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Radio-band visualization of the MHD simulations for the astrophysical jet

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Astrophysical jets are emitted from compact stars, such as protostars, X-ray binaries and active galactic nuclei (AGNs). The characteristic of jets is a well collimated structure whose length reaches about billion times longer than the emitted region. For example, a famous jet object SS433 which is a Galactic X-ray binary has a well collimated jet whose length and propagating speed reach about 60 pc from the center and 0.26*c*, respectively (Abell & Margon 1979; Eikenberry et al. 2001). SS433 is embedded in the center of a radio nebula W50 which is located at galactic latitude of ~2° from the galactic plane. W50 has been extended in the east-west direction on an axis shared with the jets of SS433. Therefore, it is believed that the structure of W50 is convolution of supernova shell and SS433 jet (Goodall et al. 2011).

As the distinctive characteristic of SS433/W50 system, molecular clouds associated with the jets were found by Yamamoto et al. (2008). The model of these molecular clouds formation is the coupling of the compression and thermal instability. Since the jet travels through high density HI shell of W50, the density of the bow shock increases. When the density becomes high enough, thermal instability leads the formation of the molecular clouds. Indeed, because HI gases surround the radio continuum shell of W50 (Dubner et al. 1998), SS433 jet has to pass through the HI shell. This scenario has been verified by magneto-hydrodynamic numerical simulation and it has been shown that bow shocks compressed to form molecular clouds as jets penetrate cold and dense regions from warm and low density regions (Asahina et al. 2014). Recently, Sakemi et al. (2018) have shown that the magnetic field of the terminal shock and bow shock have a parallel structure of the contour of the radio continuum. They analyzed Faraday rotation measures (RMs) corresponding to the intensity of the line-of-sight magnetic field and revealed the difference of RM distribution between northern and southern part. In this paper, we carried out the observational visualization using the numerical data providing by Asahina et al. (2014).

In order to investigate the jet propagation, Asahina et al. (2014) assume that the jet is continuously injected with kinetic energy and toroidal magnetic field at the region with a diameter of 2 pc. They have assumed that the jet injected region is a low density and high temperature. The high density and low temperature region smoothly connected to the injected region. The magnetic fields of jet which coil round the cocoon can be seen with the jet propagation. In addition, a number of turbulent vortices are formed in the inner cocoon. In order to compare with the observational results and the numerical simulation results, we calculate a Faraday depth (FD) and Stokes parameters using the results of the gas density and magnetic field distribution obtained by the numerical simulations. Figure 1 shows the two-dimensional distribution of the FD whose inclination is the edge-on. The magnetic field reversal leads the reversal of the FD because FD is proportional to the direction of the magnetic field. The filamentary structure can be seen in FD distribution because magnetic flux tubes coil around the cocoon of the jet. This reflects that a flux tube coils around the jet cocoon has the inhomogeneous density. Because the inner jet cocoon becomes turbulent, negative FD appears in places even in the positive x-axis region. In this calculation, however, we found no significant change in FD along the terminal shock. Moreover, we introduce the comparison of 3D structure of magnetic field directly obtained from our numerical calculations with two-dimensional averaged polarization vector map.

References

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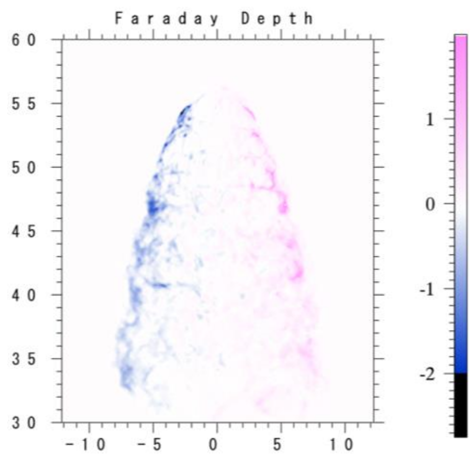

Figure 1. FD contour map of the simulated jet. The FD has units of rad m^{-2}.