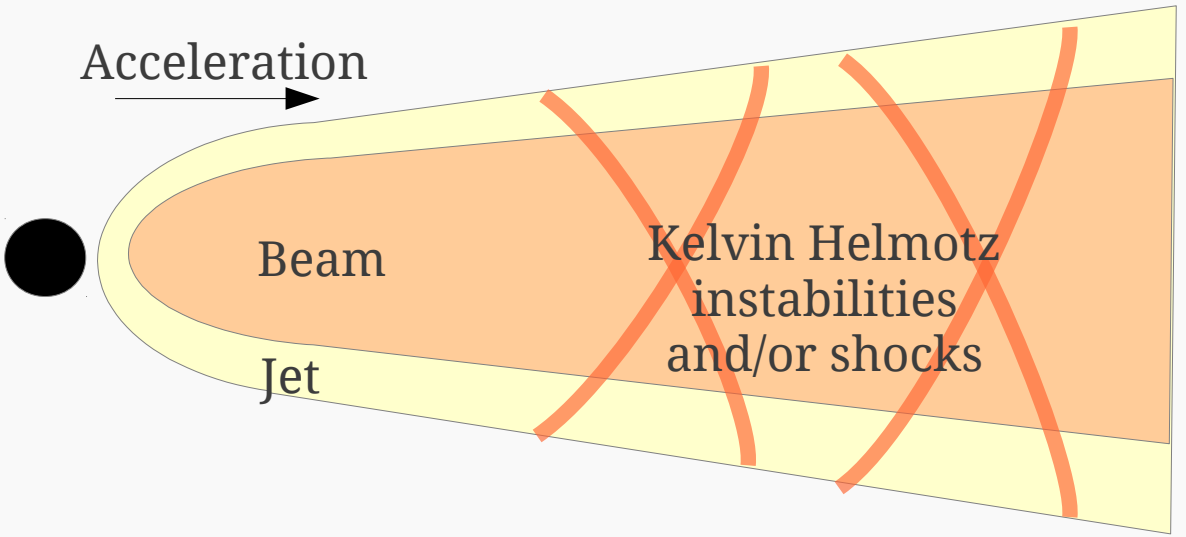
Longitudinal and transverse velocity fields in parsec-scale jets

Florent Mertens, Andrei Lobanov (MPIFR, Bonn)

Max-Planck-Institut
für
Radioastronomie

2D structure of jets

- Complex flow:
  - Relativistic
  - Stratified
  - Residual rotation
  - Instability and shocks



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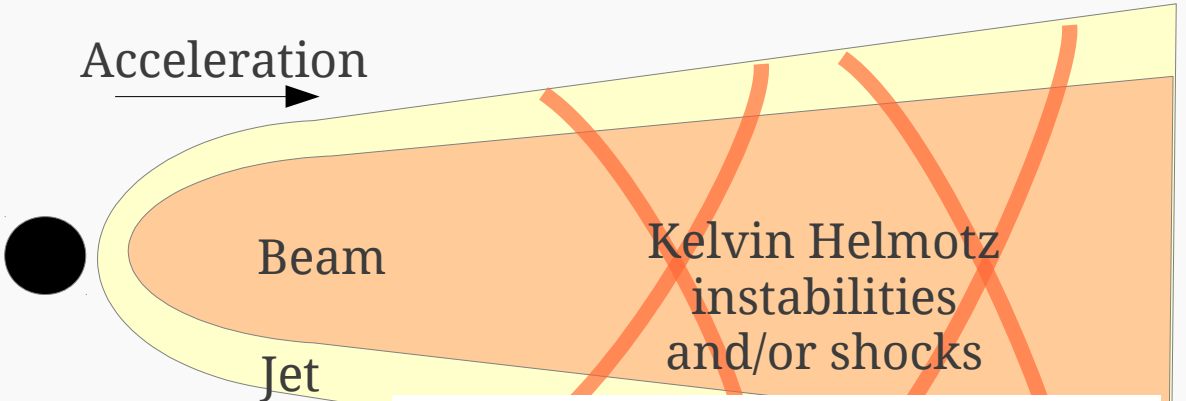
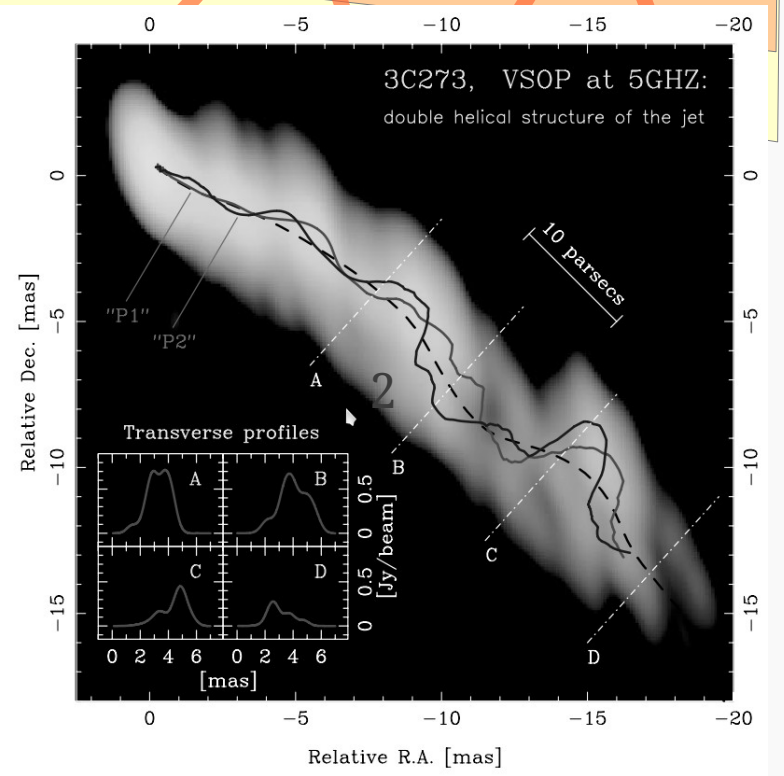
  - Model fitting: 1D
  - Ridge-line analysis
  - Jet transverse profiles





A. Lobanov & A. Zensus 2001

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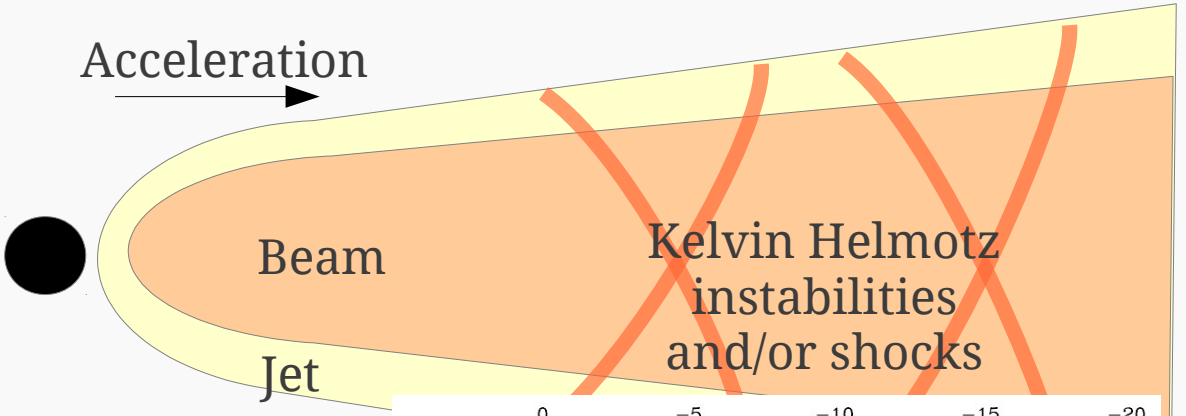
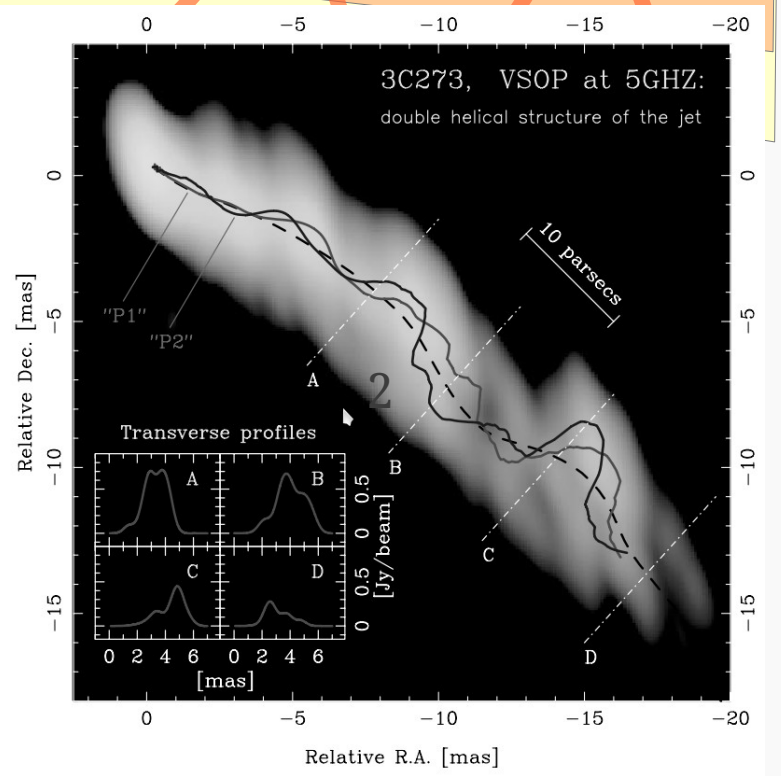




