Shocks in relativistic transverse stratified jets

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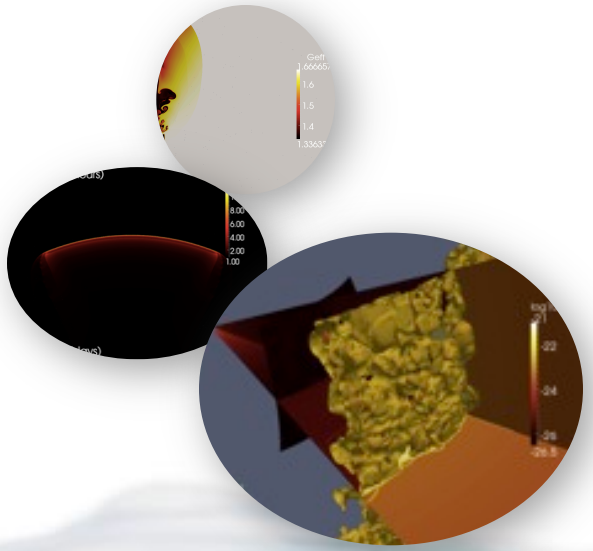
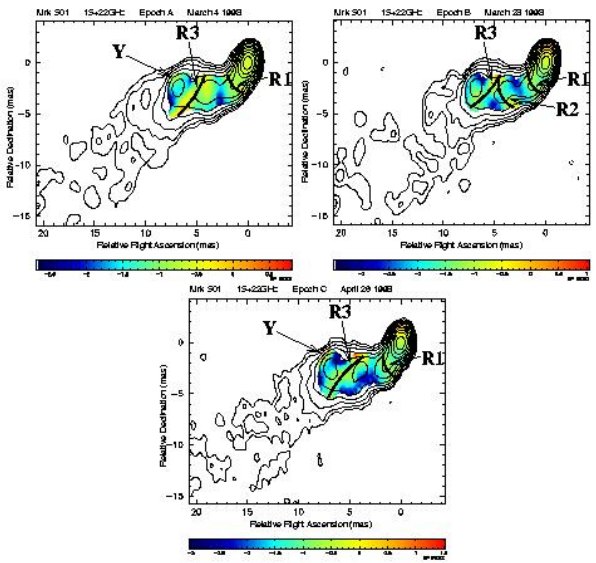


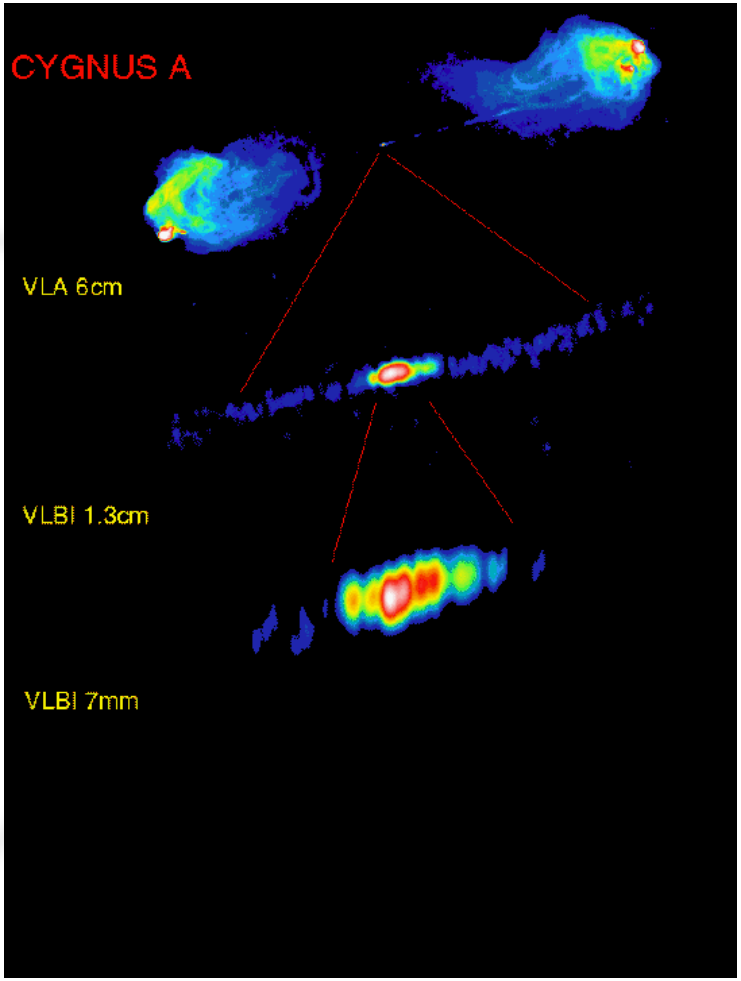
Active Galactic Nuclei jet

Jet at all scales

- AGN jets are observed to Mpc
- It can be stable to large scale
- Reach a Lorentz factor 3-50
- Magnetic field is important ingredient
- Synchrotron radiation (polarisation)
- Current models focus on MHD

