Three-Dimensional Numerical Magnetohydrodynamic Simulations of Magnetic Reconnection as the Origin of X-ray Gas in the Galaxy

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Abstract. We suggested a magnetic reconnection model for the origin of the X-ray gas in the Galaxy. In this paper, we examine this model by performing the three-dimensional magnetohydrodynamic simulation of the magnetic reconnection triggered by a supernova shock in the interstellar medium. The magnetic reconnection heats the interstellar gas by releasing the interstellar magnetic energy. The magnetic reconnection is a possible mechanism to generate the X-ray gas in the Galaxy.

1. Introduction

Strong thermal X-ray emission, called Galactic Ridge X-ray Emission, is observed along the Galactic plane (Koyama et al. 1986). The origin of hot (\( \sim 7 \) keV) component of GRXE is not known, while cool (\( \sim 0.8 \) keV) one is associated with supernovae (Kaneda et al. 1997, Sugizaki et al. 2001). We propose a possible mechanism to explain the origin; locally strong magnetic fields of \( B_{\text{local}} \sim 30 \mu G \) heat interstellar gas to \( \sim 7 \) keV via magnetic reconnection (Tanuma et al. 1999). There will be the small-scale (< 10 pc) strong magnetic fields, which can be observed as \( \langle B \rangle_{\text{obs}} \sim 3 \mu G \) by integration of Faraday Rotation Measure, if it is localized by a volume filling factor of \( f \sim 0.1 \).

2. Numerical Simulations and Results

In order to examine this model, we solved three-dimensional (3D) resistive magnetohydrodynamic (MHD) equations numerically to examine the magnetic re-
Figure 1. (Left) Time variation of the 2D distribution of the gas pressure at the reconnection region ($x$-$y$ plane of the 3D simulation). The magnetic reconnection starts long after the supernova shock passes a current sheet. The magnetic energy is released by the magnetic reconnection. The interstellar gas of 0.8 keV is heated to $\sim$ 7 keV (Tanuma et al. 1999, 2001). The high-pressure region is confined by the magnetic field. (Right) Time variations of the 2D distribution of the thermal flux. We compare 3D model with 2D model with higher spatial resolution. In 2D model, X-ray flux is strong in the plasmoids and current sheet. The released magnetic energy is determined only by the magnetic field strength. The results such as the magnetic energy-release rate are same between 2D and 3D models.

connection triggered by a supernova shock (fig.1). We assume that the magnetic field is $B_x = 30 \tanh(y/20\text{pc}) \mu G$, $B_y = B_z = 0$, and the temperature is uniform, at the initial condition. We put a supernova explosion outside the current sheet. The supernova-shock, as a result, triggers the magnetic reconnection. The magnetic reconnection heats the interstellar gas to $\sim$ 7 keV in the Galactic plane, if it occurs in the locally strong magnetic fields of $B_{\text{local}} \sim 30 \mu G$. The heated plasma is confined by the magnetic field for $\sim 10^{5.5} \text{ yr}$.

3. Discussion

The required interval of the magnetic reconnections (triggered by anything) is $\sim 1 - 10 \text{ yr}$. The magnetic reconnection will explain the origin of X-rays from the Galactic ridge, furthermore the Galactic halo, and clusters of galaxies.

References

Koyama, K. et al. 1986, PASJ, 38, 121
Tanuma, S. et al. 1999, PASJ, 51, 161