# General Relativistic Simulations of Jet Formation by a Rapidly Rotating Black Hole

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The radio observations have revealed the compelling evidence of existence of relativistic jets not only from active galactic nuclei (AGNs) but also from "microquasars" in our Galaxy [1]. It is believed that in the cores of these objects a rapidly rotating black hole exists and magnetic phenomena occur near the black hole to form the relativistic jets [2, 3, 4, 5]. To simulate the jet formation in the magnetosphere, we have newly developed the Kerr general relativistic magnetohydrodynamic (KGRMHD) code [6, 7]. We report here the numerical result of the jet formation [8].

Our study is based on the general relativistic equations of conservation laws about mass, momentum, and energy of conductive fluids and Maxwell equations. We use the Kerr metric with spin parameter $a = 0.95$, which provides the spacetime around the near maximumly rotating black hole. We employ *simplified total variation diminishing* (TVD) method. As the initial condition, we assume a transonic free fall corona and a relativistic Keplerian disk with a uniform magnetic field.

Figure 1 shows the result of the case of the counter-rotating disk to the black hole rotation at $t = 47\tau_S$. The disk falls toward the black hole rapidly because of no stable-orbit at $R < 4.5$. A part of the disk enters the *ergospher*. The jet has two layers; the plasma beta of the head and skin of the jet is high and the magnetic field azimuthal component $B_\phi$ is negative, while that of the root and the center of the jet is low and $B_\phi$ is positive. The high beta jet is gas pressure driven jet due to the shock in the disk. On the other hand, the low beta jet is the magnetically driven jet caused by strong magnetic field and the rapid frame dragging almost inside the ergospher. This acceleration mechanism is thought to be identical to the Blandford-Znajek mechanism [2].

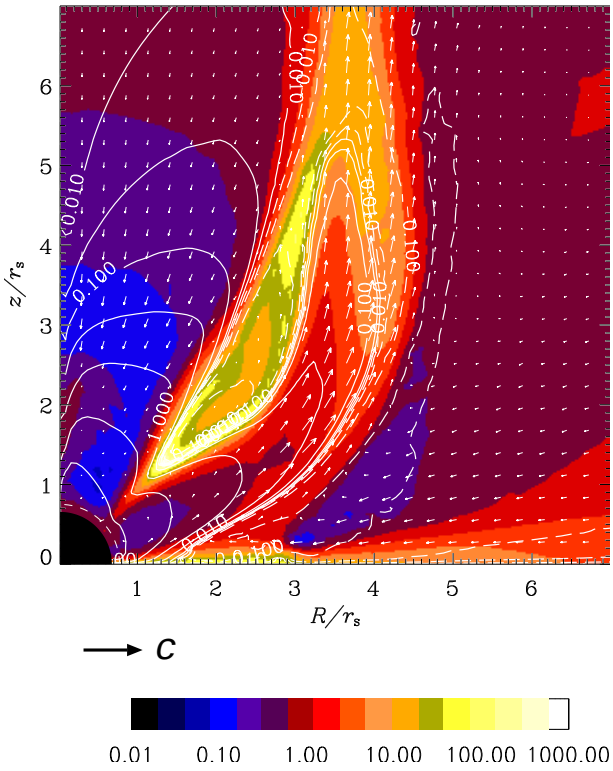


Fig. 1. The plasma beta (gray-scale) and the azimuthal component of the magnetic field $B_\phi$ (contour) of the counter-rotating disk case at $t = 47\tau_S$. The solid lines show the positive value of $B_\phi$ and the dashed lines negative $B_\phi$. The vector indicates the velocity.

References

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