Observations of supernova remnants show that electrons are heated up to about 1 keV and accelerated up to more than 10 TeV. In addition, it is believed that ions are also accelerated to make the Galactic cosmic rays. Moreover, X-ray observations suggest that the magnetic field is amplified from 3 μG to up to about 100 μG or more. These have not been completely understood theoretically, although many intensive studies have been performed for a long time.

We present the results of linear analyses and self-consistent particle-in-cell simulations of collisionless plasma instabilities in the collisionless shock to investigate above observational results.

We first investigated collisionless plasma instabilities in the transition region of the collisionless perpendicular shock to understand the electron heating mechanism and the validity of the surfing acceleration in multi-dimensional system. We performed two-dimensional linear analyses and two-dimensional particle-in-cell simulations, so that we found importance of multi-dimensional effects and a new plasma instability and we reproduced the observed electron temperature about 1 keV for the first time.

Secondly, we studied effects of neutral particles on supernova remnant shocks. There are neutral particles around supernova remnants because the interstellar matter is not fully ionized. The neutral particles have a great impact on the shock dynamics because the neutral fraction is order of unity around supernova remnants. The neural particles are mainly ionized by the charge exchange process in the downstream and the precursor region of the collisionless shocks. We showed that the charge exchanged ions excite plasma instabilities and can amplify the magnetic field up to 100 μG. Moreover, the charge exchanged ions change the shock structure and the spectrum of accelerated particles.