Departament
d'Astronomia
i Astrofísica

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Simulations of the parsec-scale relativistic jet in 3C 273

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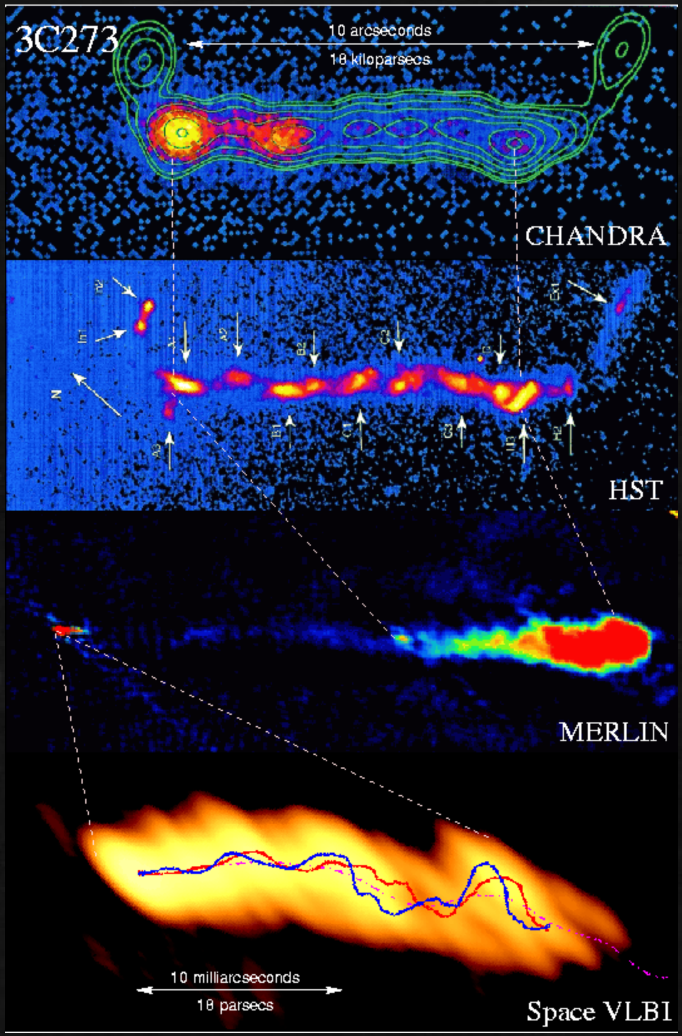
Outline

- Introduction.
- Linear analysis.
- Numerical simulation.
- Discussion and conclusions.

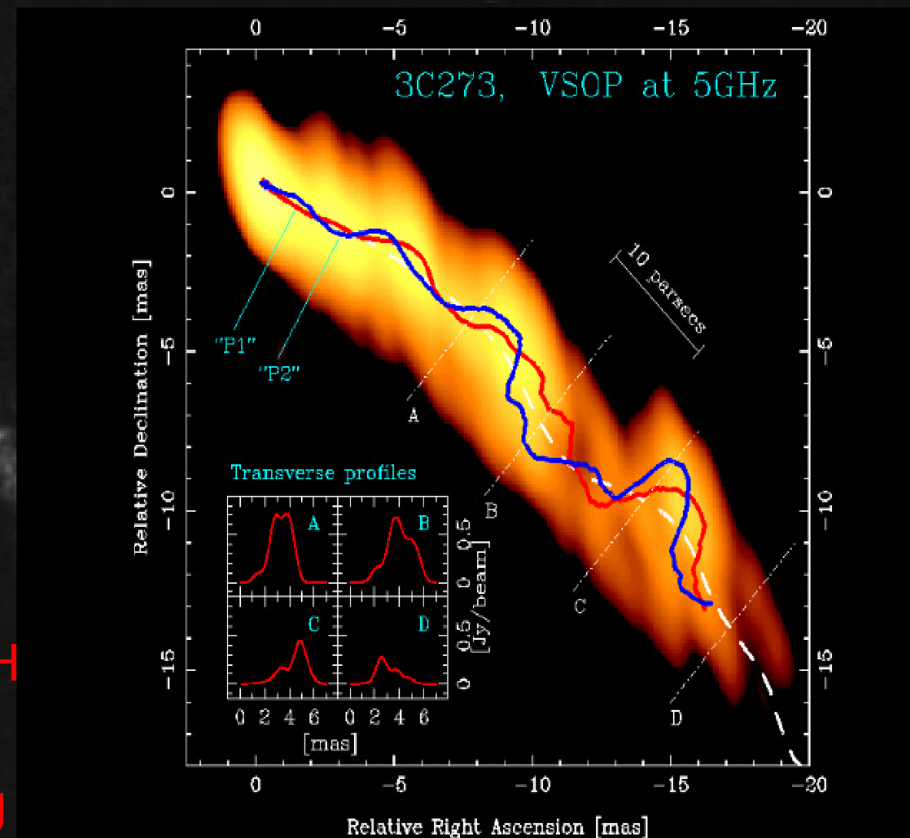
Introduction (from kpc to pc scale)

