

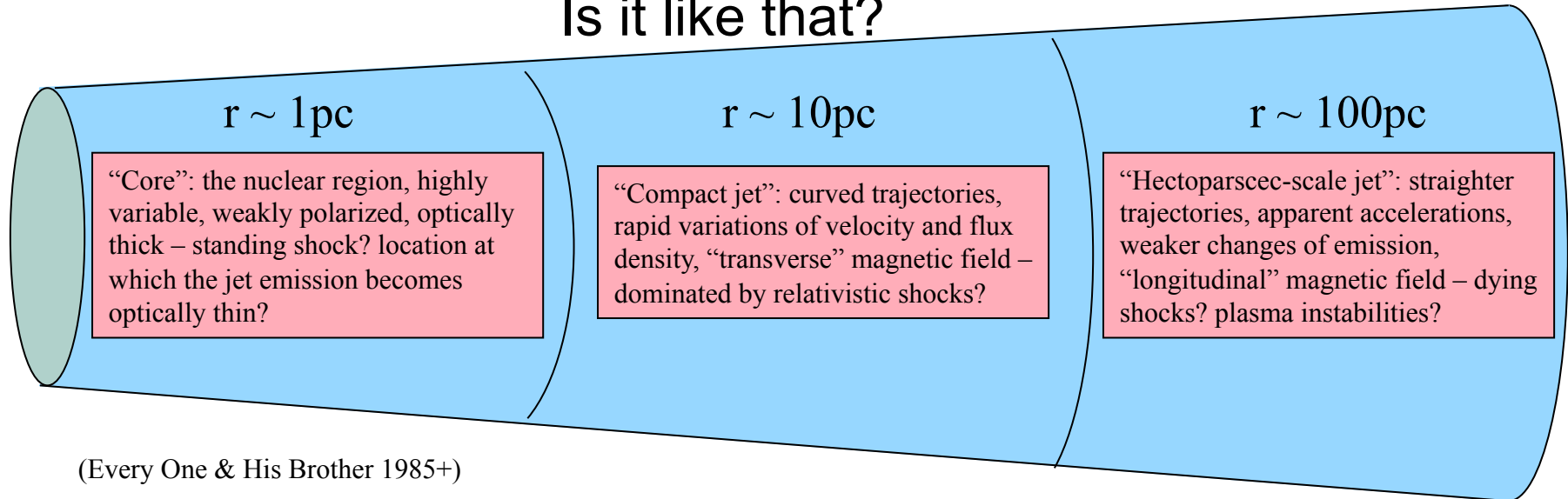
# **What's There in Jets: Shocks and Threads or Cords and Frets?**



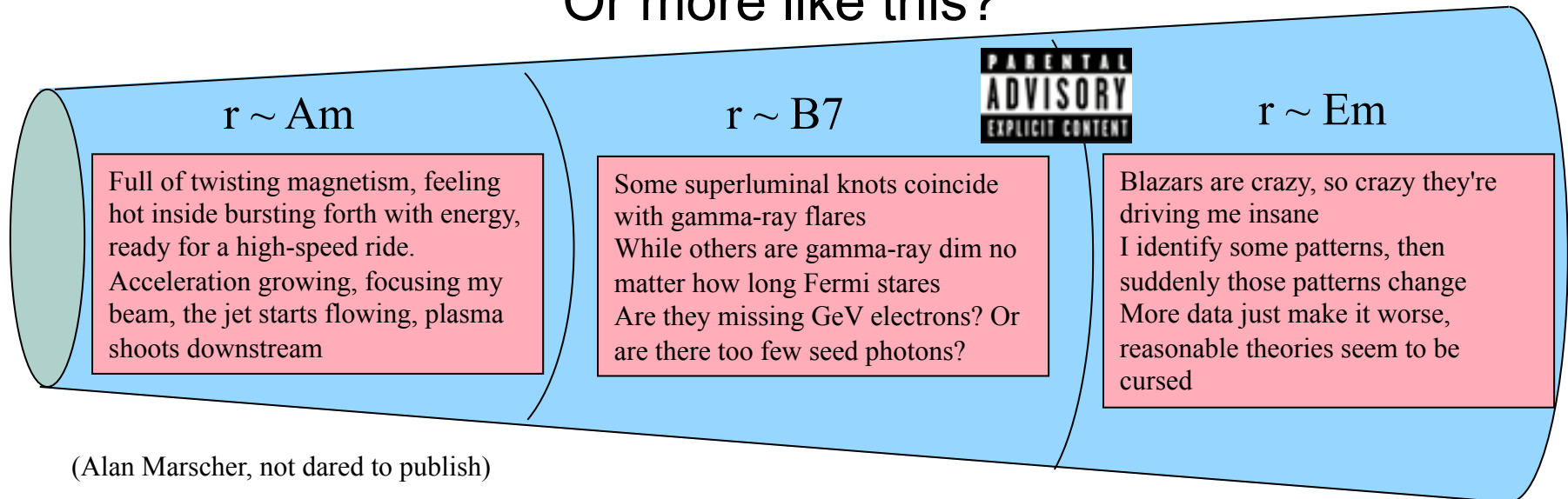
Andrei Lobanov  
MPIfR, Bonn

# What's there indeed?

## Is it like that?



## Or more like this?



# In other words: Are jets ...

like that?



Postliminary RadioAstron image of M87; for more details, pay attention at Tuomas Savolainen's talk

or like that?



The never presented *real* output from nearly every numerical simulation of jets

# 1.7 Gigaseconds of Jet Studies Religion

## ☐ Prehistoric Superluminal Mysteries

- „In the beginning was the Word, and the Word was ~~God~~ superluminal“

## ☐ Cannonball Paganism

- „Your own personal ~~Jesus~~ Gaussian component“

## ☐ Standard Yardstick Monotheism

- „One ~~ring~~ Lorentz factor to rule them all“

## ☐ Age of Shock(ed) Prophets

- „Hear ye, hear ye! The end of the ~~world~~ jet is near!“

## ☐ Two-fluid Herecies

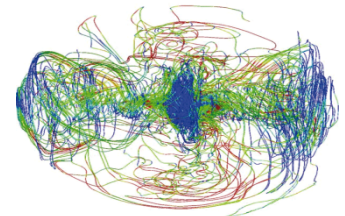
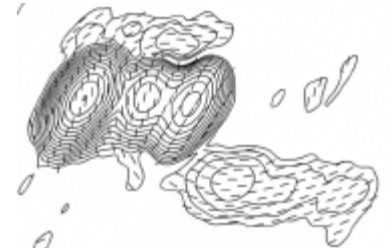
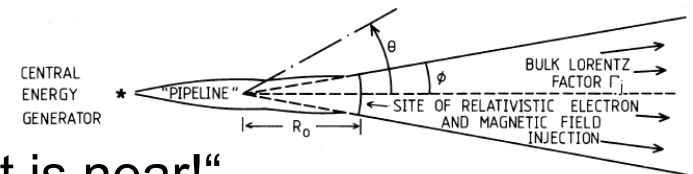
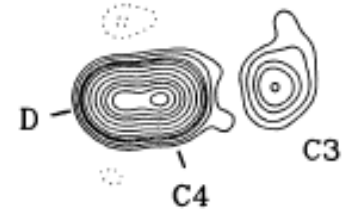
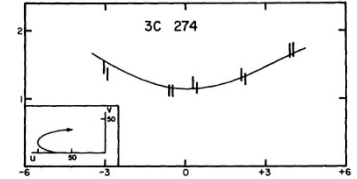
- „My God, it's full of ~~stars~~ threads“