A. Lobanov & A. Zensus 2001

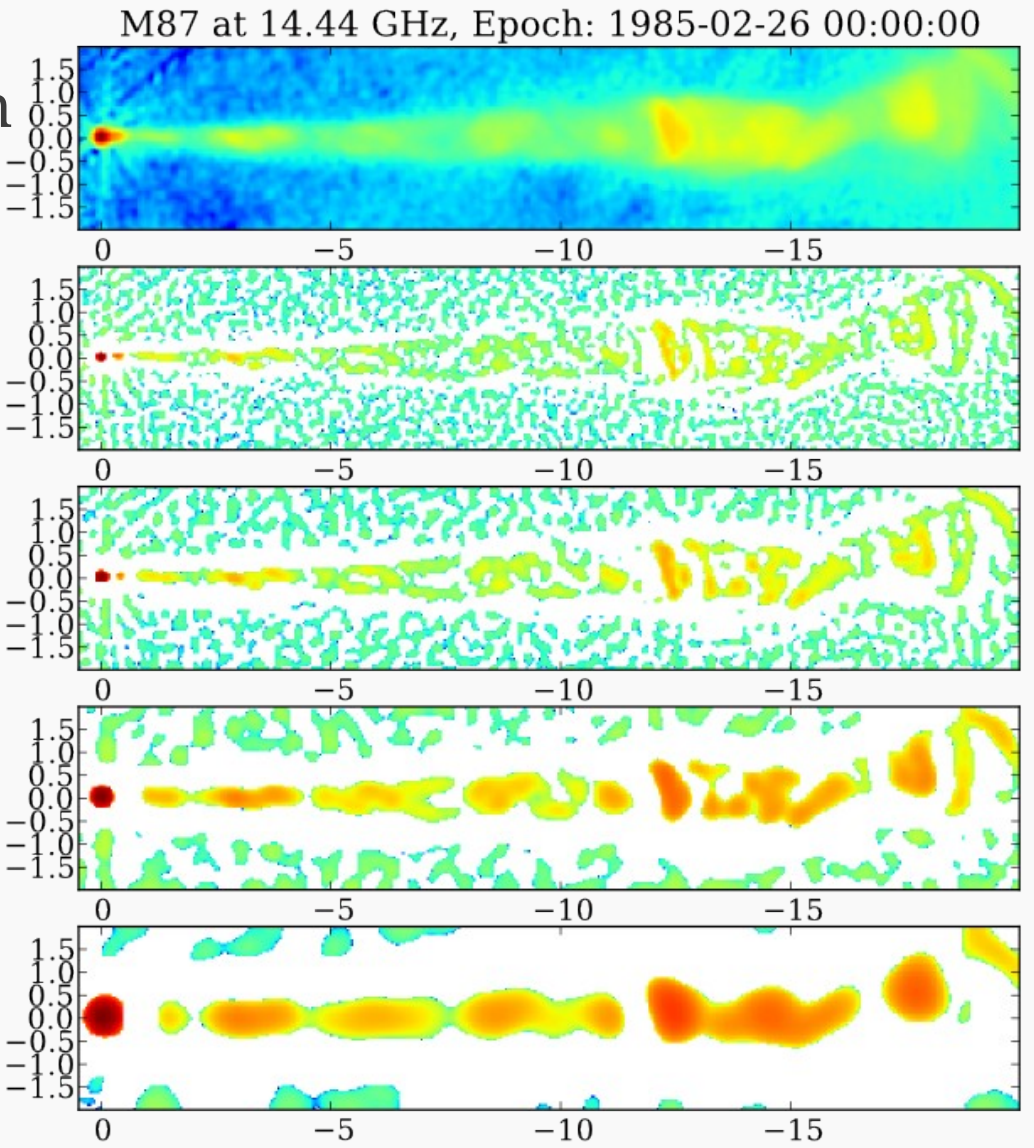
- Margin of improvement between the information from observation and output
- **We need an automatic and robust tool for feature identification**

Talk outline

- Structure analysis (WDS method):
  - **W**avelet **D**ecomposition
  - **S**egmentation
- Kinematic analysis: **M**ulti **S**cale **C**ross **C**orrelation (MSCC)
- Analysis of the velocity field of the jets of 3C273 and M87

Wavelet transform

- Time-frequency transformation
- Representation of signal as a linear combinations of a wave like function which is scaled and translated
- Provides a 2D power distribution over a range of spatial scale in the image
- **Robust tool for identification of significant structural patterns (SSP)**



VLA map: Owen et al. (1989)