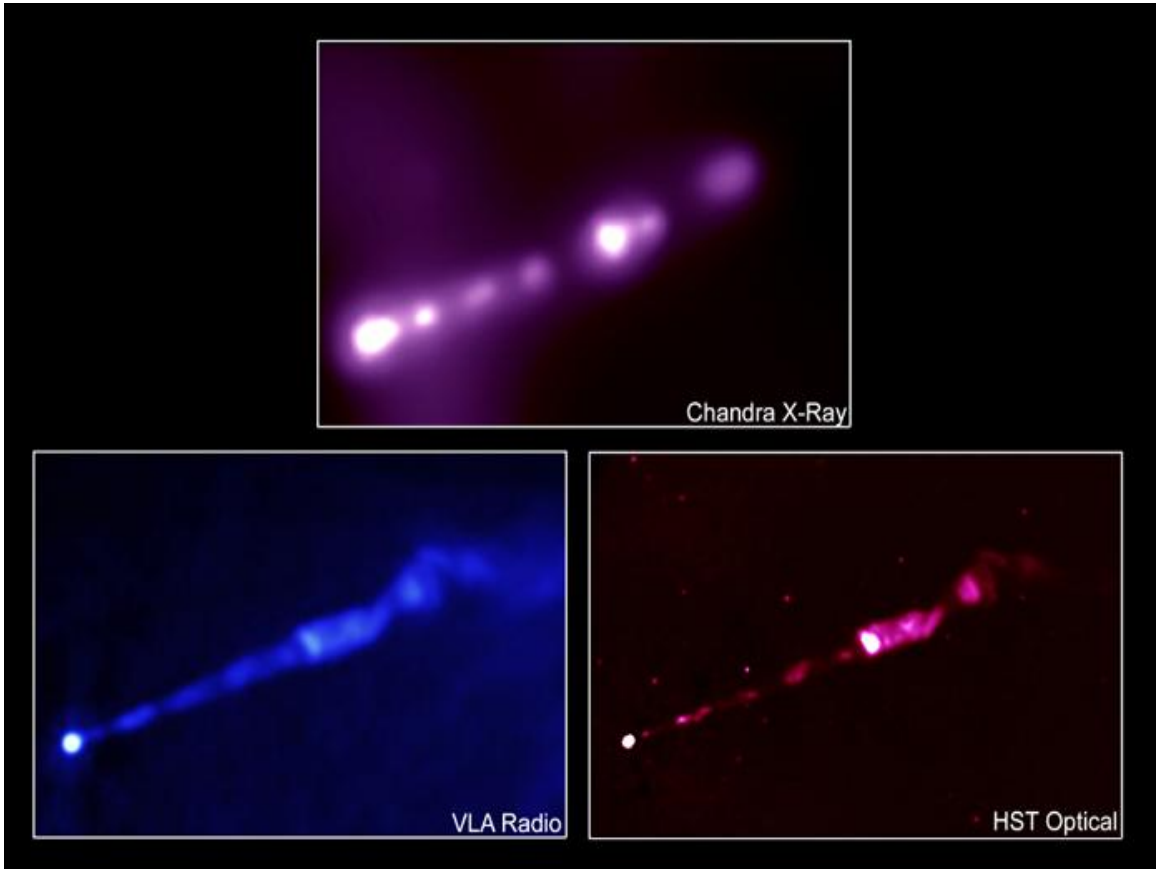


Lesscertain

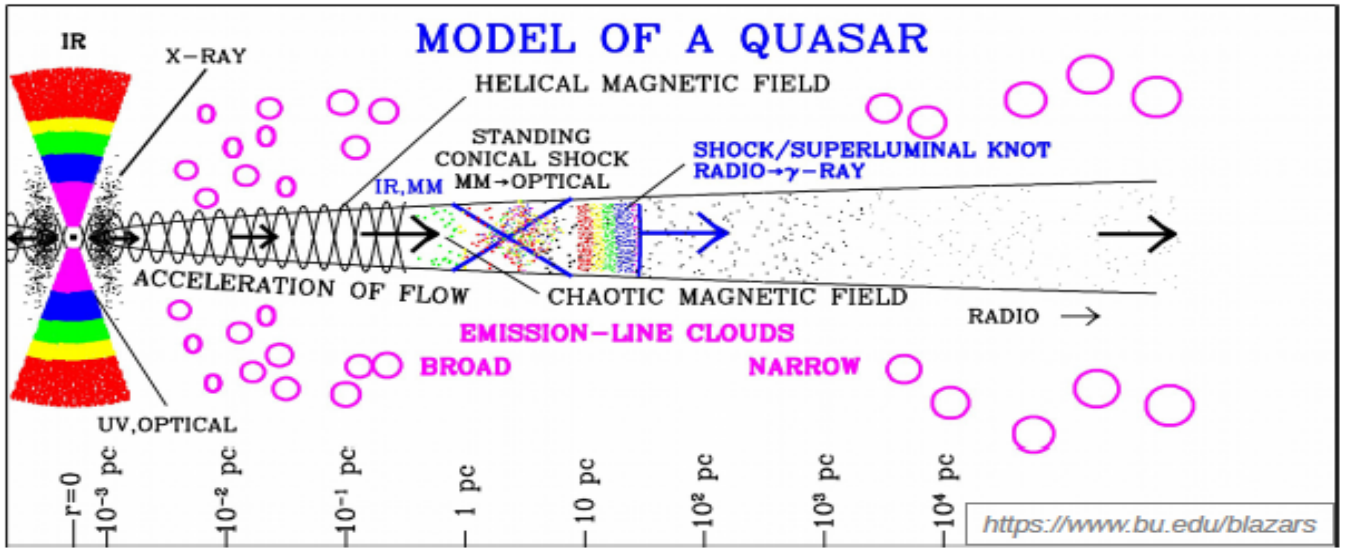


Jet re-collimation knots in AGN

- Steady and moving knots along jet
- Observed at all wavelength



Recollimation shocks – Jet model



Marscher & Gear 1985

Over pressured jet

The relativistic jet covered a large distances covered in galactic medium

- Jet becomes over pressured

Gómez et al 1996, Agudo et al. 2001, Mimica et al. 2009, Fromm et al. 2016, …

Result

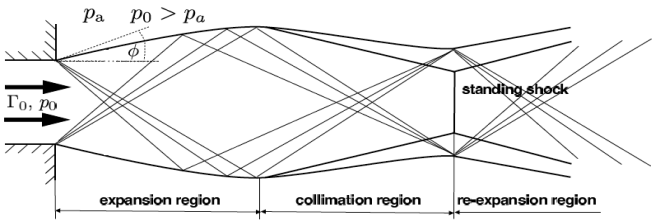
- re-collimation shocks
- Re-acceleration of the jet

