Structural variability in BL Lacertae

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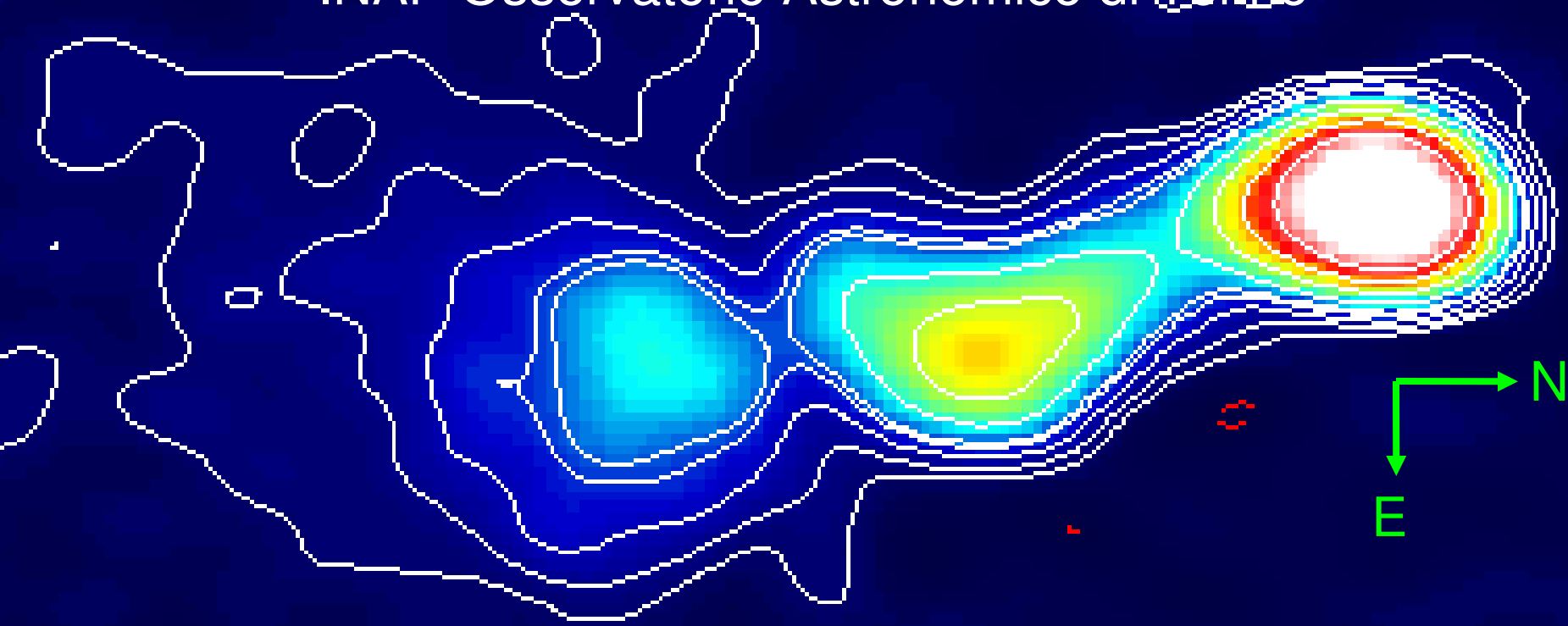
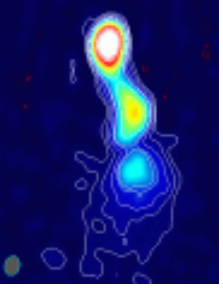
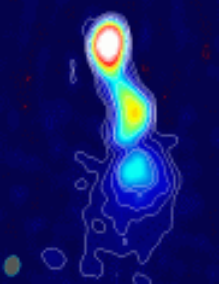


in collaboration with: M. Villata, C.M. Raiteri (INAF-OATo), I. Agudo (MPIfR, Bonn), H. Aller, M. Aller (U. Michigan), G. Denn (MSC, Denver), J.L. Gomez (IAA, Granda), R.L. Mutel (U. Iowa), H. Terasranta, et al.

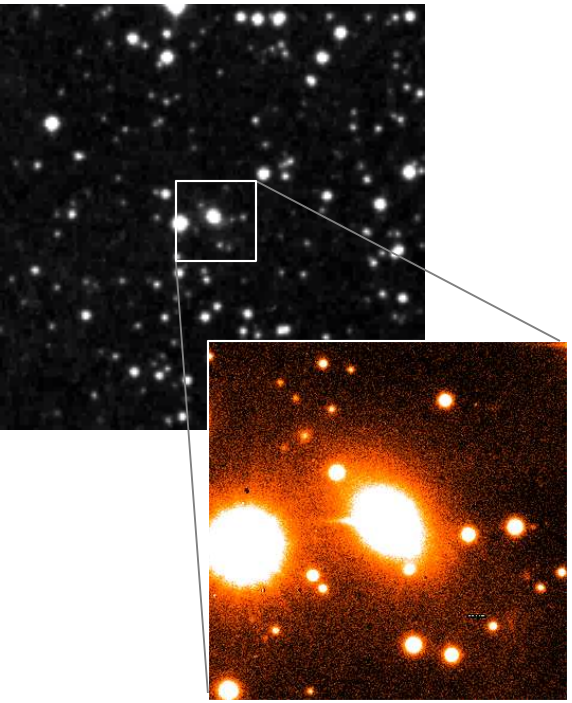


Contents

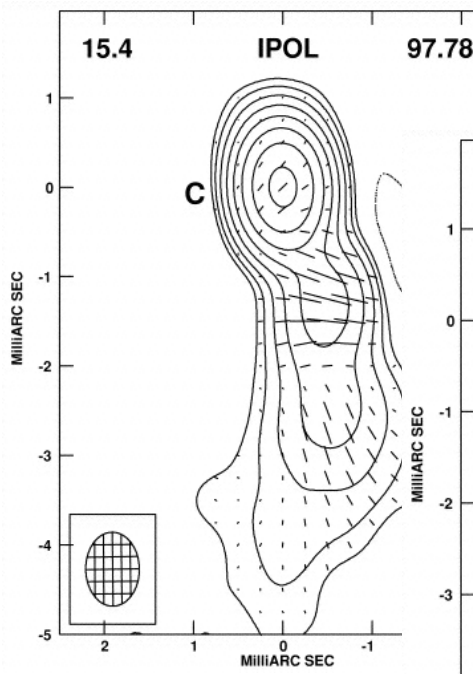
- Short introduction
- BL Lac on parsec-scales
  - VLBI images
  - light curve
  - spectral index
- Cross-correlation results and discussion
- Summary
- Outlook