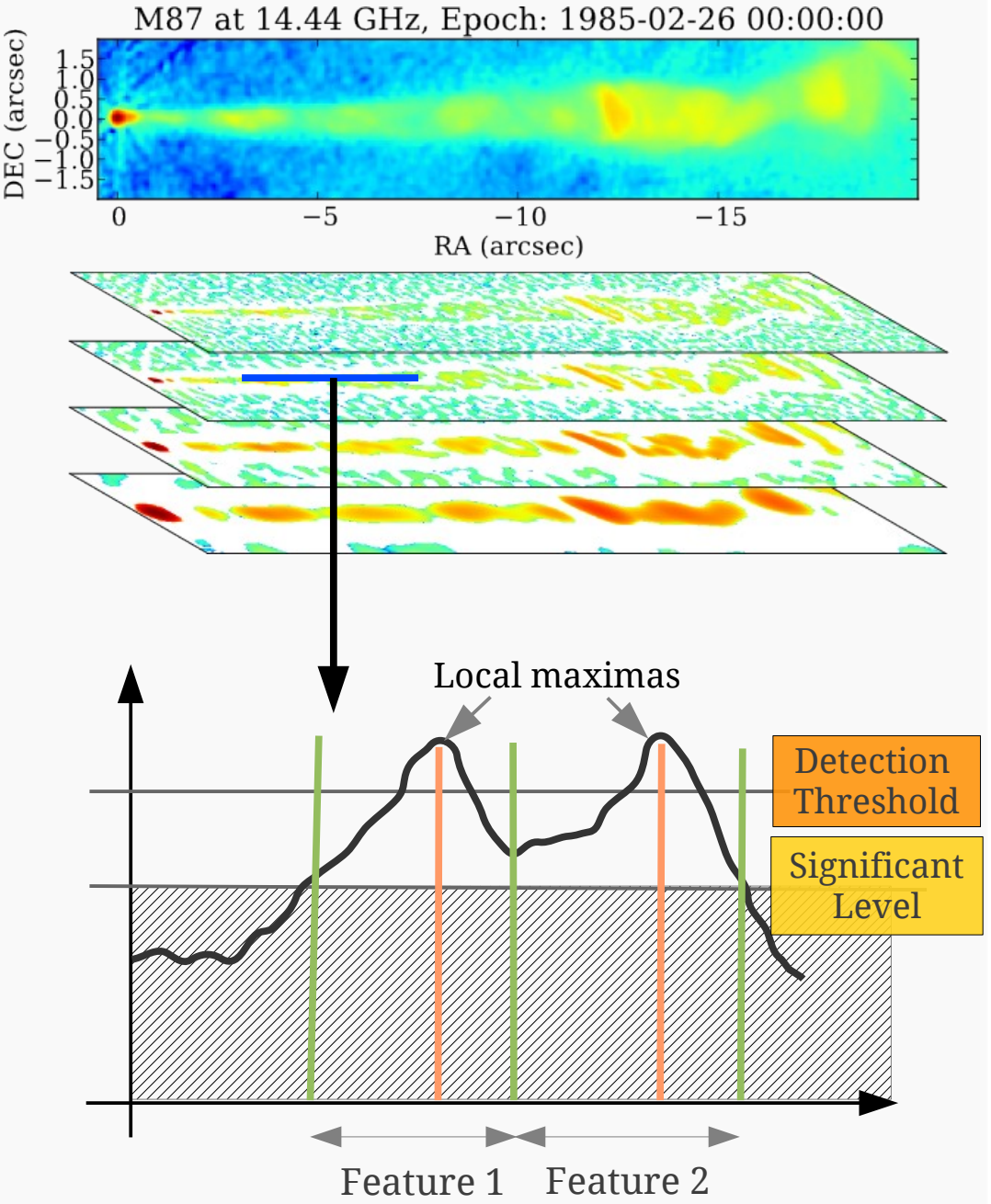
Feature detection

1. Thresholding: Statistically significant wavelet coefficients are extracted at each scales.

2. Detection of features: Local maxima in the wavelet space are the positions of features

3. Segmentation: Watershed segmentation is used to delimit the regions (segments) associated with those positions

This result in a set of **SSP**

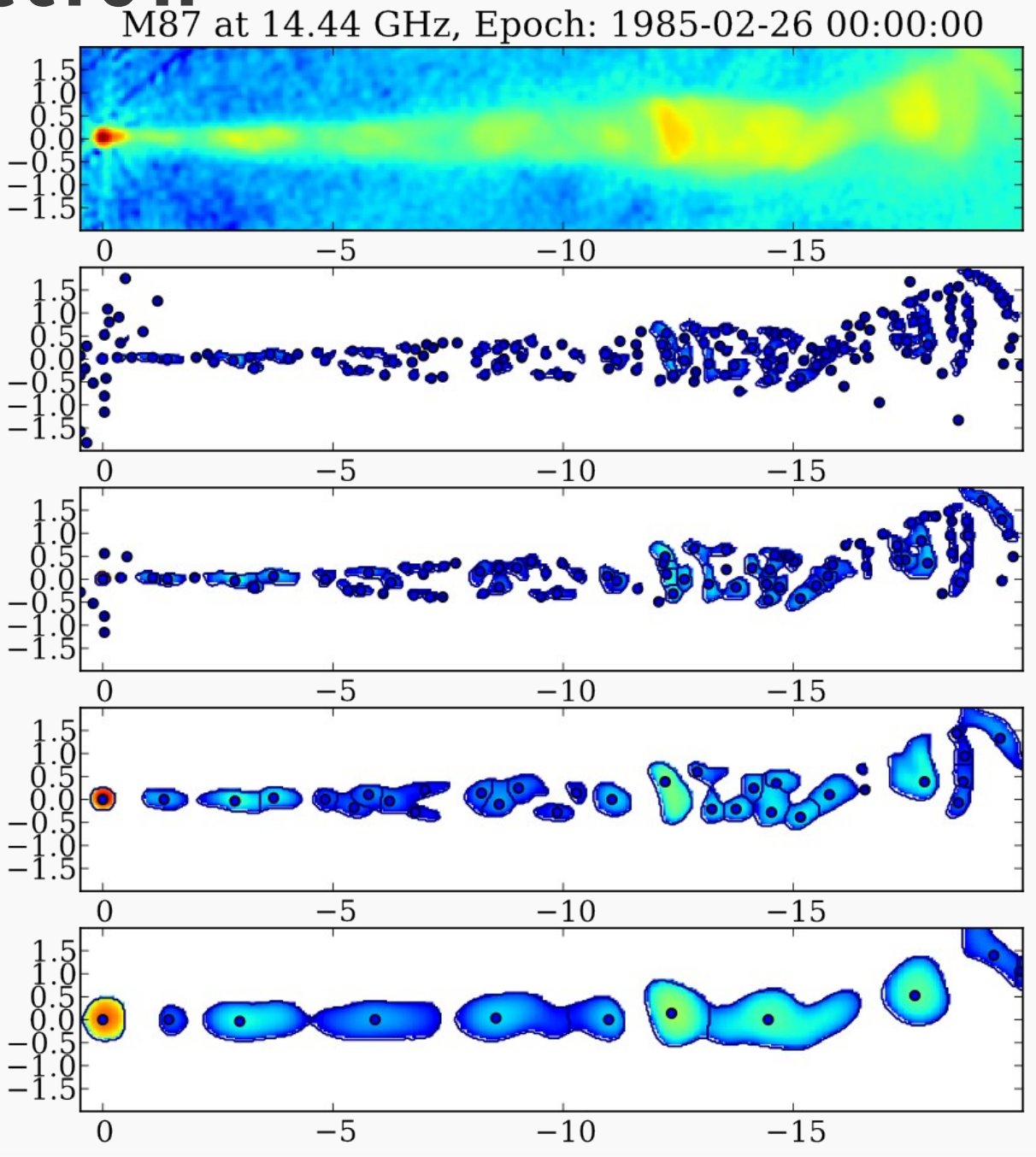


Feature detection

Finest scales:
Detailed description down to ~0.25 FWHM
Provide 2D velocity field

Intermediate scales:
Ridge-line detection

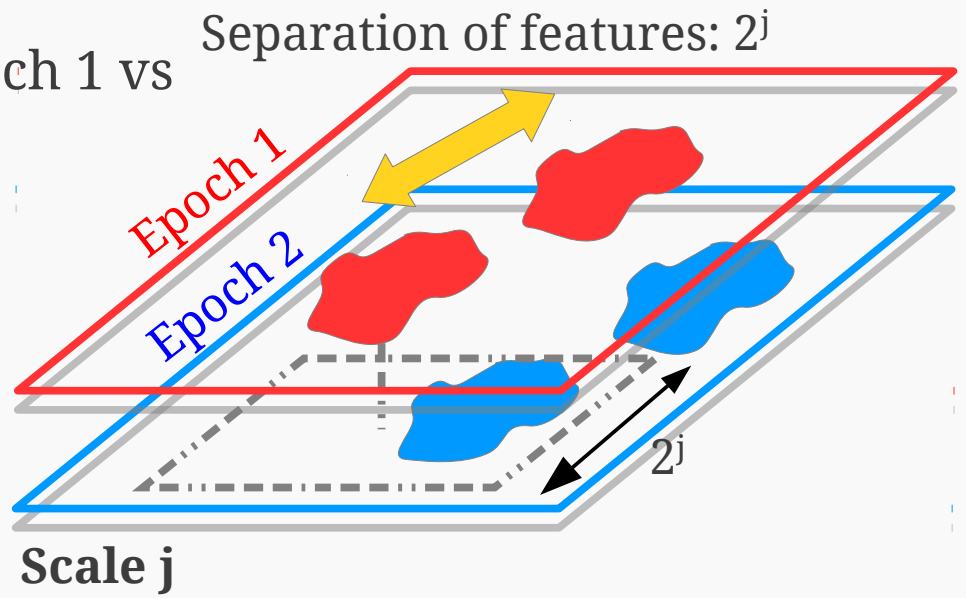
Coarse scales:
Equivalent to model-fit



MSCC detection of structural changes

- Cross Correlation of each SSP at epoch 1 vs image at epoch 2
  → Weighted Normalized CC

- Separation of features at scale j ~ 2^j
  → j chosen so that expected Δ < 2^j
  → CC on a 2^j x 2^j window



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- Separation of features at scale j ~ 2^j
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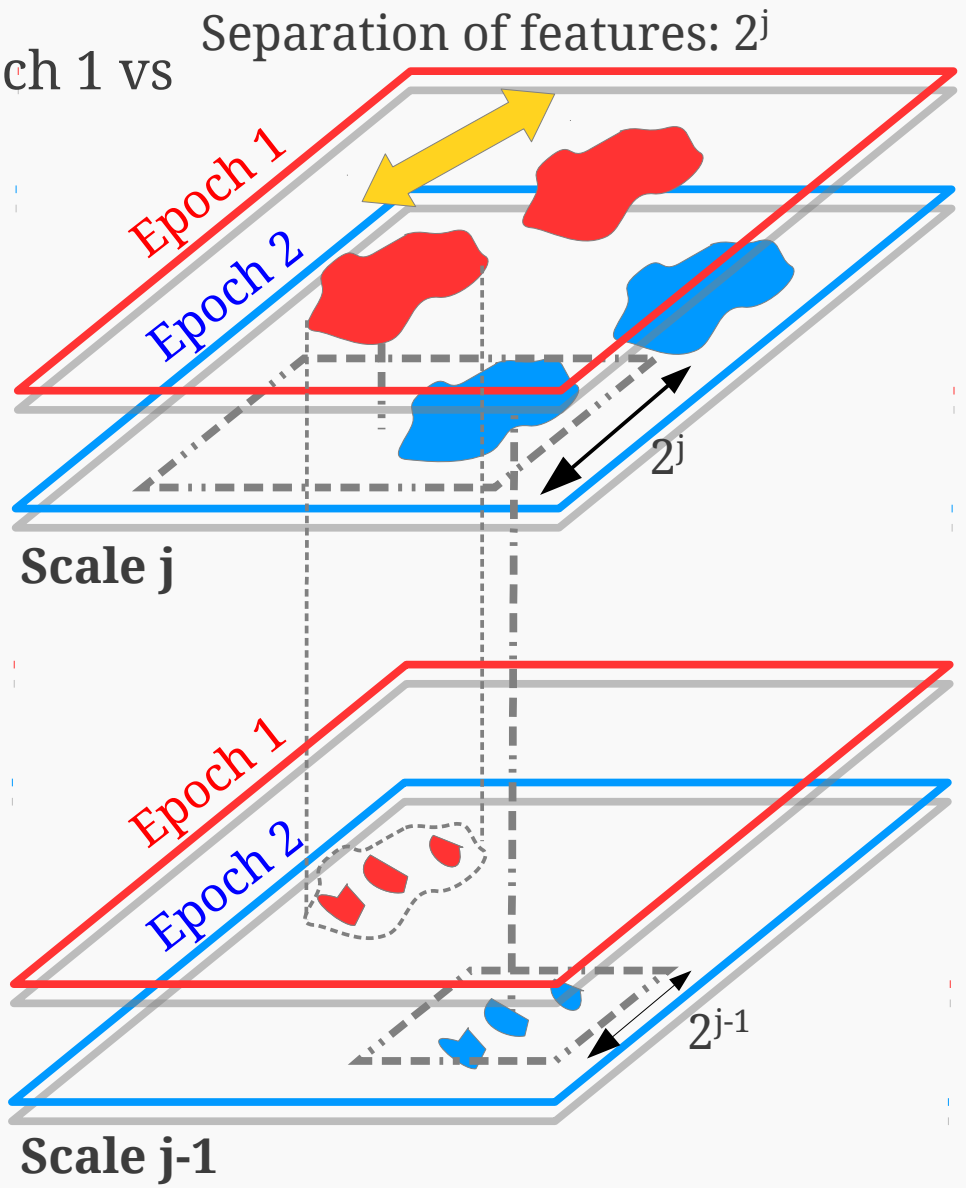
  → CC on a 2^j x 2^j window
- Features inside a same upper scale feature move in average like it:
  → Define the location of the CC window