- Kpc scale jet:
  - Observed up to 60 kpc.
  - No counter jet (relativistic beaming or asymmetry?).
  - Observed from radio to X-rays.
- pc scale jet:
  - Superluminal speeds: 5-8 c (Abraham et al. 1996).
    - ~15º to the line of sight.
    - γ ~5-10.
  - Jet/counter-jet flux assymetry: γ >3.
  - Periodicities in emission (Abraham & Romero 1999, Qian et al 2001):
    - ~ 15 yrs (precession).
    - ~ 1 yr (superluminal component ejection).
    - Ejection velocity decreasing.
  - Higher frequencies show more compact jet (stratification).



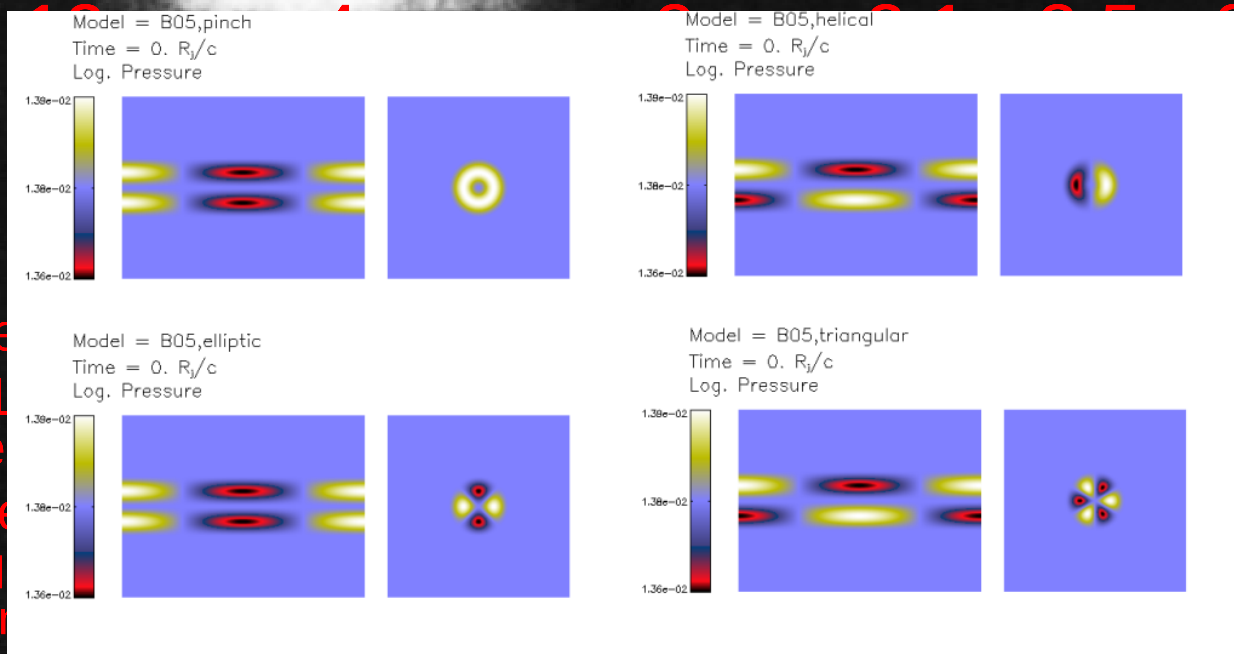
Introduction (pc scale jet)

- Lobanov & Zensus 2001.
- VSOP observations:
  - 240 emission profiles. 2 - 3 components.
  - Central (strong) component seems to move ballistically.
  - Fitted profiles to double gaussians.
  - Obtained characteristic wavelengths (double helix) and interpreted them as modes of KH instability.
  - Fitted physical parameters using linear stability theory approximations (Hardee 2000).