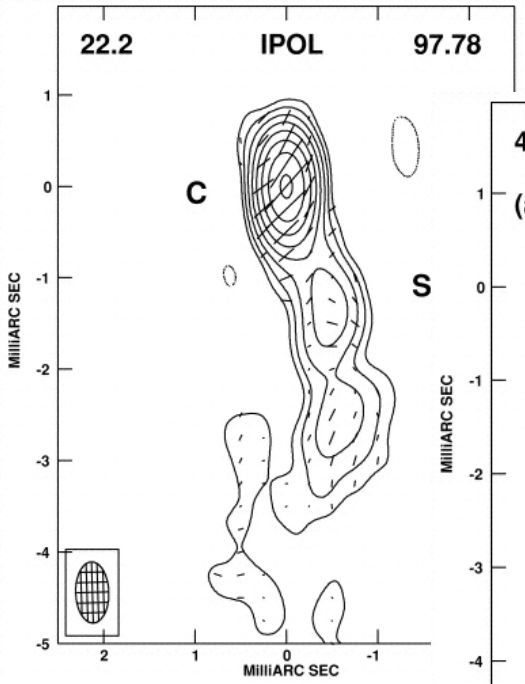


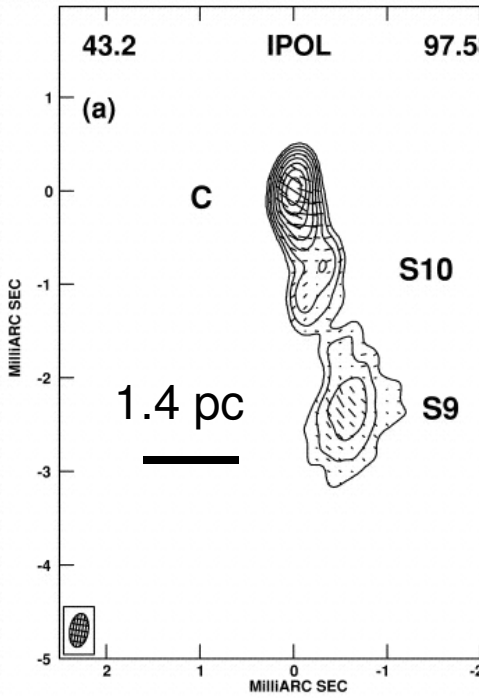
BL Lacertae



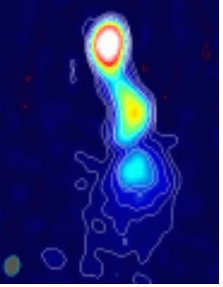
$z = 0.069 \sim d_L = 300$ Mpc.



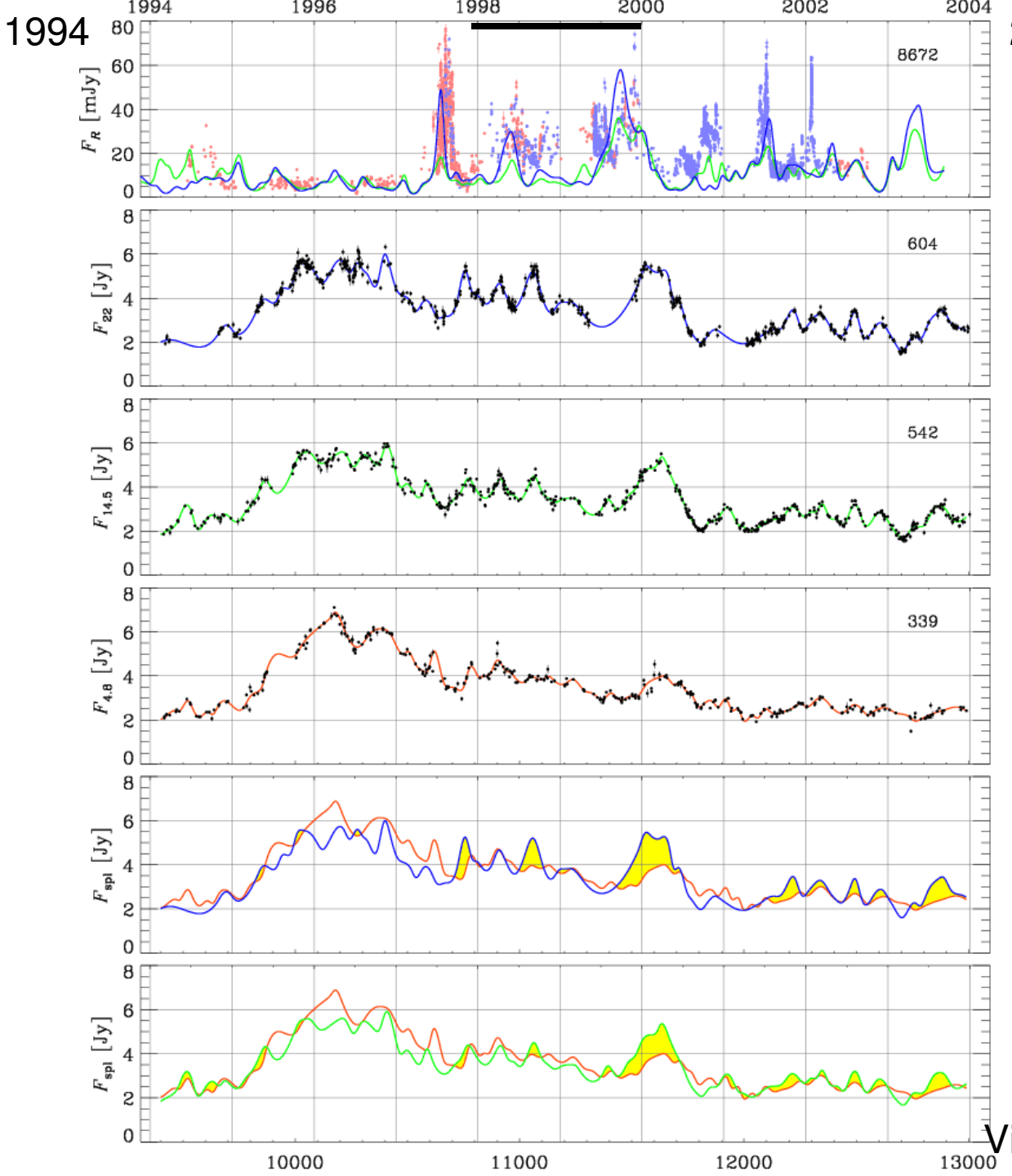




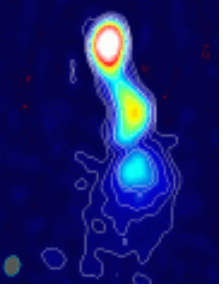
Optical: DSS and NOT images; radio: Denn et al. 2000