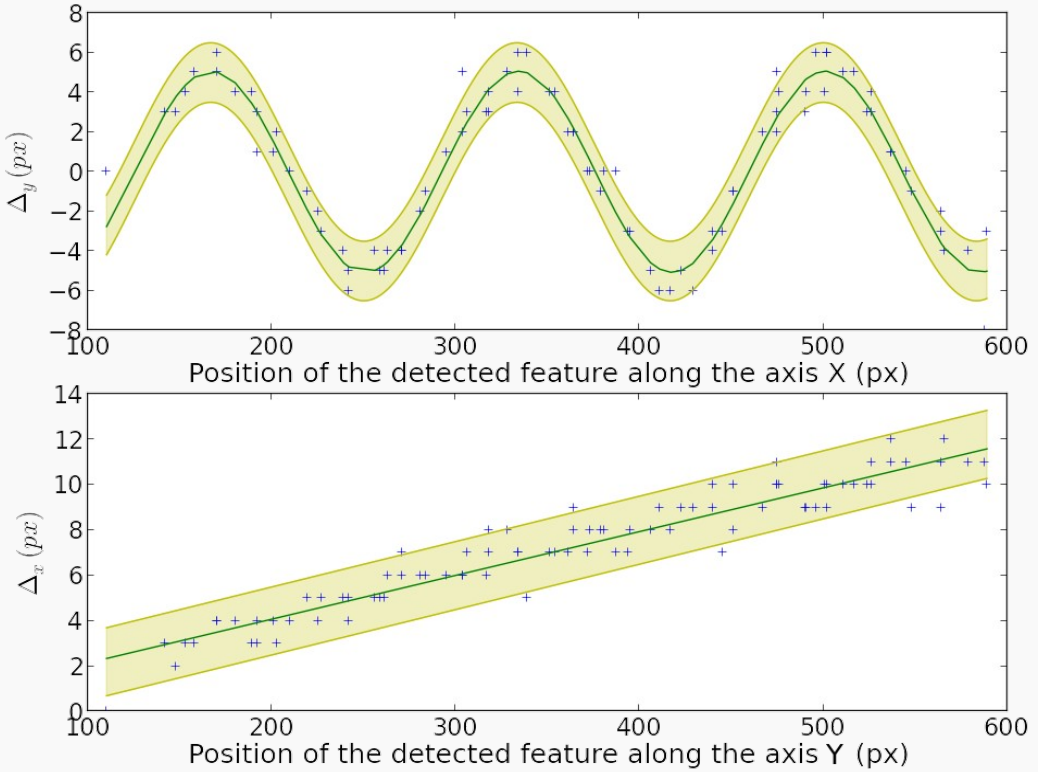
Joined analysis at all wavelet scales provide robust match of structural changes up to **~5 beam sizes**



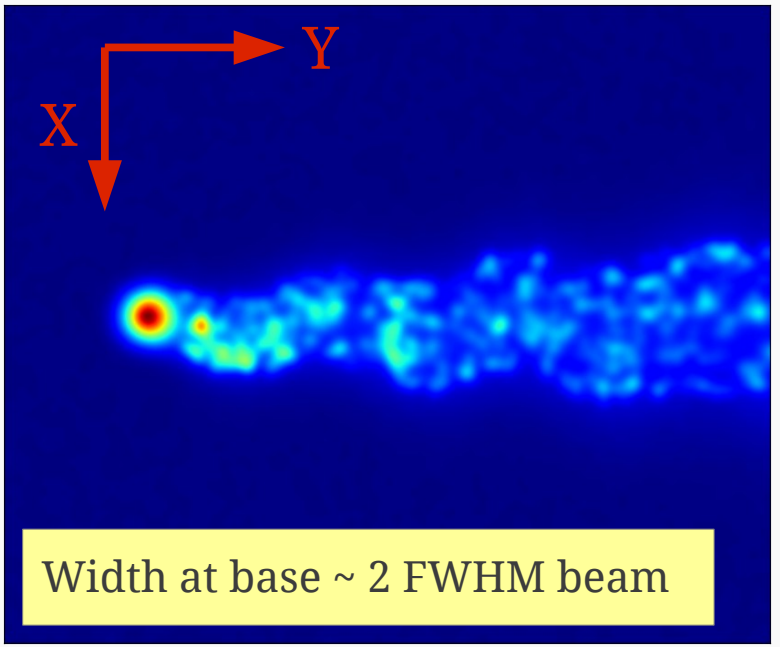
Testing the WDS and MSCC

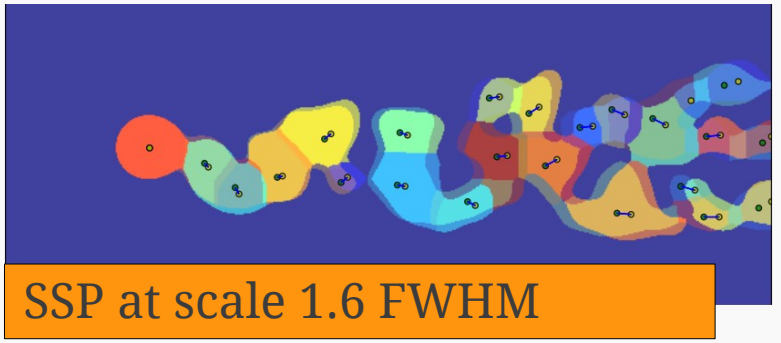
WDS and MSCC has been tested on simulated image with analytically defined model and:

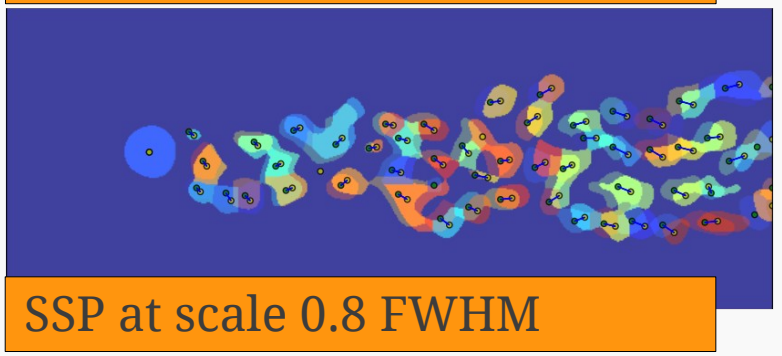
- Gaussian noise
- Uncertainty on features positions