## ☐ Poynting Flux Enlightenment

- „~~Video~~ Polarization killed the radio star“

## ☐ Augmented GRMHD Reality (Atheism)

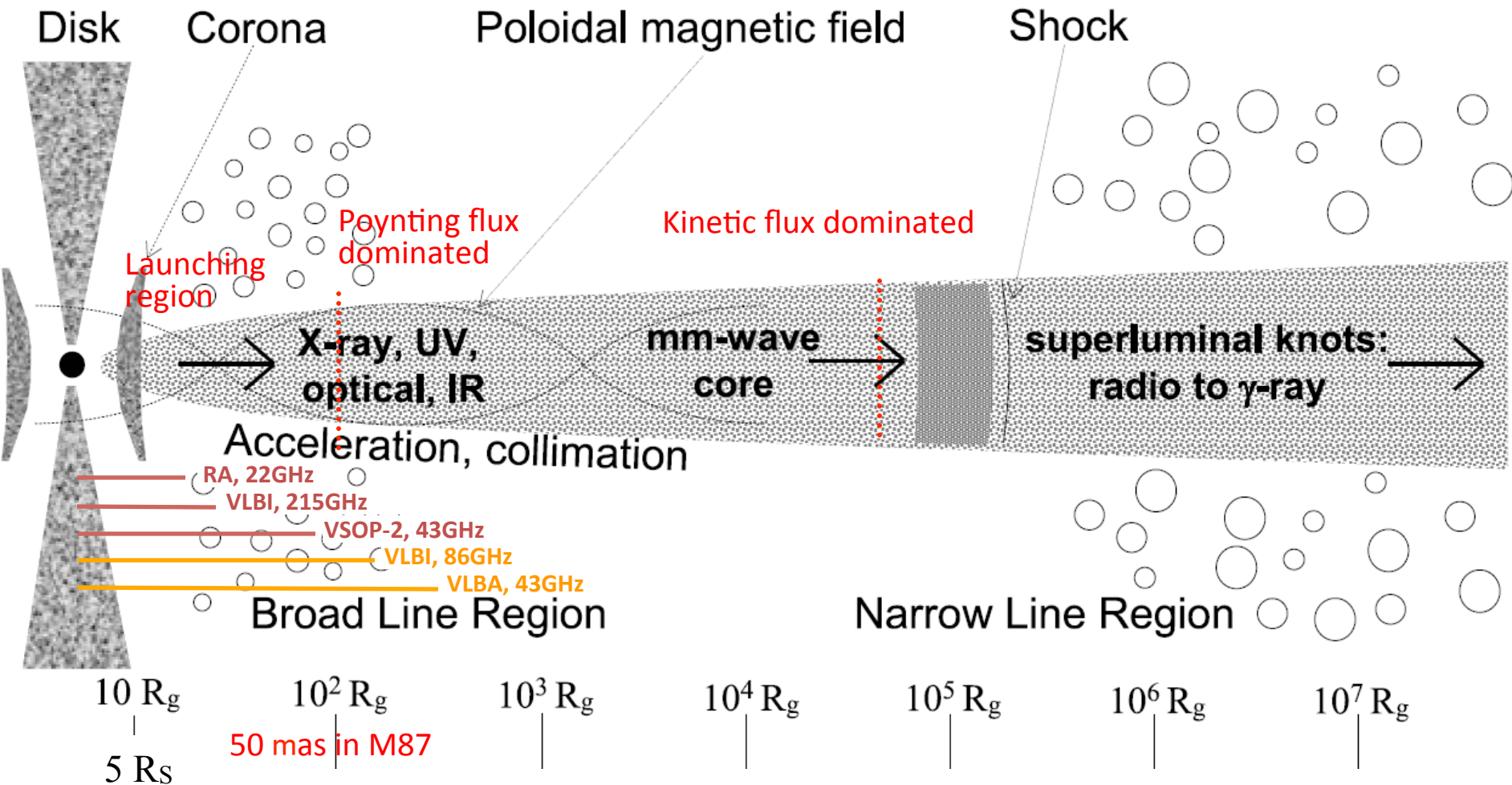
- „Losing my religion“ and „calling ~~Elvis~~ Albert“





# Modern Pillars of Jet Religion

Nearly ten commandments of jet religion: weakly emitting launching region, mm-wave core, standing/moving shocks, instabilities/waves.