$$dZ = 2MR$$

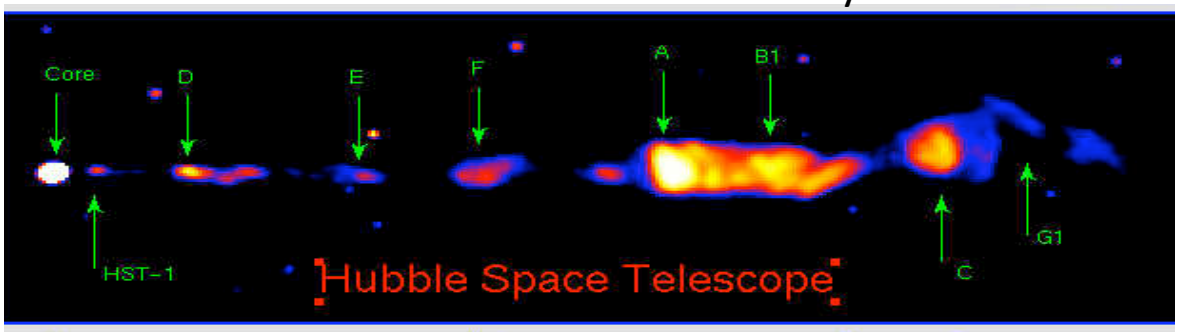
$Z =$

Uniform jet

- Equidistance for cylindrical jet
- Increasing distance for the conical jet



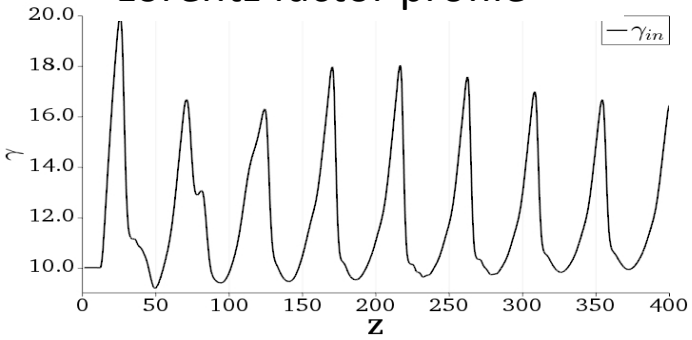
Daly & Marscher 1988



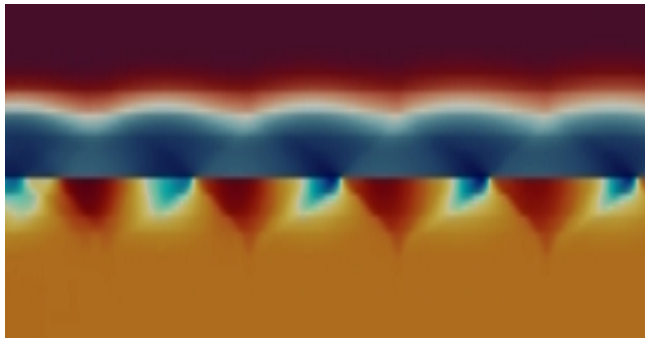
Re-collimation shocks

- Re-collimation shocks appears with density and pressure increase,
- Rarefaction waves appears with Lorentz factor increase.

Lorentz factor profile



Density



Pressure

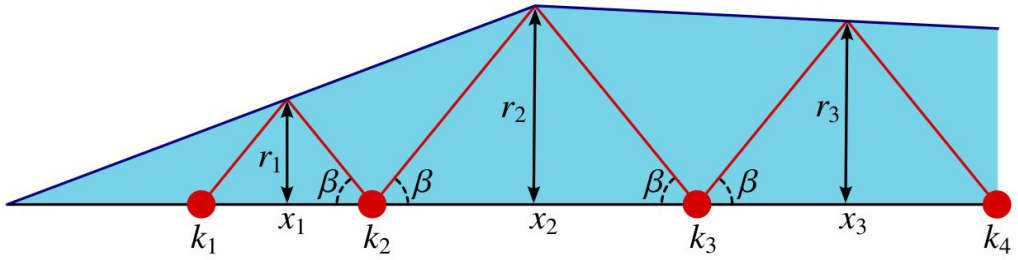
Radio knots as re-collimation shocks

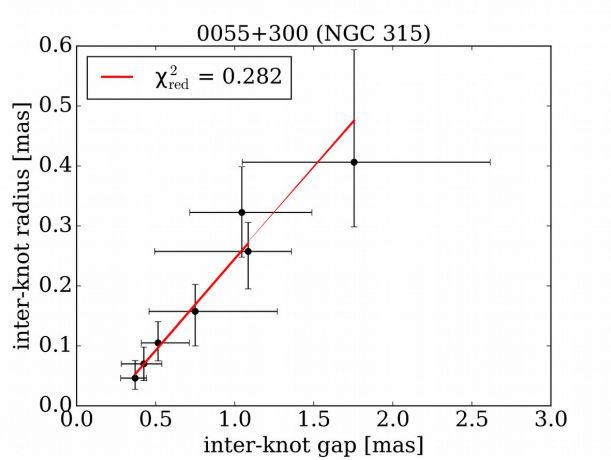
Assumptions :