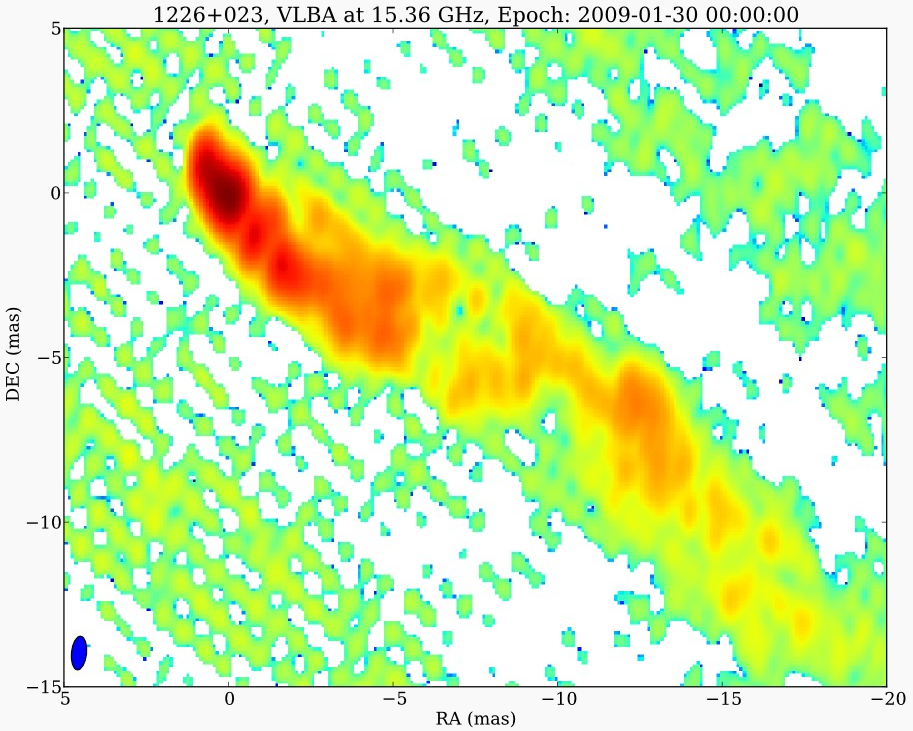
Input: sinusoidal velocity field



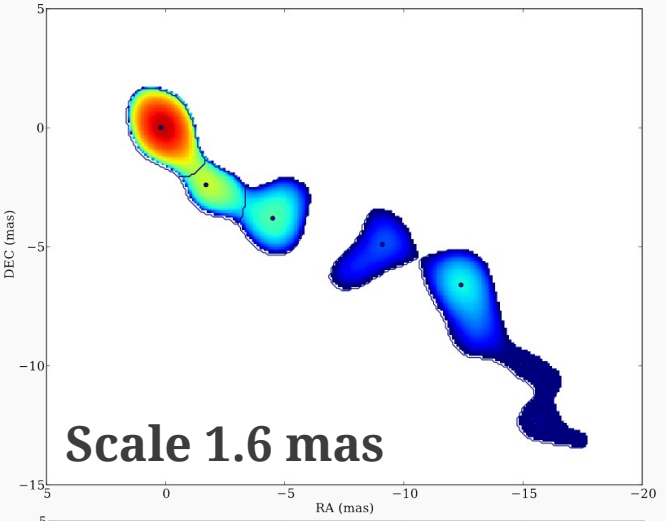


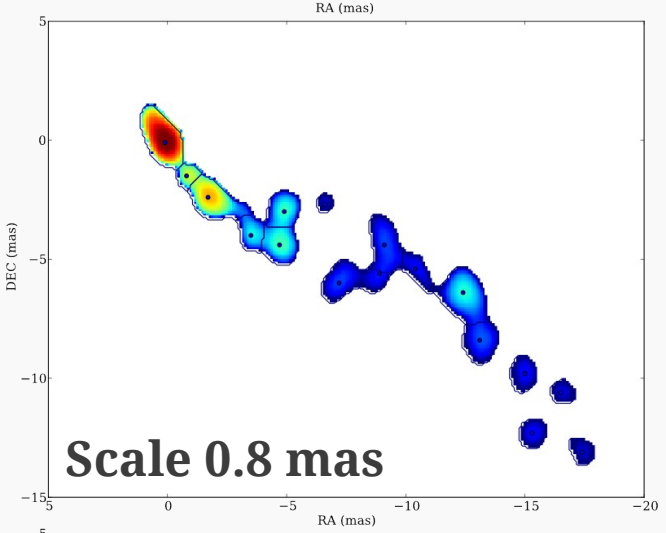


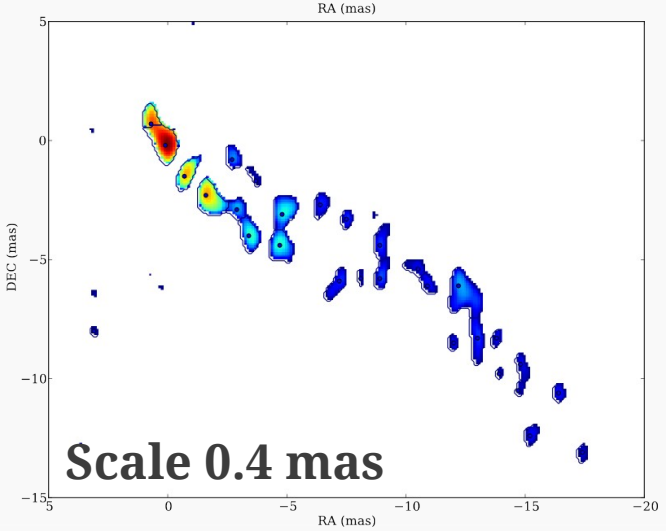
3C273



WDS

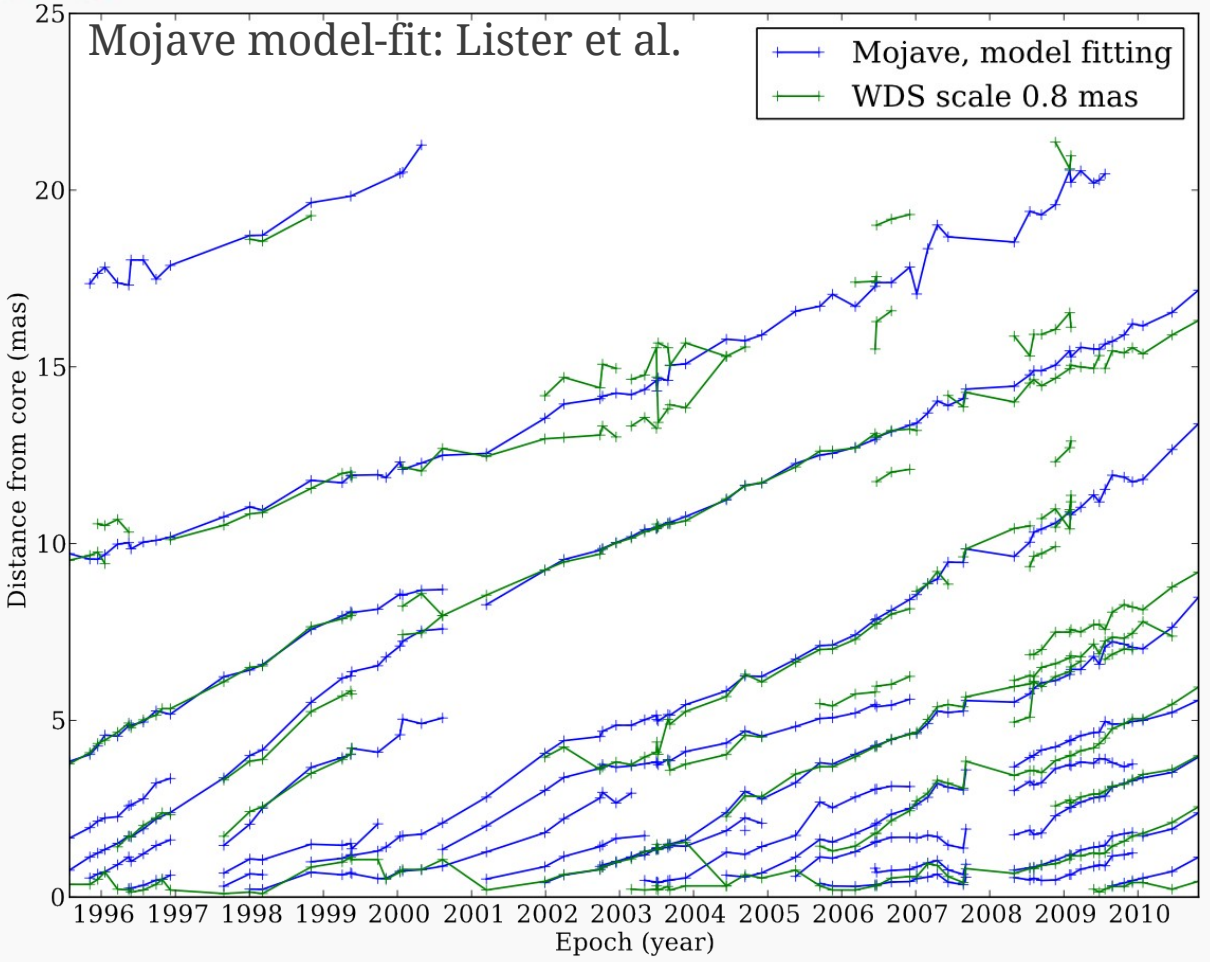




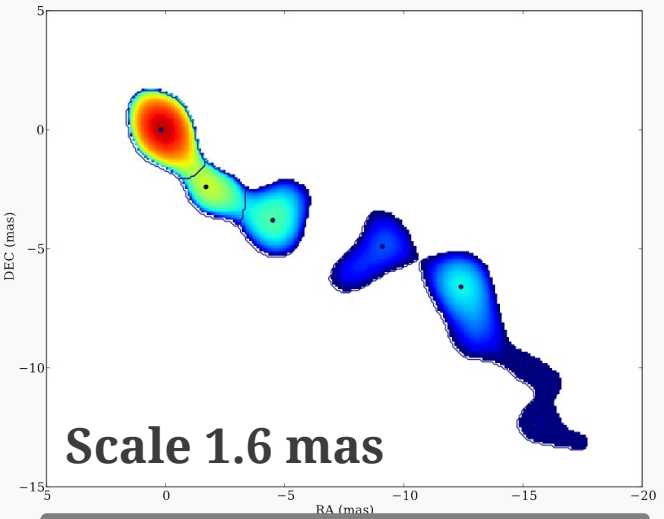


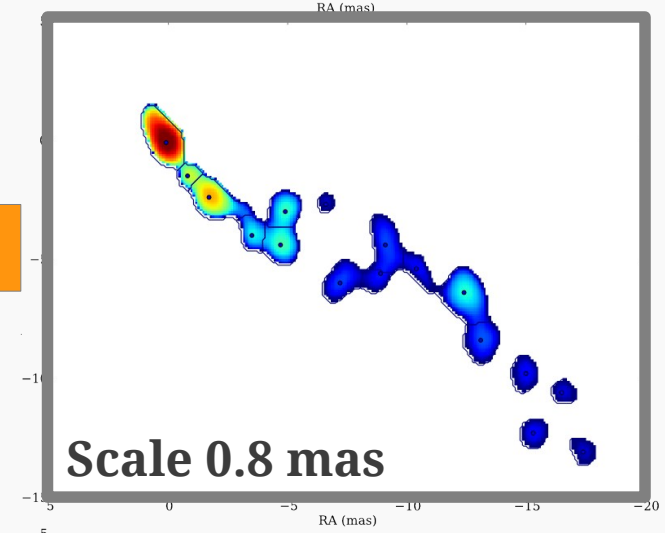
- Observed as part of the MOJAVE survey
- Transversely resolved flow
- z ~ 0.158

