From: "lyutikov@gmail.com" <lyutikov@gmail.com>
Subject: **Laboratory Plasma Astrophysics**
Date: February 14, 2008 10:01:37 PM CST
To: liang@rice.edu

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Gentlemen, the last attempt. Here is the text, put in your comments and send them back to me, I will compile them together,

Maxim

Turbulent dissipation and particle acceleration in astrophysical plasmas.

Many astrophysical plasmas exist in a strongly turbulent state, when the local properties like density or electromagnetic fields experience quasi-random fluctuations. These fluctuations are typically driven by large scale forces, like motion of macroscopic bodies or plasma elements. Dissipation of turbulent motion leads to plasma heating, generation of magnetic field and, most importantly, acceleration of particles to supra-thermal energies. Astrophysical turbulence provides a way for the macroscopic energy to be dissipated into kinetic energy of particle motion, which in turn produces a wide range of observed radiation form plasma. Thus, interpretation of many astrophysical observations, especially those related to high energy astrophysics requires understanding of turbulent processes.

Examples of astrophysical turbulence applications include, to name a few, (i) plasma heating and particle acceleration in Solar flares; (ii) heating and acceleration of the Solar wind; (iii) angular momentum transport in accretion disk around pre-main sequence stars and compact objects; (iv) numerous turbulence-related processes in the interstellar medium, like support of molecular clouds against gravitational collapse and, inversely, seeding of collapsing proto-stellar clouds; (v) acceleration of cosmic rays, both protons and electrons, in galactic supernova remnants, clusters of galaxies and jets of Active Galactic Nuclei; (vi) heating of intercluster medium in clusters of galaxies.

Though these environments are very different in terms of plasma parameters, the turbulent processes can be generally separated into several categories:
\begin{itemize}
\item Collisional MHD turbulence. This most basic type of plasma turbulence remains an unsolved problems: what are the spectra and anisotropic properties?
\item Whistler/Hall turbulence. As the turbulent cascade propagates to smaller scales, the typical frequencies of fluctuating electromagnetic field may become high enough so that ions stop responding to them. Alternatively, in neutron star crusts, ions may be fixed in an ion lattice. What are the spectra and anisotropic properties in this case?
\item Turbulence in collisionless high beta plasmas. In many astrophysical applications binary collision times are much longer than plasma dynamical time scales and the cyclotrons and plasma oscillations periods (plasma in clusters of galaxies are, perhaps, the best example of such regime). How does dissipation proceed at sub-viscous scales?

\item There is potentially a new plasma turbulence regime which takes place in a number of astrophysical setting (\eg\ corona of magnetars, AGN and GRB jets): turbulence in strongly magnetized plasmas, where energy density of magnetic field dominates plasma energy density, including rest mass. What are the spectra and anisotropic properties of turbulence in this case?
\end {itemize}
Virtually in all of these turbulence types the key questions are the same: what are the spectra and anisotropic properties of the fluctuating quantities and what are the possible spectra of particles accelerated, presumably, by Fermi mechanism.

In fact, beside Fermi-type acceleration in a turbulent medium, there are alternative ways to produce a non-thermal population of high energy particles. Particles may be accelerated in a DC type electric field in reconnection cites. This is especially promising route in a magnetically-dominated plasma, where most of the energy is stored in magnetic field.

Potential Experiments ?????????

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1. **Applications**: Solar wind, ISM, accretion disks, intercluster medium (ICM), astrophysical jets
2. **Types of turbulence**:
    - MHD (collisional): spectra and anisotropy
    - Whistler/Hall: spectra and anisotropy
    - Shock- and reconnection-generated turbulence, Fermi acceleration
    - Turbulence in collisionless high beta plasmas: dissipation at sub-viscous scales
    - Turbulence in strongly magnetized plasmas (sigma >1): spectra, anisotropy, acceleration spectra
3. **How particles are accelerated in all these turbulence types?**
4. **Potential Experiments**
    - Need facility that can do high beta and high Alfven Mach number with small collisions and strong magnetization of the ions
    - Next-generation (less collisional) reconnection experiment
    - ?????

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