Linear analysis

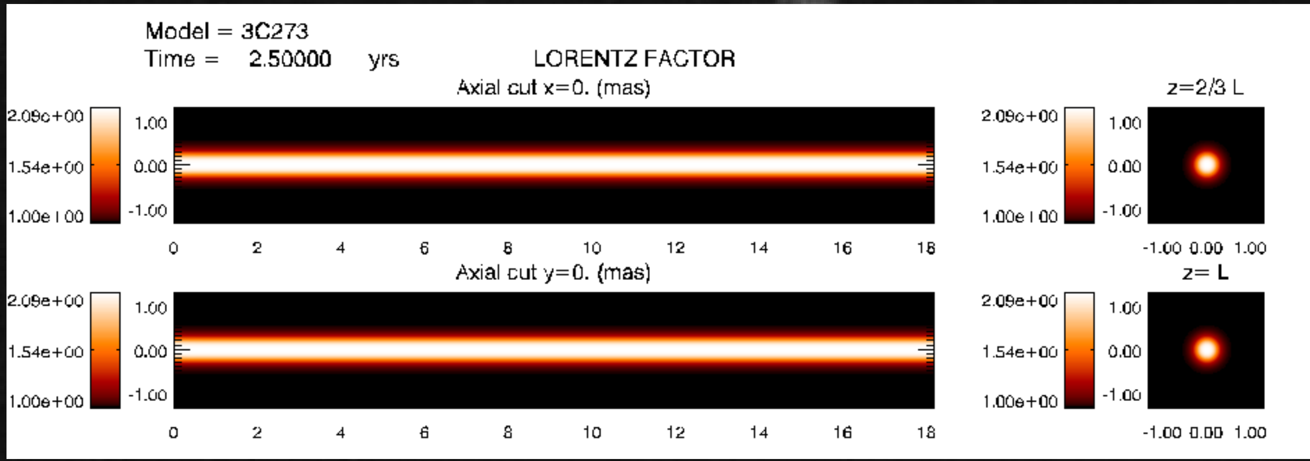
λ(Hs) Amp (mas)	λ(Es) Amp (mas)	λ(Hb1,Eb1) Amp (mas)	λ(Hb3,Eb2) Amp (mas)	γ	$M_{j,rel}$	η	R_j (pc)
18						.023	0.8
1.5							



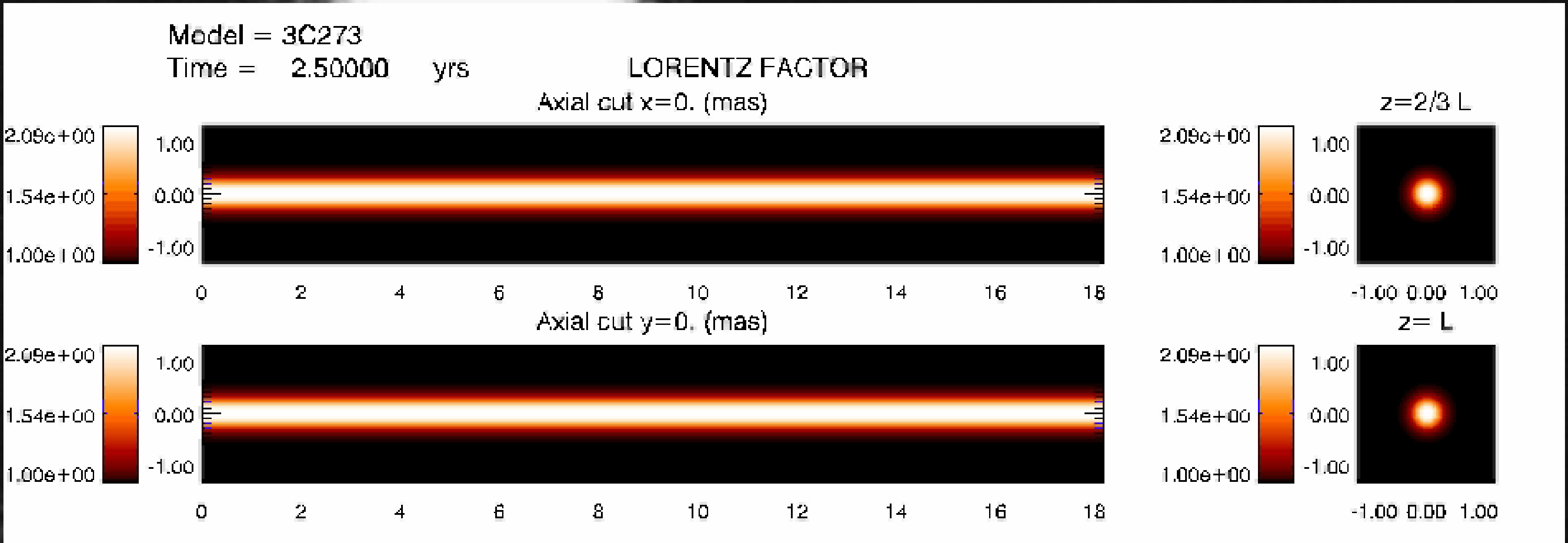
- Powe
- γ~2.1 … es to unde
- Is line
  - N … al. 2004a) ar

