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Radiation Properties of High-Energy Astrophysical Plasmas

Kuniaki Masai[1]

[1] none

http://www-astro.phys.metro-u.ac.jp/

We discuss radiation properties of the plasmas particularly in high-energy astrophysics with a keyword 'non-equilibrium': non-LTE level populations in radiation transfer, nonequilibrium ionization due to rapid heating/cooling or photoionization, and non-Maxwellian distribution function of electrons undergoing acceleration. Astrophysical topics are supernova remnants, intracluster/interstellar media, accretion gas onto a neutron star or black hole, and afterglow of gamma-ray bursts.

1) Non-LTE level population
To establish LTE populations, transitions between atomic levels must be dominated by collisions. While the collision rates are nearly independent of atomic number Z, competitive spontaneous emission rates increase with the as Zˆq (q = 4 for E1 and greater than 4 for non-E1 transitions). Therefore, for heavy elements level populations are far from their LTE values at densities of practical interest.

2) Nonequilibrium ionization
Young supernova remnants are ionizing plasmas, because collisional ionization cannot immediately follow rapid heating by shocks in the low-density interstellar medium. In contrast, in accretion-powered sources the accretion gas is photoionized to be a recombining plasma. Non-equilibrium ionization states, ionizing or recombining, significantly affect radiation processes in the plasmas.

3) Non-Maxwellian distribution function
In the interstellar gas of galaxies or intracluster gas of galaxy clusters,

stochastic acceleration of thermal electrons, e.g. by weak turbulence/fluctuation in the magnetic field, is expected to form quasi-thermal electrons. Even if the fraction is small, quasi-thermal electrons cause nonequilibrium emission through the interaction with the thermal bulk ions, unlike nonthermal electrons that are almost collisionless.