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Nonlinear Alfvén Waves in the Solar Wind

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Alfvén waves, discontinuities, proton perpendicular acceleration and magnetic decreases (MDs) observed in the solar wind are shown to be interrelated. Discontinuities are the phase-steepened edges of Alfvén waves. Magnetic decreases are caused by a diamagnetic effect from perpendicularly accelerated (to the magnetic field) protons. The ion acceleration is associated with the dissipation of phase-steepened Alfvén waves, presumably through the Ponderomotive Force. Proton perpendicular heating, through plasma instabilities, can lead to the generation of both proton cyclotron waves and mirror mode structures. Electromagnetic and electrostatic electron waves are detected as well. The Alfvén waves are thus found to be both dispersive and dissipative, conditions indicting that they may be intermediate shocks. The resultant "turbulence" created by the Alfvén wave dissipation is quite complex. There are both propagating (waves) and nonpropagating (mirror modes, MDs) byproducts. Interplanetary Alfvén waves are shown to rapidly phase-steepen at a distance of 1 AU from the Sun. A steepening rate of ~35 times per wavelength is indicated by Cluster-ACE measurements. Interplanetary (reverse) shock compression of Alfvén waves is noted to cause the rapid formation of MDs on the sunward side of corotating interaction regions (CIRs). Although much has been learned about the Alfvén wave phase-steepening process, many facets are still not understood. Several of these topics are discussed for the interested researcher. Computer simulations and theoretical developments will be useful in making further progress.