3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Balmer lines as diagnostics of collisionless shocks: acceleration of non-thermal particles, the nature of shock precursor and ion-electron temperature ratio

Jiro Shimoda[1,2]

[1] Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, [2] Astronomical Institute, Tohoku University

e-mail (speaker): j-shimoda@astr.tohoku.ac.jp

Cosmic-rays are charged, energetic particles, in particular, those coming from an extrasolar origin have an energy from 1 GeV to 0.1 ZeV. Their energy spectrum around the Earth shows a power-law form and significant deviation from a Maxwellian distribution at a high energy range. That indicates they have been experienced an acceleration.

The cosmic-rays with an energy about 1 GeV occupy most of their energy density that is measured as 1 eV/cc around the Earth. This energy density is comparable to energy densities of main components of our galaxy such as stellar light, pressure of thermal gas and magnetic field. In our galaxy, the pressures of magnetic field and cosmic-rays support matter against its own weight in the Galactic gravitational potential (e.g. Boulares & Cox 1990). Moreover, the cosmic-rays ionize a dense, cold molecular gas, which is site of star formation. Since the ionization degree of gas characterize the gas dynamics via the frozen-in of magnetic field, the cosmic-rays can regulate the star-formation (e.g. Goodman et al. 1993; Crutcher 1999; Inutsuka 2012).

The origin of cosmic-rays is a long-standing unresolved issue in Astrophysics. For cosmic-rays with an energy until 3 PeV, they are usually called 'Galactic cosmic-rays'. Collisionless shock waves of supernova remnant in our galaxy are considered to be the best candidate of the origin of Galactic cosmic-rays. The 'collisionless' means that the shock transition occurs on a length-scale much shorter than that associated with a particle mean free path to Coulomb scattering. Therefore, thermal equilibrium is much less strongly enforced. If roughly a tenth of supernova explosion energy is consumed for cosmic-ray acceleration, the energy density measured around the Earth can be explained. Thus, the physics of particle acceleration is one of the most important issue of the collisionless shocks.

An important concern is to be specify the density of accelerated particles in the supernova remnant shocks, a necessary step toward confirming the shocks as the main source of Galactic cosmic-rays. In addition, it allows us to quantify the back reaction of accelerated particles on the background shock structure. If the amount of accelerated particles is significant, in other words, if a large fraction of shock kinetic energy goes into non-thermal particles due to the particle acceleration, the downstream temperature becomes considerably lower than the case of an adiabatic shock, that is, there is some missing thermal energy. This energy loss from the shock has been widely investigated (e.g. Hughes et al. 2000; Helder et al. 2009; Hovey et al. 2018). In the latest development, we showed that the linear polarization degree of hydrogen Balmer lines (especially, H-alpha and H-beta) observed at the supernova remnant shocks depends on the energy-loss.

The hydrogen Balmer line emissions from supernova remnant shocks are relied on as a probe of the physics of collisionless shock. They can be used to diagnose the resulting departures from equilibrium, such as effects on ion-electron temperature ratio, the nature of shock precursor, and acceleration of non-thermal particles (e.g. Raymond 1991; Heng 2010; Shimoda et al. 2015, 2018, Shimoda & Laming 2019). In this talk, we review the role of cosmic-rays in our galaxy, issues of their origin and the latest development of Balmer line emission models as useful probe of the collisionless shock physics.

References

Boulares & Cox, 1990, ApJ 365, 544
Crutcher 1999, ApJ, 406, 528
Goodman et al., 1993, ApJ 406, 528
Helder et al., 2009, Science, 325, 719
Heng 2010, Publ. Astron. Soc. Aust., 27, 23
Hovey et al., 2018, ApJ, 862, 148
Hughes et al., 2000, ApJL, 543, 61
Inutsuka 2012, PTEP, 01A307
Raymond 1991, PASP, 103, 781
Shimoda et al., 2015, ApJ 803, 98
Shimoda et al., 2018, MNRAS 473, 1394
Shimoda et al., 2018, MNRAS 480, 2200
Shimoda & Laming, 2019, MNRAS 485, 5453

Note: Abstract should be in 1 page.