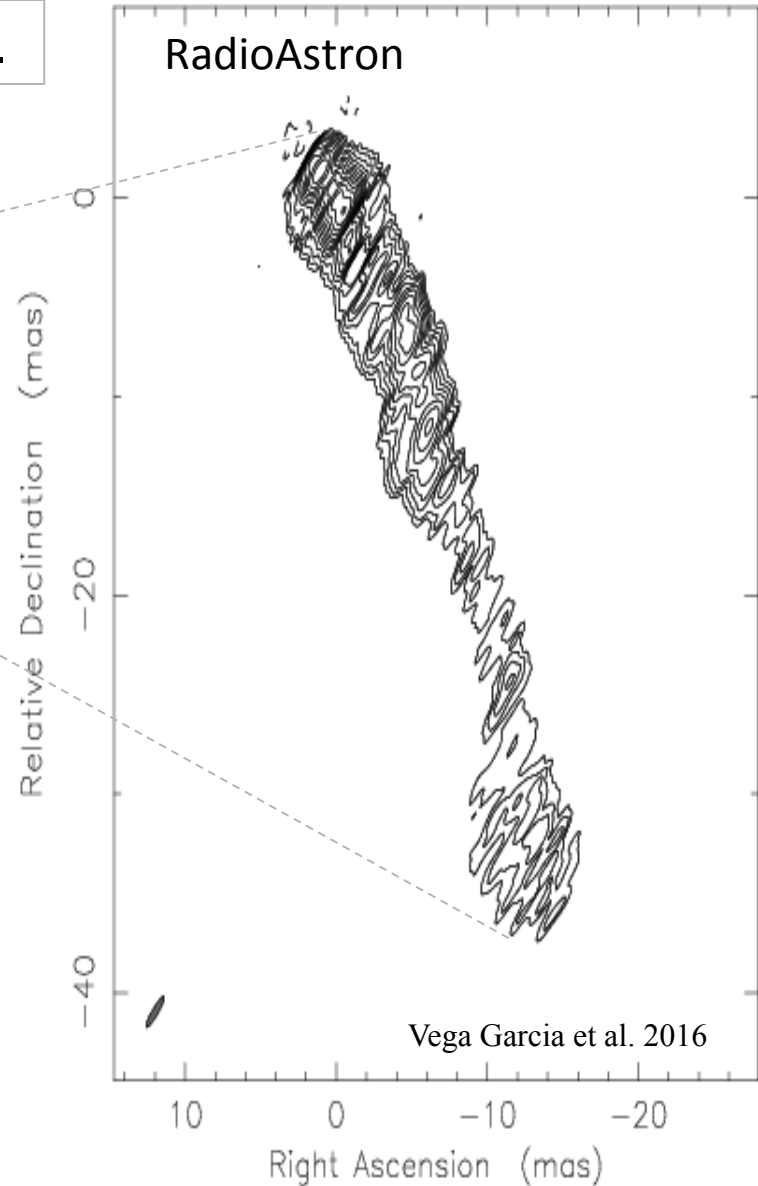
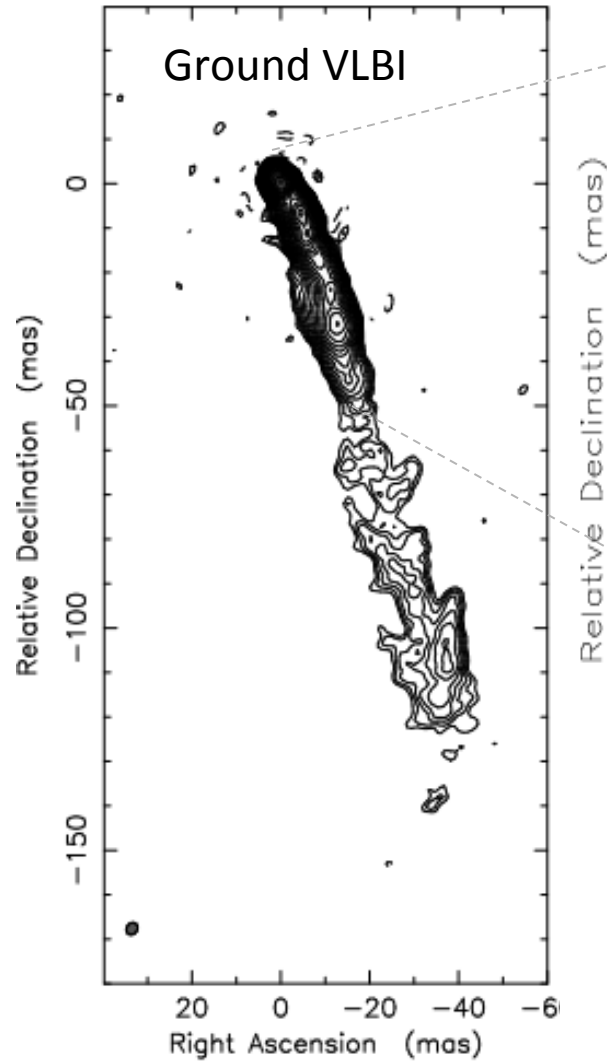
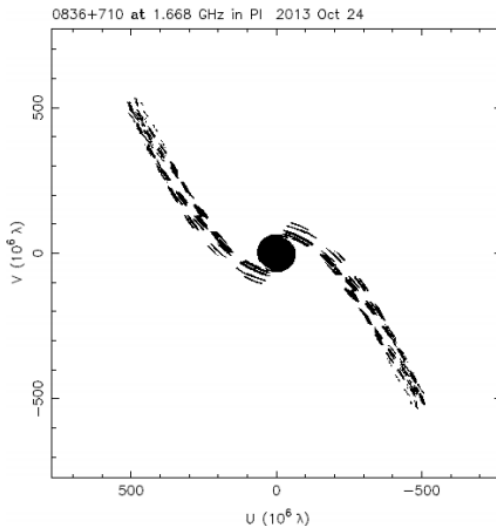
# Fluid One, Fluid Two, Fluid ...

Complex transverse structure: many streams.

**0836+710 with  
RadioAstron at 1.6 GHz:**

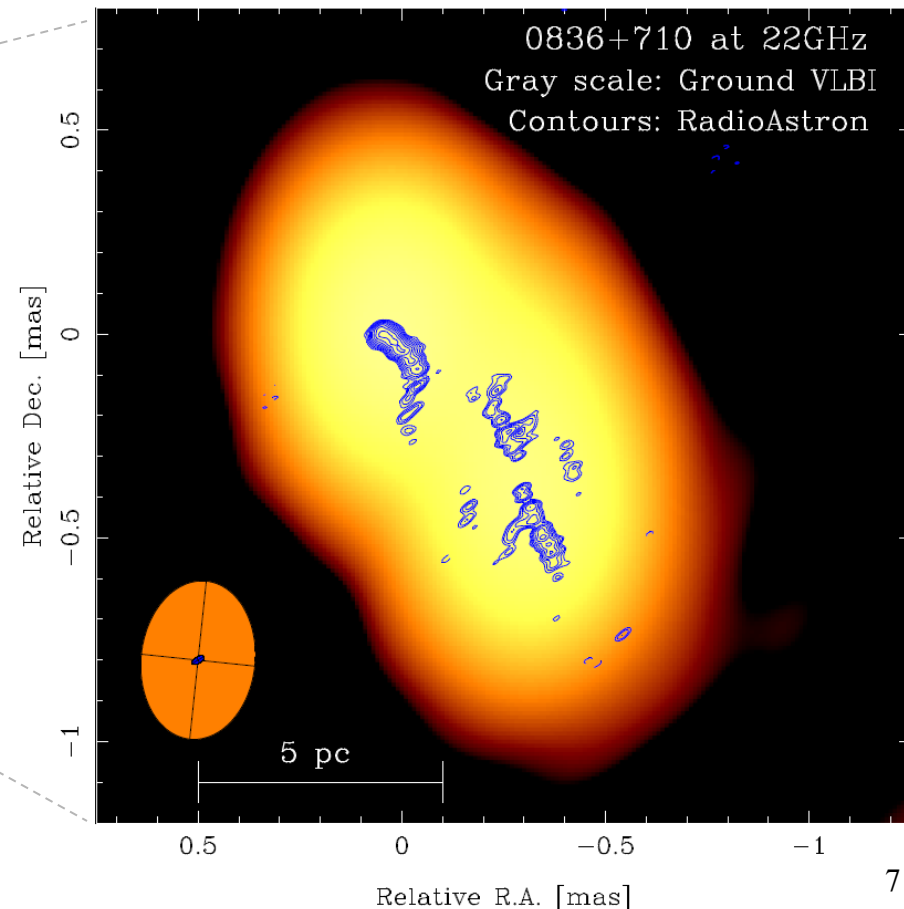
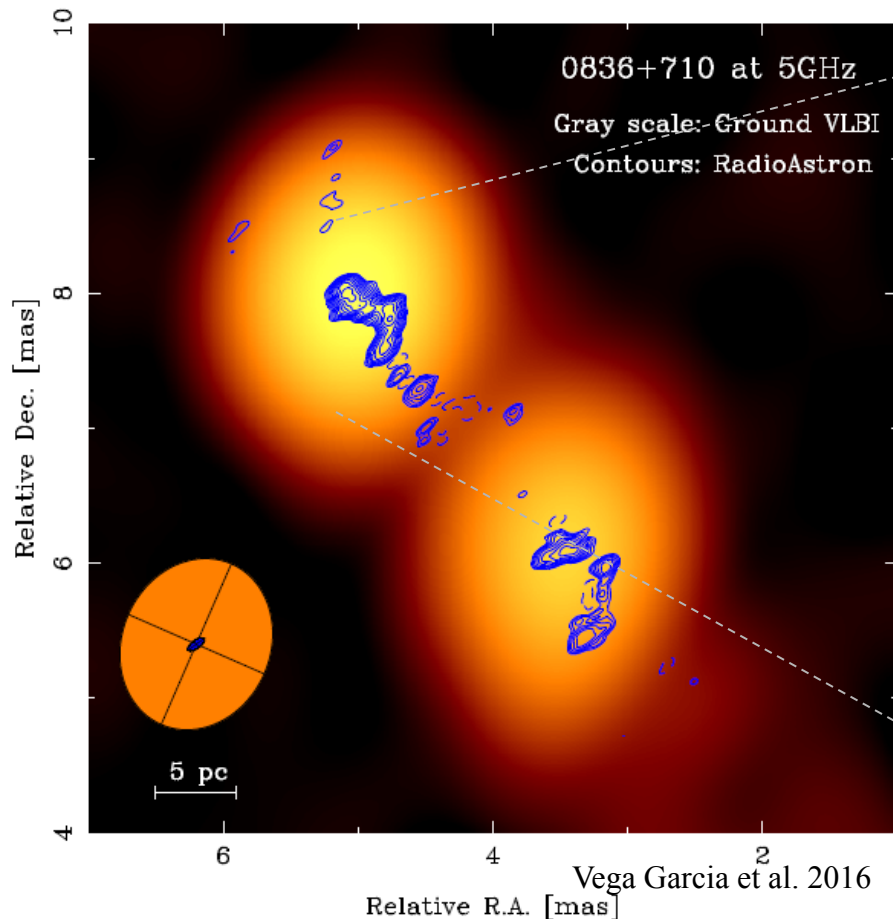
Ground array: D=8000:1,  
Beam  $2.8 \times 2.4$  mas

