Structure formation, energy release, and inter-region interactions in plasma

Masayoshi Tanaka[1]; Hideaki Kawano[2]; Takaaki Yokoyama[3]

[1] Kyushu Univ.; [2] Earth and Planetary Sci., Kyushu Univ.; [3] School of Science, Univ.Tokyo

Structure formation has been an important topic in laboratory plasma physics from the early stage of research in 1970's. Sheath formation, double layer, soliton, hole, shock wave, vortex are the examples of structure in plasmas, in which nonlinearity commonly plays an essential role. Attention to nonlinear phenomena was stimulated by the discovery of ion acoustic soliton, and occurrence of convective cells in confined plasmas. Phase space structure (hole) has much relation to space plasma physics. It was initially observed in the laboratory and then found to be identical to BEN (broadband electrostatic noise).

One of the recent topics of laboratory plasma physics is vortex formation in plasmas. The experiments on vortex dynamics using a pure electron plasma has been attracting much attention from the view point of fluid mechanics and statistical physics. Generation of zonal flow from turbulence is also a topic in plasma confinement research, which has recently been confirmed.

Space plasma around the Earth can directly be measured by instruments such as spacecraft, which provide, along with remote-sensing type measurements, useful information on physical processes of plasma.

The space around the Earth consists of several regions associated with different values of physical parameters (e.g., plasma density and temperature, and the magnetic field strength), i.e., the solar wind region, the magnetosheath, the magnetosphere, and the ionosphere. The interactions among these regions affect the dynamics of the plasma around the Earth. Also, at boundaries between these regions, the interactions (such as

reconnection and the KH instability) generates structures.

Space storms and substorms release a lot of energy and thus are important in the above-stated system. At space storms (or magnetic storms), lasting a few days, solar-wind energy is input into the magnetosphere, enhances plasma convection there, and accelerates particles there; as a result, strong currents flow in the magnetosphere-ionosphere system.

At substorms, energy-release processes commence at about an hour after the convection enhancement. That energy is released by instabilities such as reconnection, in which instabilities cross-scale coupling plays an important role. It is also noted that, for both the space storm and the substorm, magnetosphere-ionosphere coupling processes play an important role.

In astronomical objects, there are various energy release phenomena. Among them, those in the solar atmosphere are prototypes of such phenomena. In a solar flare, stored magnetic energy of 10^{29} to 10^{31} erg is released in several tens minutes to several hours. The physical engine of flares is now thought to be the magnetic reconnection. But there still remained questions such as the storage of the magnetic energy, trigger of the reconnection, micro-physics of the diffusion etc. The coronal heating problem is another interesting issue. The corona is steadily keeping its temperature around a few million Kelvin although it is located at the outside of the cool atmosphere. Two main mechanisms are proposed but both are not still conclusive. One is heating by numerous small reconnection, and the other is heating by dissipation of MHD waves. The SOLAR-B sattelite will challenge this issue.

A supernova is enormously explosive energy release that is a manifestation of the end of a star's life. The energy source of a class of gamma-ray bursts is considered to be a hyperend of the supernovae, called the 'hyper-nova'. However, there remains a big issue on the supernovae physics. The physical mechanism of the explosion itself of type-II supernovae is not still completely understood. Recently, in addition to the various effects, such as neutrino transport, equation of states, much attention is paid to the effect of global asymmetry. In particular, the effect of thermal convection, strong rotation, magnetic field are discussed.