An extremely curved relativistic jet in PKS 2136+141

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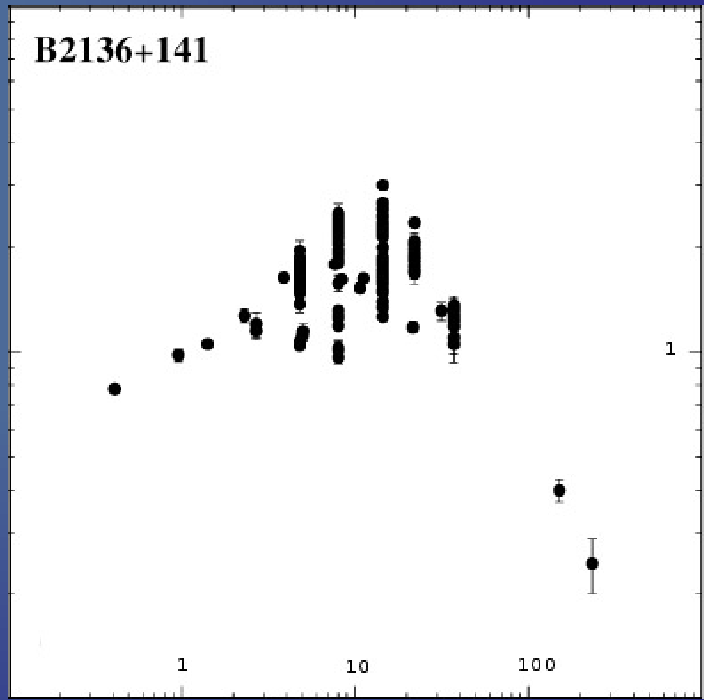
A description of the original project

- On May 2001 we made multi-frequency polarimetric observations of four high peaking GPS-sources using the VLBA.
