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MHD Simulation in Galactic Center Region with Radiative Cooling and Heating

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In the field of astronomy, the Milky Way Galaxy is the most familiar galaxy. Its innermost sub-kpc region, known as the Galactic Center region, contains a dense, high-temperature complex of interstellar gas clouds. This region may be closely linked to strong magnetic fields and high cosmic ray ionization rates, though the association is still under investigation.

We performed three-dimensional global MHD numerical simulations to investigate the effect of magnetic fields on interstellar space in the Galactic Center region. Our simulations is adopted radiative cooling and heating processes to treat the thermal state of interstellar gas. We analyzed these numerical results in detail, focusing on the interaction between magnetic activity and the interstellar medium.

One of the results of this numerical simulation is that the magnetic field plays an important role in the thickness structure of the global interstellar gas complex in the Galactic Center region[1]. As mentioned above, the dense gas is tend to be cooler due to the effect of radiative cooling. The gas density is higher due to accumulate near the Galactic plane under the gravitational field. Therefore, the gas temperatures tend to cool near the Galactic plane, and as a result, the thickness of gas above the Galactic plane becomes thinner.

However, the magnetic field is not directly affected by radiative cooling and heating. For this reason, the magnetic field strength-dependent magnetic pressure can support the thickness of the gas in the Galactic center region to the extent that it is lost due to the lower gas temperature alternatively.

In fact, the results of numerical simulations show that a magnetic pressure-dominated region with plasma β (ratio of gas pressure to magnetic pressure) smaller than 1 is formed at the area above the galactic plane, which plays a very important role in supporting the global gas distribution structure.

We further analyzed the numerical simulation results to investigate the magnetic field structure in more detail. It is confirmed that the toroidal magnetic field is dominant on the galactic plane, but the z-directional component of the magnetic field (poloidal magnetic field) becomes dominant at the upper layers from the Galactic plane. Figure 1 shows the φ-z diagram for a radius of R = 0.5 kpc. We can see from this figure that the magnetic field lines in the region above the galactic plane, which contribute to the thickness of the gas structure, form an arch or thread-like structure in the z-direction. Furthermore, the density structure is also distributed in association with these characteristic magnetic field line structures.

References

[1] K. Kakiuchi et al. **ApJ**, 966, 230 (2024)

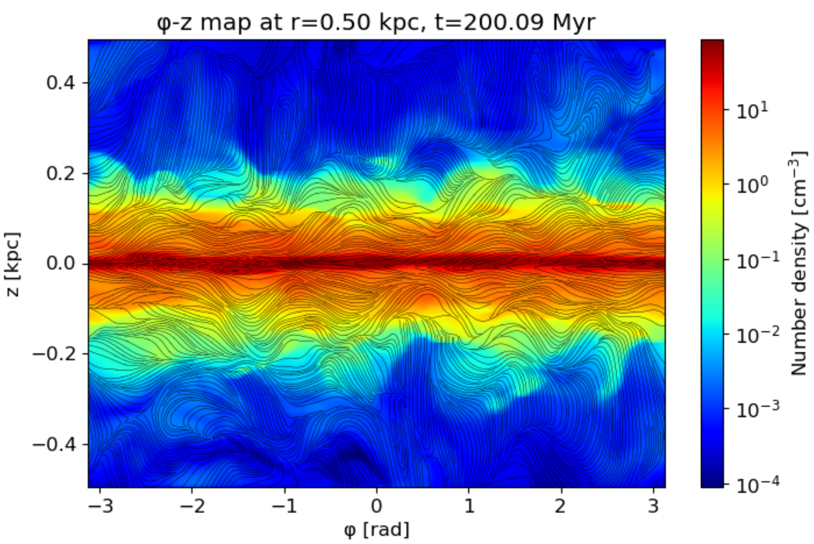

Figure 1 Color map of the φ-z plane at radius R=0.50 kpc and time t=200.09 Myr. The color scale indicates the number density. Black streamlines illustrate the magnetic field lines derived from the magnetic field vectors in the φ-z plane.