Space image: D=310:1  
Beam  $1.9 \times 0.4$  mas



# Observer's Version of GRMHD Atheism

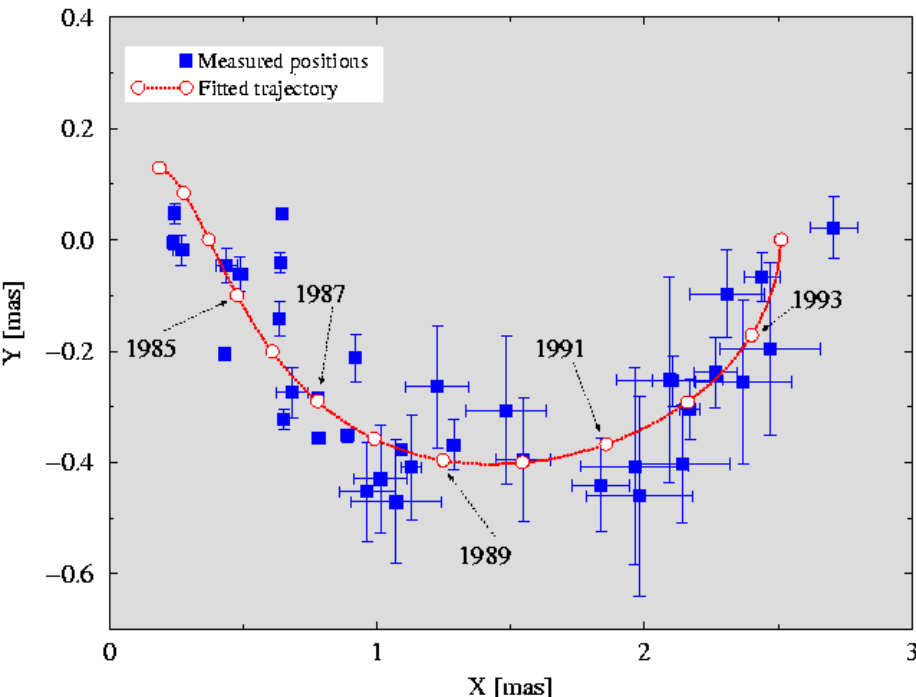
Destructive influence of RadioAstron: What is „Core“ from the ground is „Core No More“ when viewed from space. Instead, it's „threads“ inside the flow. Are these the jet chickens or the eggs of some even deeper shocks?



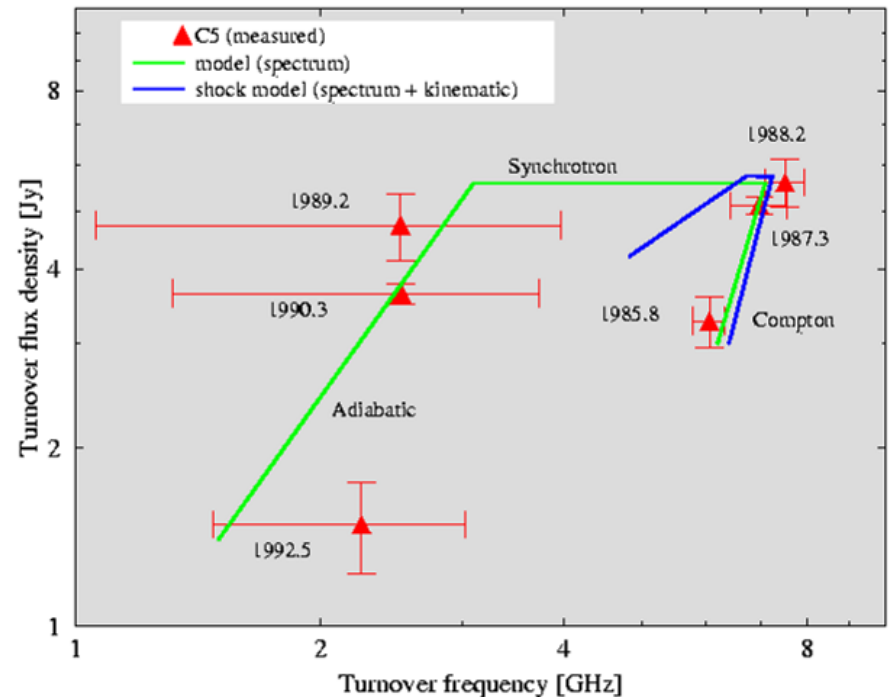
# Shocks on parsec scales

Shocks are definitely there on parsec scales. But they dissipate rapidly while approaching hectoparsec scales: shock models can no longer explain kinematic and spectral evolution observed in jets on these scales.

