A Novel Jet Model: Magnetically Collimated, Radiation-Pressure Driven Jet

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Relativistic jets from compact objects are ubiquitous phenomena in the Universe, but their driving mechanism has been an enigmatic issue over many decades. There are two models proposed: magnetohydrodynamic (MHD) jets which are driven by the magnetic process[1] and radiation-hydrodynamic (RHD) jets which are powered by the strong radiation-pressure force[2].

In the MHD jets, the magnetic effects work to accelerate and collimate the jets. However, we should remark that most of the previous MHD disk-jet simulations assumed that the underlying accretion flows are radiatively inefficient accretion flow (RIAF)[3,4]. The MHD jets launched from the RIAF can not account for the highly relativistic jets of the Galactic microquasars, since their high luminosities implies that the central black holes are surrounded by the luminous accretion disks. The luminous (super-Eddington) accretion flows drive the RHD jets. However, the opening angle of the RHD jets is thought to be relatively wide, since the there is no effective collimation mechanism.

Here, we propose a new type of jets, radiationmag netohydrodynamic (RMHD) jets, based on our global RMHD simulation of luminous accretion flow onto a black hole shining above the Eddington luminosity[5]. In Figure 1, the accretion flow (the gas mass density, brown) and the RMHD jet in which velocities exceed the escape velocity (the velocity, white, blue) are plotted. The high-speed jet (~0.6c–0.7c) is represented by blue. White lines indicate the magnetic field lines. The zz-component of the radiation-pressure tensor (color), P_0^{zz}, overlaid with the radiation-pressure force vectors (arrows) on the meridional plane is projected on the left wall surface, while the magnetic pressure from the azimuthal component of the magnetic field (color), $B_\phi^2/8\pi$, overlaid with the Lorentz force vectors (arrows) on the meridional plane is projected on the right wall surface.

We find that the RMHD jet can be accelerated up to the relativistic speed by the radiation-pressure force and is collimated by the Lorentz force of a magnetic tower, inflated magnetic structure made by toroidal magnetic field lines accumulated around the black hole, though radiation energy greatly dominates over magnetic energy. This magnetic tower is collimated by a geometrically thick accretion flow supported by radiation-pressure force. This type of jet may explain relativistic jets from Galactic microquasars, appearing at high luminosities.

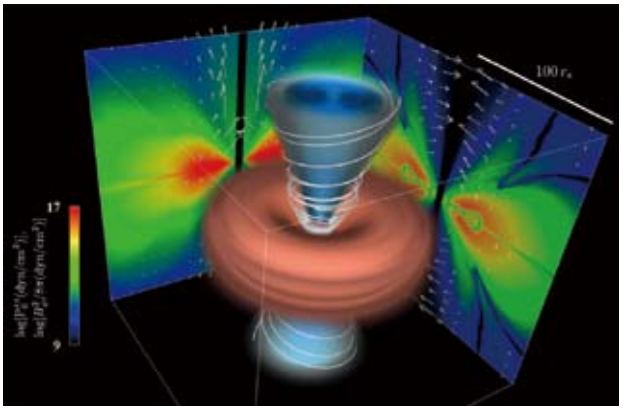

Figure 1: Bird's-eye view of the luminous accretion flow and the associated RMHD jet. The RMHD jet (blue) is accelerated by the strong radiation-pressure force from the super- Eddington disk (brown) and is collimated by the Lorentz force of a magnetic tower (white lines).

References

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