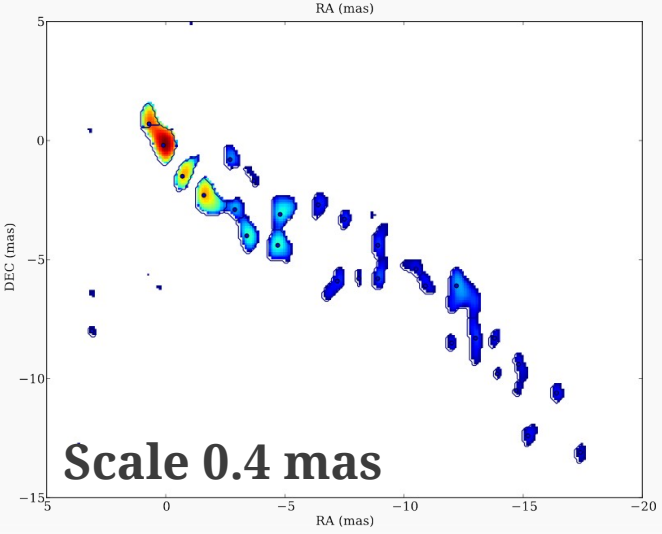
3C273



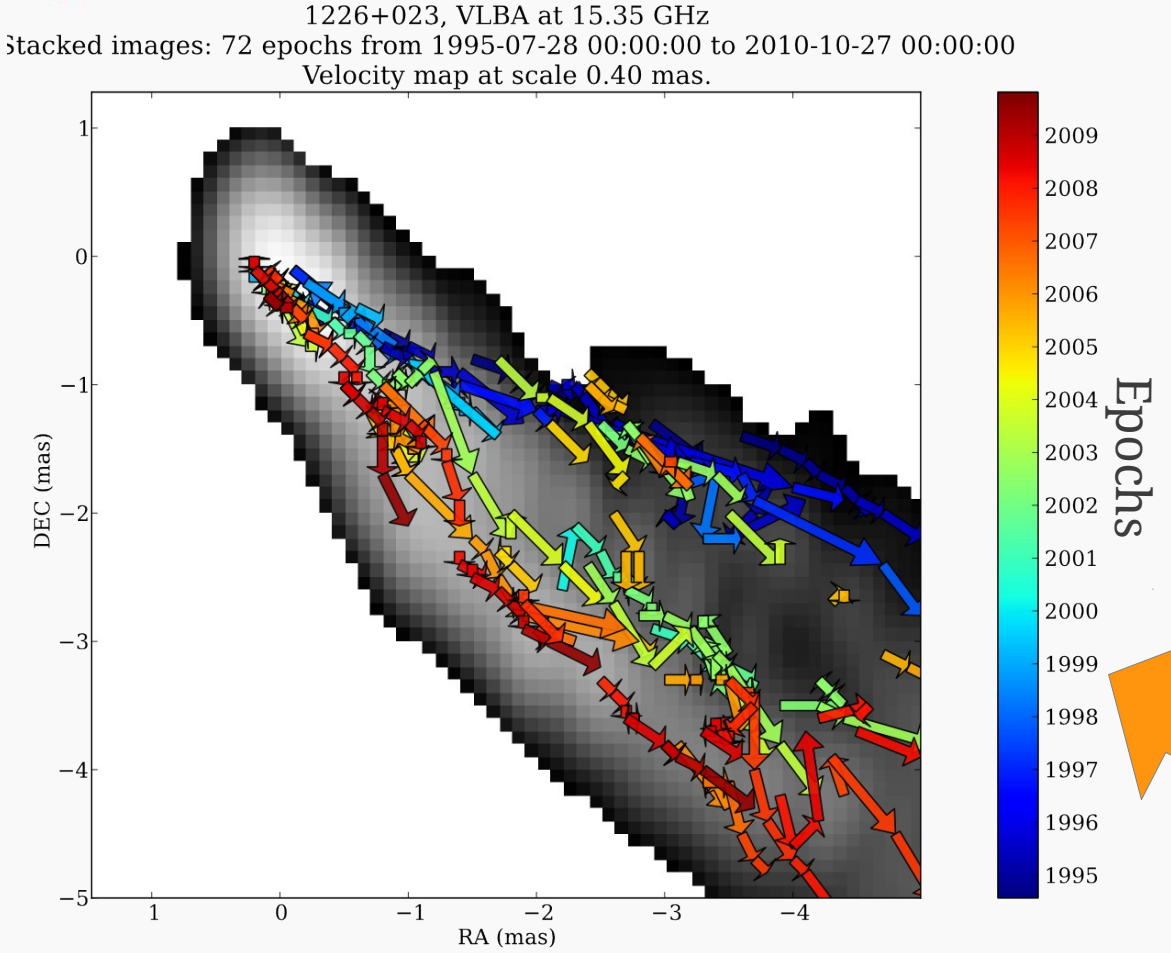
Good agreement between WDS and model-fitting

