Correlations between plasma density and magnetic field strength in MHD turbulence in space

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Large amplitude magnetohydrodynamic (MHD) turbulence is ubiquitous in space plasma, for example, in the solar wind, in the foreshock region (Narita, World Scientific, 2010) and in the sheath region of the earth's bowshock (e.g., Pollock et al., J. Atmosph. Solar Terr. Phys, 2018). Moreover, recent Voyager observations of large amplitude density and magnetic field fluctuations in the heliosheath behind the termination shock arouse a vivid discussion on the compressible nature and the origin of the observed turbulence (Burlaga and Ness, ApJ, 2009; Gutynska et al., ApJ, 2010). An obvious way of generating the density fluctuations is via the presence of compressive wave modes, such as obliquely propagating MHD waves. The density response is linear to the magnetic field perturbations in this case, and it vanishes in the limit of parallel wave propagation. In a finite (large) amplitude Alfvenic turbulence the density perturbation may be mainly generated via the "frozen-in" of the magnetic field to the plasma or the static balance between the plasma pressure and the magnetic field. Both of these processes result in the quadratic response of the density to the magnetic field perturbations, although their correlation is positive for the former and negative for the latter. This simple fluid picture, sometimes referred to as the "quasi-static" approximation, is known to be significantly modified when the ion response to the turbulence is kinetically treated (Mjolhus and Wyller, Phys. Scripta, 1986; Medvedev and Diamond, Phys. Plasmas, 1996). In this presentation, we address this unsolved issue of the correlations between the plasma density and the magnetic field amplitude in the presence of finite amplitude MHD turbulence by performing hybrid simulations (kinetic ions + fluid electrons), and by examining the in situ Cluster spacecraft data of the foreshock plasma (Narita and Hada, Earth, Planets and Space, 2018).

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