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Instabilities, magnetic reconnection and particle acceleration in Blazars

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Abstract. We will perform relativistic 3D MHD simulations of a jet, with an helical magnetic field, subject both to KH and to CD instabilities. Recently Striani et al. (2016) showed that instabilities favour reconnection leading to the so called fast reconnection regime. We need very high resolution to maintain a sufficient number of cells in the reconnection regions.

1. Introduction

Among Active Galactic Nuclei, Blazars display extremely intense and varying non thermal emission, in a very large range of frequencies, from radio to gamma-rays. Variability occurs in all bands and over a wide range of time scales, from minutes to years. Blazar models involve relativistic jets, one of them pointing closely at the observer, leading to a dramatic relativistic boost of apparent luminosity. The rapid variability requires efficient mechanisms for the dissipation of the jet power, for the non-thermal particle acceleration and for their radiation. The energy dissipation can be due to jet instabilities and potential sources of instability can be identified either in the velocity jump between the jet and the ambient medium (Kelvin-Helmholtz instability, KH) or in the magnetic field configuration (Current driven instability, CD). The instability evolution may lead to shocks and magnetic reconnection, where a fraction of the jet power is dissipated. Shocks and magnetic reconnection can be sites of relativistic particle acceleration. In particular magnetic reconnection has been shown to be a more viable candidate for particle acceleration in jets. This project has been intended as a starting step towards a full study of the particle acceleration process in realistic jet models. We have performed relativistic 3D MHD simulations of a jet, with an helical magnetic field, subject both to Kelvin-Helmholtz and to current driven instabilities, the evolution of the instabilities leads to the formation of reconnection sites and, as shown by Striani et al., (2016) may favour the onset of the so called fast reconnection regime, in which the reconnection rate becomes independent from the Lundquist number.

2. Results

We performed many tests with different parameters and one successful simulation, where the nonlinear evolution of CD instabilities favoured the formation of reconnection regions. The simulation was performed at very high resolution, with 50 points on the jet radius. The high resolution is necessary for resolving the very small regions where reconnection occurs. We used the following parameters: Lorentz factor of 10, density ratio of 0.01 between jet and ambient medium and jet magnetization of 0.5. The simulations have been performed with the PLUTO code (Mignone et al.

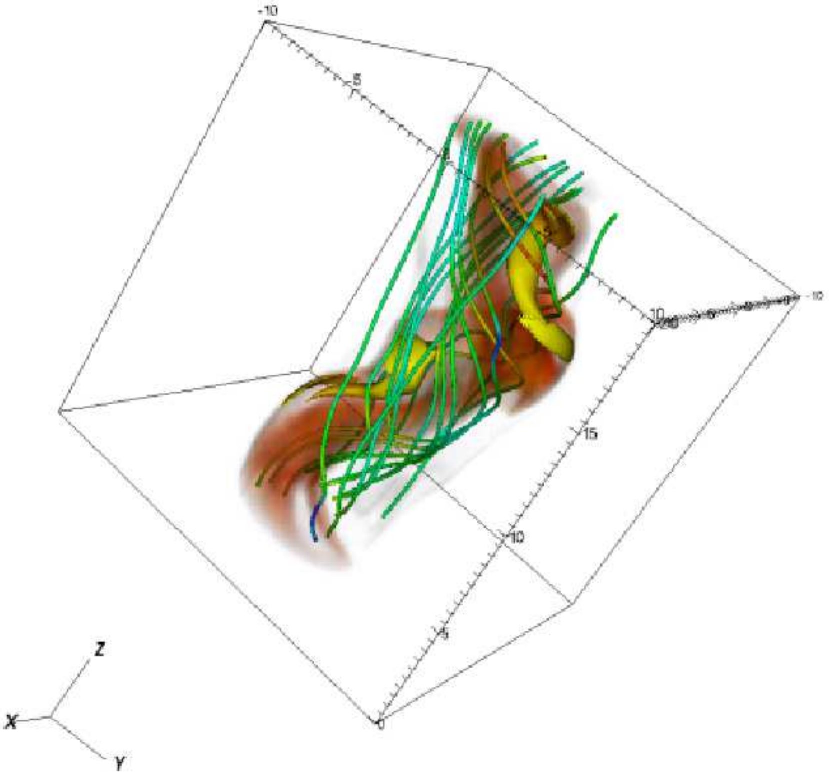

Fig. 1. Volume rendering of the density distribution (dark red), magnetic field lines (green), isosurfaces of the current distribution (yellow).

2007). The figure shows a volume rendering of the density distribution in dark red, some representative magnetic field lines and isosurfaces of the current distribution in yellow. The current distribution shows region of concentrated current where reconnection occurs.

The project has been preparatory for tuning the setup for further simulations in which we will use the new MHD-PIC module of PLUTO (Mignone et al 2018), that follows, together with the fluid, the evolution of non thermal relativistic particles, treated kinetically by a PIC approach. In this way it will be possible to follow the acceleration process on a scale larger than with a full PIC approach, allowing to use a more realistic jet structure. We thank the MOU INAF-CINECA for having provided us with the opportunity of obtaining in a prompt way the resources needed for the testing phase of this project, which is essential for preparing a larger allocation request.

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