- The aim was to study whether these sources with peak frequencies around 10-20 GHz belong to the same class of objects as classical GPS-sources peaking around 1 GHz, or whether they form a distinct group.
- The sample included PKS 1936-155, PKS 2008-159, PKS 2128-123 and PKS 2136+141.
- Frequencies used were 2, 5, 8, 15, 22 and 43 GHz.

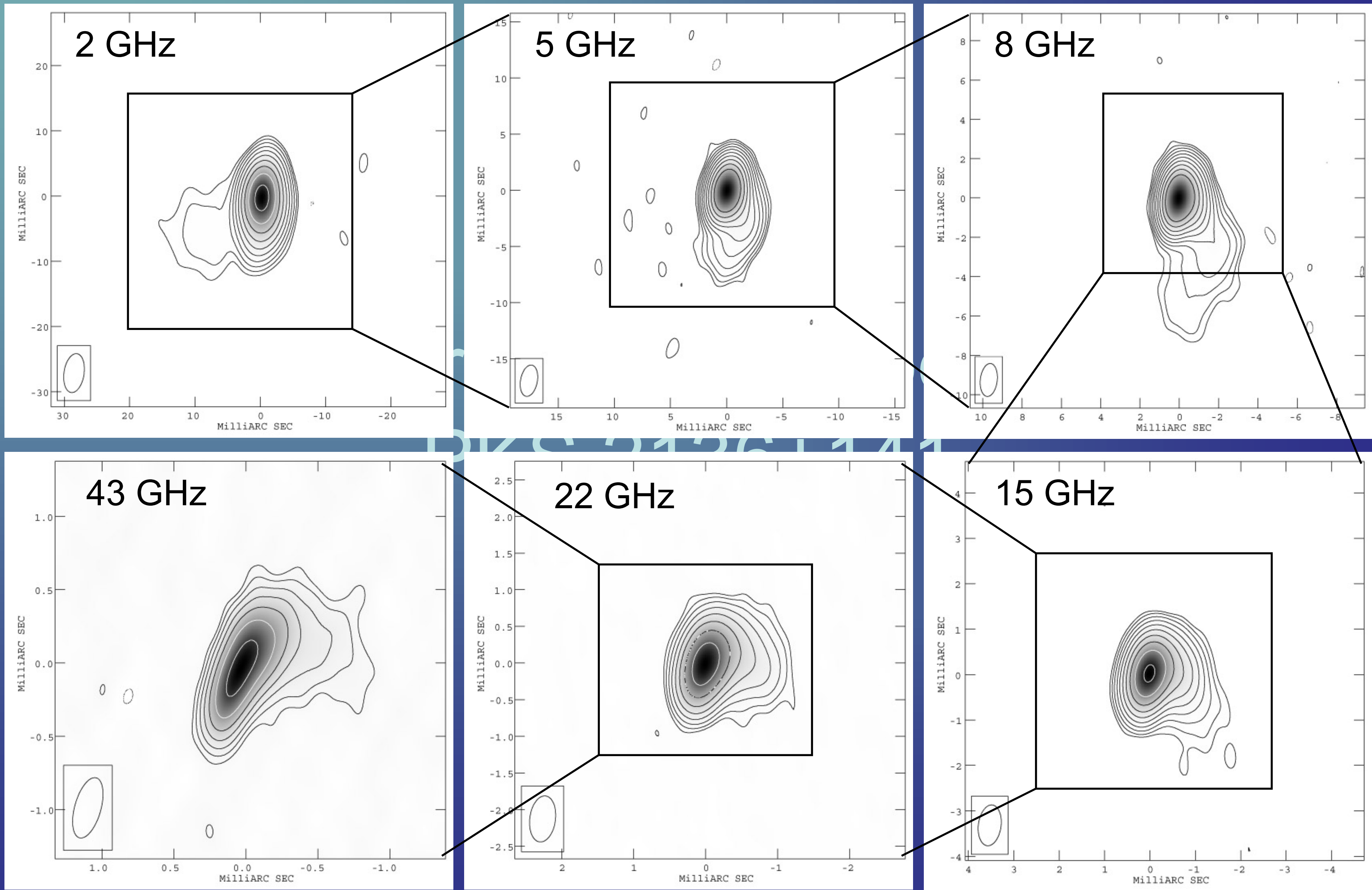
PKS 2136+141 (OX 161)