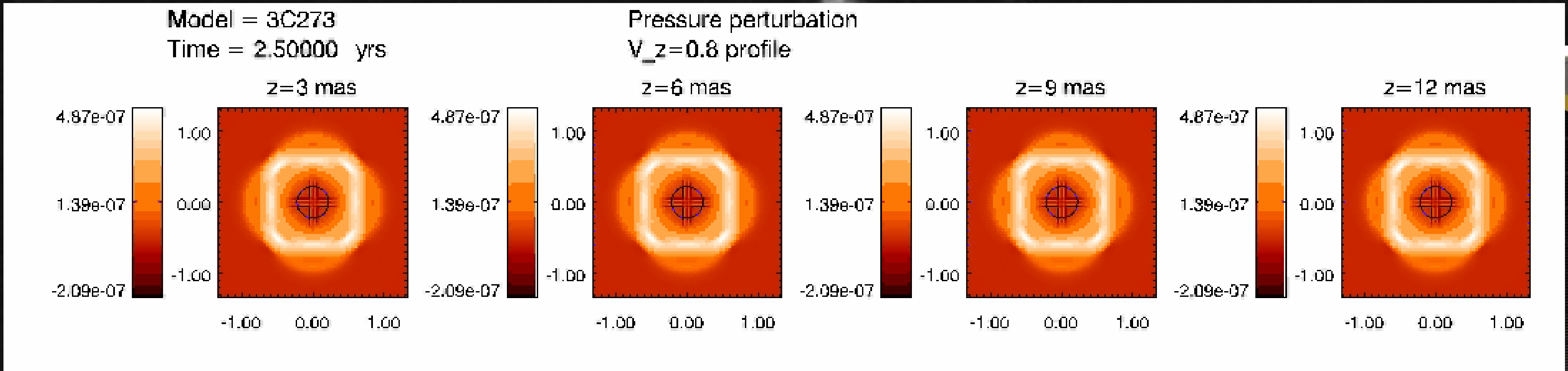
Numerical simulation (i)

- 3D RHD cylindrical jet
  - Start with a stationary jet with the given parameters.
  - Axial size corresponds to the observed region in LZ01.
  - Jet is perturbed at the inlet with appropriate frequencies.
  - 16 cells/R_j transversal, 4 cells/R_j axial.
  - Injection and ouflow boundary conditions.
  - Thick shear layer between jet and external medium.
  - 8 processors in SGI Altix *CERCA* during ~1 month.

