Plasma Instabilities in γ-ray bright AGN: Exploring the helical structure in 3C279

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Introduction

We study the **origin** and **development** of **plasma instabilities**, namely Kelvin-Helmholtz (KH) and current-driven instabilities, at the base of quasar jets such as 3C 279, which is a variable gamma-ray emitter. We study the evolution of perturbed jets via relativistic (ideal) **magnetohydrodynamical numerical simulations**.

Simulations study the growth of 2D (axisymmetric) and 3D perturbations of cylindrical jet models initially in equilibrium. We test the **stability properties** of different **magnetic field configurations**.

As a result of our simulations, we estimate the amount of kinetic energy that can be dissipated and would be relevant for **very-high-energy emission**.

Can Kelvin-Helmholtz instabilities lead to helical patterns in radio observations and account for gamma-ray emission?

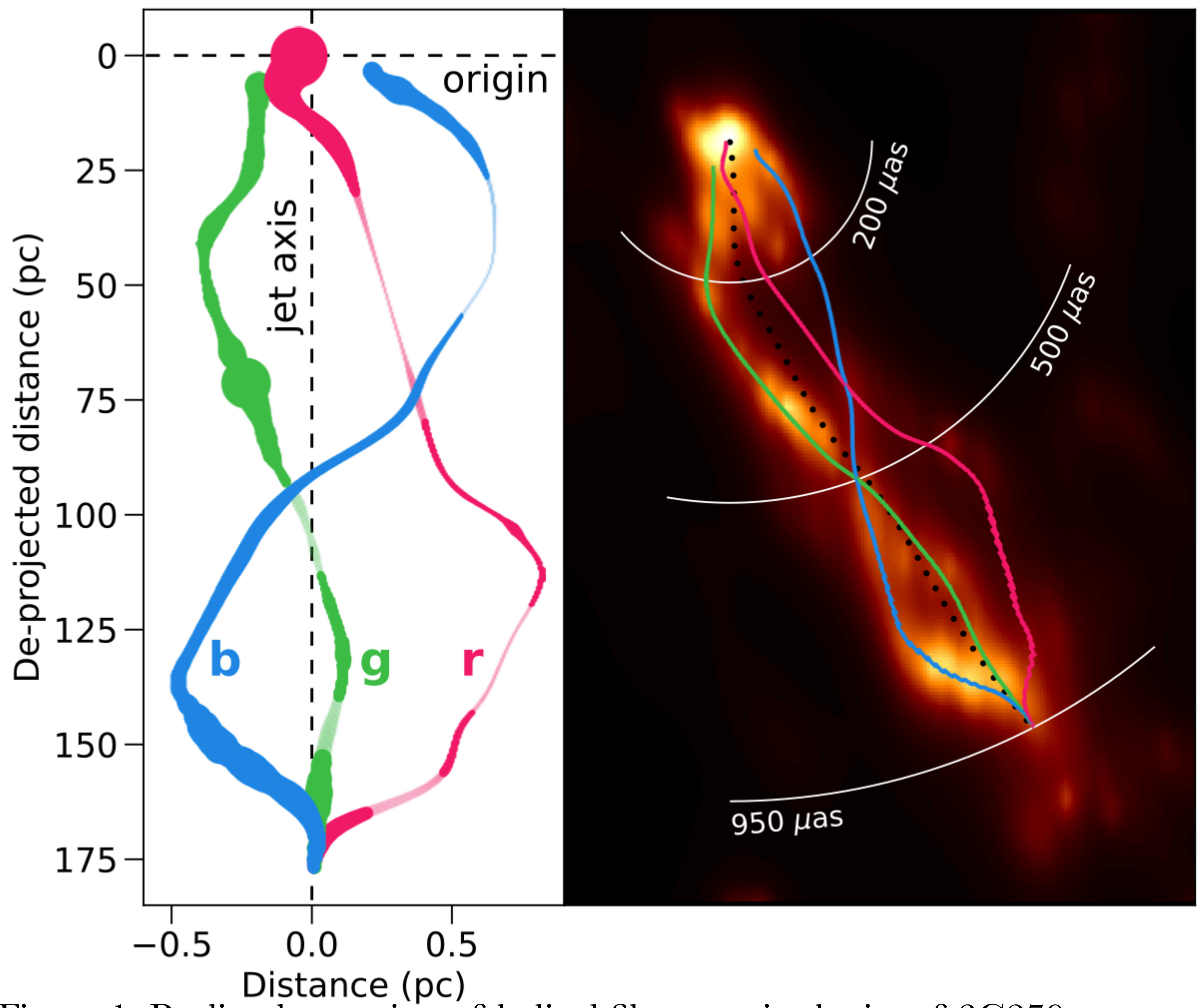

Figure 1: Radio observation of helical filaments in the jet of 3C279, potentially caused by Kelvin-Helmholtz instabilities (KHI) [1]. We are looking into KHI as a possible source of very-high-energy emission in γ-bright sources.