- A quasar type GPS source with $\nu_{max} \sim$ 8-10 GHz
- z = 2.427
- Compact in VLA images without any extended structure (Murphy et al. 1993)
- Core-jet morphology in VLBI scales (e.g. Kellermann et al. 1998)
- β_{app}= 1.8±1.4 (Kellermann et al. 2004)
- Variable at cm-wavelengths (M. Aller, private communication)

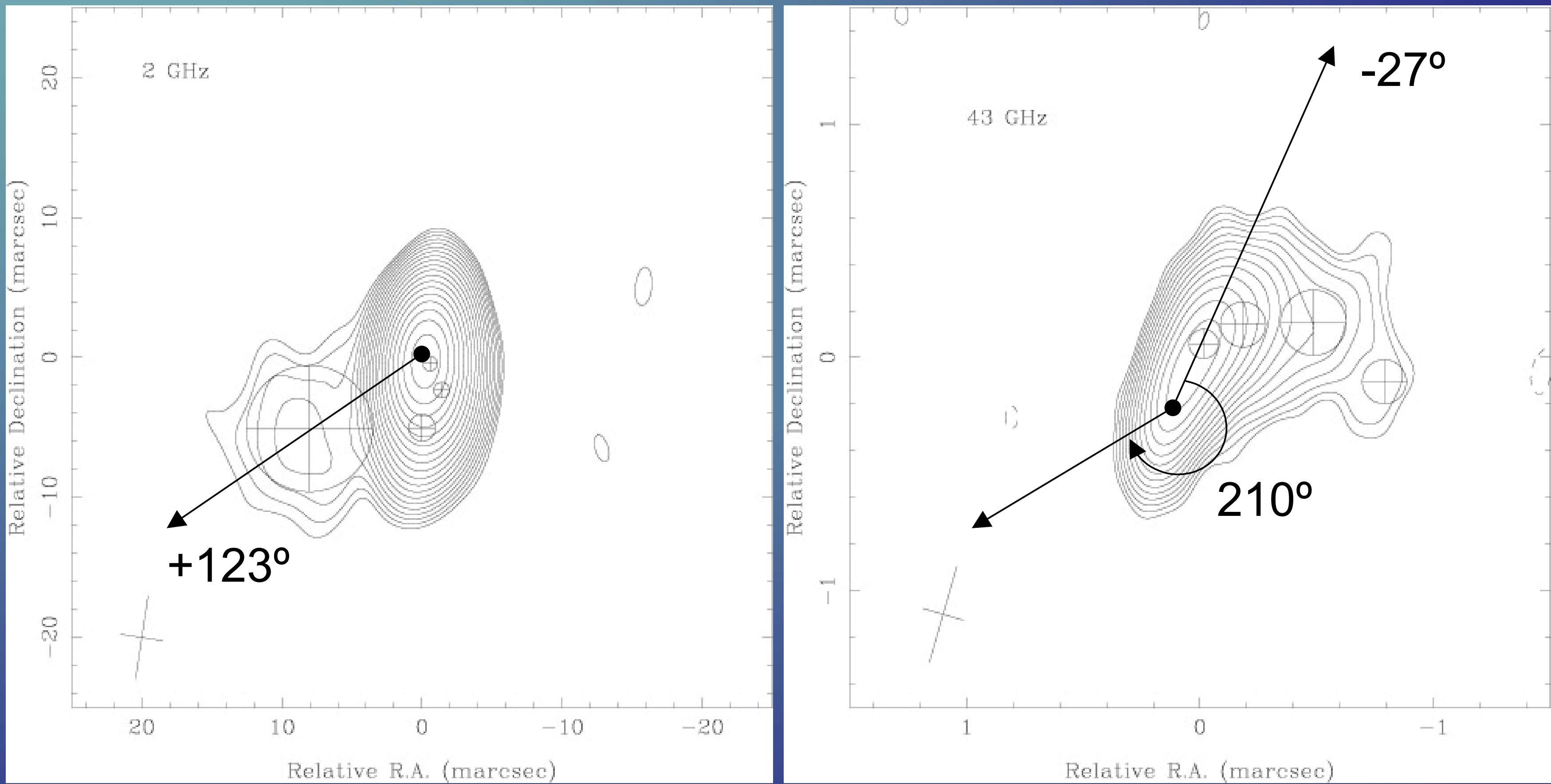


Tornikoski et al. 2001

The multi-frequency appearance of PKS 2136+141



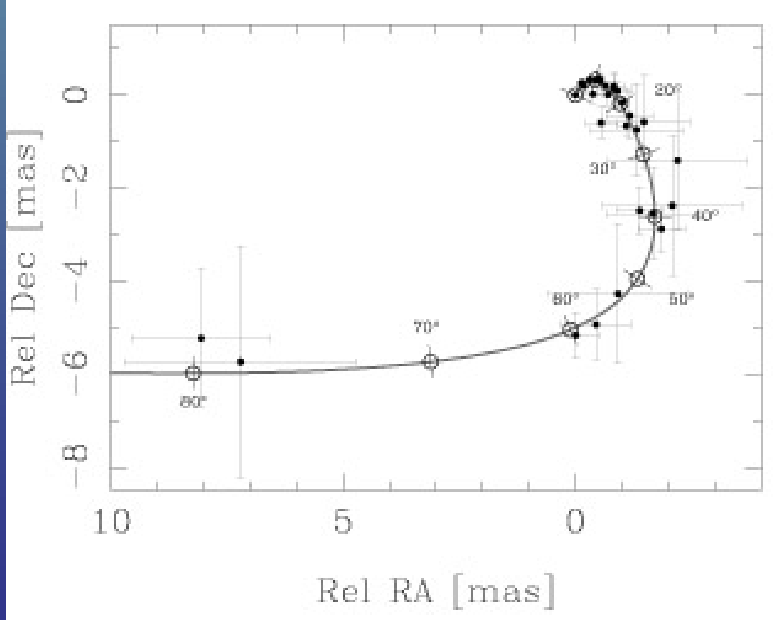
2 GHz
5 GHz
8 GHz
43 GHz
22 GHz
15 GHz
MilliARC SEC