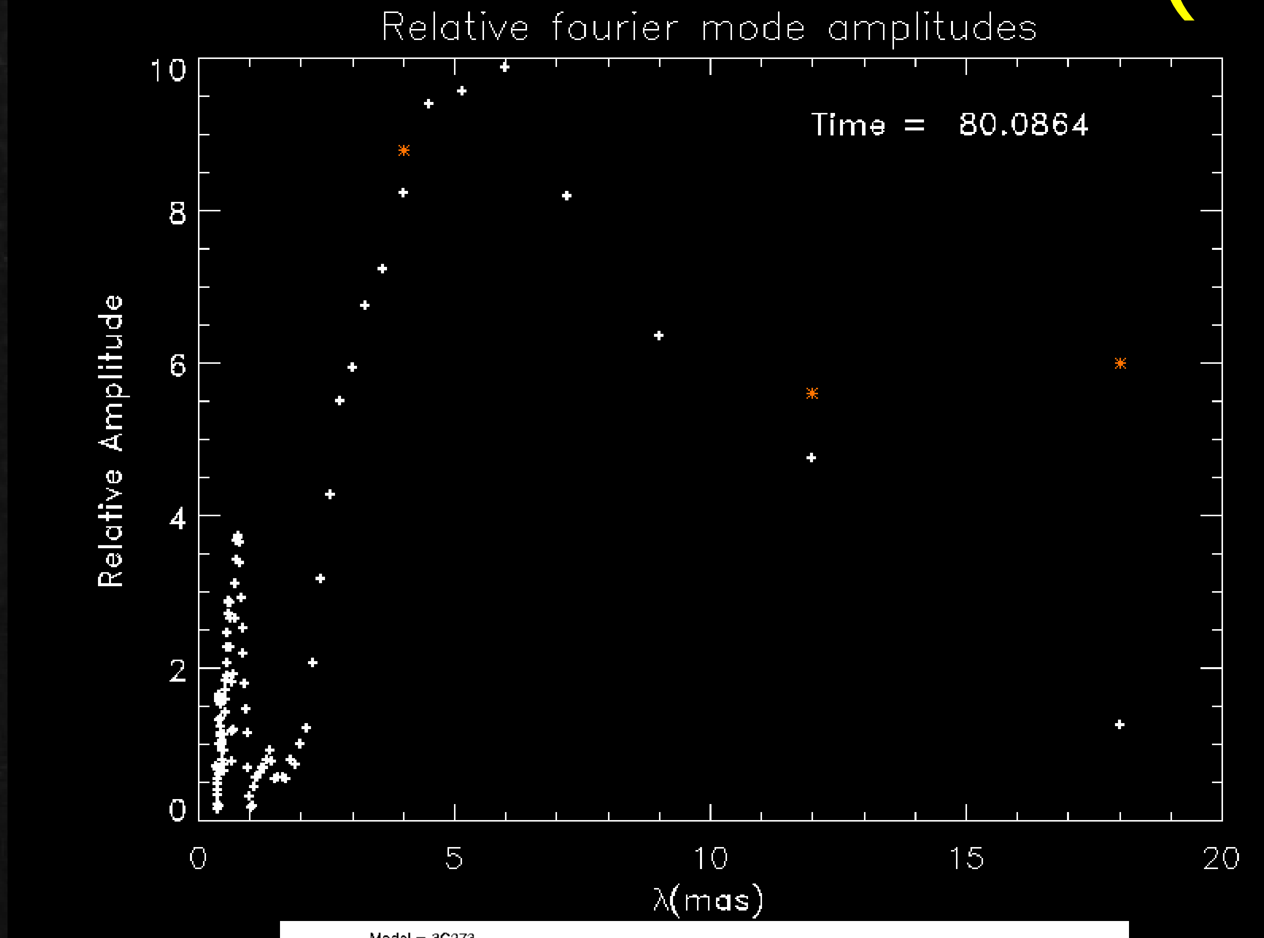


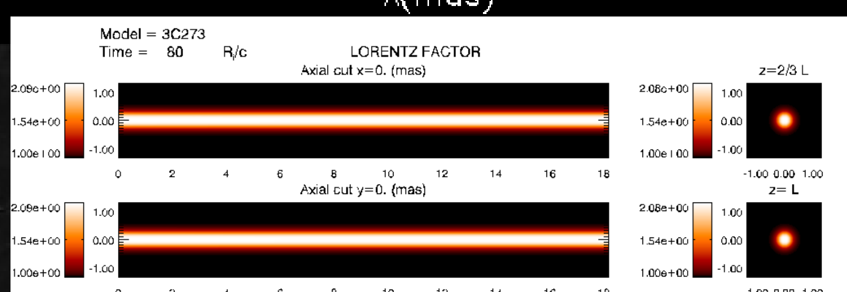
Numerical simulation (ii)