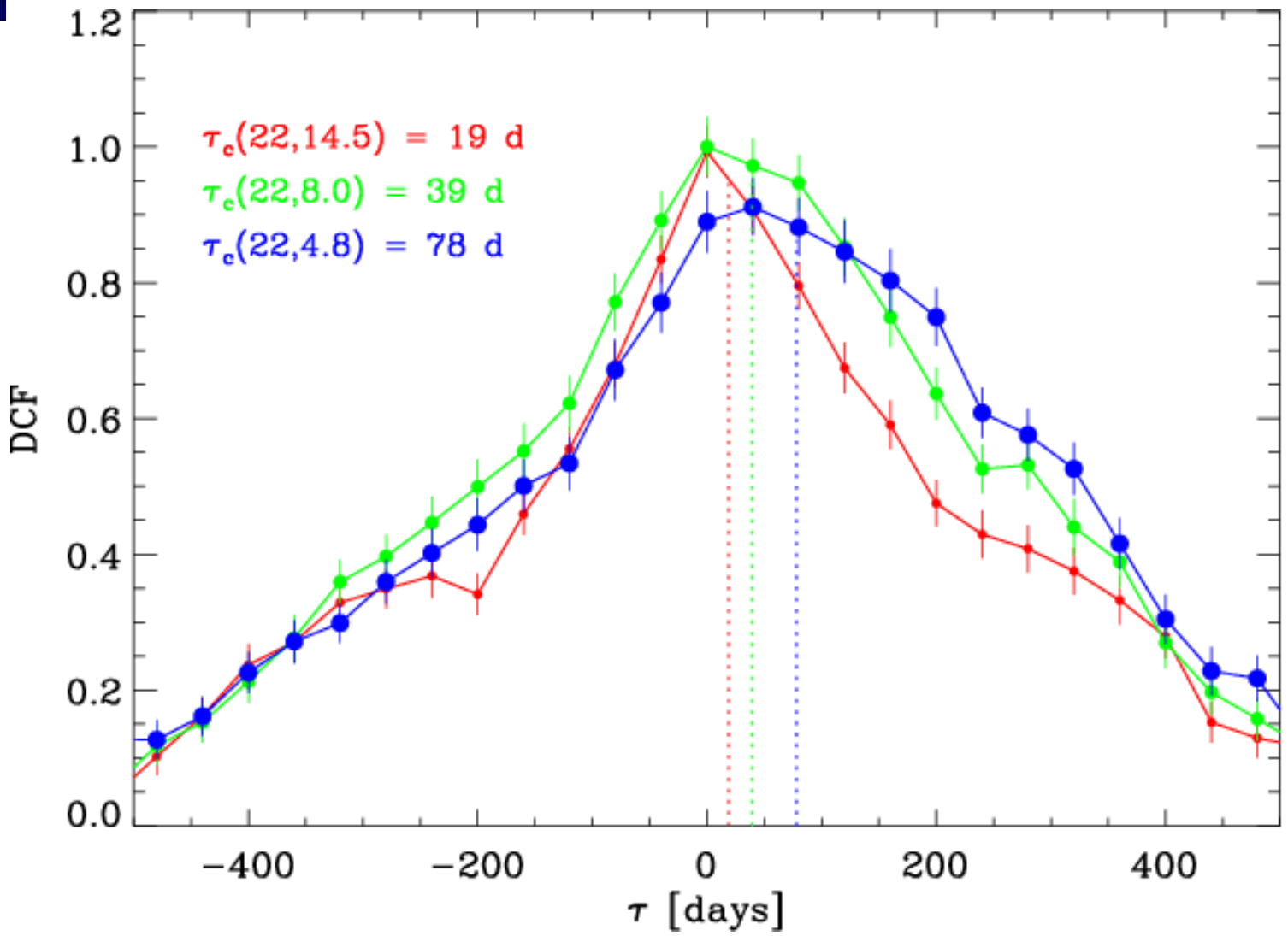
Correlated Variability



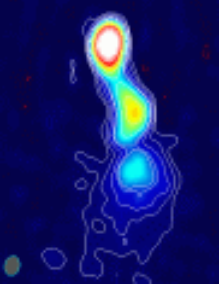
Villata et al. 2004b



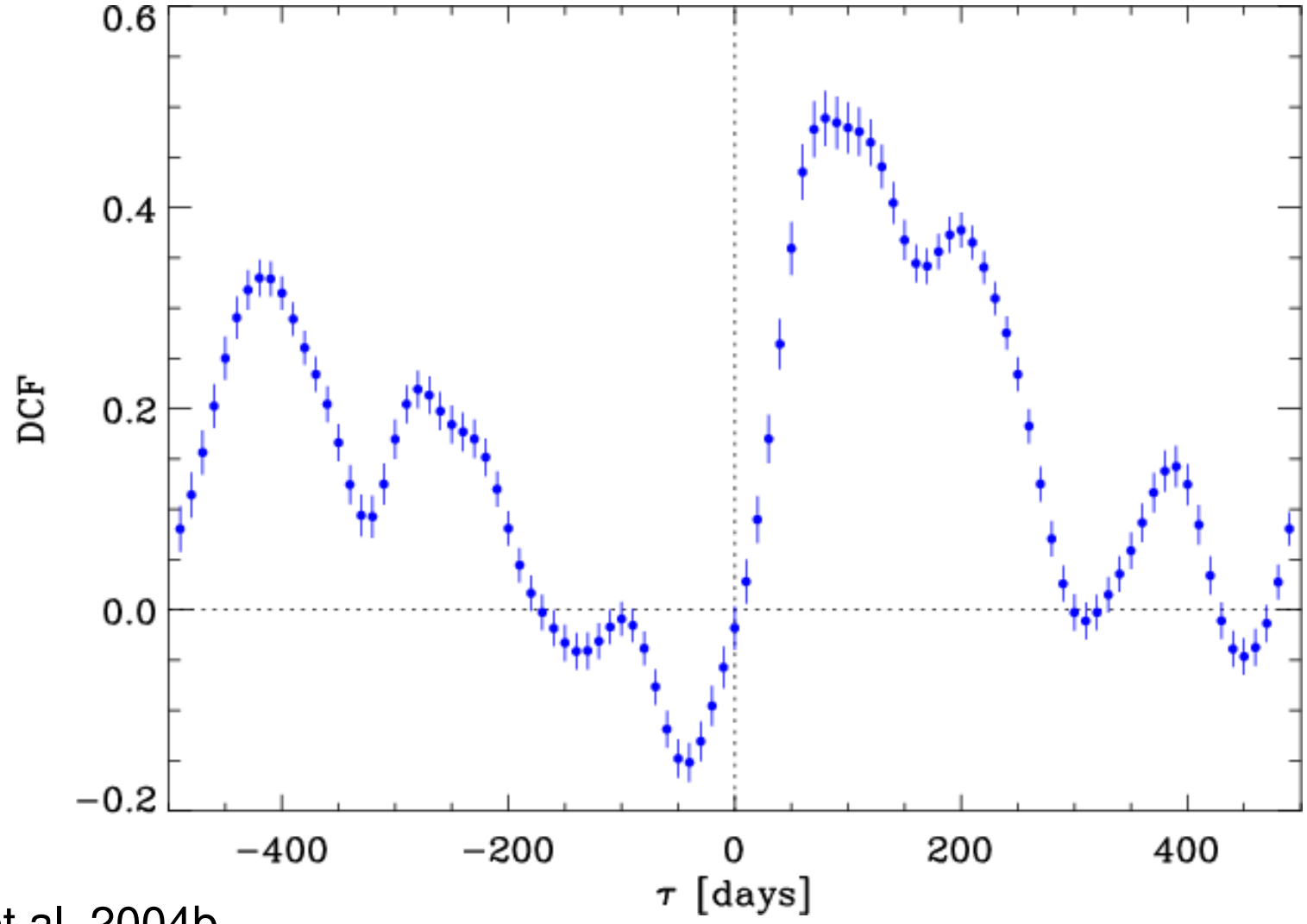
Radio Cross-Correlation



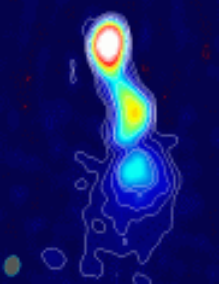
Villata et al. 2004b



Cross-Correlations
R band-$h_{22/5}$



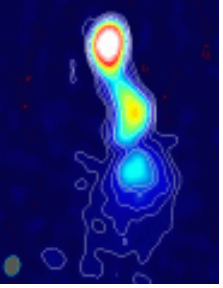
Villata et al. 2004b



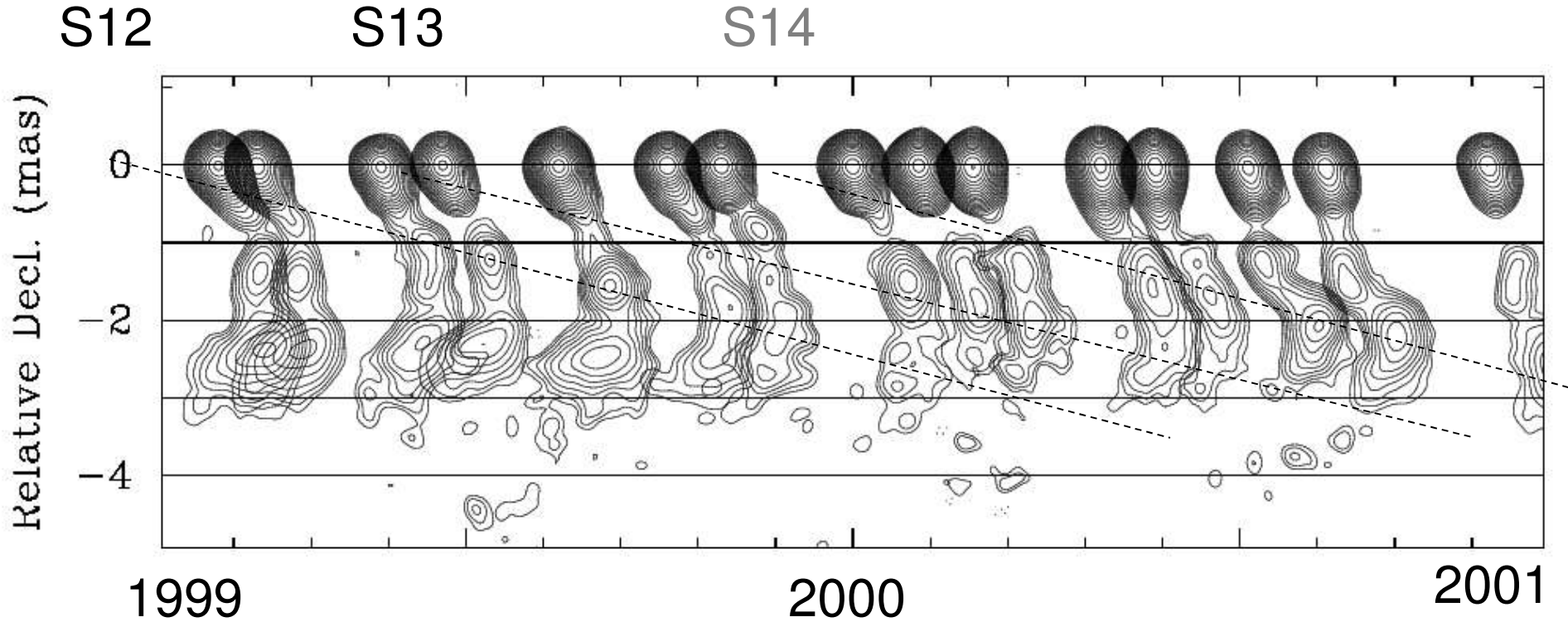
Very Long Baseline Interferometry (VLBI)

