Linear Analysis of MHD Jet in CCSNe

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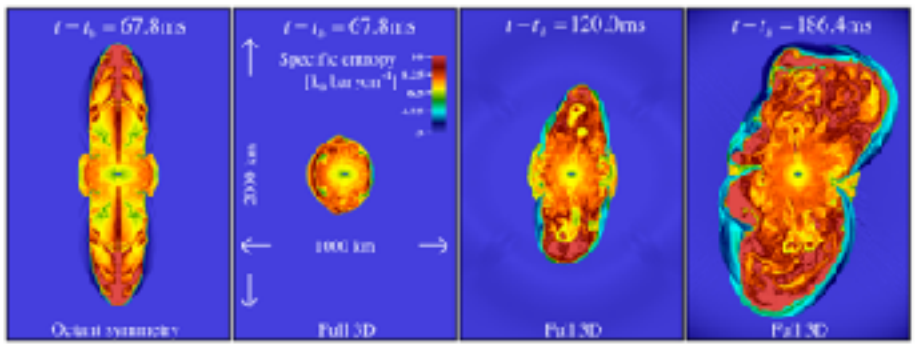
According to axisymmetric simulations of magnetized CCSNe, it is predicted that the form of the explosion is jet. But recently full 3D simulation claims that the behavior of the explosion is different from this picture because of the instability of the magnetized jet. I study this instability of the MHD jet. Especially, to provide more analytical result, I try to preform the linear analysis to this MHD jet.

Introduction

In the study of CCSNe, one of the most challenging problem is the mechanism of the explosion. The effect of rotation and magnetic field is considered as a candidate of this mechanism. According to axisymmetric simulations of magnetized CCSNe, it is predicted that the form of the explosion is jet. But the result of recently full 3D simulation is qualitatively different. The researchers of this study interpret the difference as the effect of instability of the jet. My research is to analyze this instability of the jet.



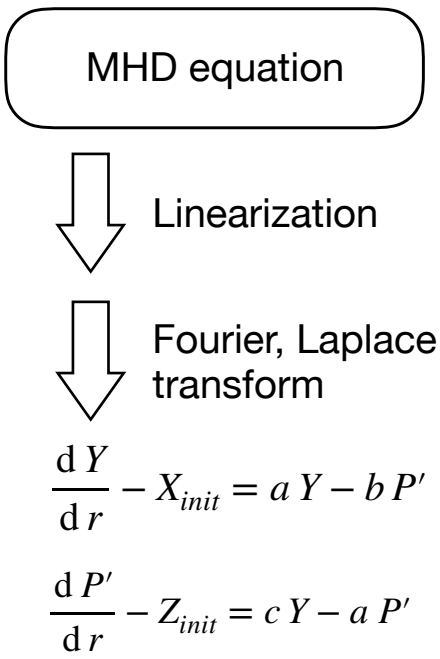
P. Mösta et al., 2014, ApJ, 785, L29

Method

Linearization

We assume that the jet obeys ideal magnetohydrodynamics(MHD). The coordinate is cylindrical. To analyze the instability, we linearize this equations, i.e. consider only the perturbation from the equilibrium. Moreover, we perform the Fourier transform to angular and polar directions, and the Laplace transform to time direction. The transformations of angular and polar directions mean the mode analysis. Particularly the first mode of angular direction is important, because only this mode is non-axisymmetric. The Laplace transform to time direction is integrated after.

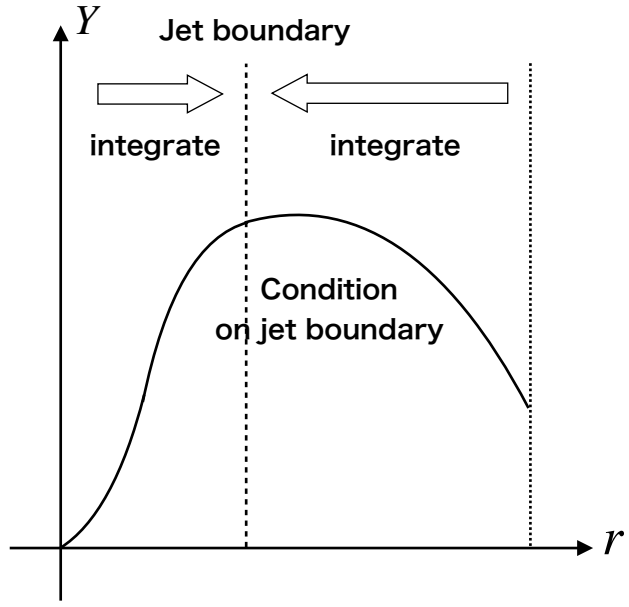
From these procedures, the equations simplify two first-order differential equation system. (S. Appl, 1992) . But strictly speaking, there are two types of this equation system. In jet region, we put the initial perturbation, on the other hand, in ambient region, we do not have any initial perturbation. From this missing initial perturbation, in ambient region, the equation system is homogeneous.



Integration

We solve this equation system by numerical integration. Because of the difference between jet and ambient region, the integrations are performed two times: one starts with the axis and ends with the jet boundary, and the other is from infinity to jet boundary. At the jet boundary, the value and differential should be equal between two integrations. We have two degree of freedom: one is the differential at the axis and the other is scale of ambient region. In ambient region, the equation system is homogeneous, then we can multiply the scale.

After that we obtain the result of integration about radius, we do inverse Laplace transform about time. From this transform, we can obtain the pole related to the instability mode (K. Takahashi, 2016).



Current status

The current status is code testing. I try to integrate about radius, but actually these quantity are complex, then I have to do two-dimension Newton method. I do not succeed to make this method converged yet.

Reference

P. Mösta et al., 2014, ApJ, 785, L29

S. Appl, M. Camenzind, 1992, Astron. Astrophys., 256, 354

K. Takahashi, W. Iwakami, Y. Yamamoto, S. Yamada, 2016, ApJ, 831, 75