Weibel Instability driven by Temperature Gradients

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We showed that magnetic fields are generated in the plasma which have the temperature inhomogeneities. The mechanism is the same as the Weibel instability because the velocity distribution functions are at non-equilibrium and anisotropic under the temperature gradients. The Weibel instability has been paid attention to as one of the generation processes of cosmic magnetic fields. We applied this process to clusters of galaxies.

Clusters of galaxies are the largest gravitationally bound systems in the universe, with sizes of a few Mpc (a Mpc is about 3 million light-years). Clusters contain the hot and thin plasma ($n_e¥sim a few 10^{-2}-10^{-3} cm^{-3}$ and several keV) with magnetic fields of $¥sim 0.1-1¥mu$G. The origin of cluster magnetic fields is still debated. One of the proposed processes is that cluster magnetic fields are generated by the Biermann battery effect and then grow via the dynamo effects. However, the initial magnetic fields necessary to explain the observed values are much higher than those expected by the battery effect. Those process are based on hydrodynamic effects, while the Weibel instability is a microscopic plasma instability. The saturated magnetic fields by the Weibel instability are in good agreement with the observed values. It is well-known that the spatial scales of the generated magnetic fields become longer by inverse-cascade process and the values decrease. The critical problem of the Weibel instability is that the spatial scales are much smaller than the hydrodynamical scale. It is very difficult to know whether the fields evolve to the hydrodynamical scales, by particle-in-cell (PIC) numerical simulations, because the simulation box and running time are finite.

The Weibel instability driven by the temperature gradient predicates that the magnetic fields exists at which there are temperature inhomogeneities. We derived the map of magnetic field strength from the observed temperature map. The field maps constrain the origin of cluster magnetic fields, compared with the maps measured in the near future.