Flux variability from ejecta in structured relativistic jets

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Introduction

We investigate the light curves of a variable stratified relativistic jet by means of relativistic magneto-hydrodynamics simulations. Indeed, astrophysical jets in active galactic nuclei seem to be transversely stratified, with a fast inner jet and a slower outer jet. As it is likely that the launching mechanism for each component is different. In the other hand, the steady and moving knots properties are observed along these jets.

Results: With the proposed model, we were able to explain the observed asymmetry flares in radio resulting from interaction between moving and standing shock. This asymmetry results from remnant emission of the shocked standing shocks.

Over pressured jet

- **Jet covered a large distances**
  - Jet becomes over pressured.
- **Result**
  - Re-collimation shocks.
  - Local re-acceleration of the jet.
- **Uniform jet**
  - Equidistant for cylindrical jet.
  - Increasing distance for the conical jet.

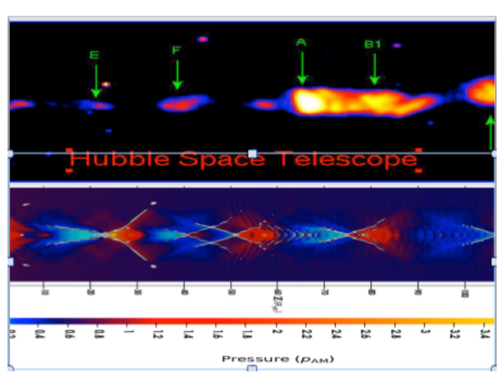

Figure 1: Knots in jet (observation/model).

Two-component jet model and variablity

Setting

- Total kinetic energy flux L $=[10^{43}, 10^{46}]$ erg/s.
- Jet radius $R_{\rm out} = 0.1pc$ at the parsec scale.
- Inner jet radius $R_{\rm in} = R_{\rm out}/3$.
- Lorentz factor of the inner component $\gamma_{\rm in} = 10$.
- Lorenz factor of the outer component $\gamma_{\rm in} = 3$
- Initial pressure ratio relative to the external medium: $\eta_{p,\rm in} = 1.5$, $\eta_{p,\rm out} = 1.0$.
- Over-dense ejecta $\rho_{\rm e} = 10^3 \rho_{\rm jet,in}$ at the jet base inlet.
- Various energy flux ratios between inner and outer jet component are investigate.

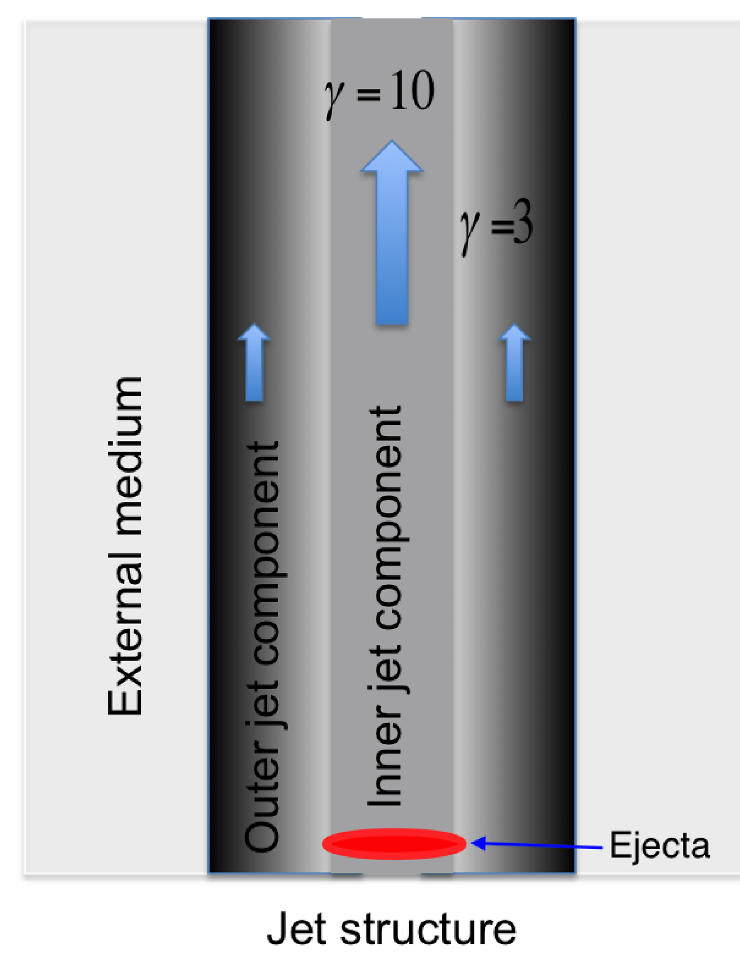

Figure 2: Two-component jet model.

Synthetic image

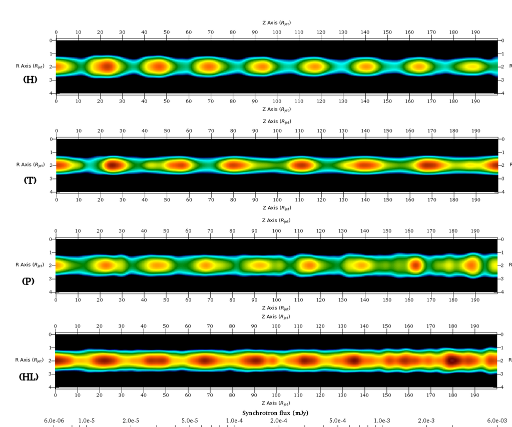

Figure 3: Synchrotron emission map at ν = 1GHz of the different types of jets. From top to down :Hydro (H) and with Toroidal (T), Poloidal (P) and Helical (HL) magnetic field.

