5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Magnetic reconnection study around a Kerr black hole using resistive GRMHD numerical simulation

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The observed emission from Sgr A*, which is associated with the supermassive black hole at the Galaxy Centre, is variable at radio, infrared (IR), and X-ray frequencies[1]. The flux variability in the radio band is of the order of 20 per cent or less, but in the IR and X-ray wavelength, there are large amplitude variations ('flares'). They are possibly caused by magnetic reconnection, just like the solar flares[2]. In fact, around a rotating black hole in the galactic activity center area, General Relativistic Magnetohydrodynamics with zero-resistivity (ideal GRMHD) simulations indicate that anti-parallel magnetic fields are formed spontaneously[3]. Under such magnetic field configuration, magnetic reconnection is expected to happen, and play a significant role in the high energy phenomena around a black hole.
We have performed numerical simulations of resistive GRMHD (GRMHD with resistivity) to study the occurrence of magnetic reconnection in a split-monopole magnetic field around a Kerr black hole. Magnetic reconnection occurs near the black hole at its equatorial plane spontaneously. In a previous paper, we described a case for the Schwarzschild black hole[4].

We performed the resistive GRMHD simulations of plasmas around the Schwarzschild black hole and Kerr black hole (spin parameter a=0.9) with the resistivity $\eta = 0.001 r_S$ (r_S is the Schwarzschild radius), i.e. the global magnetic Reynolds number $S = 10^3$. Figure 1 shows the numerical results of the magnetic reconnection near the Schwarzschild black hole (left panel) and the Kerr black hole (right panel) at $t = 9\tau_S$ (where τ_S is the Schwarzschild radius divided by the speed of light). At the initial state ($t = 0$), the magnetic field is the split monopole type; above the equatorial plane of the black hole, the magnetic field lines are directed toward the black hole, and below the equatorial plane the field lines are directed away from the black hole. In the Schwarzschild black hole case, single magnetic reconnection occurs around the current sheet near the horizon at $r \sim 1.2\, r_S$, $\theta = \pi/2$. The reconnection region is point-likely narrow and the slow shock waves are seen, as the Petschek reconnection model. In the Kerr black hole case, reconnection point locates at $r \sim 1.1\, r_S$, $\theta = \pi/2$. As can be seen from the color, the spin of the black hole drags the magnetic field in the azimuthal direction. We investigated the black hole spin parameter dependence on the magnetic reconnection. The magnetic reconnection rate is a little larger compared to the Schwarzschild black hole case until $\sim 4\tau_S$. After that, the magnetic reconnection rate increases in time, similarly to the Schwarzschild black hole case. The detail will be shown in the presentation.

References
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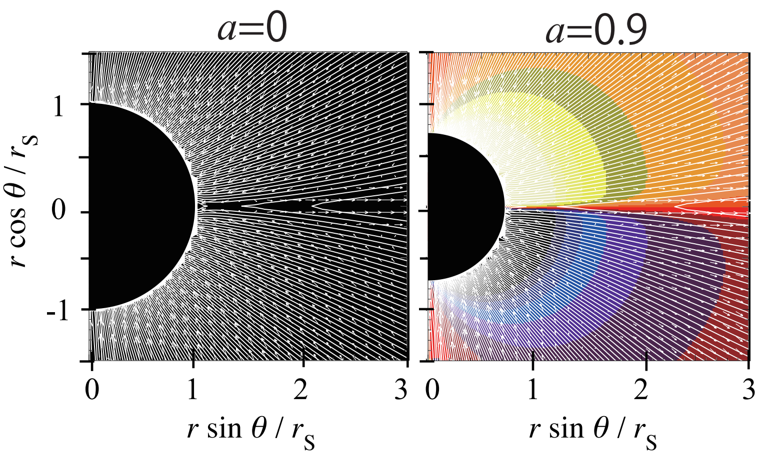

Figure 1. Azimuthal component of the magnetic field (color), magnetic field surfaces (white lines), and velocity (white arrows) by the resistive GRMHD simulations with the resistivity $\eta = 0.001 r_S$ (r_S is the Schwarzschild radius), i.e. the global magnetic Reynolds number $S = 10^3$. Black semicircles at the left in the panels show the horizon of the black hole.