- Collected 108 epochs of VLBI data* (1995-2003):
  47 at 43 GHz, 29 at 22 GHz & 32 at 15 GHz.
- Spectral index maps (22/43 GHz) for all simultaneous epochs (#28)
- Separated light curves for the core and different parts of the jet

* VLBA 2cm Survey, MOJAVE, Mutel et al., Marscher et al., Gomez et al., own data

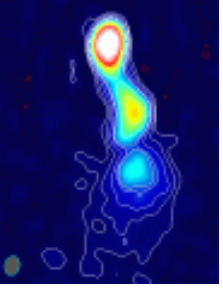


Series of 43 GHz Images



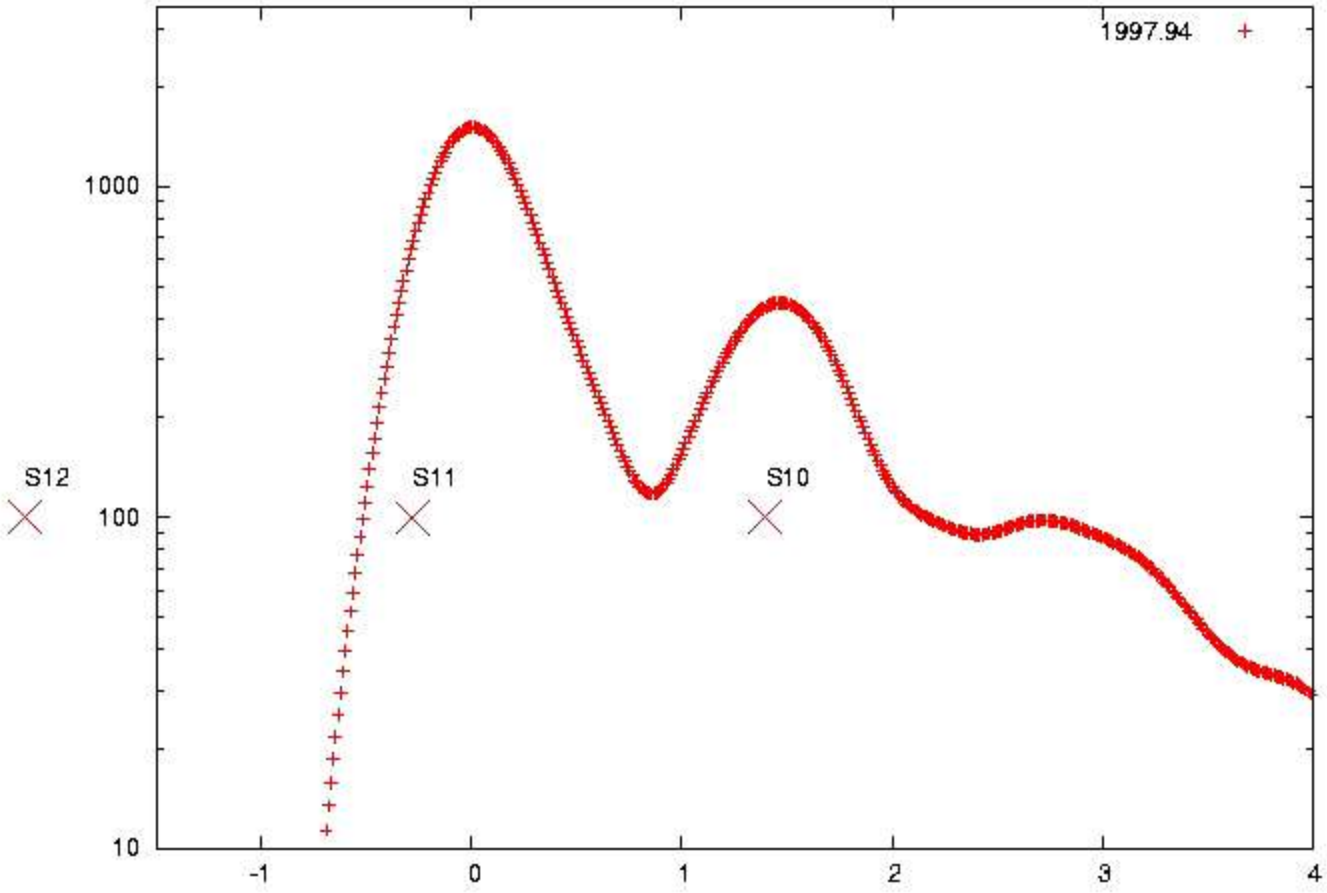
Beam size: 0.3 x 0.3 mas
Lowest cont.: 6 mJy

