Growth of Rayleigh-Taylor and Richtmyer-Meshkov Instabilities in Relativistic Jets

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Relativistic jets are ubiquitous phenomena in astrophysical systems consisting of a compact object surrounded by an accretion disk, such as active galactic nuclei, microquasars, and potentially gamma-ray bursts. The interaction of the jet with the surrounding medium is a key process for the dynamics and stability of the jet. Many studies have been done in order to investigate the propagation dynamics of the relativistic jet assuming the axisymmetric geometry. However, the non-axisymmetric evolution of the jet is still not understood well although it might have a potential impact on the overall dynamics and transverse structure of the jet.

In this research [1], the stability of the transverse structure of the relativistic jet is investigated using two-dimensional special relativistic hydrodynamic simulations. An intriguing finding in our study is that Rayleigh-Taylor and Richtmyer-Meshkov type instabilities can destroy cylindrical jet configuration as a result of the naturally induced radial oscillating motion (Figure 1).

A radial inertia force naturally arises from a pressure mismatch between the jet and surrounding medium when the jet propagates through the ambient medium. The inertia force drives the radial oscillating motion of the jet, yielding the reconfinement region inside the jet [2]. When we consider the non-axisymmetric evolution of the jet, the radial oscillating motion of the jet can excite the Rayleigh-Taylor instability at the jet interface.

The reconfinement region inside the jet is enclosed by the oblique shock. The convergence of the oblique shock results in the excitation of an outward-propagating shock wave at the center of the jet. When the shock wave encounters the corrugated interface of the jet due to the Rayleigh-Taylor instability, the Richtmyer-Meshkov instability is secondarily excited between Rayleigh-Taylor instability fingers.

During the radial oscillating motion of the jet, these instabilities are amplified and repeatedly excited at the jet interface, and finally deform the transverse structure of the jet. This result suggests that the non-axisymmetric nature is essential for the stability of the relativistic jet to the oscillation-induced instabilities.

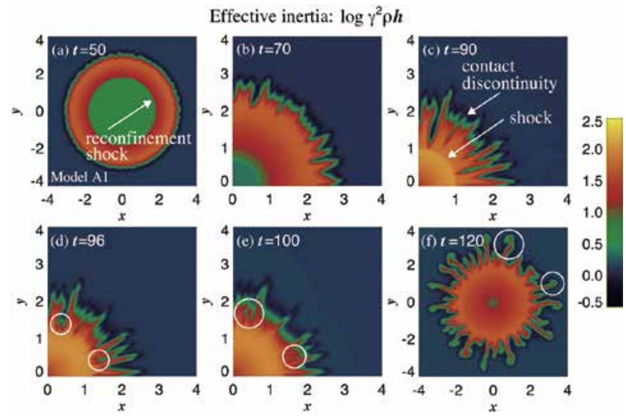

Figure 1: Time evolution of the effective inertia $\gamma^2\rho h$ in the jet-external medium system. γ, ρ, and h are the Lorentz factor, density, and specific enthalpy, respectively. At the early evolutionary phase (top panels), the Rayleigh-Taylor instability grows at the interface between the jet and the surrounding medium. After an outward-propagating shock wave excited at the center of the jet collides with the contact discontinuity (jet interface), the Richtmyer-Meshkov instability is secondarily excited between Rayleigh-Taylor instability fingers. Two of the Richtmyer-Meshkov instability fingers are marked by open circles. Almost all fingerlike structures in panel (f) have their origin in the Richtmyer-Meshkov instability.

References

[1] Matsumoto, J., Masada, Y.: 2013, *ApJ*, **772**, L1.
[2] Matsumoto, J., Masada, Y., Shibata, K.: 2012, *ApJ*, **751**, 140.