Journées SF2A 2022
Besançon, France

Numerical MHD simulations of recollimation shocks among astrophysical jets

Abstract

The most successful scenario to explain the origin of astrophysical jets requires the presence of a large-scale magnetic field anchored in a rotating object (black hole or disk) to extract its rotational energy and transfer it to the jet to accelerate it. Besides generating an acceleration force, the interplay of the large-scale magnetic field and the associated electric currents provides a confinement mechanism similar to Z-pinch systems, used for example to confine hot plasma in a tokamak. In order to provide a hoop stress able to compress the jet on such large scales, this Z-pinch requires a non-vanishing asymptotic electric current inside the jet. But linking this asymptotic current to the source remains a long standing pending issue.

As a first step towards this goal, we performed a set of 2.5D MHD simulations of non-relativistic jets emitted from keplerian accretion disks, using the PLUTO code. In these platform simulations, the disk is a boundary condition and only the jet acceleration and collimation are self-consistently computed (e.g. Ouyed & Pudritz 1997, Anderson et al 2005, Ramsey & Clarke 2019). Thanks to a novel numerical method, our simulations have been successfully carried out at unprecedented time and spatial scales, reaching a steady state up to a distance larger than 5000 times the inner disk radius.

We found that standing recollimation shocks on the axis are systematically obtained for a certain set of parameters, as proposed in the Jet Emitting Disk self-similar calculations of Ferreira (1997) or discussed in, e.g, Polko et al. (2010). Some astrophysical consequences on the collimation properties of AGN and X-ray binary jets will then be briefly discussed. In particular, the presence of a steady recollimation shock may explain some internal structures seen at the subparsec scale in AGNs such as M87 (Asada & Nakamura (2012)).

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