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Plasma physical problems in high-energy heavy-ion collisions

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A quark is a fundamental constituent of matter. The quarks are bound by the strong interaction that is mediated by gluons and are normally confined in hadrons. However, in the early universe, the quarks and gluons were weakly bound or unbound because the temperature of the universe was too high to form hadrons. This extreme state of matter is called as quark-gluon plasma (QGP).

The only way to recreate the QGP in the laboratory is through high-energy heavy-ion collisions (HIC). The HIC enables us to achieve very high temperature and density where the quarks and gluons are liberated from the nucleons (protons and neutrons). Several huge international collaborations at the Relativistic Heavy Ion Collider (RHIC) or the Large Hadron Collider (LHC) succeeded in creating the QGP. The QGP discovered at those experiments was found to behave as nearly perfect fluid. However, the whole space-time evolution of the HIC is quite complicated, and details of the dynamics have not been clarified yet.

A rapid thermalization or hydrodynamization process in the early stage of the HIC, pre-QGP stage, is one of the unsolved important problems in the HIC. Since the dynamics of the pre-QGP matter, the so-called glasma, may be governed by the interaction of color charged particles with color electromagnetic fields, non-Abelian plasma instabilities and dynamics must be important. In addition, an extremely strong magnetic field is expected to be generated in non-central HIC events. Therefore, magnetohydrodynamic (MHD) effects may play a role in the dynamics of the QGP.

Thus, the dynamics of the electromagnetic plasma should give some useful hints for that of the QGP. In this study, we investigate the applicability of physical processes of the electromagnetic plasma to unexplained evolution of the HIC, and discuss the possibility of the expansion of the plasma physics.