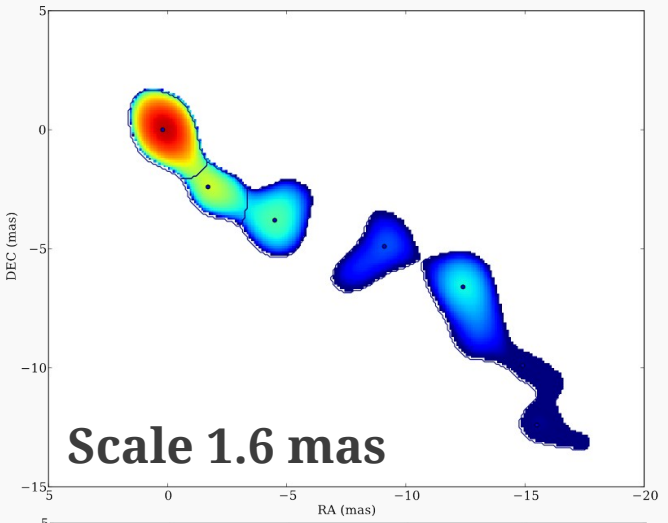


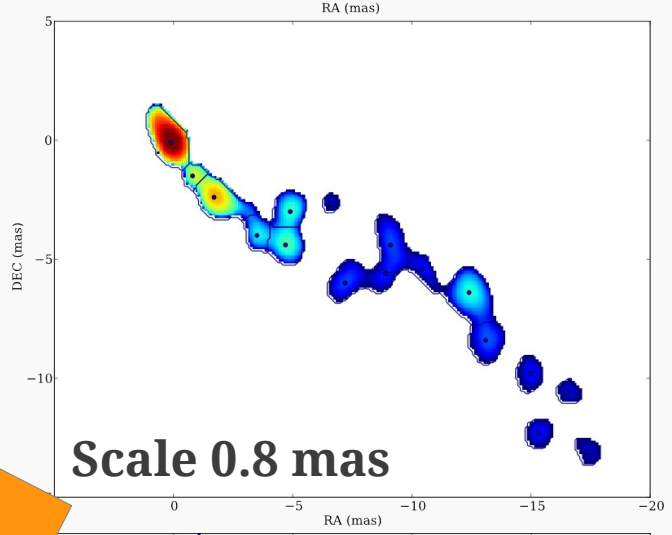


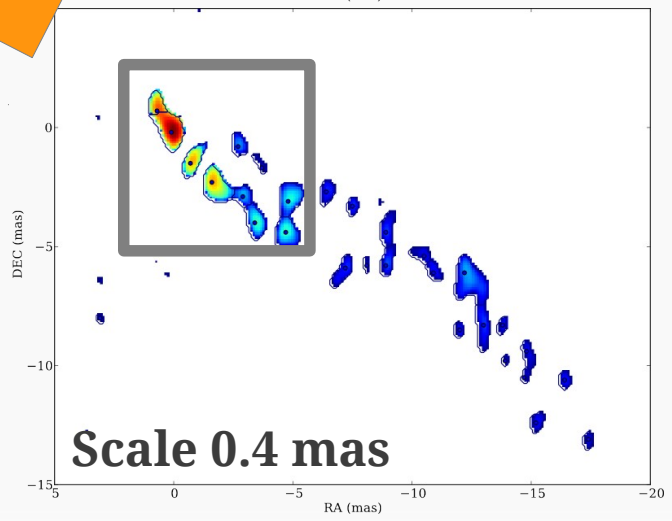


3C273



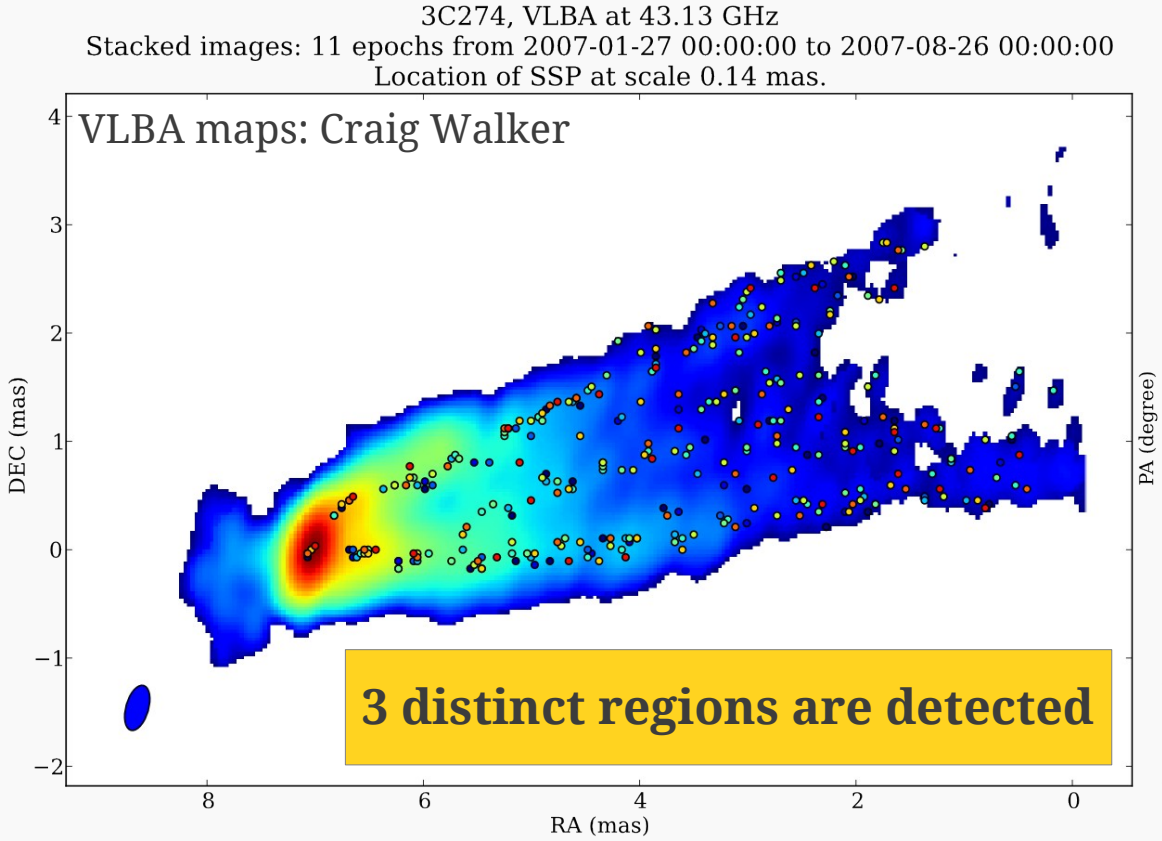


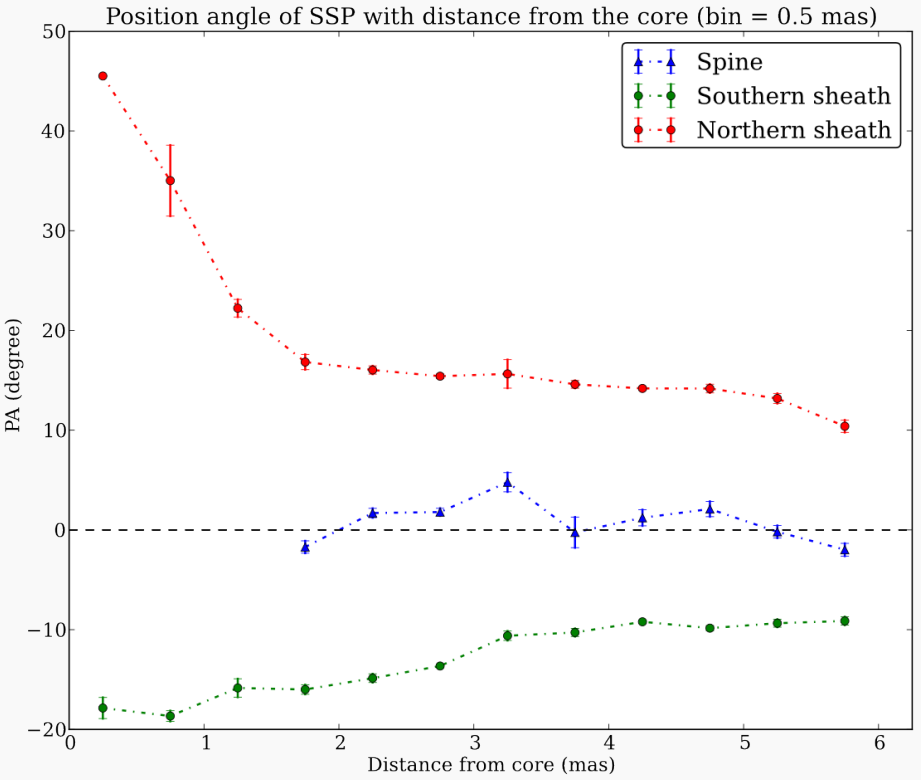




- 2D velocity field
- Helical patterns propagating in the flow
- Change of flow direction

M87

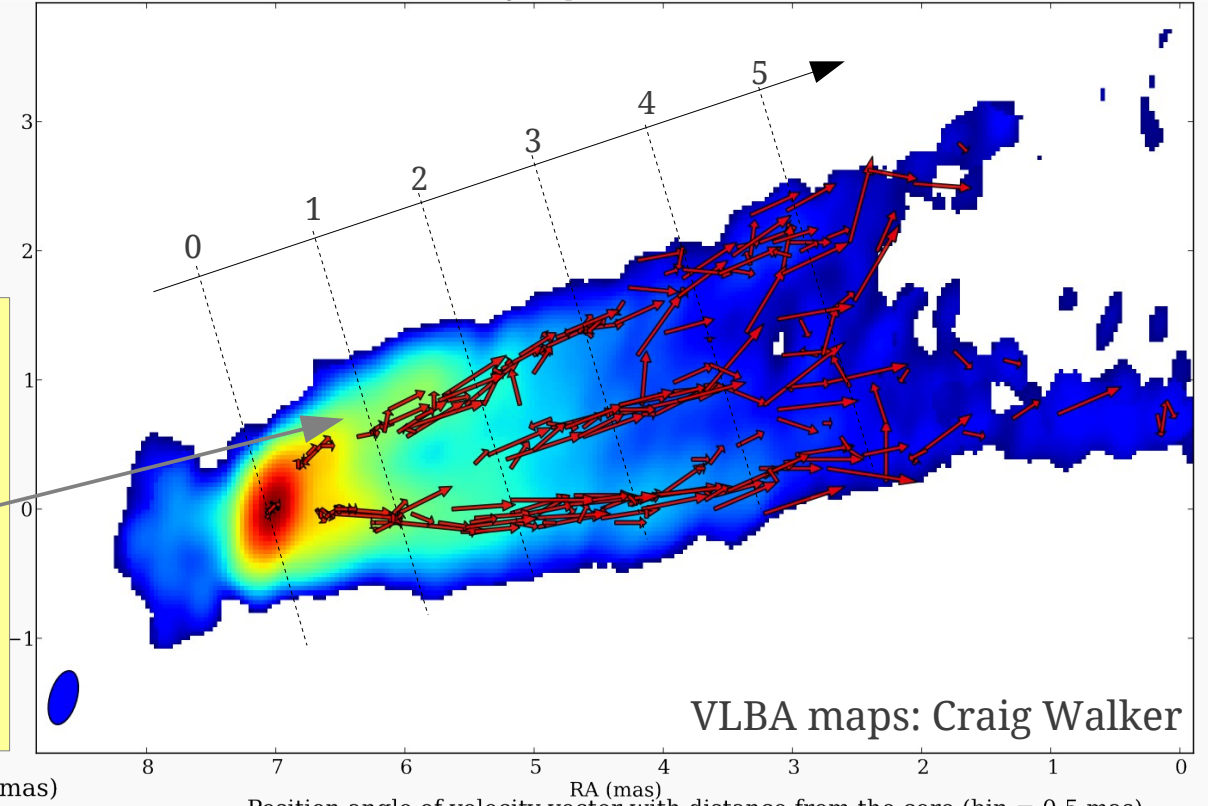


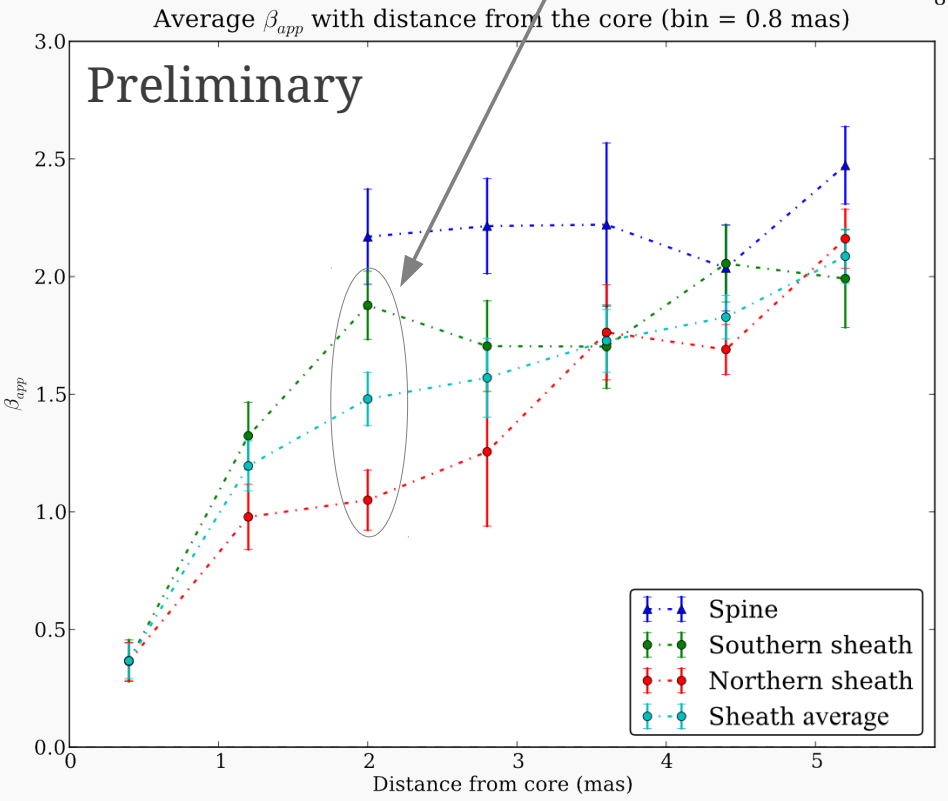


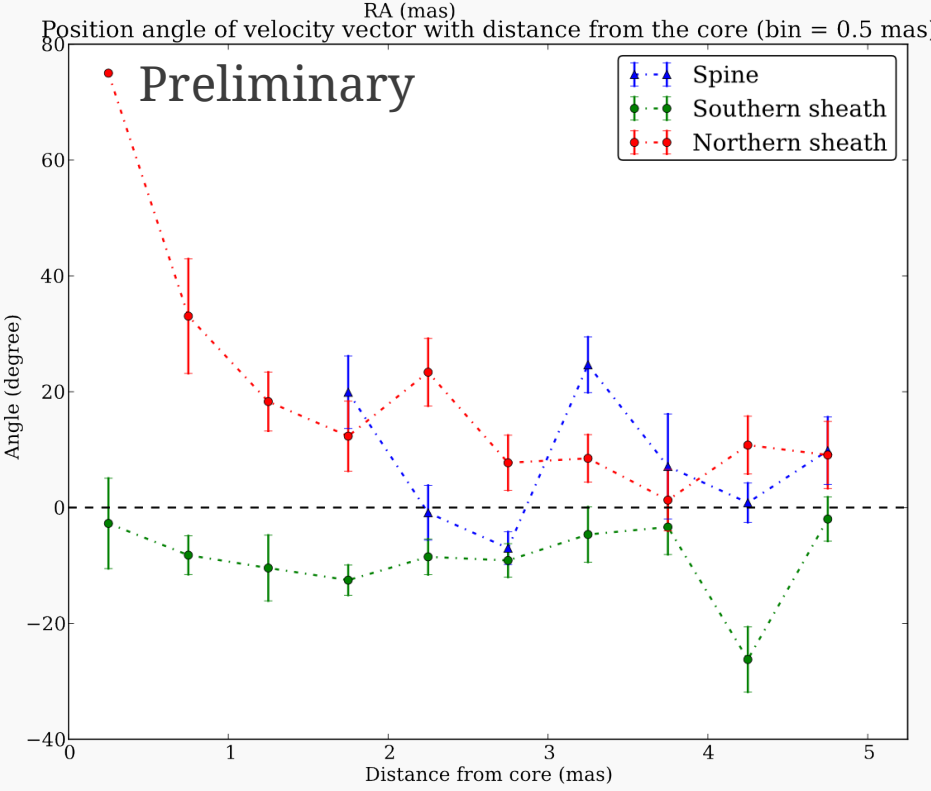
11 VLBA observations between 2007/01/27 and 2007/08/26,
at 43 GHz (**1 mas ~ 0.089 pc**) with **3 weeks** interval