Relativistic Magneto-Hydrodynamic (RMHD) Simulations

Initial Setup:

- Steady state in transversal equilibrium
- Depends on jet and ambient densities, jet overpressure, jet flow speed, magnetization, and jet magnetosonic Mach number
- Recovering pure HD: magnetization set to 0
- Shear layer to smooth out the transition between jet and ambient medium

Equation of State (EOS):

- Ideal gas
- Later: Synge EOS to consider different particle species

Magnetic Field Configurations:

- $B_\phi \propto \frac{r}{1+r^2}$ as in [2]
- $B_\phi \propto \frac{1}{r}\left(1-\exp(-r^4)\right)^{1/2}$ as in [3]

Resolution:

- High resolution captures growth of perturbations from the linear phase properly
- High computational effort
- 600 cells/beam radius (transversal direction, 2D)

Kelvin-Helmholtz Instability

Emergence (in jets):

- Triggered by small perturbations at transitions/contact discontinuities between the jet and the ambient medium
- 3C279: KHI suspected source of helical filaments [1]

Emission from KHI:

- From high pressure region
- Turbulence leads to acceleration of charged particles

Instability analysis:

- RHD: linear analysis available
- RMHD: linear analysis only in few, simplified cases; in general, numerical approach needed

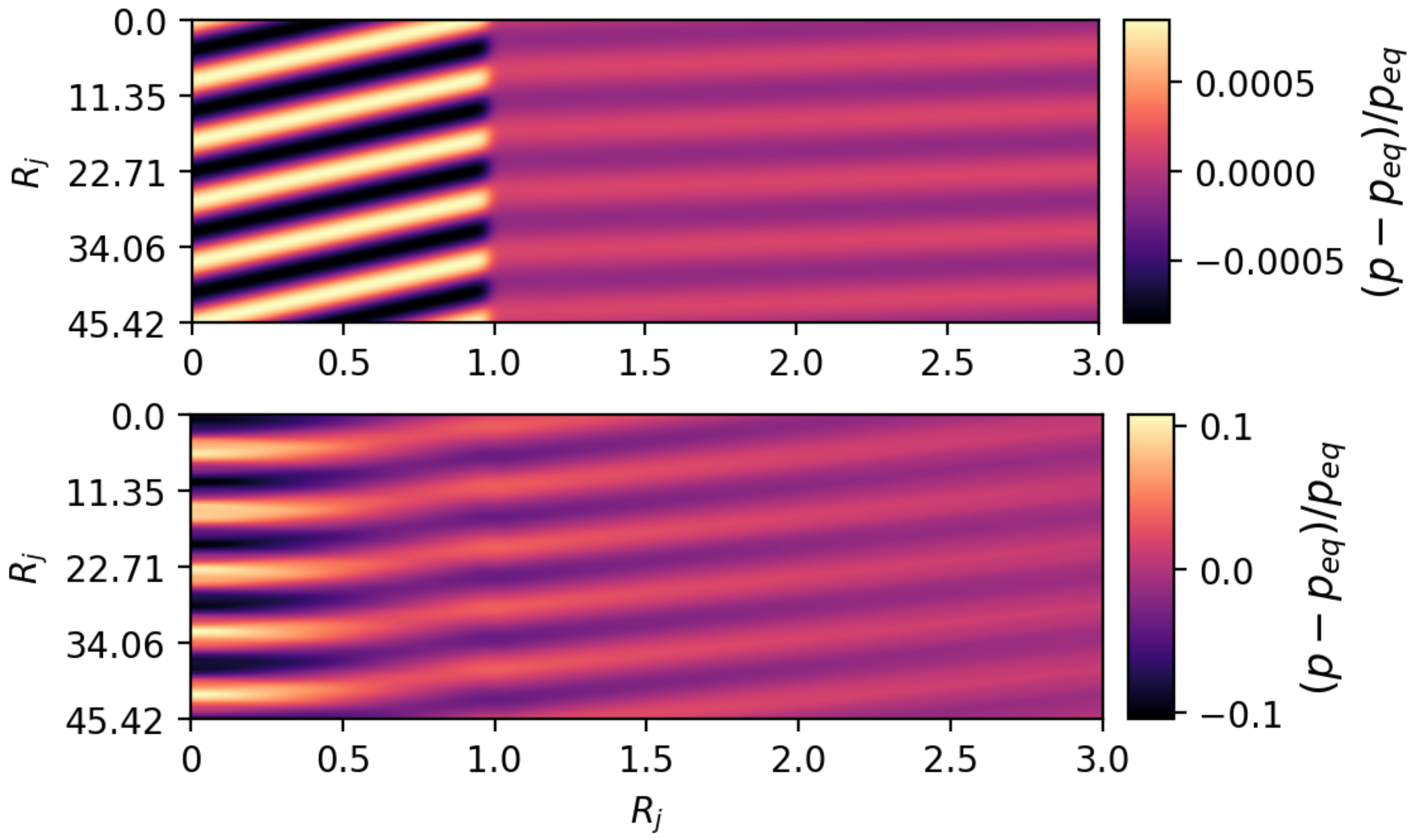

Figure 2: Exemplary initial state of a RHD simulation with imposed periodic perturbations on an axially symmetric jet in equilibrium (top panel) and the evolved state by the end of the linear phase (bottom panel). Shown is the pressure map in length units of the jet radius R_j. The vertical axis goes along the jet axis. The transition from jet to ambient medium can be seen at $R_j = 1$ on the horizontal (radial) axis. Note the difference in scales along the axial and radial directions in the figure panels, showing the growth of the modes during the linear phase by multiple orders of magnitude.

Discussion and future work

- KHI candidate to explain helical structures in 3C279 (Fig 1.)
- Potential source for γ-ray emission
- R(M)HD simulations of perturbed jets (Fig. 2)
- Radiative transfer code RIPTIDE [5] to assess the multi-wavelength non-thermal emission
- Comparing RHD vs RMHD and different magnetic field configurations
- Following up on work by [3], [4] and [6]
- Role of KHI in helical filaments: 3D simulations necessary

References and acknowledgments

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