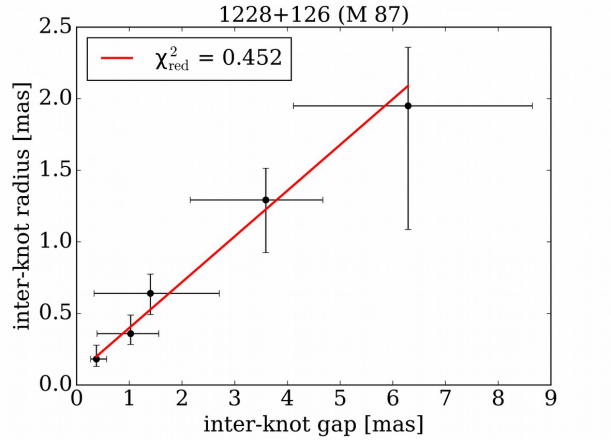
- Constant speed
- Constant sound speed

Results

- Constant Mach number
- Inter-knot distance dZ =2M R



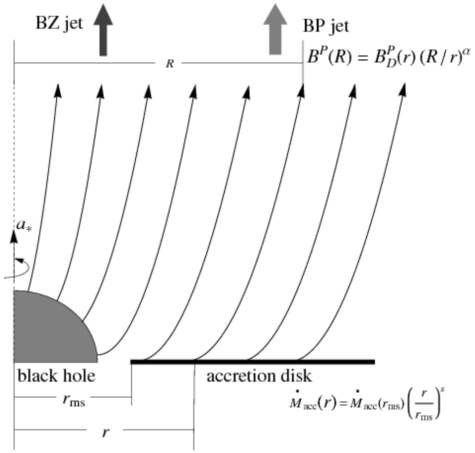




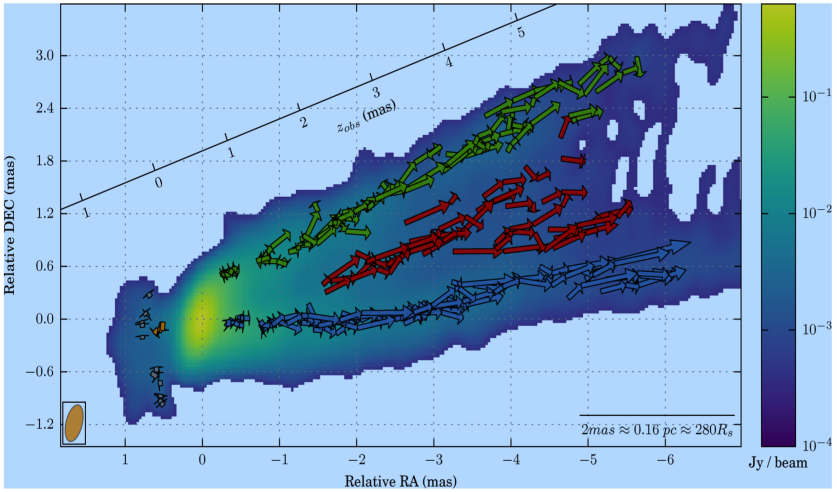
Models (Two-component outflow)

Two flow model (Sol et al. 1989)

- Mildly relativistic sheath composed of e−/p+ and driven by MHD forces → transports most of the kinetic energy
- Ultra-relativistic spine composed of e−/e+ pairs → responsible for most of the emission