$\beta_{app} \approx 8\ c$

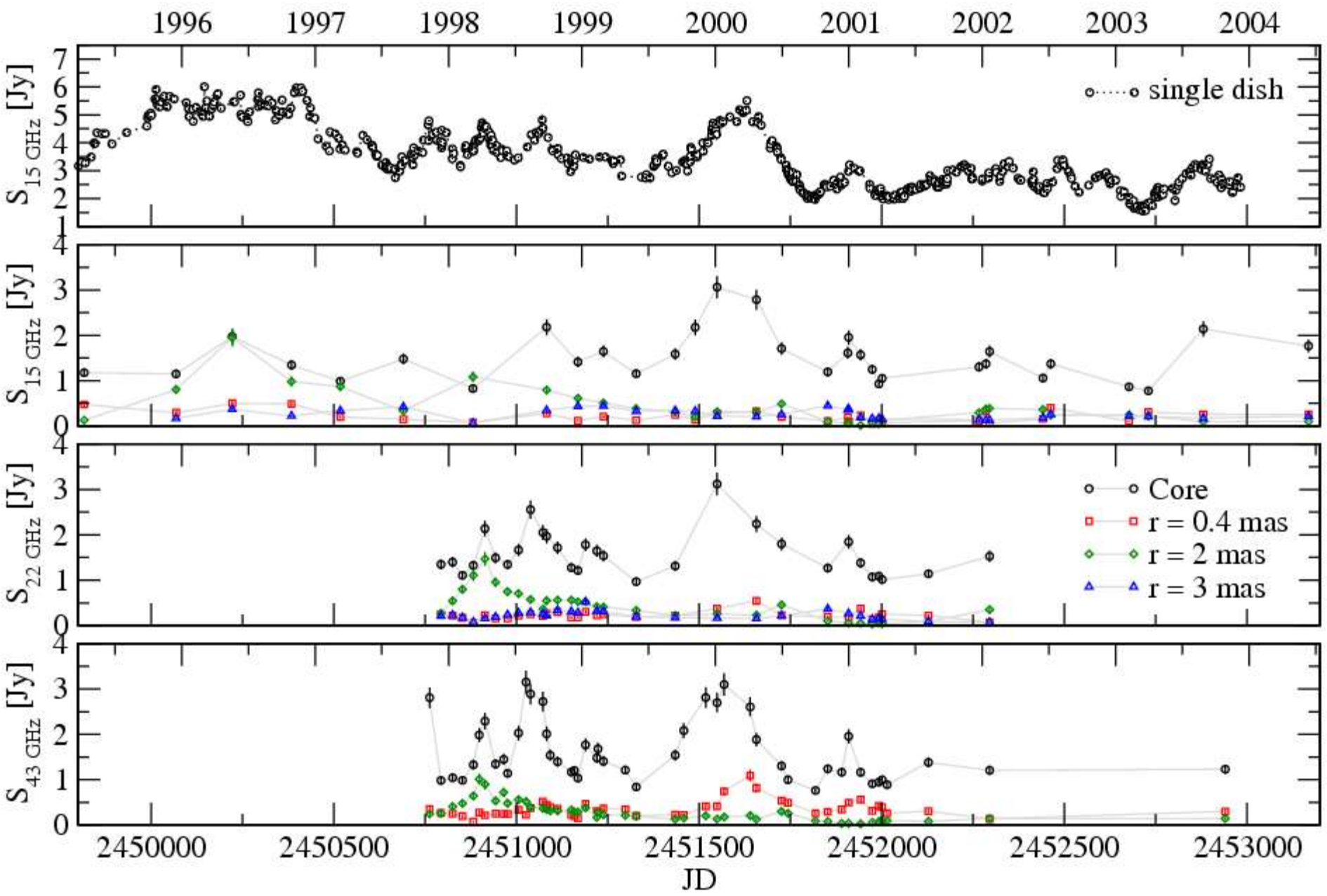


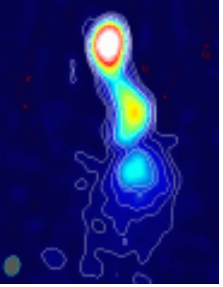
Source Intensity Profiles

1997.9 – 1999.7



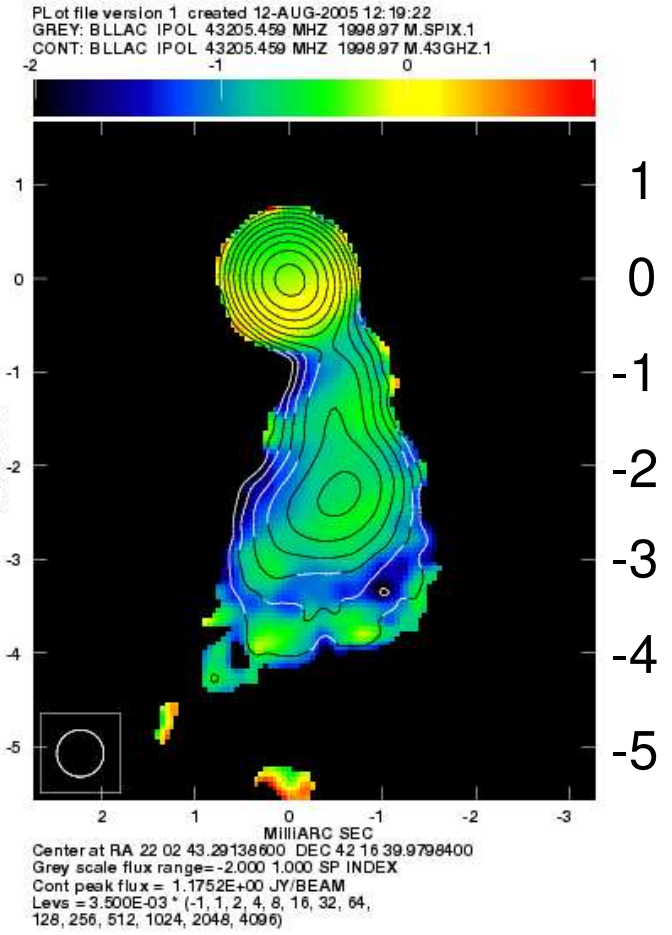
Light Curves



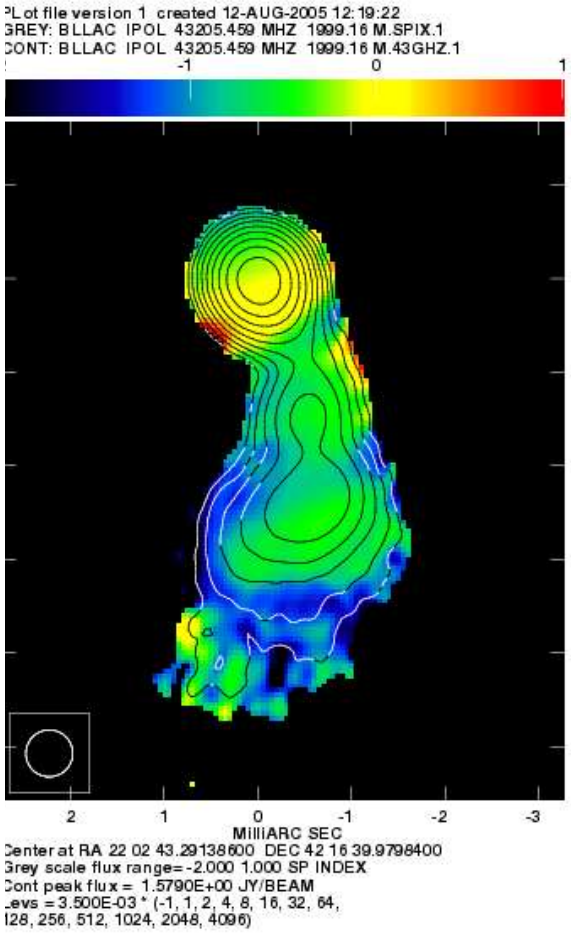


Spectral Index Images

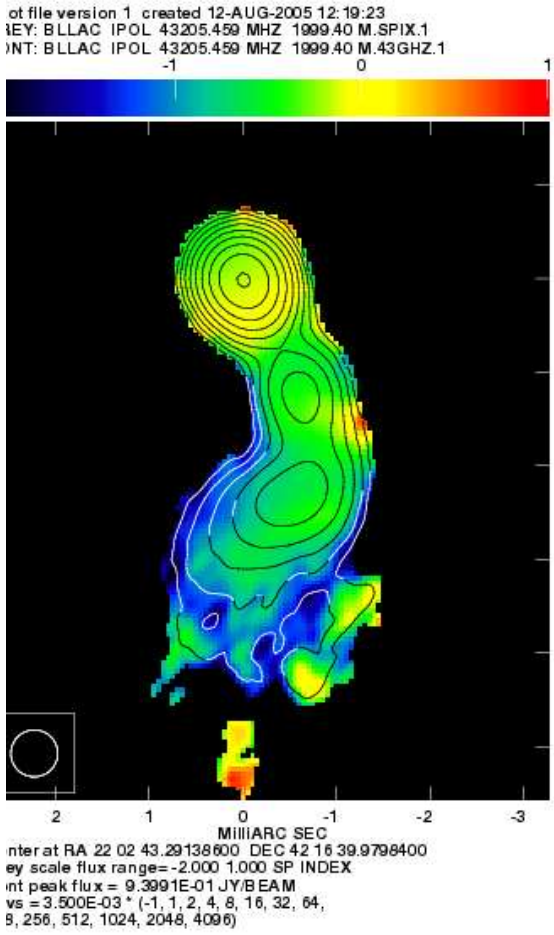