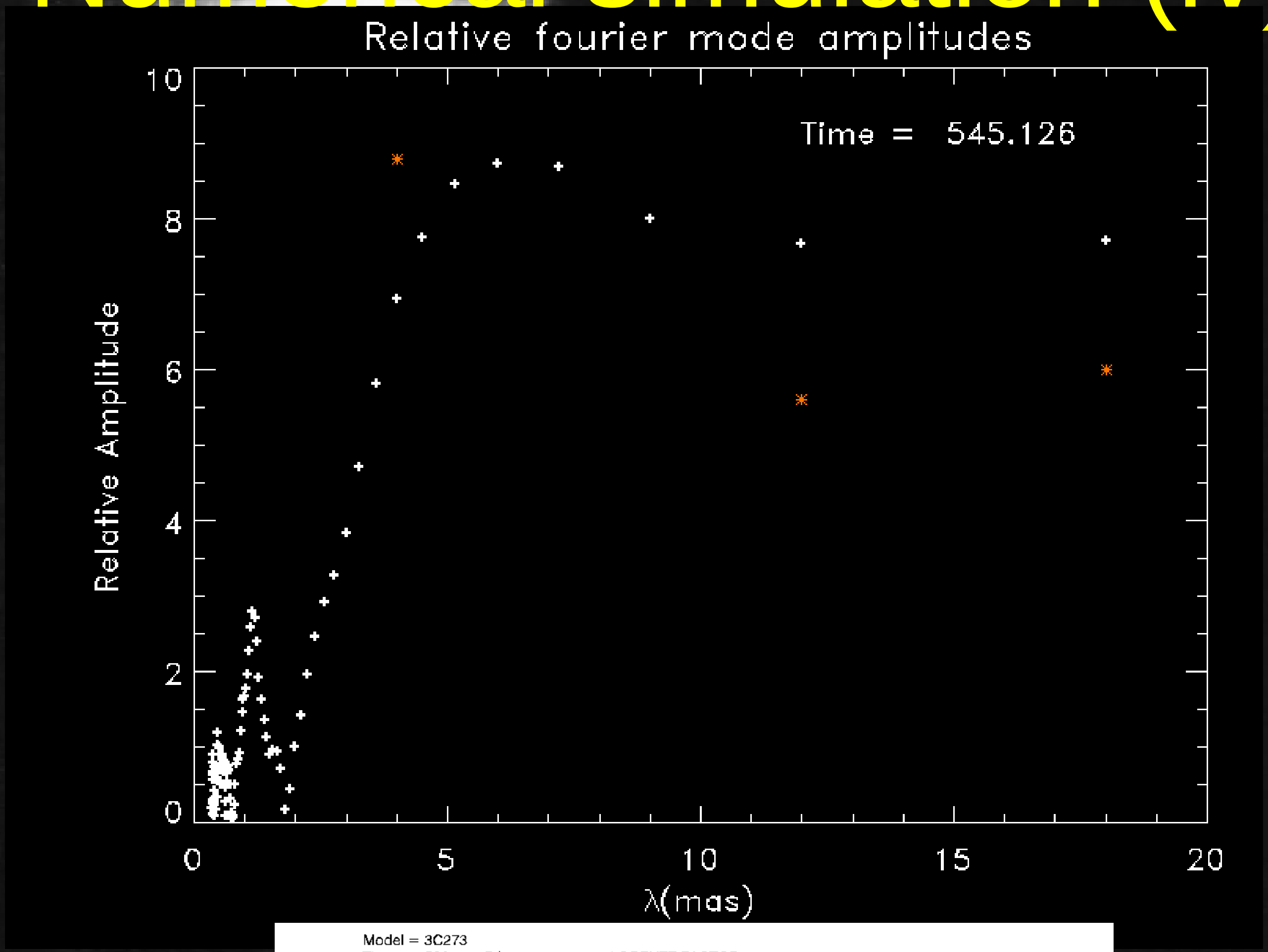


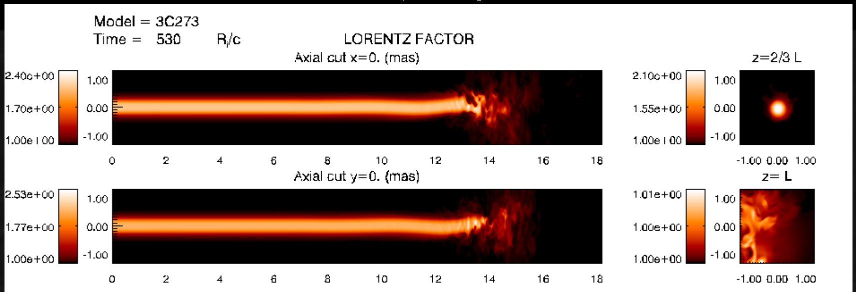
Numerical simulation (iii)