- Jets with poloidal magnetic field have more diffuse emission.

Light curve at $\theta_{\rm obs} = 90°$

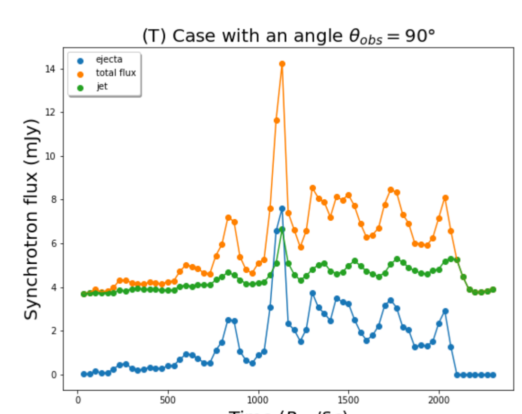

Figure 4: 1 GHz Light curve for the variable jet.

- Stronger flare associates with less stable knot.
- The flares are asymmetric with slow decay.

Light curve at $\theta_{\rm obs} = 2°$

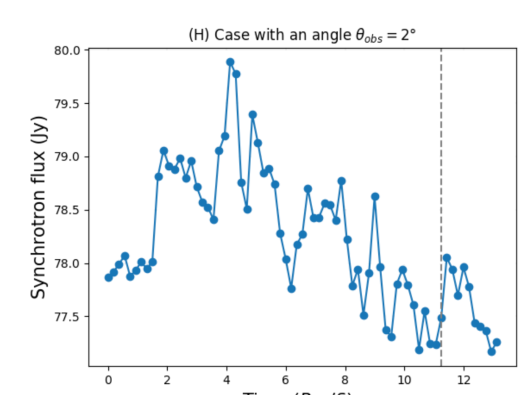

Figure 5: 1 GHz Light curve for the variable jet

- The flares are shorter in duration due to the Doppler effect and self absorption.
- Flares intensity decreases with time due due to self absorption.

Results and link with observations

- The introduction of large-scale magnetic fields is seen to cause an intrinsic opening of the jet
- At small observation angle, the effect of the absorption of the moving shock increases and hiddes the standing knots behind.
- Temporal assymmetry associated to the relaxation phase of the shocked standing knot is well visible for the strongest flares.
- Our scenario of moving ejecta interacting with standing shocks inside a two-component jet provides a good description of the kinematics and light curves seen in the jet of the FSRQ type blazar 3C 273 with VLBI and single-dish radio observations (fig. 6).

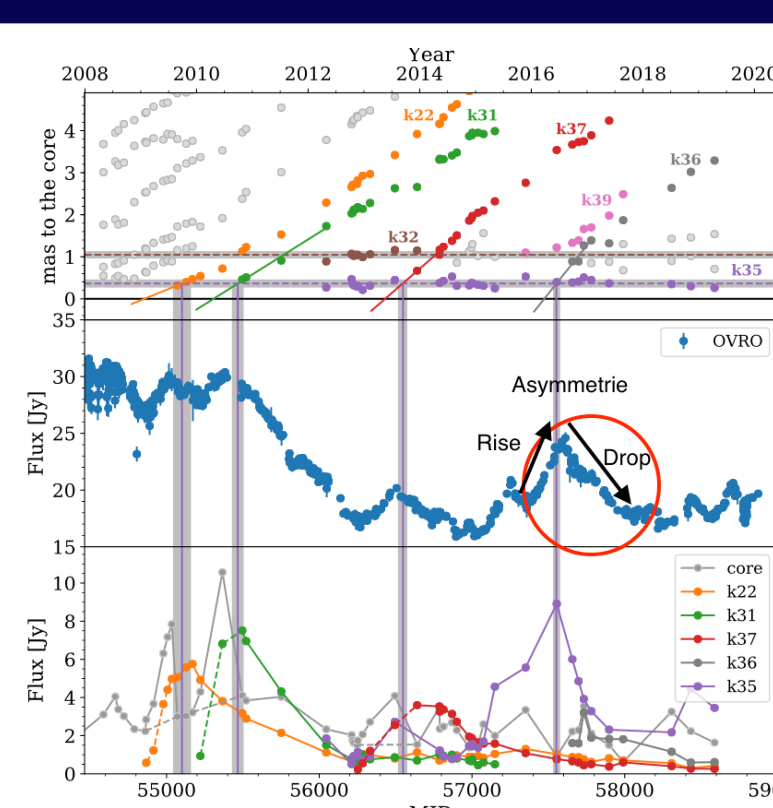

Figure 6: 3C 273 observed at 15.3 GHz. Top panel: distance to the core of radio knots analyzed by MOJAVE. Middle panel: radio jet light curve observed by OVRO. Bottom panel: measured flux of the radio core and moving knots.

References

1. G. Fichet de Clairfontaine et al., A&A 647, A77, 2021
2. O. Hervet, et al. A&A, 606, A103, 2017