Xie et al. 2012



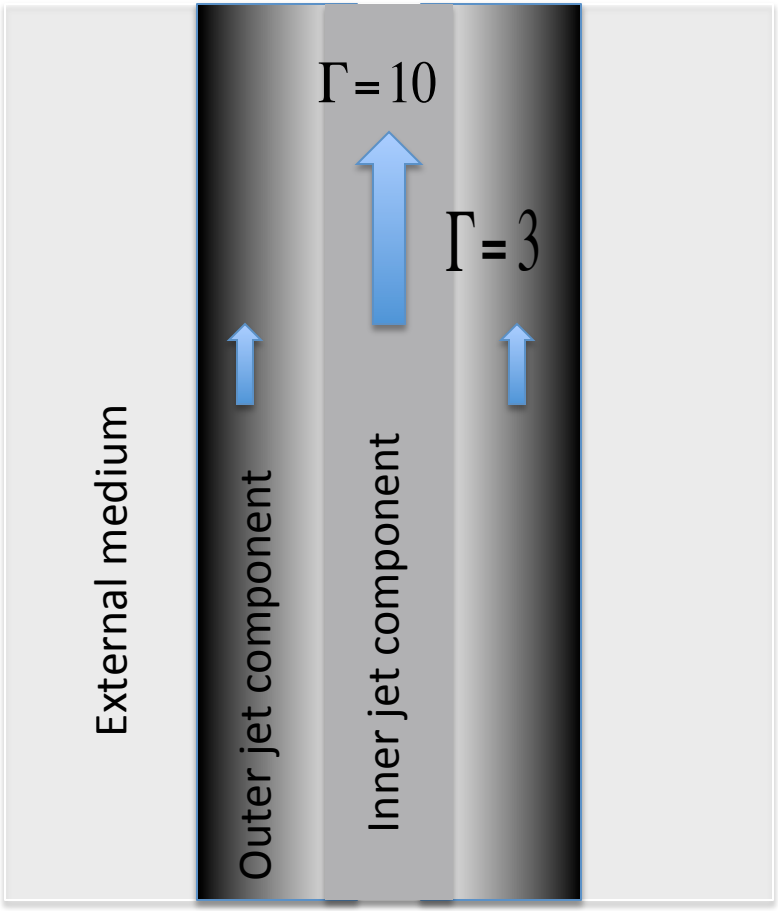
Merten et al. 2016

O. Hervet, Z.Meliani, A. Zech, C. Boisson, V.Cayatte, C. Sauty, H. Sol, 2017

Two-component jet model

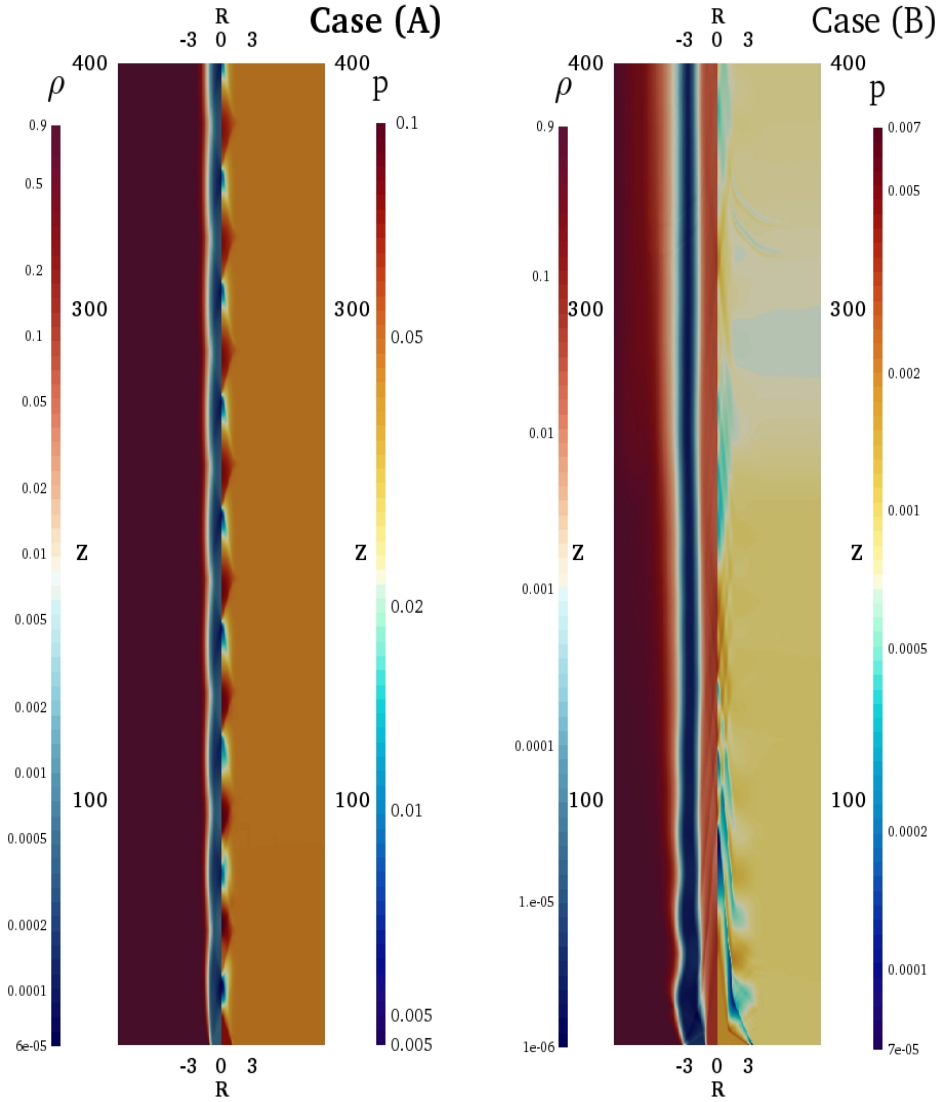
Model and aim

- Two-component jet with fast inner component and slow outer component,
- Mainly classified following the kinetically power between inner and outer jets.

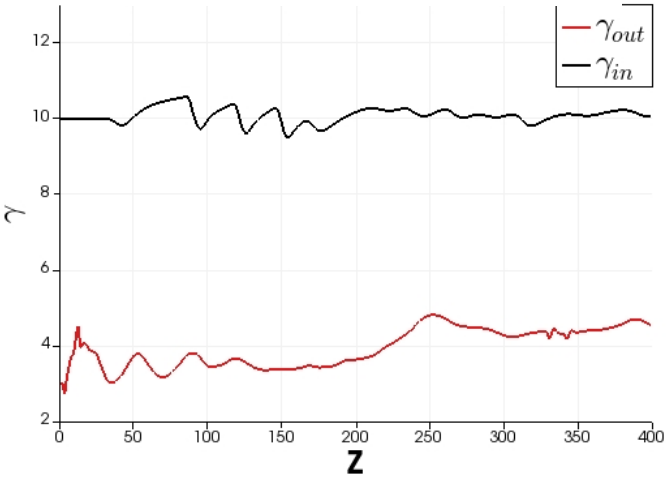


Jet structure

Powerful inner jet component



Lorentz factor profile



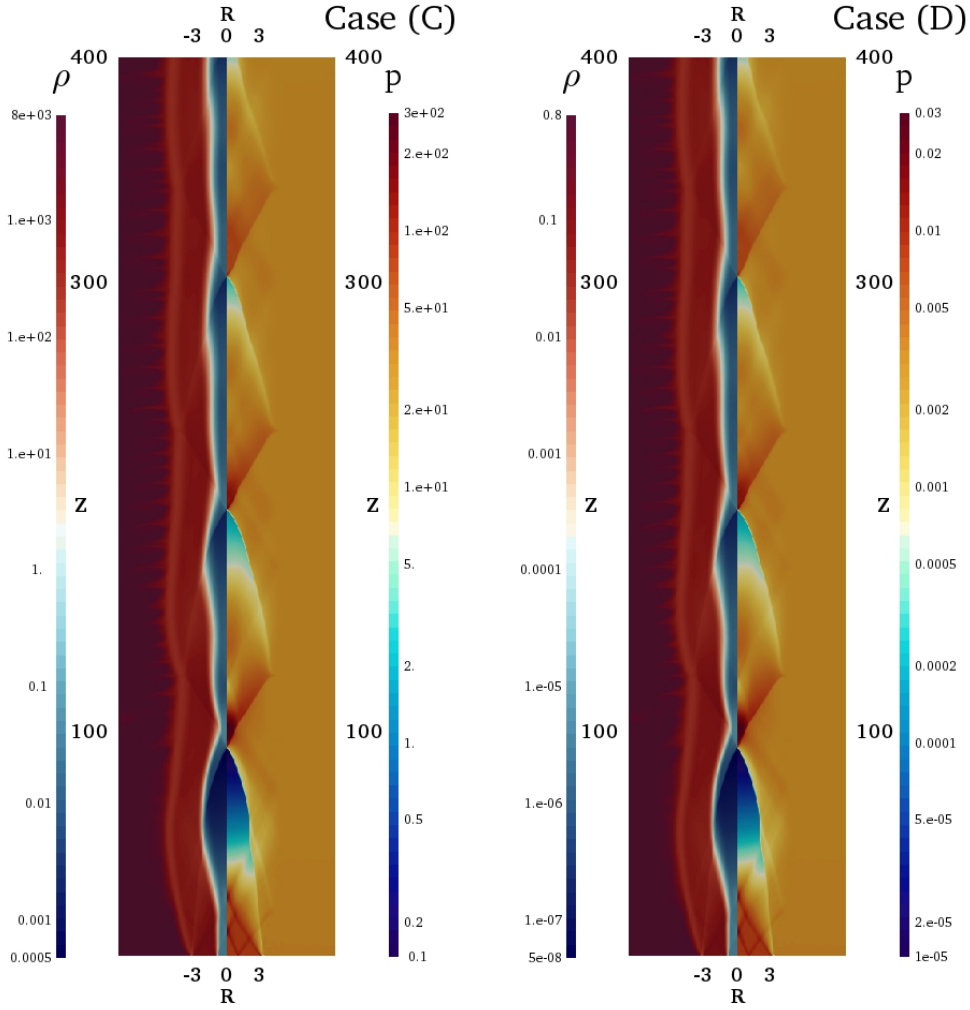
Uniform jet: case (A)