3C345: trajectory of C5

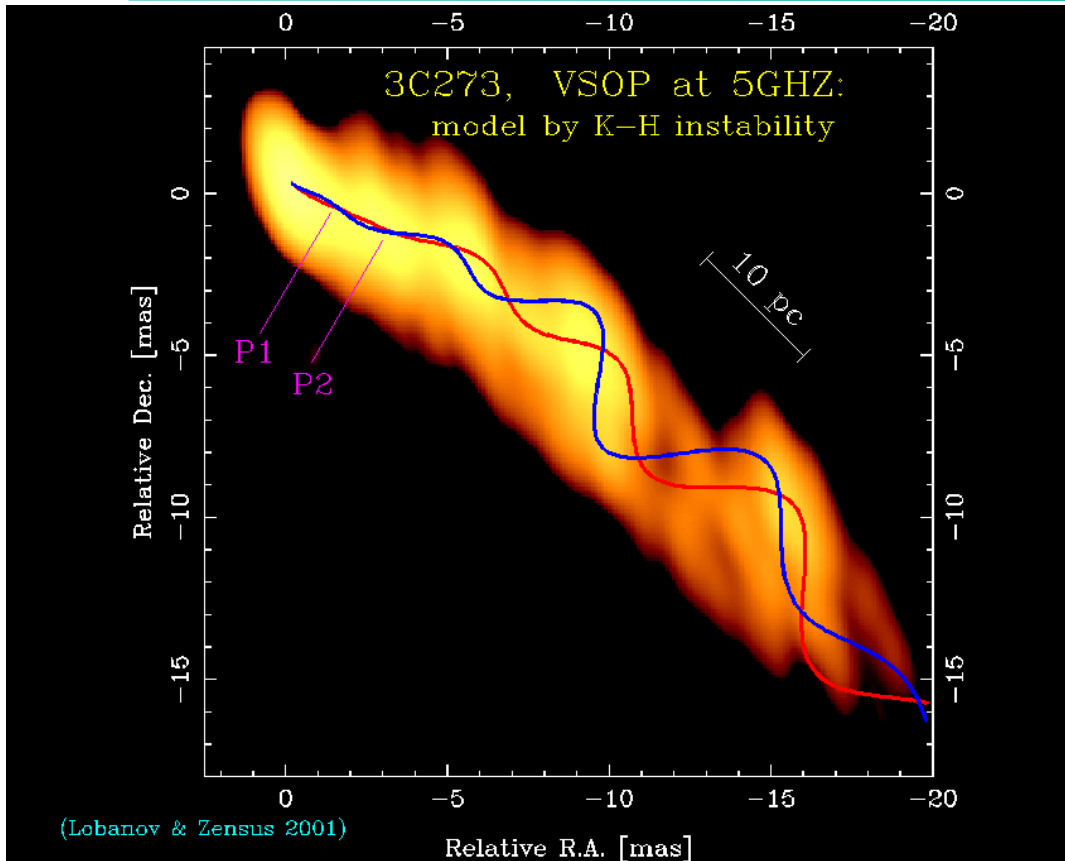


Turnover frequency evolution in C5 (3C345)





# Jet Elements: Sheath, Wind, Spine?



Wavelengths of the modes:

$$l_{Hs}=18.0, l_{Es}=12.0, l_{Eb1}=4.0, l_{Eb2}=1.9 \text{ [mas]}$$

Jet parameters:

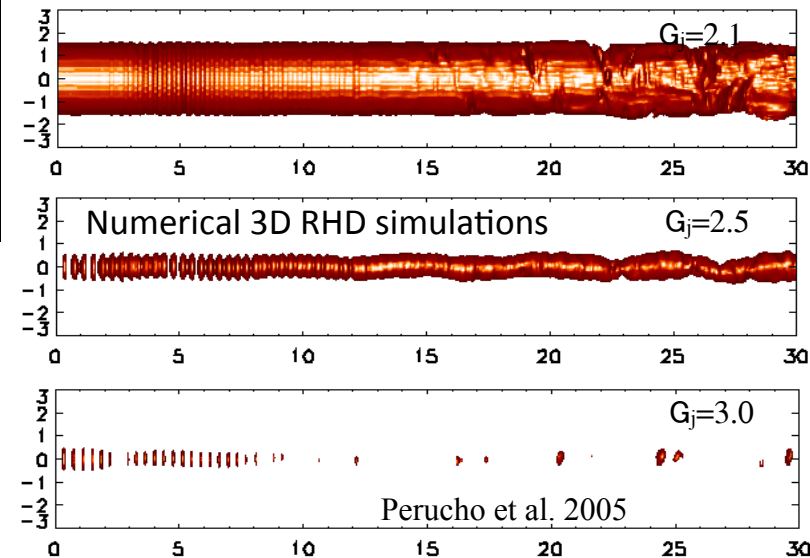
$$G_j=2.1, M_j=3.5, h=0.02, a_j=0.53, v_w=0.21c$$

Shocks dissipate at distances of  $>10^7 R_g$ , giving way to Kelvin-Helmholtz instability as the major factor determining the morphology and dynamics of the flow.

What is then the jet:

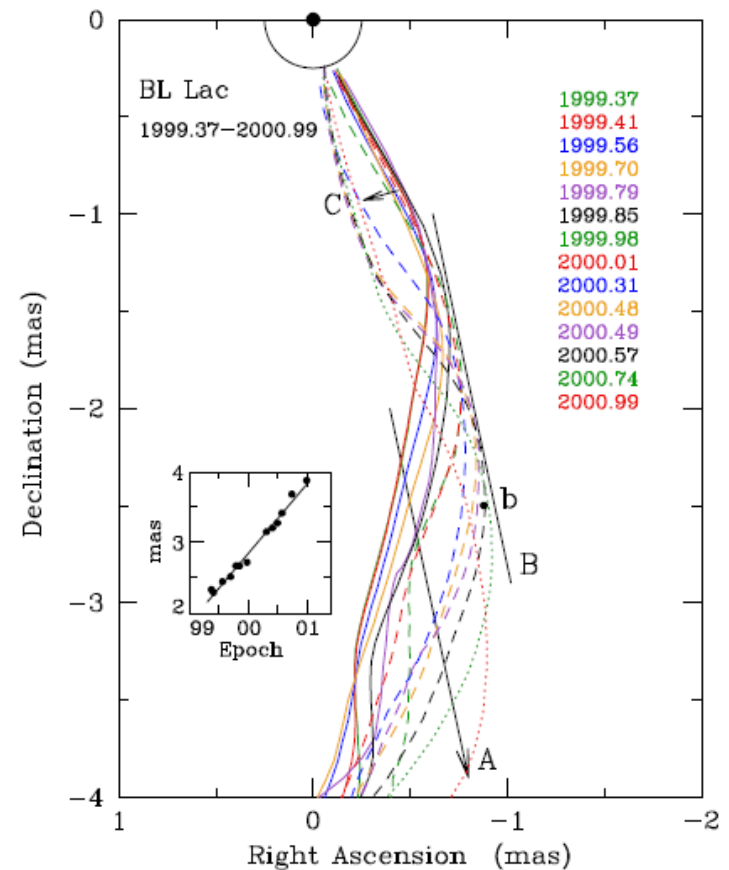
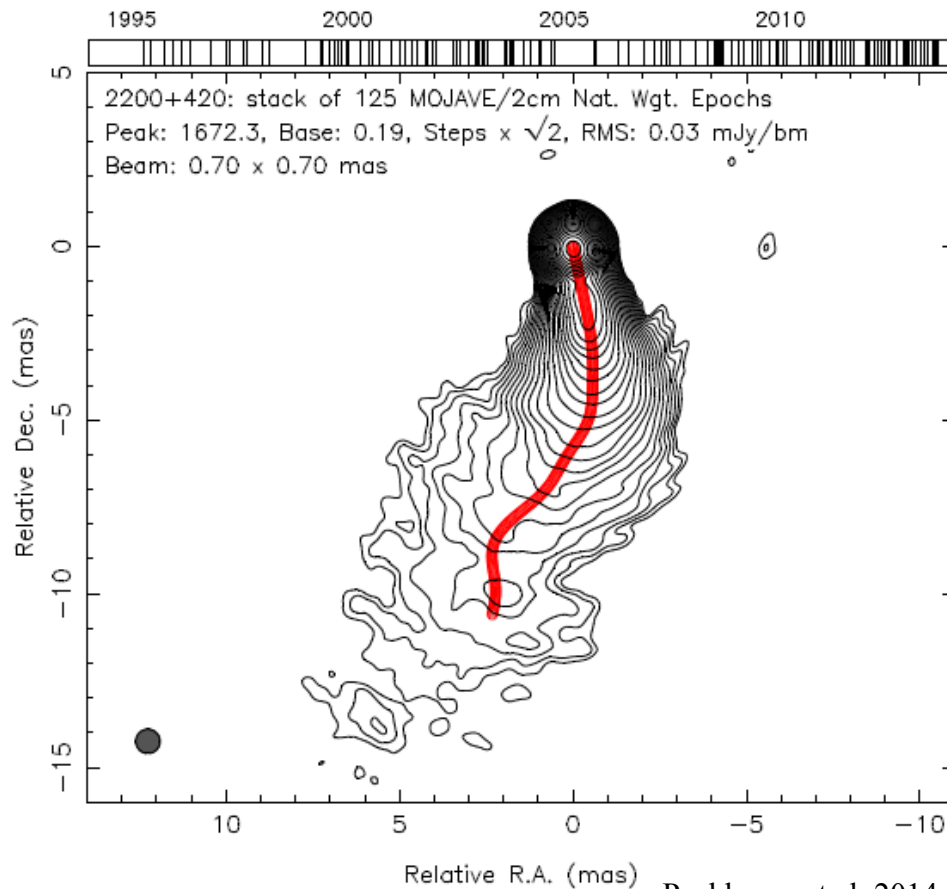
-- spine/sheath?

-- spine/sheath/wind?



# Jets That Don't Bend

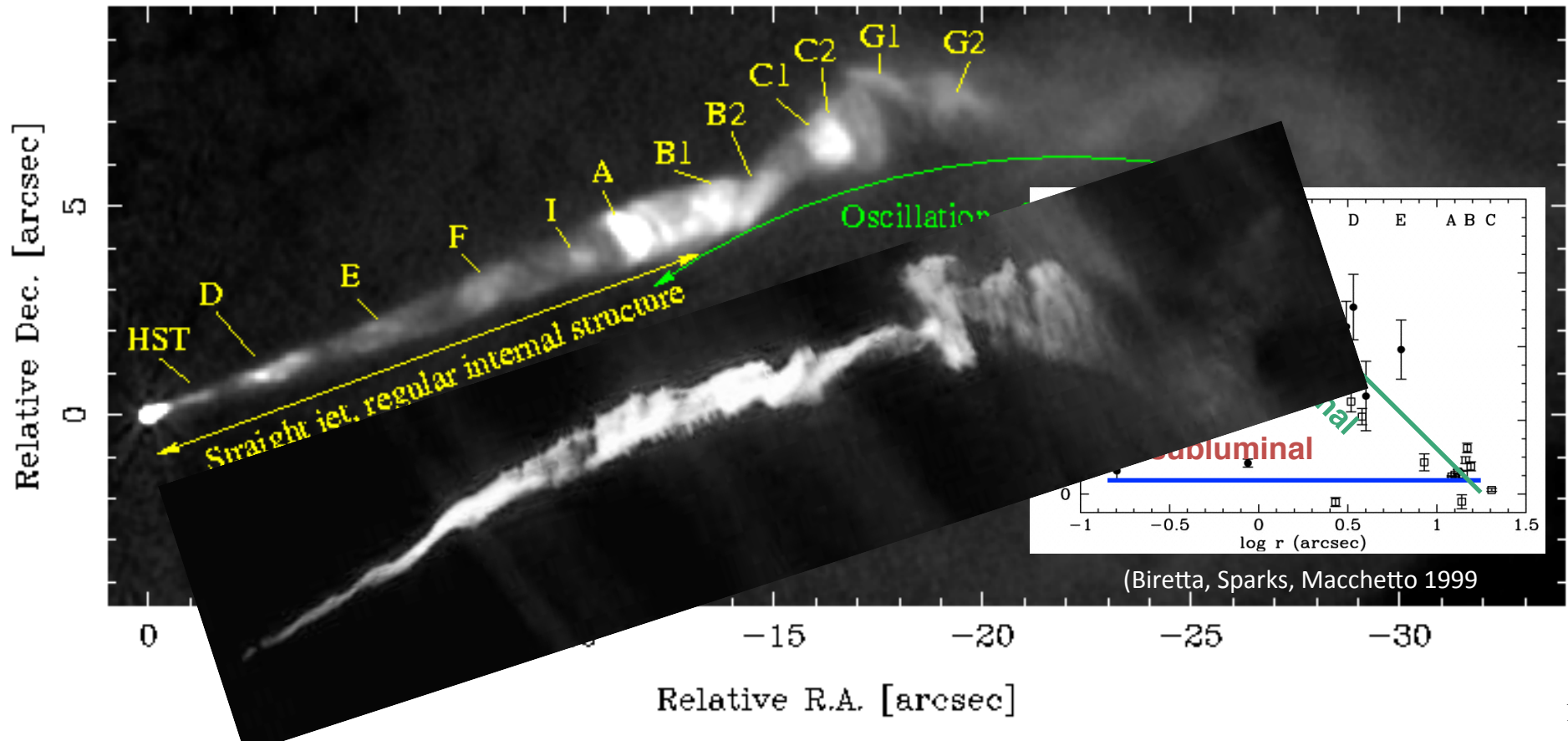
Instability/wave creates a curved pattern inside an otherwise straight, expanding flow. Plasma condensations light up this pattern -- without actually moving along those „helical paths“. So the jet should exhibit pattern/wind speed, plasma (sheath) speed, and condensation (jet component) speed.