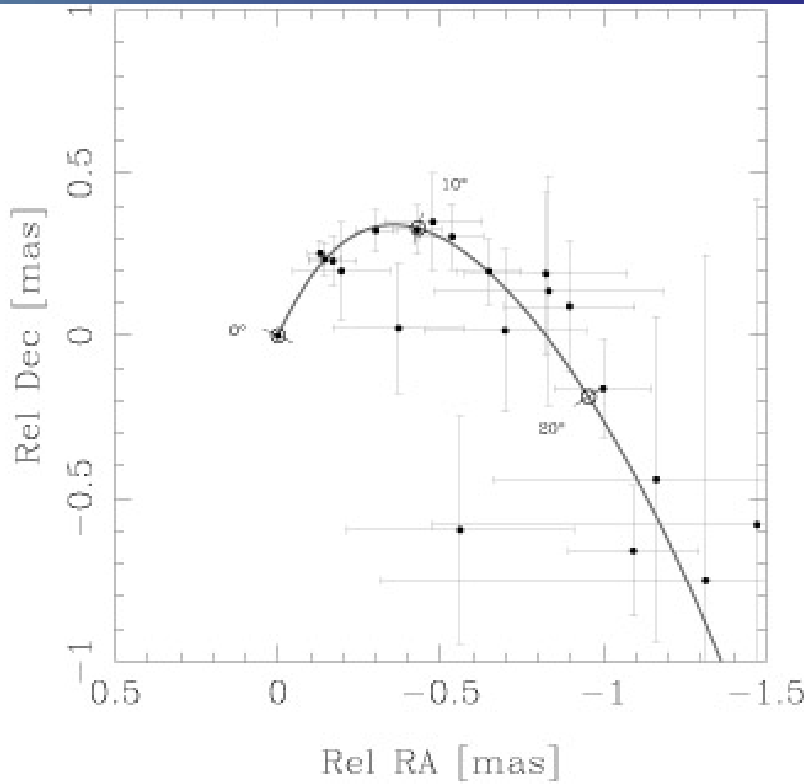


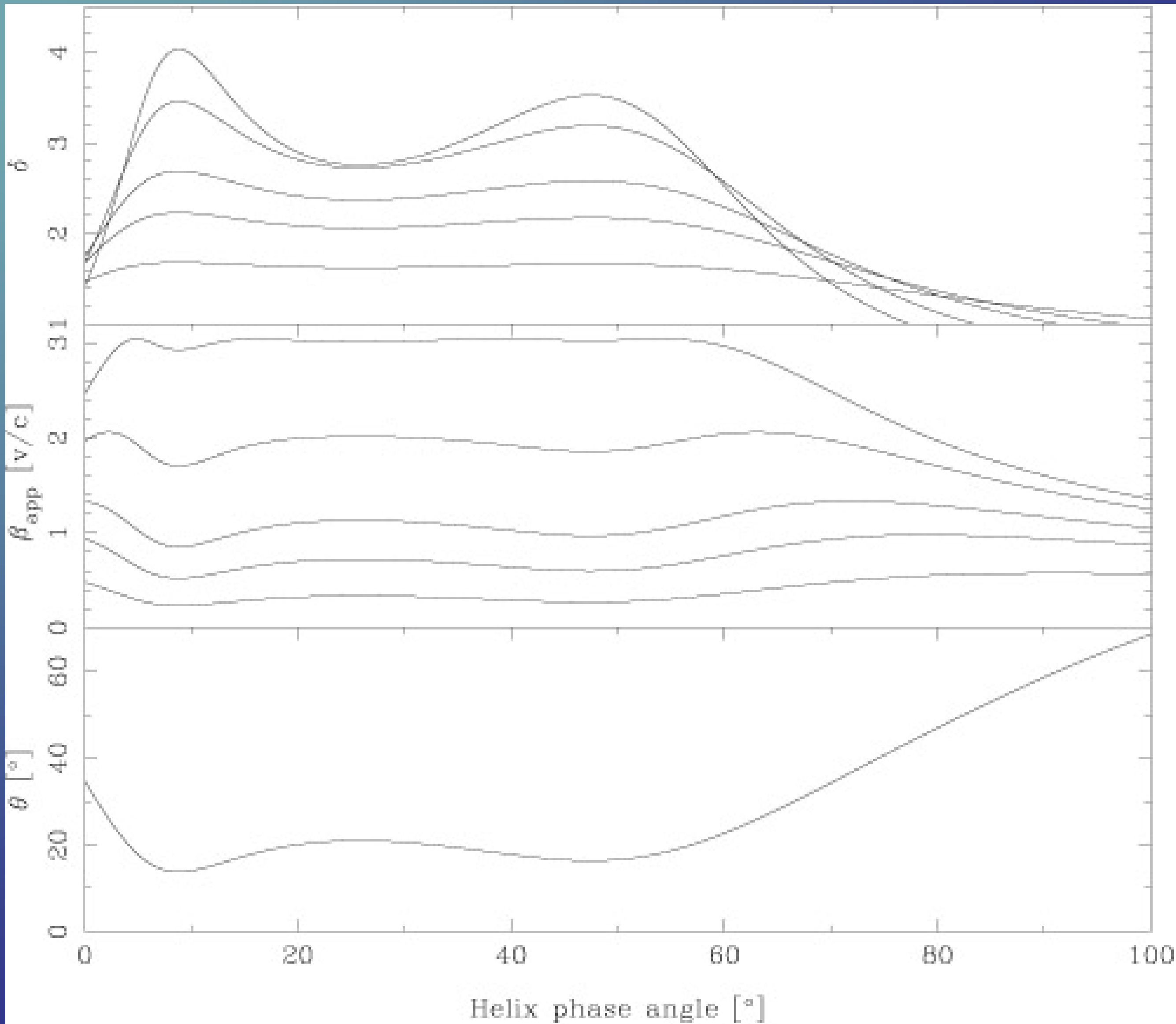
Largest ever observed ΔP.A. in an extragalactic jet!