- Equidistance shocks

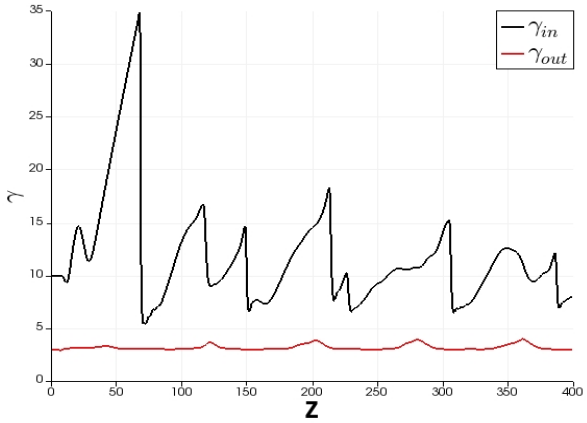
Weak shear layer: case (B)

- Shock waves damping
- Energy transfer to outer jet component

Jet with the two components of the same power



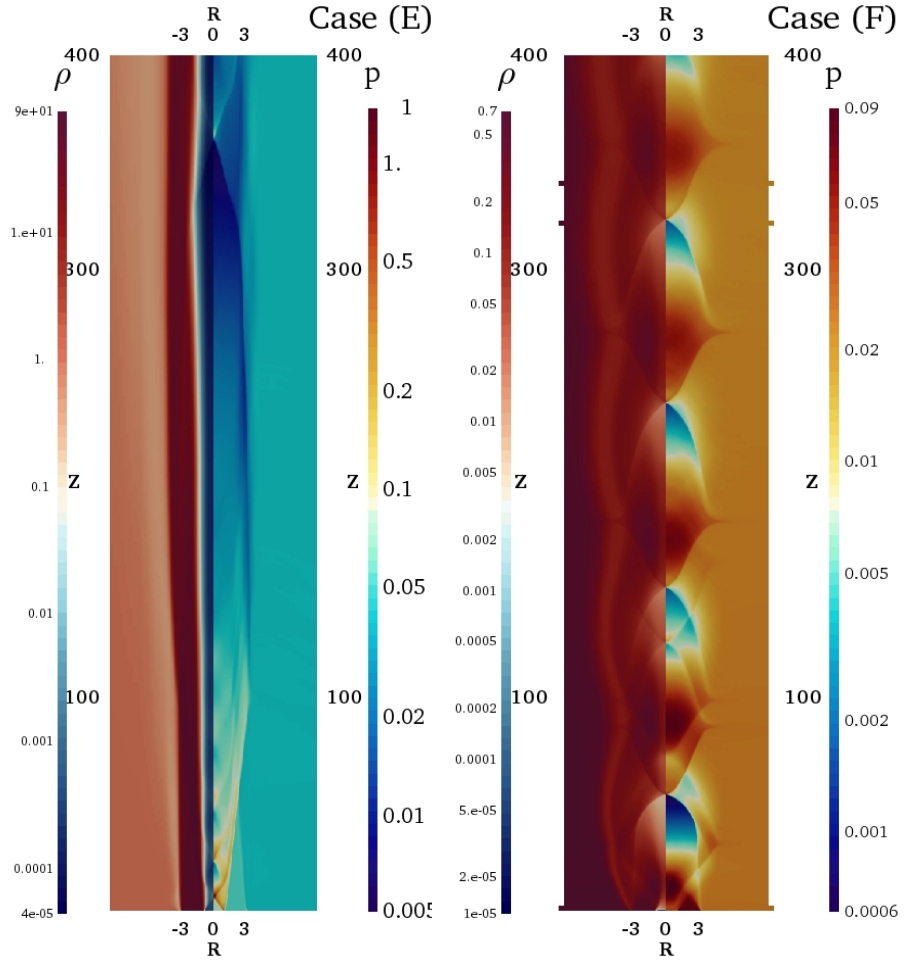
Lorentz factor profile

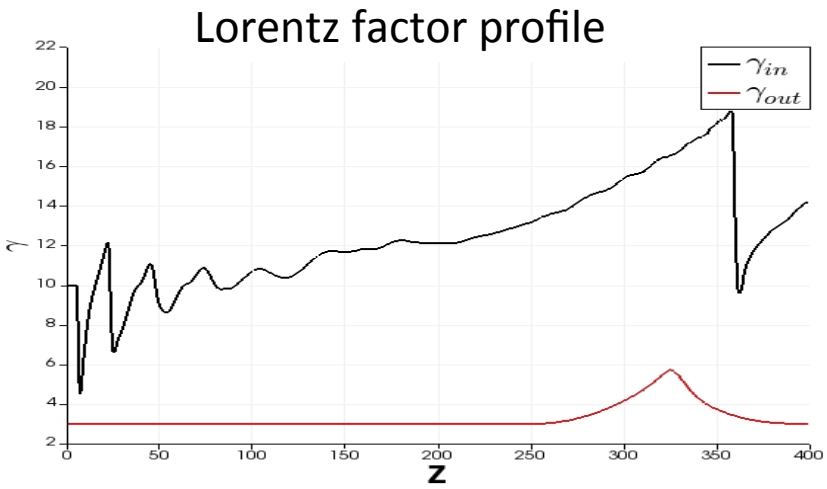


Jet components with same power:

- Strong first acceleration,
- Shock wave damping,
- Two-shock wave length.

