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The many faces of the Shear Alfvén Wave[1]

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One of the fundamental waves in a magnetized plasma is the shear Alfvén wave. This wave is responsible for rearranging current systems and, in fact, all low frequency currents ($f < f_{ci}$) are shear waves. It has become apparent that Alfvén waves are important in a wide variety of physical environments. They play a central role in the stability of magnetic confinement devices, give rise to aurora formation in planets, and are thought to contribute to heating and ion acceleration in the solar corona. Shear waves of finite transverse scale have electric fields parallel to the local background magnetic field, which is key to understanding current systems, and they can also cause particle acceleration over considerable distances in interstellar space. One may also consider magnetic flux ropes as low frequency shear waves. Shear waves can become nonlinear and in astrophysical environments this is proposed to result in turbulent cascades and the generation of structures. Measurements on board the Polar satellite indicate that the power of earthward bound shear waves equals that of the auroral electron beam. Alfvén waves have been directly observed in the solar wind, the auroral ionosphere and magnetotail, in the sun's corona, and in fusion devices. Currently there is much interest in the properties of toroidal Alfvén eigenmodes in tokamaks because they can be triggered by resonant alpha particles and thus could negatively affect particle confinement if they were to grow to large amplitudes. Shear waves of various forms have been a topic of experimental research for more than fifteen years in the Large Plasma Device (LAPD) at UCLA. The waves were first studied in both the kinetic and inertial regimes when excited by fluctuating currents with transverse dimension on the order of the collisionless skin depth $\frac{c}{\omega_{pe}}$. The three dimensional currents associated with the waves have been mapped and the ion motion which closes the currents across the magnetic field observed with laser induced fluorescence. The propagation in inhomogeneous magnetic fields and density gradients has been studied as well as effects of collisions and reflections from boundaries. Heating of the plasma electrons and ions has also been observed. The waves have been launched with antennas, but have also been generated by secondary processes such as mode conversion of microwaves at the upper hybrid layer followed by Cherenkov radiation by fast electrons. They are also produced by an exploding laser produced plasma in a background magnetoplasma. Magnetic field line reconnection has been observed when Alfvénic current systems interact. Flux ropes as well as temperature filaments also exhibit shear wave phenomena. Three-dimensional data illustrating these processes will be presented along with relevant theory. Part of the presentation will be in 3D!

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