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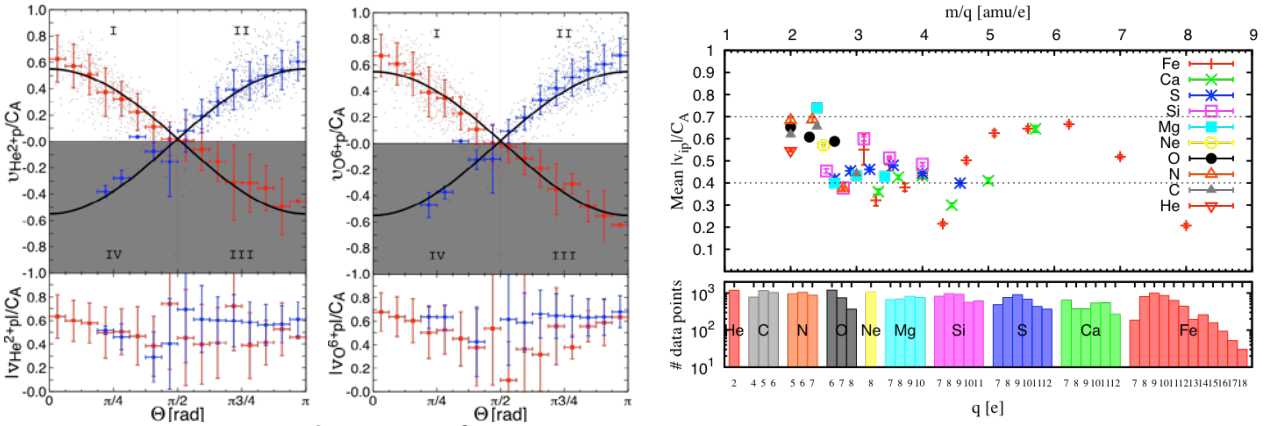
Ion-Proton Differential Streaming in the Solar Wind



Left two figures: Left He^{2+}; Right O^{6+}; ***Upper panels:*** Scaled observed differential flow versus angle spanned by $\mathbf{v_p}$ and **B**; Dots, 12 minute measurements; symbols with error bars, mean values with standard deviation (y-error bars) for Θ bins (x-error bars). Red and blue denote in- and outward magnetic field polarity. The black lines show the expected behavior for constant proton velocity and constant Alfvén velocity if $\mathbf{v_{ip}}$ does not depend on Θ; ***Lower panels:*** Symbols with error bars, the same as in the upper panels but for reconstructed differential flow. ***Right figure: Upper panel:*** Mean scaled differential streaming versus mass per charge of all 44 analyzed ions; ***Lower panel:*** Number of 12-minute measurements for each ion. (From Berger, Wimmer-Schweingruber, and Gloeckler; PRL 106, 151103; 2011; see this for more details).

Solar wind minor ions are known to exhibit non-thermal features. One is ion-proton differential streaming. The minor ions tend to outrun protons by a fraction of the local Alfvén speed. So far systematic measurements of this differential flow exist only for He^{2+} (e.g. Kasper, Lazarus, and Gary; PRL 101, 261103; 2008). In the case of He^{2+} the difference vector $\mathbf{v_{ip}} = \mathbf{v_i} - \mathbf{v_p}$ can be determined directly from the 3D measurements. There is ample observational evidence that $\mathbf{v}_{He^{2+}p}$ is aligned with the interplanetary magnetic field **B**. This alignment with **B** complicates measurements of minor-ion differential flow because **B** changes direction on time scales that are short compared to the typical cadence of 1 hour or longer in which minor-ion velocities can be obtained. Additionally only 1-D measurements are available for minor ions, and thus, only $|\mathbf{v_i}|$ can be determined.

We have studied the ion-proton differential streaming at 1 AU for a large number of ions (44 species) and an extended period in a systematic way (Berger et al. 2011). The period covered two fast streams of opposite magnetic polarity from Jan 6 to 20 in 2008 We analyzed data with a maximum likelihood analysis technique based on Poisson statistics that allows determining ion velocities at the highest time resolution allowed by SWICS (Berger; PhD-thesis; CAU-Kiel; 2008). The obtained differential flow shows a clear dependence on the direction of **B** (upper panels of 2 left figures). Comparing minor-ion results to He^{2+} strongly indicates that differential flow of minor ions is also aligned with **B**. Thus, the difference vector $\mathbf{v_{ip}}$ was reconstructed by combining 1-D SWICS measurements with 3-D SWEPAM and MAG measurements (lower panels of 2 left figures). The right figure shows the mean differential flow values for all 44 analyzed ions. In the solar wind frame all ions appear to flow along **B** at speeds comparable to the local Alfvén speed C_A.

This study has measured the small differential flow between heavy ions and solar wind protons to unprecedented precision. This flow, which is a remnant signature of coronal heating and solar wind acceleration, has previously been observed for only a handful of ions. These new observations provide significant new information about coronal heating and solar wind acceleration.

This item was contributed by Lars Berger and Robert F. Wimmer-Schweingruber, Institute for Experimental and Applied Physics (IEAP), University of Kiel, Germany, and George Gloeckler, University of Michigan. Questions and comments can be addressed to berger@physik.uni-kiel.de.