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Turbulence and Plasma Physics in Clusters of Galaxies[1]

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The intracluster medium appears to be in a turbulent state. It is also threaded by randomly tangled magnetic fields. In the past few years there has been a dramatic increase in the quantity and quality of observational data on cluster turbulence and magnetic fields. The observed magnetic fields are strong enough to be dynamically important. The turbulence and magnetic field regulate the viscous heating and heat transport that determine the thermal structure of clusters. A coherent theory of magnetized cluster turbulence is necessary for understanding cluster behaviour on both large and small scales. The strength and certainly the structure of the cluster fields are determined by their interaction with the turbulence. This talk will first describe the fundamental properties of the turbulent generation of magnetic fields: (1) what type of field structure can be produced and maintained; (2) how a dynamical saturated state is achieved; (3) what are the observable signatures of the field structure in clusters. The field structure in no small measure depends on the nature of the viscous and magnetic cutoffs. These are determined by the plasma physics of the intracluster medium, which has very low collisionality. It will be shown that, under very general conditions, cluster plasmas threaded by weak magnetic fields are subject to firehose and mirror instabilities. These are driven by the anisotropies of the plasma pressure (viscous stress) that naturally arise in any weakly magnetized plasma that has low collisionality and is subject to stirring. The effect is captured by the extended MHD model with Braginskii viscosity, but, as the instability growth rates are proportional to the wavenumber down to the ion gyroscale, MHD equations with Braginskii viscosity are not well posed and a fully kinetic description is necessary. The instabilities may lead to the amplification of magnetic fields in clusters to the observed strength of $\sim 10\mu$G on cosmologically trivial time scales ($\sim 10^8$ yr). The saturation of the instabilities controls the effective transport properties of the cluster plasmas.

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