M87

- Fast spine, slower sheath: **stratified flow**
- **Acceleration in the sheath**
- Velocity difference between northern and southern sheath: suggests **clockwise rotation** (jet or K-H instability pattern rotation)







M87

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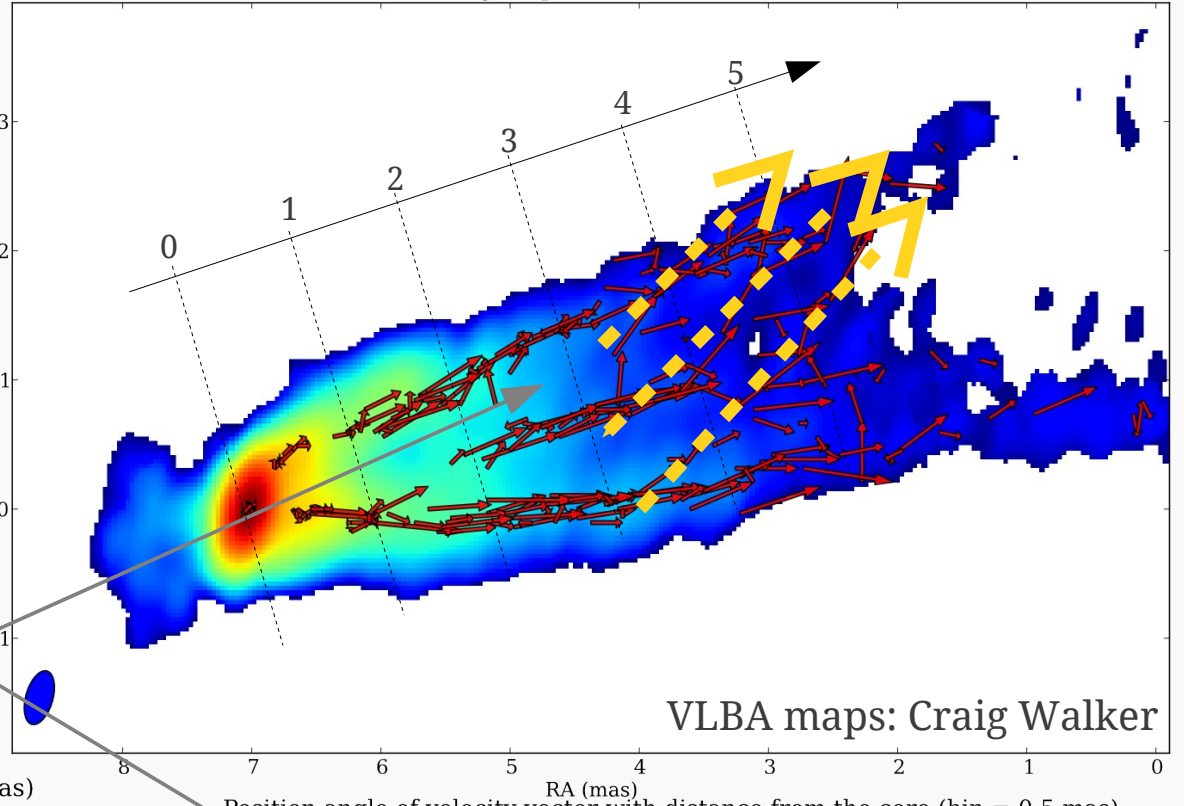
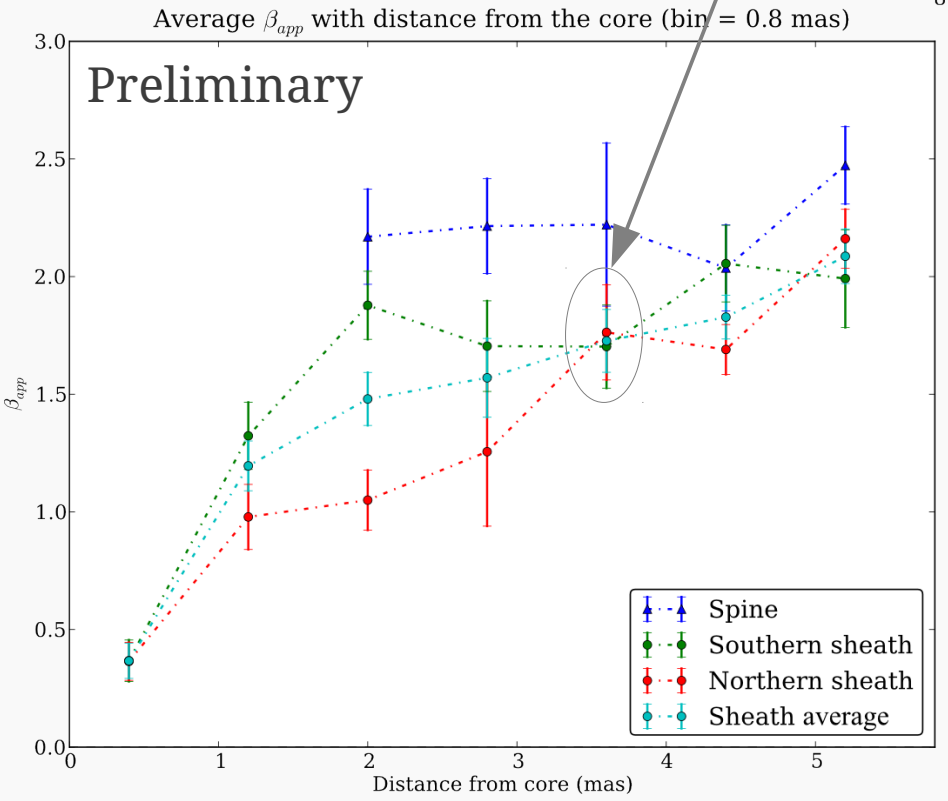
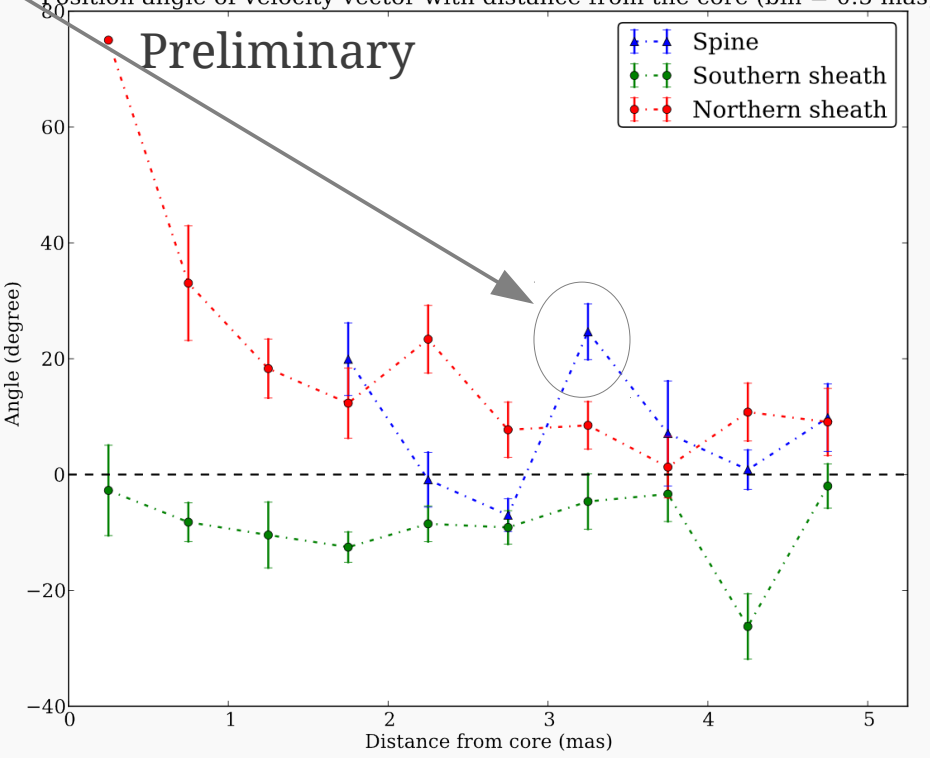
- Lateral displacement due to rotating pressure enhancements: visible > 3 mas







Summary

- The WDS technique provides reliable reconstruction of the velocity field in transversely resolved flows.
- This can considerably enhance the output of high resolution radio images.
- Result shows **excellent agreement** with global kinematic changes obtained from model-fit analysis of VLBI images.
- Ongoing detailed analysis of M87 velocity field promises interesting results:
  - Results suggest a **stratified flow** with a fast spine and a slower sheath
  - We detect an **acceleration in the sheath**

Thank you for your attention!

Email: fmertens@mpifr.de