# Where Are Those Multiple Speeds?

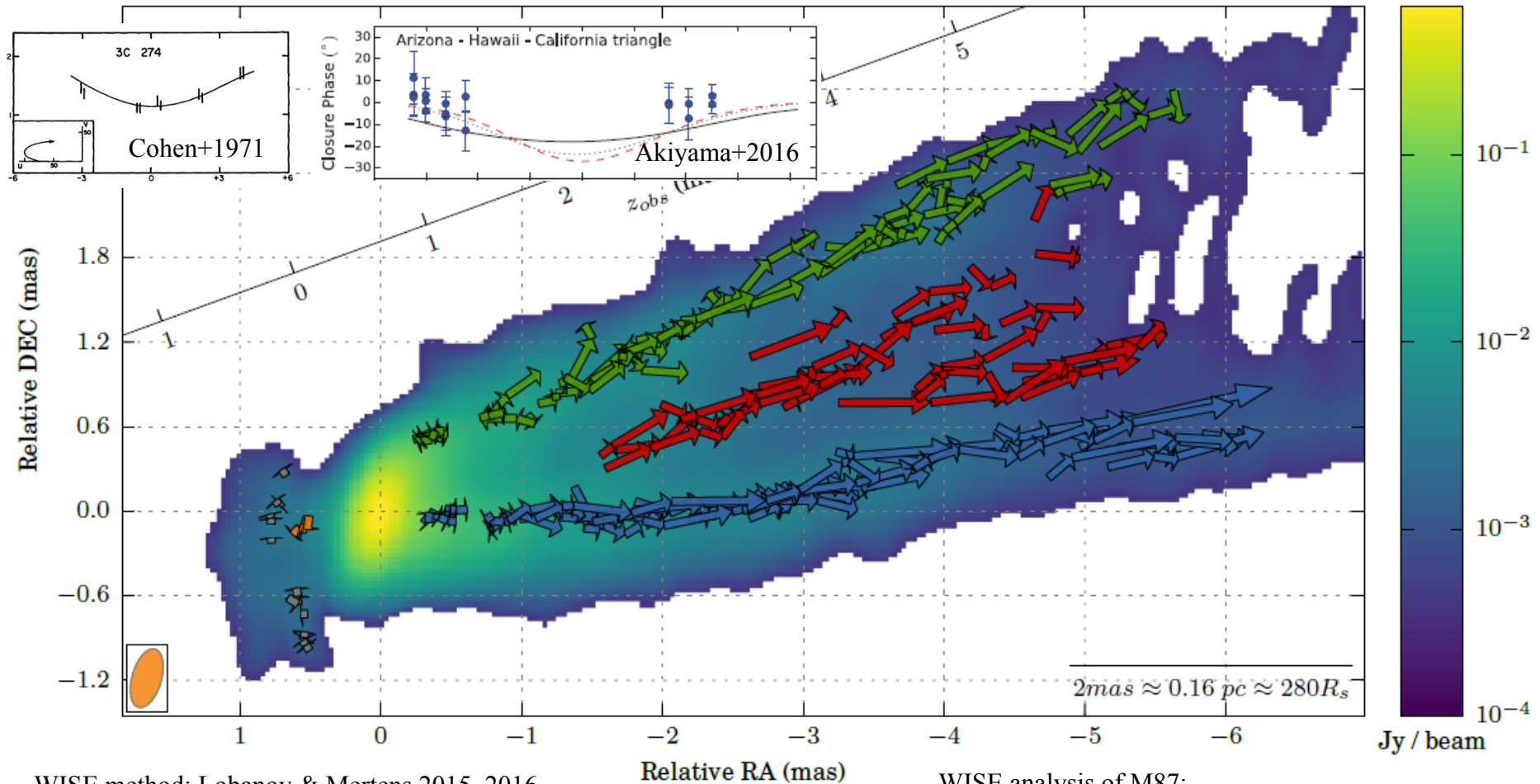
Well, in M87! Multiple speeds (0.5-6 c) are measured at same locations in the jet. TeV activity may require an even higher  $\gamma$  (hence deboosted spine?).

P.S. And if you did not believe that my postliminary RadioAstron chimney smoke was indeed coming from M87, here's the proof:



# Dealing WISEly with M87

Wavelet Image Segmentation and Evaluation (WISE) analysis of 43 GHz VLBA images of M87 (see Craig Walker's talk for full detail)



WISE method: Lobanov & Mertens 2015, 2016.  
Try it at home: <http://flomertens.github.io/wise/>

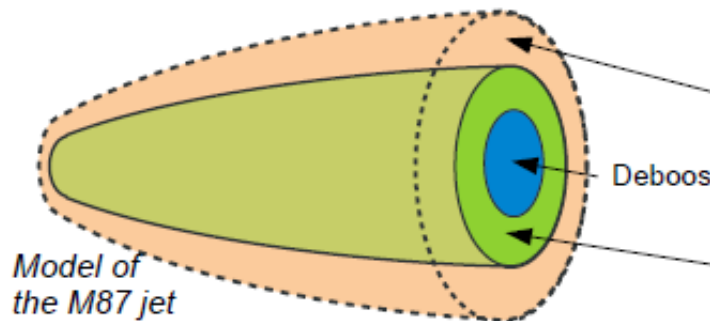
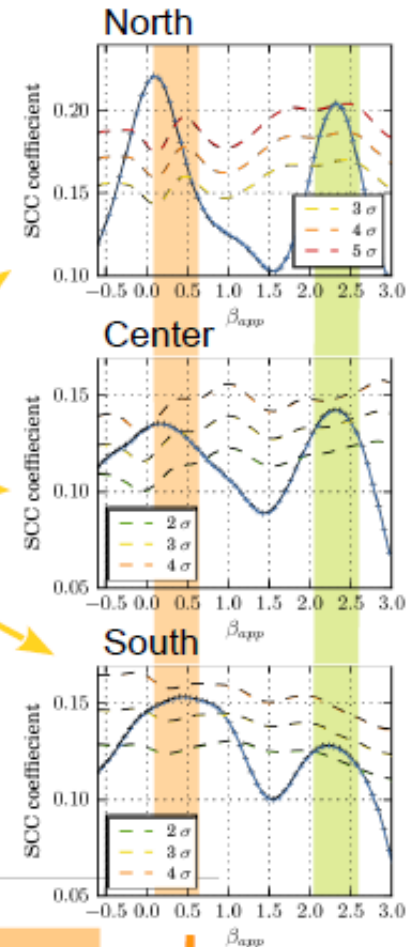
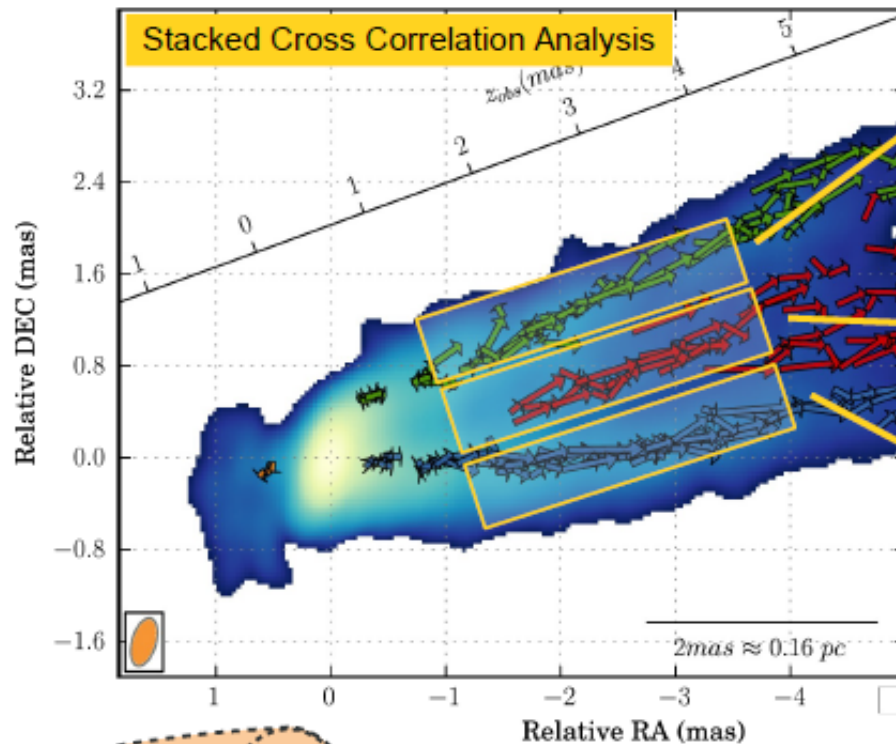
WISE analysis of M87:  
Mertens, Lobanov, Walker, Hardee 2016