1998.97

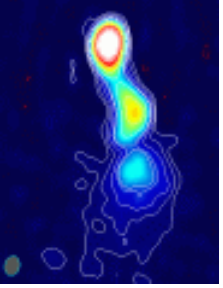


1999.16

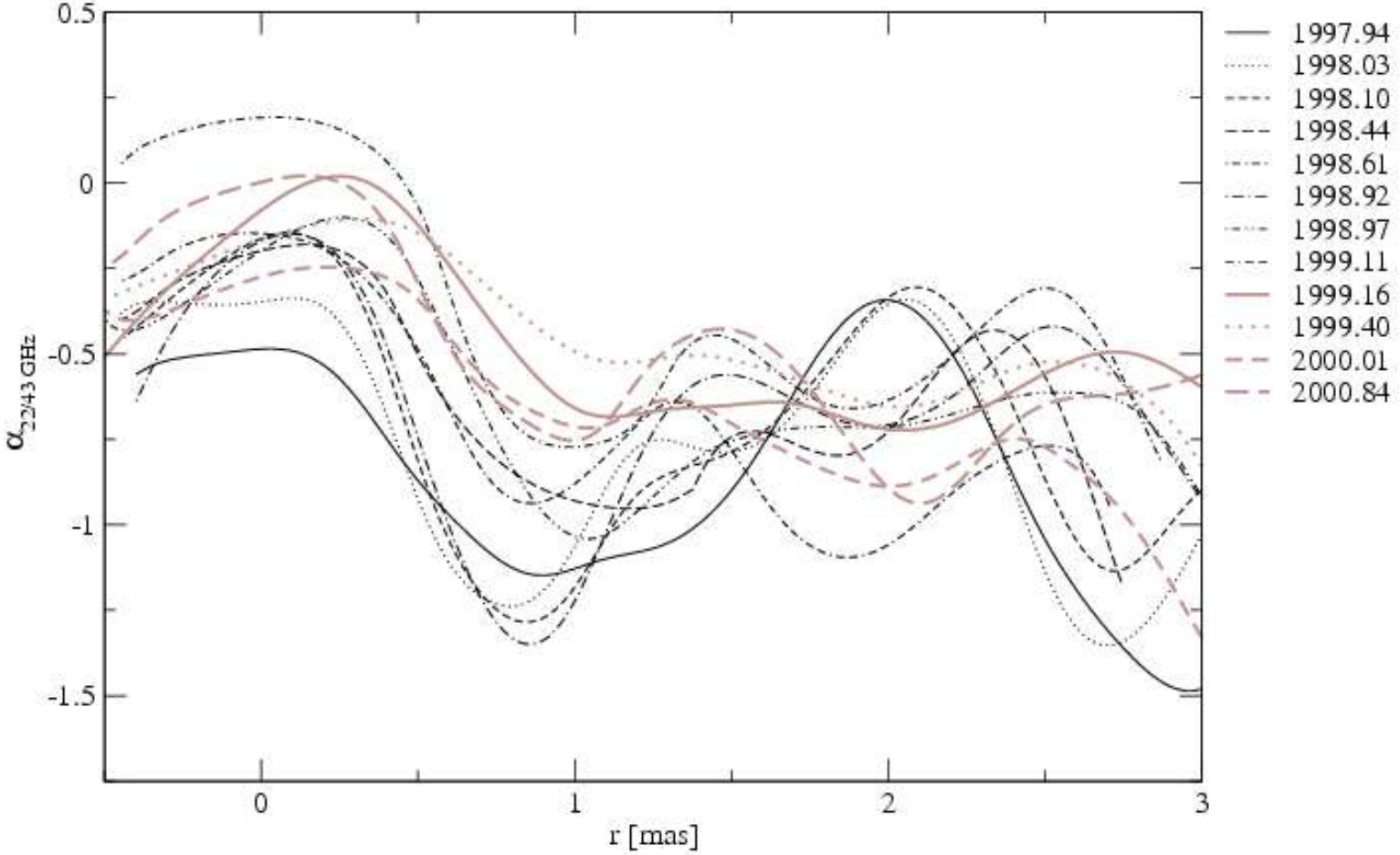


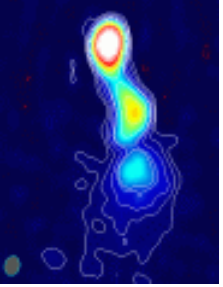
1999.40



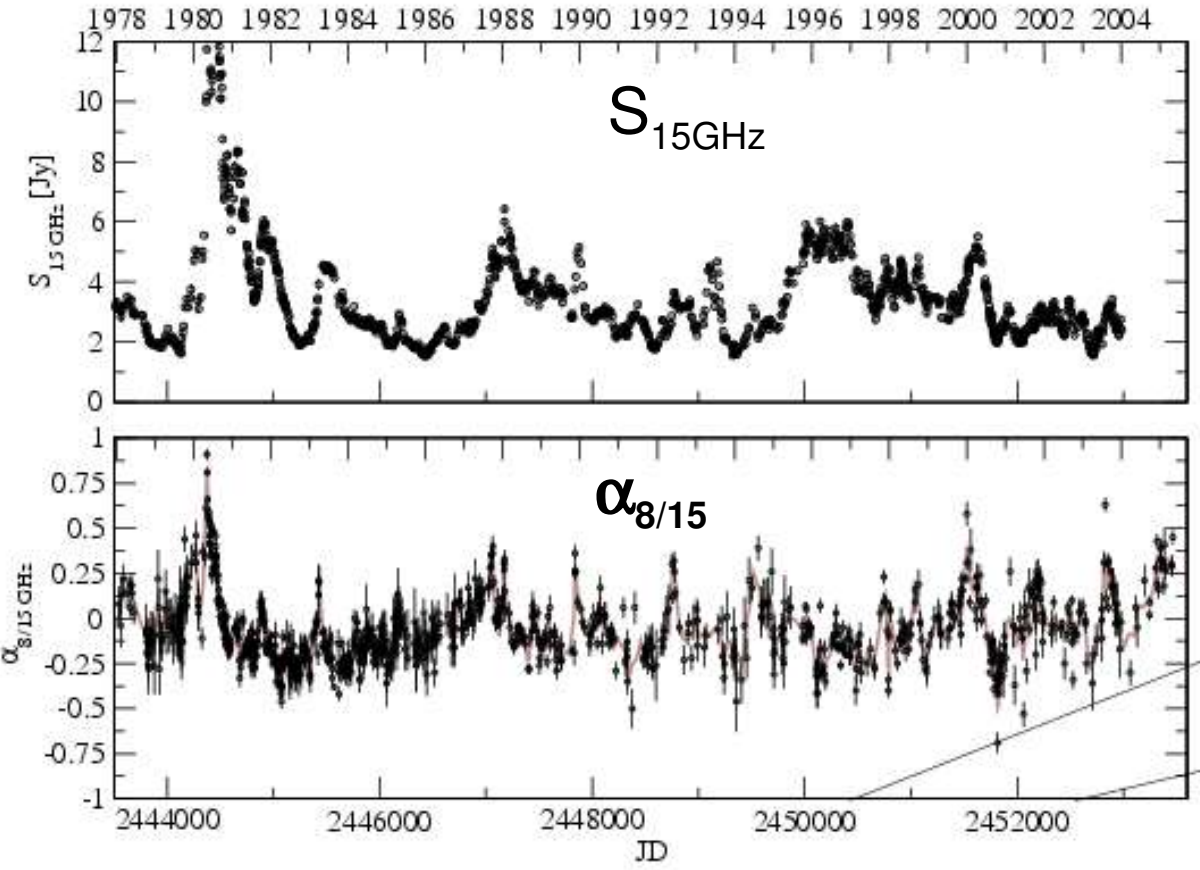


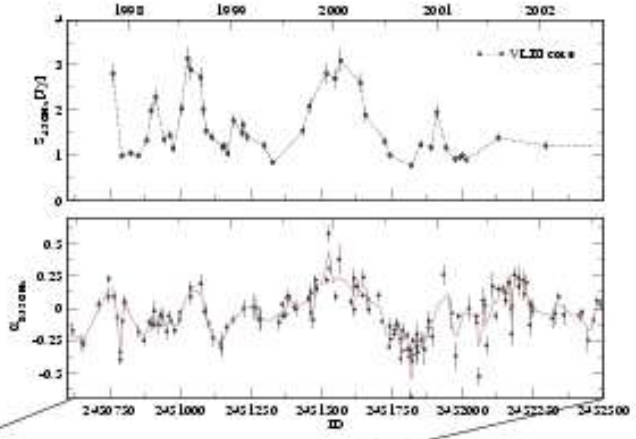
Evolution of $\alpha_{22/43}$ ($S \propto \nu^{\alpha}$)

