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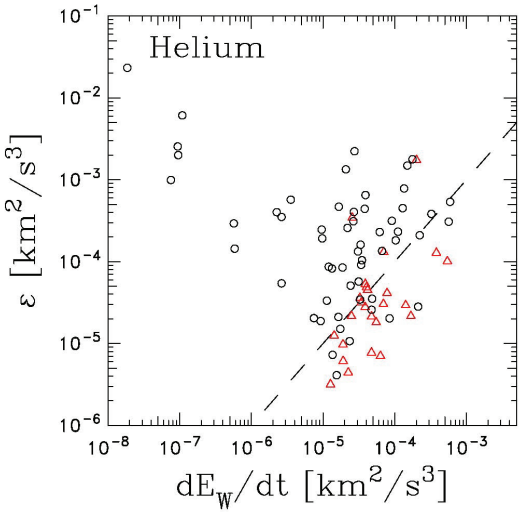
Analysis of Waves Due to Newborn Interstellar Pickup He^+

ACE News #181 reported the discovery of magnetic waves at the He^+ cyclotron frequency that were argued to arise from the scattering of newborn interstellar pickup ions. The discovery was made using the daily spectrograms of magnetic field data described in ACE News #176 that are now available at the ACE Science Center spanning the lifetime of the mission. Interstellar pickup ions originate as neutral atoms passing slowly through the heliosphere. The dominant neutral atoms are Hydrogen, but only a small fraction of these manage to penetrate to 1 AU.

A total of 25 events have now been tabulated and analyzed [Fisher et al., ApJ, 830, 47, 2016]. The average duration of the wave events as seen in the data is ~2 hours. This represents the relative filling of space by wave events rather than the actual lifetime of a physical event. We have no direct measure of how long an event may persist in space, but we do estimate that it requires from 10 to 20 hours for the instability to reach the observed energy levels. This is significantly slower than the ~15 minutes required for waves upstream of the Earth's bow shock that are excited by reflected solar wind ions. Twenty-five events over 18 years of data averaging 2 hours in duration represent only 0.05% of the time, so these observations are not common.



Comparison of wave growth rates dE_W/dt vs turbulent energy cascade rate ε for wave events (red triangles) and control intervals (black circles).

The observations possess the expected characteristics of waves excited by pickup He^+ in that spacecraft-frame frequencies slightly exceed the He^+ cyclotron frequency, are transverse to the ambient mean magnetic field, and are generally left-hand polarized in the spacecraft frame. Two events agree with theory in every regard except that they are right-hand polarized in keeping with observations of waves due to interstellar pickup H^+ where ~10% of those waves also possess the wrong polarization. Waves are seen throughout the solar cycle. The observations are more common in December and January when the spacecraft passes through the Helium focusing cone (ACE News #153), but this is not the dominant consideration for exciting observable wave levels.

Our analysis shows that the waves are seen when the background turbulence is weak, thereby allowing the wave energy to slowly accumulate over the required period of time without the destructive influence of the interplanetary turbulence cascade. To further demonstrate this point, we use 52 additional data intervals from nearby the wave observations as controls. In these instances, the energy cascade rate exceeds the wave growth rate. The Figure shows the results of that analysis. With a few exceptions that can be explained by the relative simplicity of the theories available, the wave events are distinguished by having growth rates that exceed turbulence rates and the control intervals have the reverse association. Theory indicates that the instability that excites wave energy is always present, but that the waves only reach observable levels when the background turbulence is low.

Contributed by Charles W. Smith of the University of New Hampshire on behalf of the authors of Fisher et al. Address comments and questions to Charles.Smith@unh.edu. See ACE News Archives for an archive of earlier ACE News items.