The trajectory

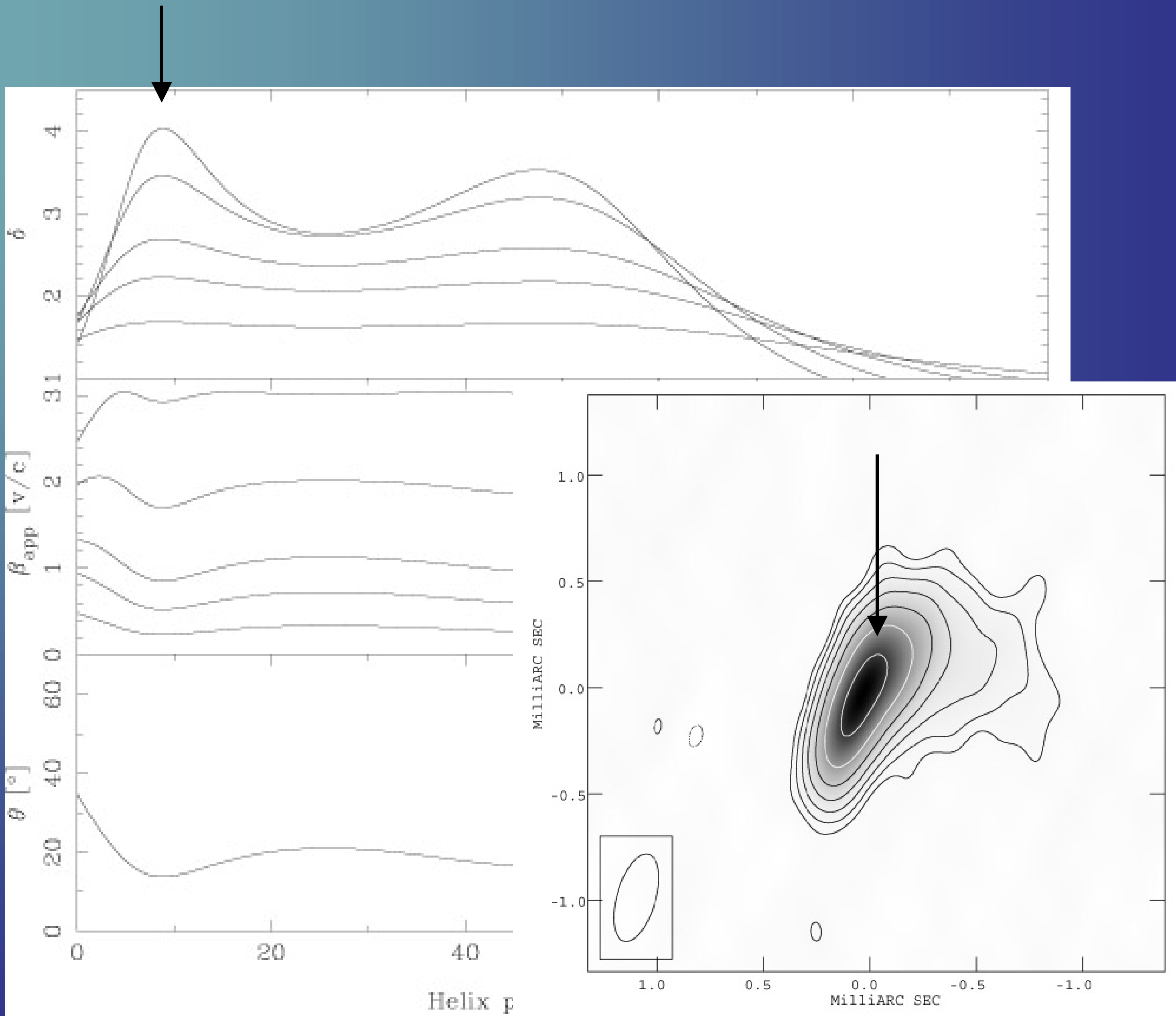
- Self-calibrated visibilities were model-fitted in DIFMAP with circular Gaussian model components
- We have fitted different helical trajectories to component positions – the figure shows our best fitting model (χ^2=1.7): a helix on a surface of a cone with linearly increasing pitch angle







