Construction of Global Magnetic Field Structure Model in Disk Galaxies with Three Dimensional Magnetohydrodynamic Simulations: Effects of Steady Spiral Arms

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We study numerically the large-scale gas and magnetic field evolution of spiral galaxies in the gravitational potential of a disk, bulge, halo, and spiral arms. We adopt a steady axisymmetric gravitational potential given by Miyamoto et al. and rigid rotating spiral potential. In order to understand the physical processes that the galactic magnetic fields are amplified and maintained, we assume initial condition is a magneto-hydro dynamically equilibrium thin disk gas component ($T \sim 10^4 K$) centered at $r = 10 kpc$ threaded by weak azimuthal magnetic fields. We carried out three-dimensional magneto-hydrodynamic simulation taken into account radiative cooling energy loss. Our models demonstrate that the magnetic fields strength are dramatically amplified by disturbance due to gravitational potential of spiral arms. Numerical results indicate that the isothermal shocks generated by gravitational potential of spiral arms. Magnetic fields are dramatically amplified due to galactic shocks and the magnetic arms are generated. Magnetic fields around the spiral arms are amplified up to a few μG at 150Myr. The azimuthal direction of mean magnetic fields in the disk changes with radius due to magneto-rotational instabilities.

The resultant structure of azimuthal magnetic fields distribution is also qualitatively consistent with the observed distribution of the Faraday rotation measure.

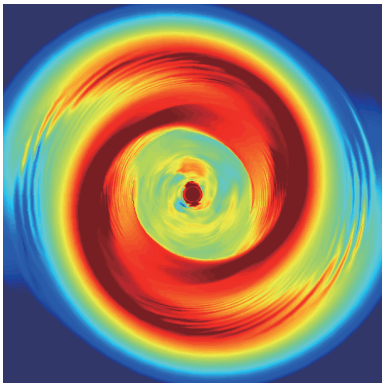

Figure 1: density

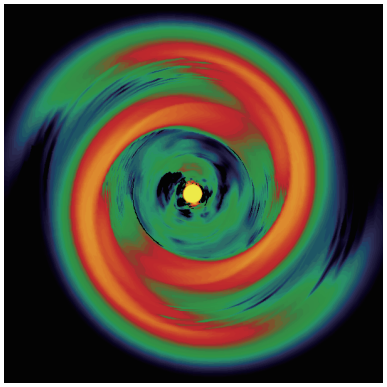

Figure 2: pressure

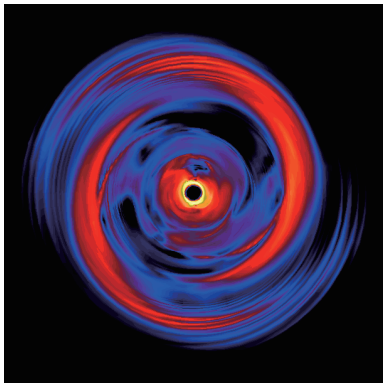

Figure 3: magnetic energy