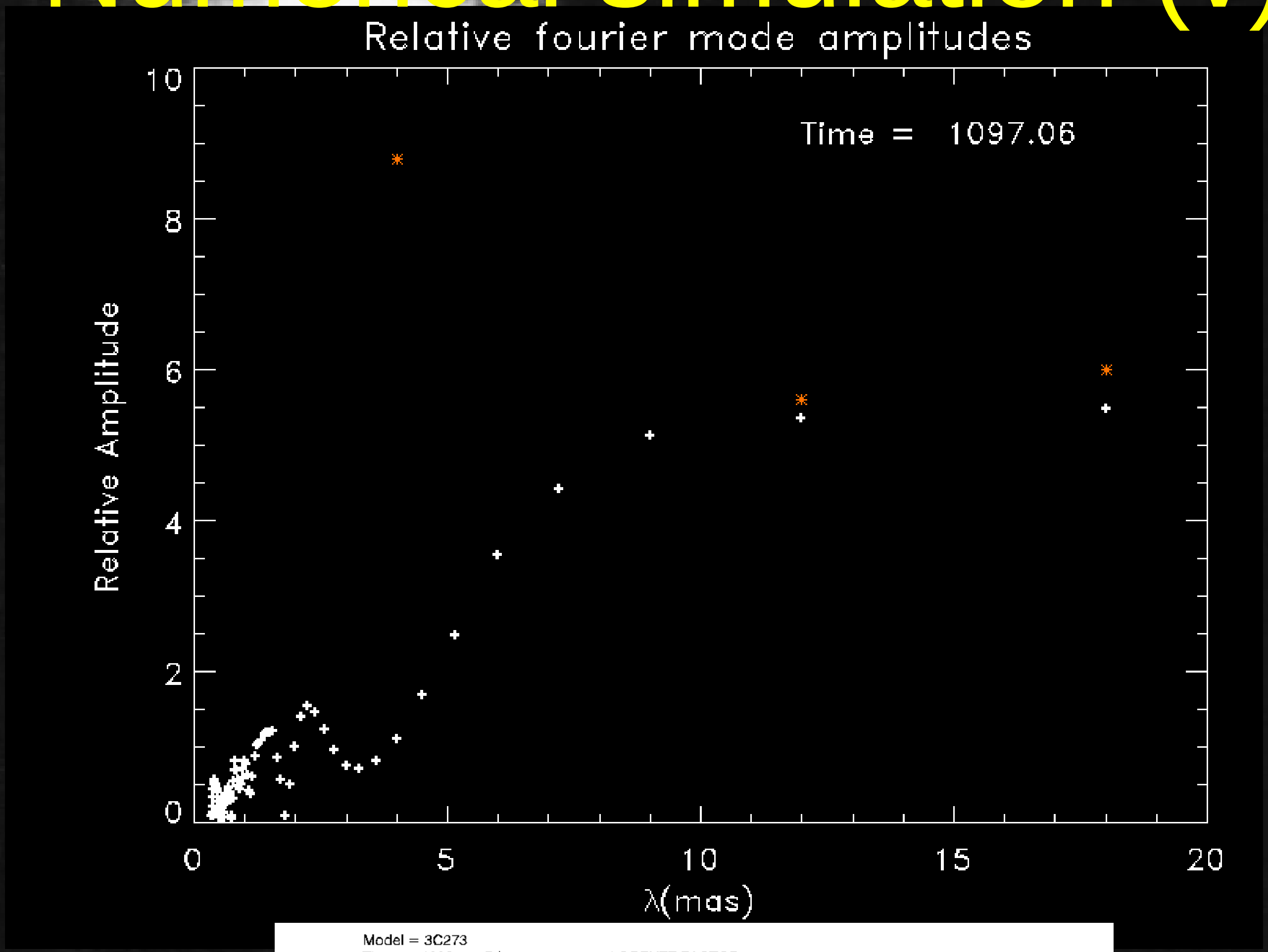


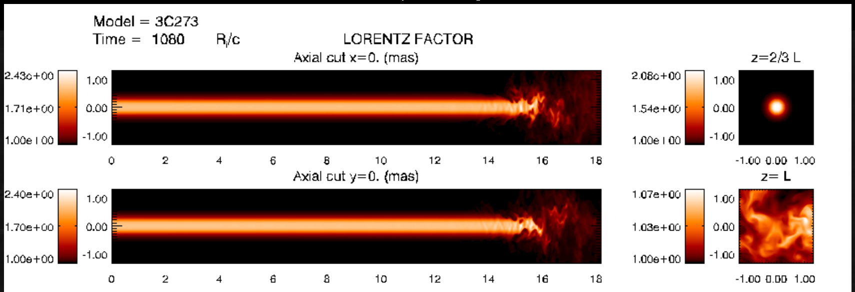
Numerical simulation (iv)





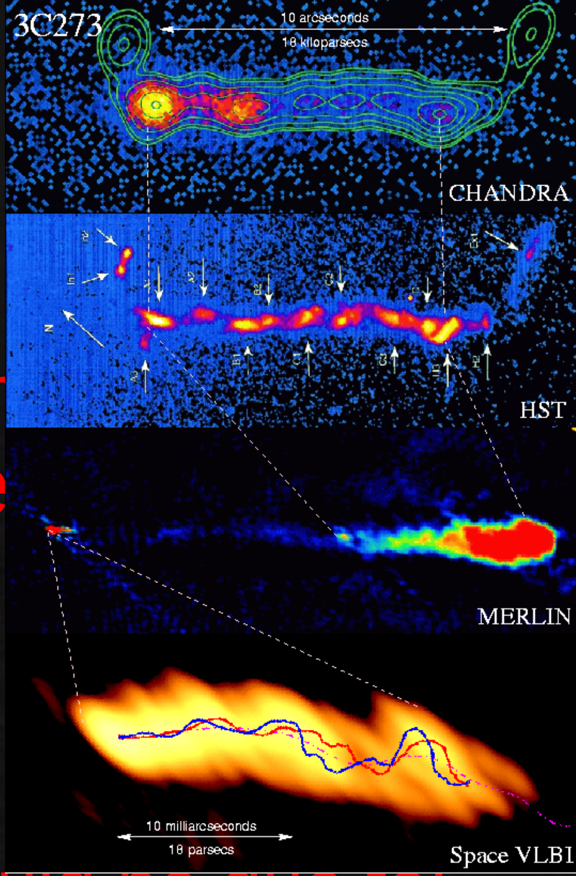
Numerical simulation (v)





Discussion (i)

- From observations and linear ar
  can obtain parameters for nume
  simulations.
- Numerical simulation: The jet is
  and the Lorentz factor drops.
  - Drop in emission after VLBI jet could be due to:
    - Disruption of underlying flow.
      - In this case superluminal components could play a central role in keeping collimation up to the kpc scale jet, where strong interaction with external medium plus reacceleration would rise emission again.



Discussion (ii)

- Adiabatic expansion (the jet keeps fast but we don't see it). Possible reasons for differences:
  - Linear theory approximations may not be accurate.
    - » Factor 1.5-2 difference in derived wavelengths with solver and approximations in Hardee (2000): π phase could explain factor 2.
  - Magnetic fields may play an important role (Asada et al. 2002).
  - KH theory and our simulation apply to underlying flow alone.
  - Superluminal components should be included:
    - » Include also periodicities? New simulations…(Abraham & Romero 1999, Qian et al. 2001)
  - Arbitrary initial amplitudes.
  - Errors from numerical methods (lack of resolution).

Discussion (iii)

- Possible stabilizing factors:
  - Superluminal components.
  - Thicker shear layer.
  - Decreasing density atmosphere.
  - Stabilizing configuration of magnetic field (RMHD simulations?).

Discussion (iv)

- Mode wavelengths found via Fourier analysis:
  - Close to observed for longer wavelengths: they dominate by the end of the simulation.
  - Shorter modes dissapear from the simulation. Maybe their amplitude is increased in the real jet by growing perturbations (superluminal components may excite them as trailing components, Agudo et al. 2001).
- This works represents our first step in trying to understand relativistic jet physics through stability analysis in combination with 3D relativistic hydrodynamical simulations.