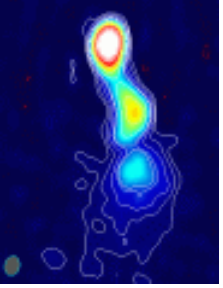




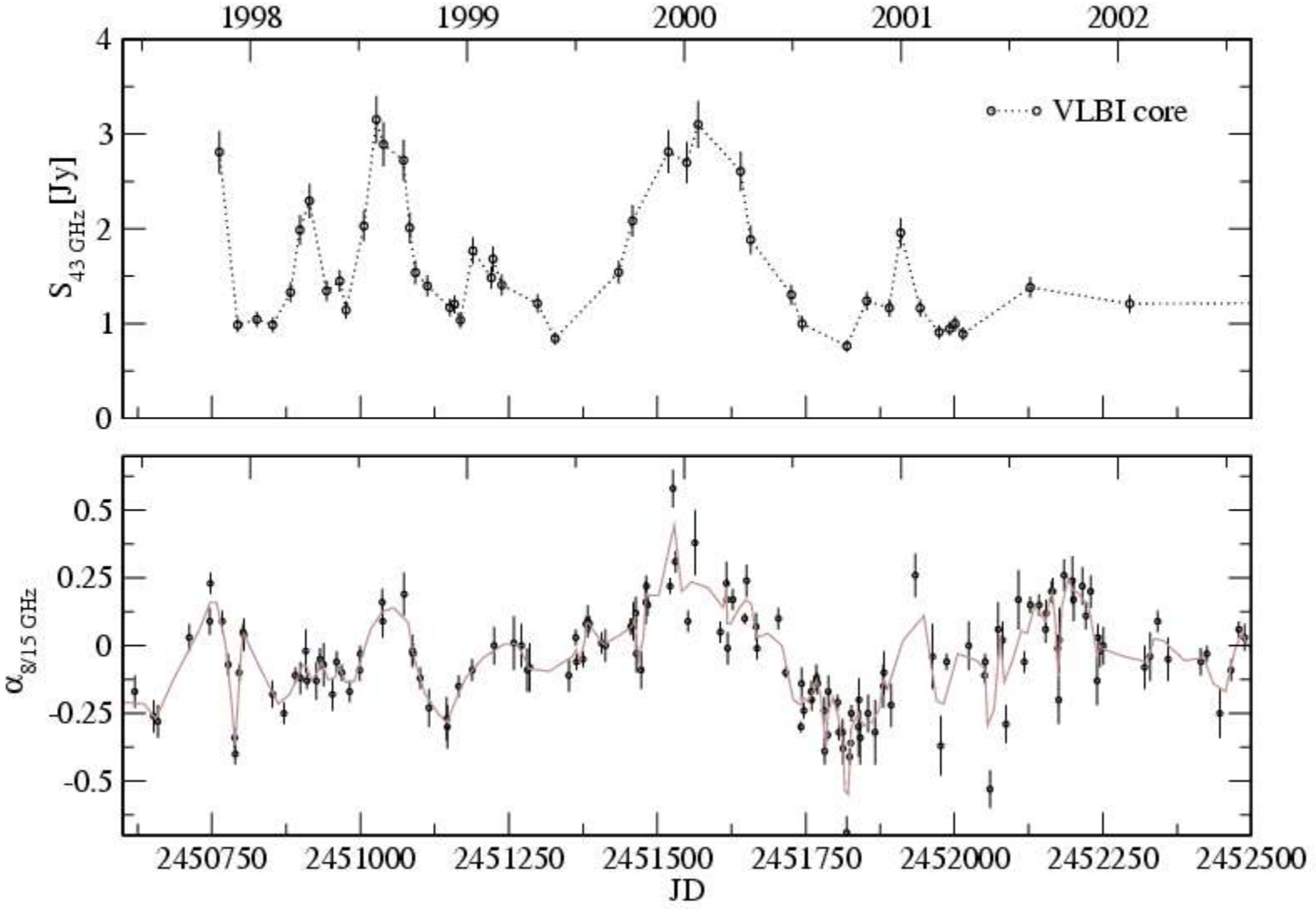
Single Dish Spectral Index

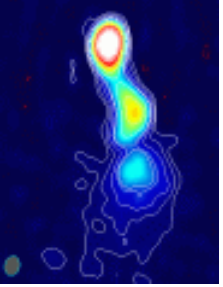




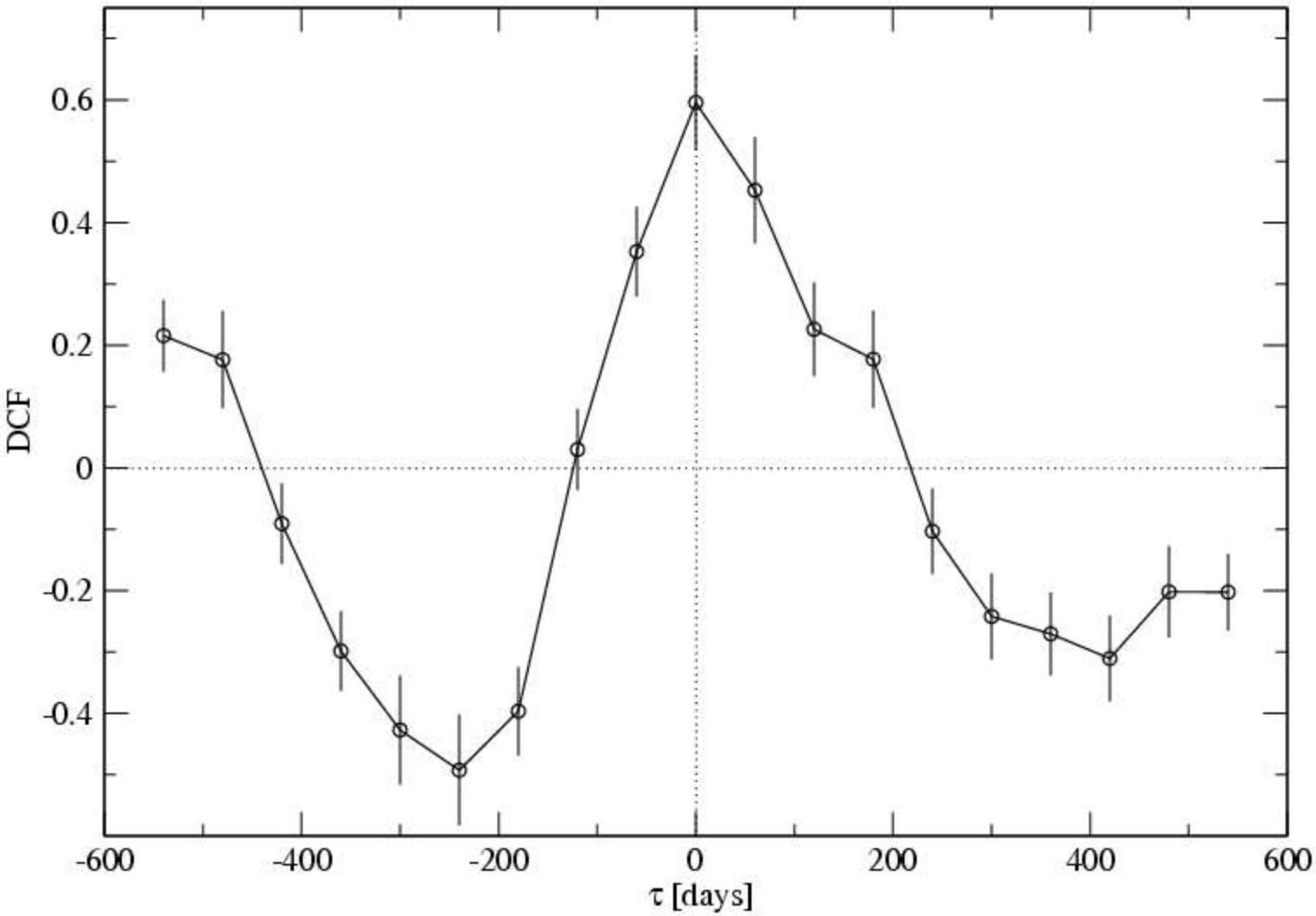