Jet with powerful outer component





Powerful outer jet component:

- Stationary shocks near the core
- Moving shocks downstream

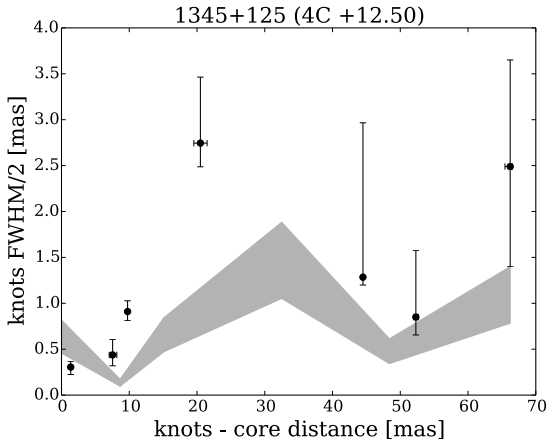
Empty spine

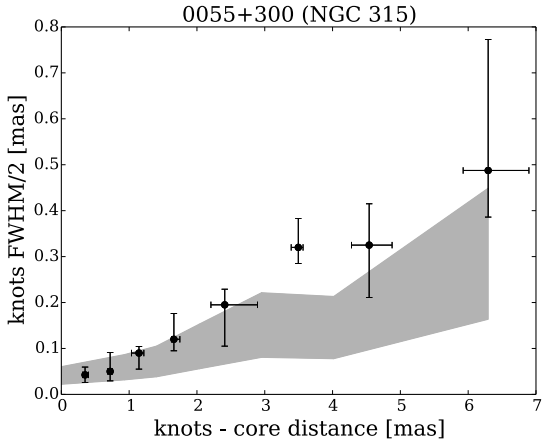
- Jet decollimation
- Increase of inter-shocks distance

Observation of knots

The stationary knot in the relativistic jets are not always equidistance

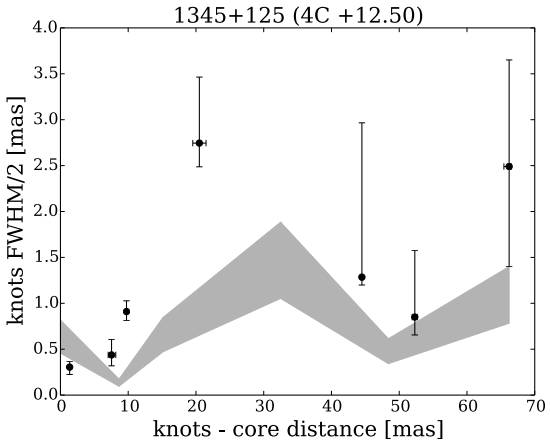
Jet radius changes with distance

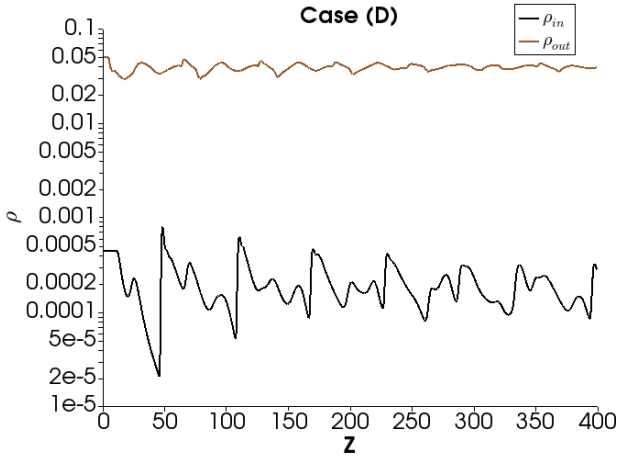




Jet with the two components of the same power

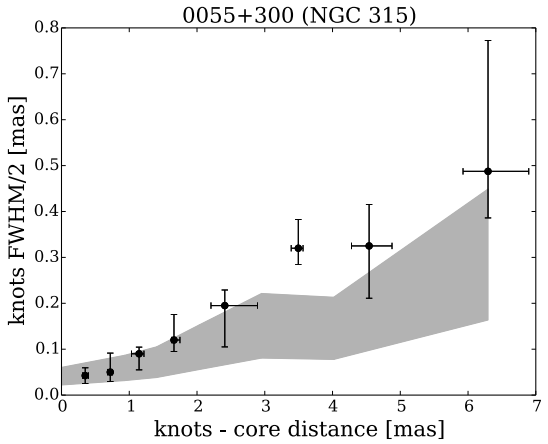
- There are two type shocks
  - Short wavelength (inner component)
  - Long wavelength (outer component)

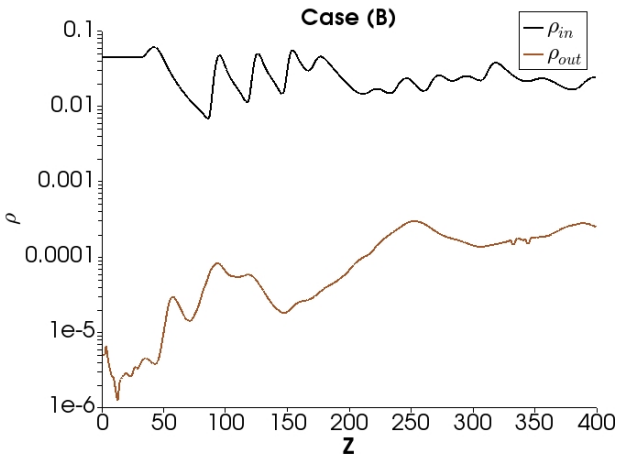




Jet with powerful inner component

- Jet is characterise by near- equidistance knot
- The distance between them is depend on the jet radius.





