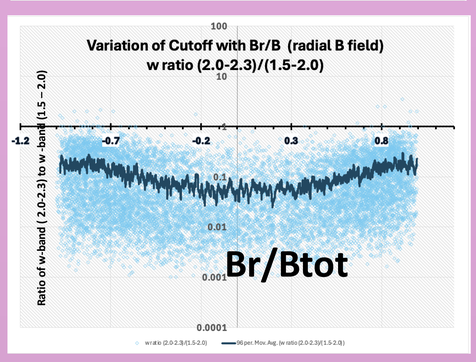
4. Longitudinal Dependence of Cutoff – Comparison with STEREO. An epoch study (Bower et al. 2019), analyzing 7 years of STEREO PLASTIC He^+ observations, confirmed the longitudinal variation in the cutoff speed first suggested by Moebius et al. (2015). Solar Orbiter sees the same trend, using the ratio technique. This trend persists, even though the SO data covers 0.3 to 1 AU, whereas STEREO A is near 0.96 AU.

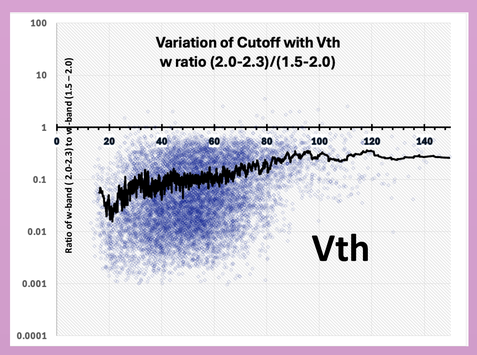












5. Survey Results – Solar Wind Parameters. Clear trends are observed in Np, Vth, Btot, and a modest trend in Vp. Br/Btot near ±1.0 is indicative of distribution coverage affected by the HIS field of view. The Bower analysis (2019) showed similar cutoff trends for Vp, Btot, and Np associated with compression regions.