δ
β_app [v/c]
θ [°]
Helix phase angle [°]
0
20
40
60
80
100


δ
β_app [v/c]
θ [°]
Helix p
MilliARC SEC
MilliARC SEC

- The peak in the Doppler factor around phase angle of 10º is almost coincident with apparent brightening at 0.28 mas from the core
- Observed β_{app}= 1.8±1.4 (Kellermann et al. 2004) is consistent with the model
- If the bending is due to helical trajectory, the helix should be quickly opening and already asymptotically approaching a straight line in the scale of 15 mas

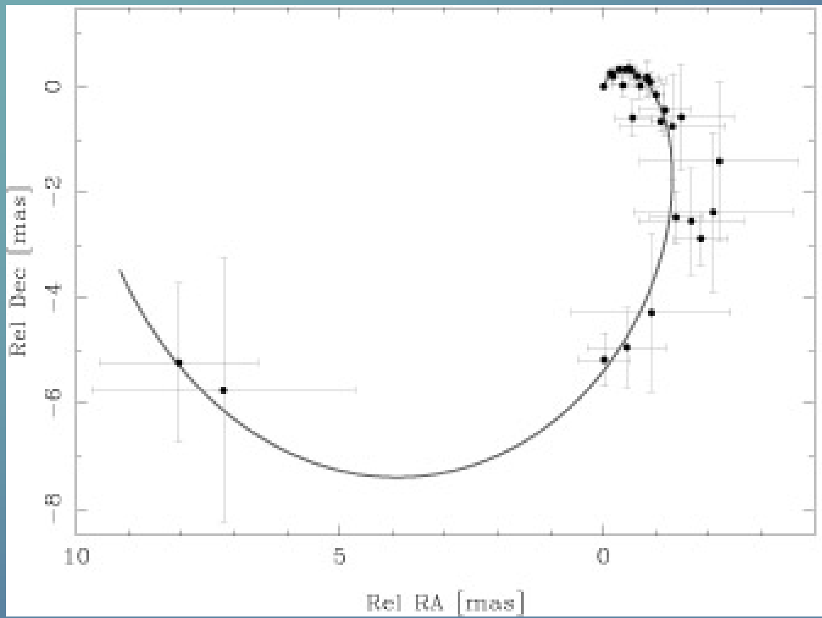
Reason for bending

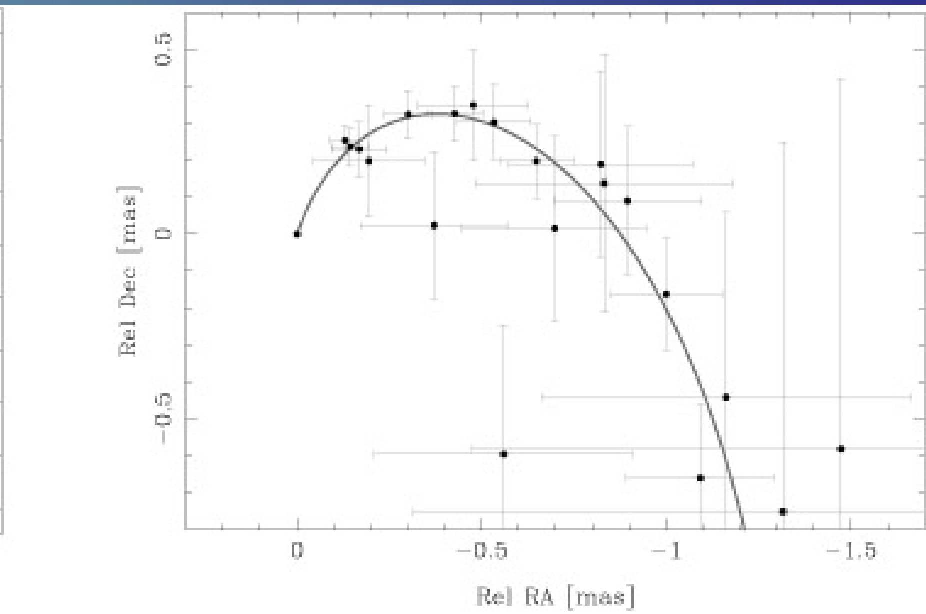
Density gradients?