Classification des AGNs

Powerful inner jet component

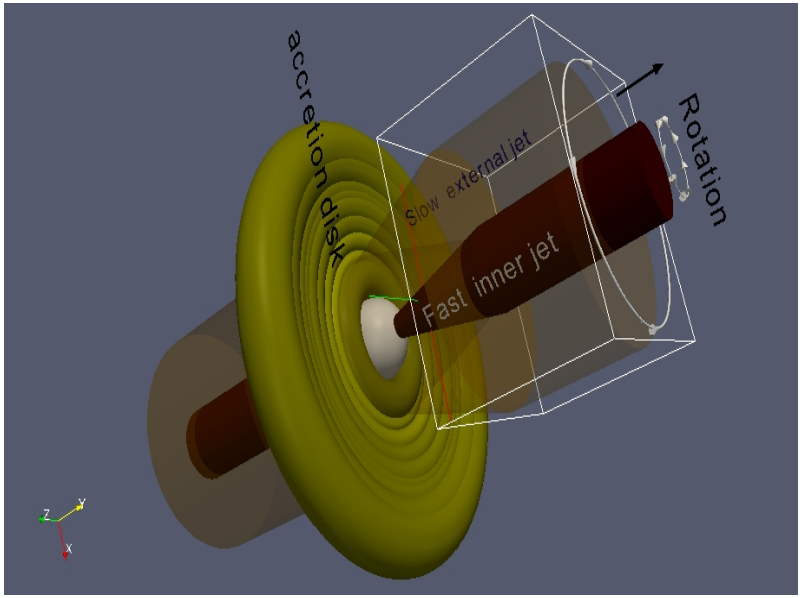
- HBLs are the less powerful AGN jet
- Successive internal shocks (Meli & Biermann 2013))
- Jet has mainly one component (Kharb et al. 2008b,a; Gabuzda et al. 2014)

Powerful outer jet component

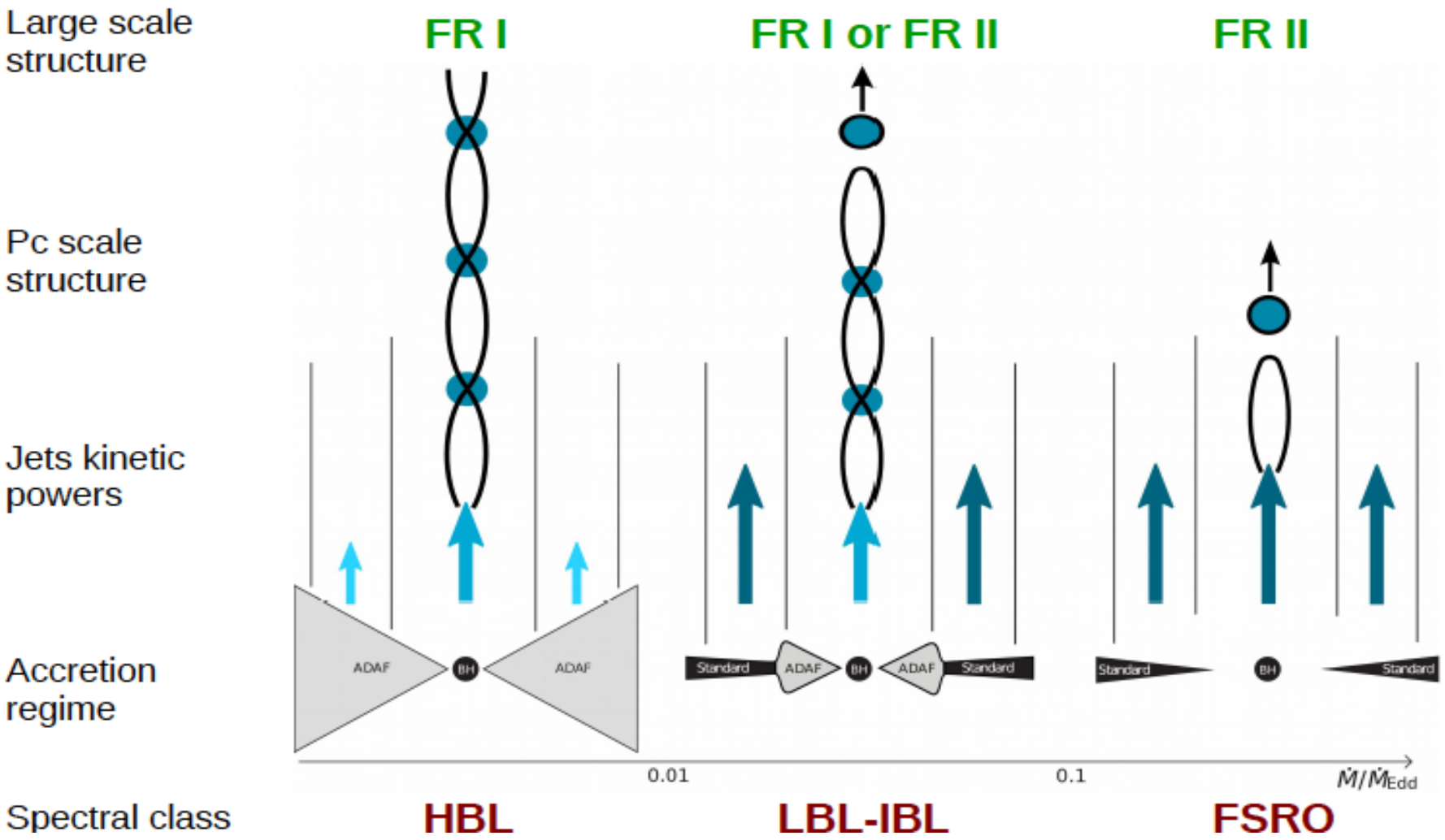
- IBL/LBL are the most powerful AGN jet
- Internal shocks close to the core
- Strong and de-structured downstream

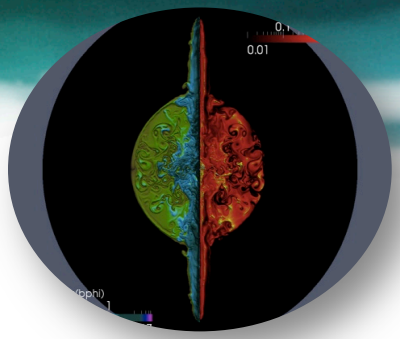
Two components with the same power

- FSRQ



AGN classification





CONCLUSION

Jet classification can be related to jet structuration and re-collimation shocks.