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Plasma Motions and Compressive Wave Energetics in the Solar Corona and Solar Wind from Radio Wave Scattering Observations

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Radio signals propagating via the solar corona and solar wind are significantly affected by compressive waves, impacting solar burst properties as well as sources viewed through the turbulent atmosphere. While static fluctuations scatter radio waves elastically, moving, turbulent or oscillating density irregularities act to broaden the frequency of the scattered waves. Using a new anisotropic density fluctuation model from the kinetic scattering theory for solar radio bursts, we deduce the plasma velocities required to explain observations of spacecraft signal frequency broadening. The frequency broadening is consistent with motions that are dominated by the solar wind at distances
$gtrsim 10\ R_{\odot}$, but the levels of frequency broadening for
$lesssim 10\ R_{\odot}$ require additional radial speeds $\sim (100-300)$ km s^{-1} and/or transverse speeds $\sim (20-70)$ km s^{-1}. The inferred radial velocities appear consistent with the sound or proton thermal speeds, while the speeds perpendicular to the radial direction are consistent with non-thermal motions measured via coronal Doppler-line broadening, interpreted as Alfvénic fluctuations. Landau damping of parallel propagating ion-sound (slow MHD) waves allow an estimate of the proton heating rate. The energy deposition rates due to ion-sound wave damping peak at a heliocentric distance of $\sim (1-3)\ R_{\odot}$ are comparable to the rates available from a turbulent cascade of Alfvénic waves at large scales, suggesting a coherent picture of energy transfer, via the cascade or/and parametric decay of Alfvén waves to the small scales where heating takes place.

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