- The observed bend > 180º. This excludes scenarios like:
  - deflection by a massive cloud in the ISM
  - bending by a uniform density gradient
- Large misalignment angle in PKS 1510-089 was explained by Homan et al. (2002) with a jet bending after it departs the host galaxy (due to a density gradient or ram pressure by intracluster winds). In PKS 2136+141 bending takes place well within 15 mas corresponding to 120 pc. Assuming typical size of elliptical hosts of radio galaxies (~30 kpc) would imply a viewing angle smaller than 0.2º, if the jet bent after departing the host galaxy. This would put our line of sight inside the jet opening angle, which is not observed. Thus, the jet bends before it reaches the outskirts of the host galaxy.

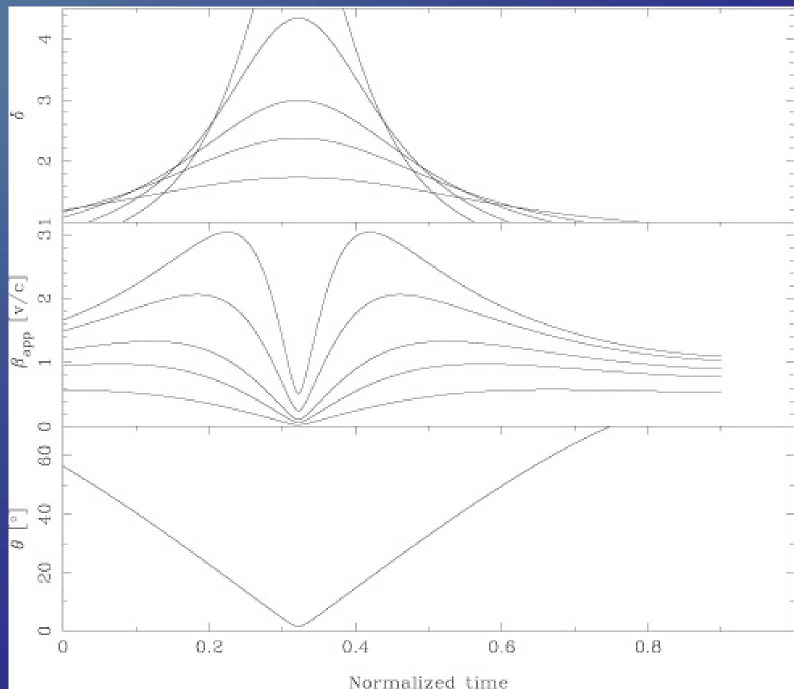
Jet precession?

- Simple model: a ballistic jet with a precessing nozzle
- Easily testable with further observations:
  - The P.A. of the most compact part of the jet should change with time
  - The components should follow straight – not curved – trajectories
- We tried to fit such a model to the our data…





A precessing ballistic jet fits rather well to the component locations, but we could not (yet?) find a solution with plausible viewing angles.



MHD instabilities?

- Bending could also be due to growing MHD instabilities (pressure driven, Kelvin-Helmholtz or current driven; see e.g. Hardee 1987, 2003)
- Difficult to measure the wave speed, the wavelength or the growth rate of the disturbance with the current data

Future observations

- With further VLBI observations, we have a good chance to determine the 3-D trajectory of the source:
  - Flux density, jet opening angle and component velocity all depend on the viewing angle. → By measuring them as a function of distance along the jet, we can try to fit for viewing angle (and its changes) and find out the 3-D structure
- High frequency VLBI observations, 2-3 times per year covering a few years, should do the job

Summary

- PKS 2136+141 shows the largest apparent bend ever observed in an extragalactic jet
- Bending is consistent with an intrinsic helical trajectory
- The jet bends before it reaches the outskirts of the host galaxy (unlike in PKS 1510-089)
- MHD instabilities or jet precession could be viable explanations. Further study is needed here.
- With VLBI monitoring, the 3-D trajectory of this jet should be tractable
- PKS 2136+141 may prove to be a good test bench for studying jet bending scenarios