# Multiple Speeds in M87

Directly detect subluminal (pattern/wind) and slow superluminal (sheath) speeds

MHD acceleration and Poynting flux conversion at work (at about  $5000 R_g$ ).

The sheath is launched from the accretion disk, at  $8\text{--}10 R_g$  (Blandford-Payne).



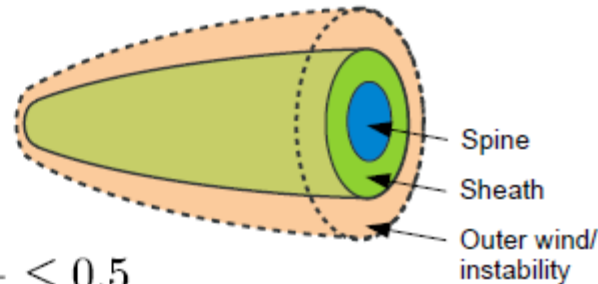
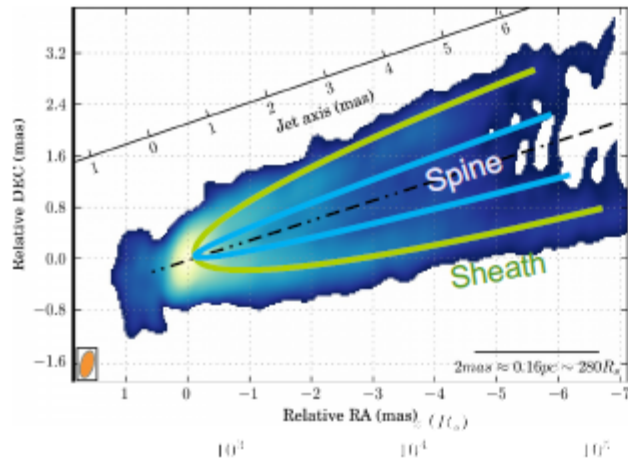
$\beta_{\text{app}} \sim 0.4 c$   
Instability pattern or outer wind

$\beta_{\text{app}} \sim 2.3 c$ , accelerating sheath  
 $\beta_{\text{north}} > \beta_{\text{center}} > \beta_{\text{south}}$



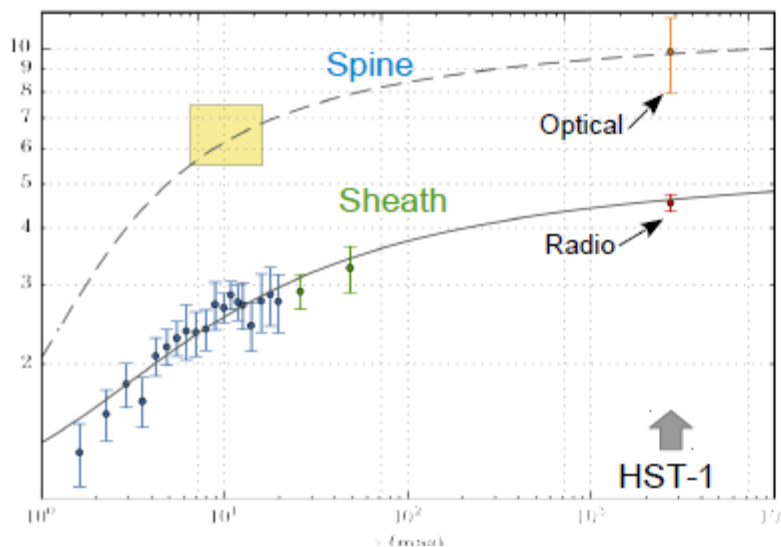
# Where Is The Spine?

The spine/sheath brightness ratio is consistent with the spine launched via the Blandford-Znajek mechanism.



$$\frac{I_{spine}}{I_{sheath}} \leq 0.5$$

$$\gamma_{sheath} \sim 2.5 \Rightarrow \gamma_{spine} \sim 6$$



$$\mu = 11$$

$$\Omega = 2.5 \times 10^{-6} s^{-1} (r_0 \sim \text{ISCO}, a \sim 0.5)$$

$$\mu = 6$$

$$\Omega = 1 \times 10^{-6} s^{-1}, r_0 \sim 4R_s$$

... and Cygnus A is probably as bad as M87,  
as Bia Boccardi has told us.

# Final ~~Confusion~~

- ❑ Patterns and pattern motions are dominant manifestations of relativistic flows. Beware of dynamic range limitations!
- ❑ Moving shocks dissipate relatively fast and do not affect strongly the flow. Standing shocks are totally other story.
- ❑ Both BP and BZ mechanisms may be acting in one and the same jet, producing a highly stratified outflow.
- ❑ So, here's how that primordial dilemma could be settled:  
**Cords and threads drive shocks and frets.**

But! We must still remember the words of one great prophet:

Blazars are crazy, so crazy they're driving me insane.

I identify some patterns, then suddenly those patterns change.

More data just make it worse, reasonable theories seem to be cursed.