MHD simulations of plasmas in cluster of galaxies including radiative cooling and heat conduction

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Recently, high resolution X-ray observations revealed that X-ray emitting plasmas in the core of cluster of galaxies are hotter than expected them from the theory. Some heat sources are required to explain this temperature distribution. Candidates are energy dissipation by a motion of member galaxies and heat transport from hotter outer plasmas toward the cluster core.

In hot rarefied cluster plasmas with 10 million degrees, the heat conduction is very efficient, and the time scale of heat conduction is much shorter than the Hubble time. Although heat conduction tends to smooth temperature distribution, magnetic fields make it non-uniform because magnetic fields suppress the heat conduction perpendicular to the direction of field lines. The coexistence of hot and cool plasmas observed in cluster of galaxies can be reproduced by anisotropic heat conduction. Therefore, magnetic fields play an essential role, even if magnetic energy is less than thermal energy.

We carried out the magnetohydrodynamic simulations including the radiative cooling and heat conduction, and investigated the time evolution of cluster plasmas. First, we set up the turbulent magnetic fields by carrying out the simulation of moving clumps in the gravitational potential of the cluster without including the radiative cooling and heat conduction. We assumed that the moving clumps initially accompany gravitationally confined plasma with dipole fields. After magnetic turbulence develops, we start the simulation by including both radiative cooling and heat conduction. Initially, we also assumed the cluster core is cooler than ambient plasmas.

In this case, the cluster core is heated up by the heat conduction. Since magnetic turbulence suppresses heat conduction, temperature distribution remains non-uniform. On the other hand, when magnetic fields do not exist, temperature becomes almost non-uniform because the heat conducts isotropically, and it is not consistent with the temperature distribution obtained from observations.

In this talk, we show the results of MHD simulations, and discuss the thermal stability and heating of cluster plasmas in the presence of magnetic turbulence.