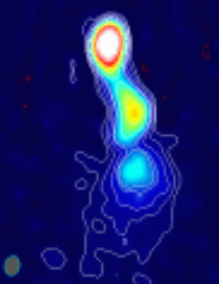
Single Dish Spectral Index



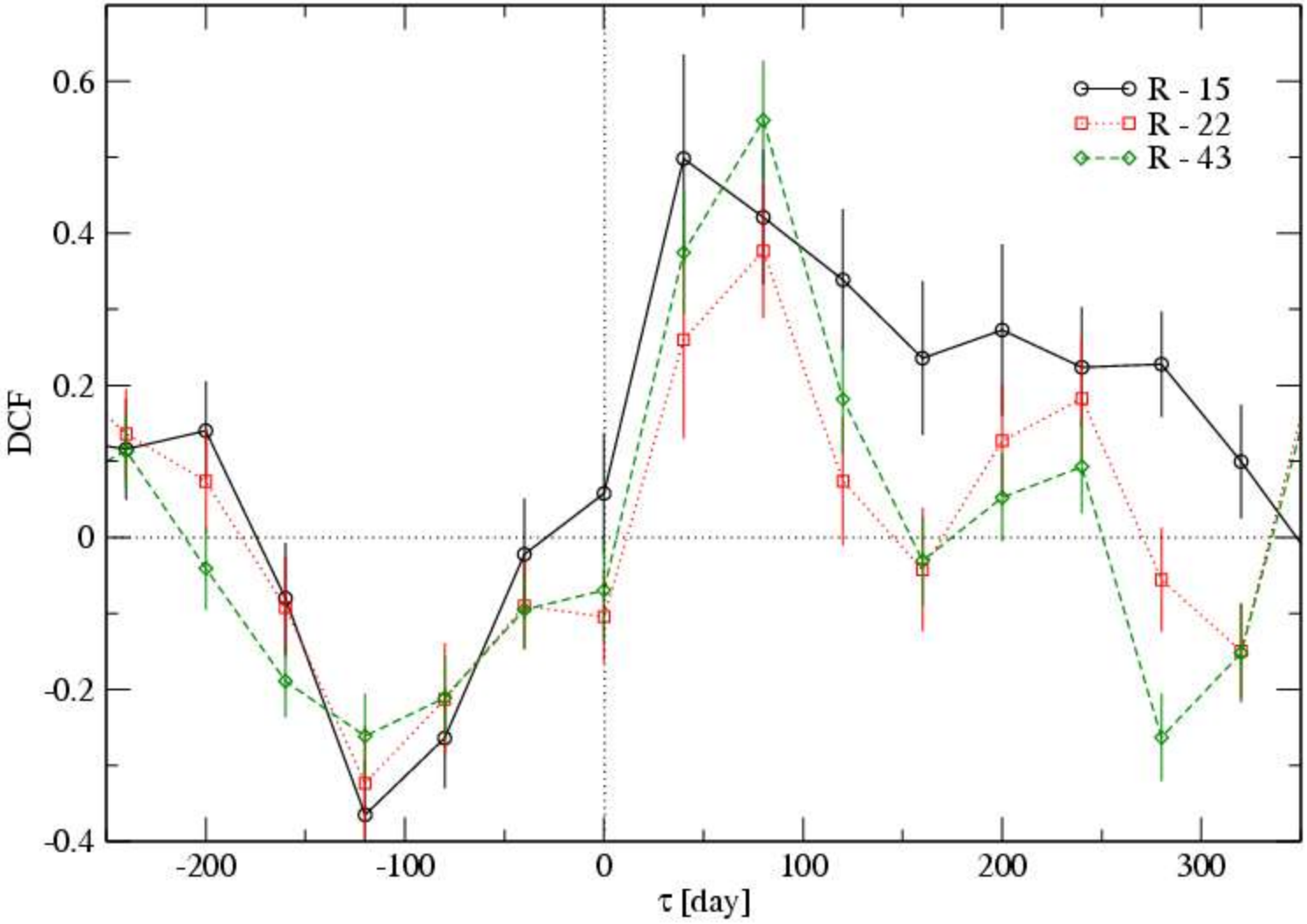


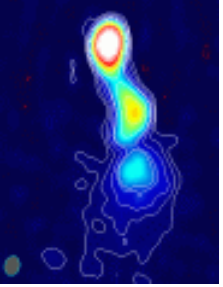
DCF: VLBI Core- $\alpha_{8/15}$



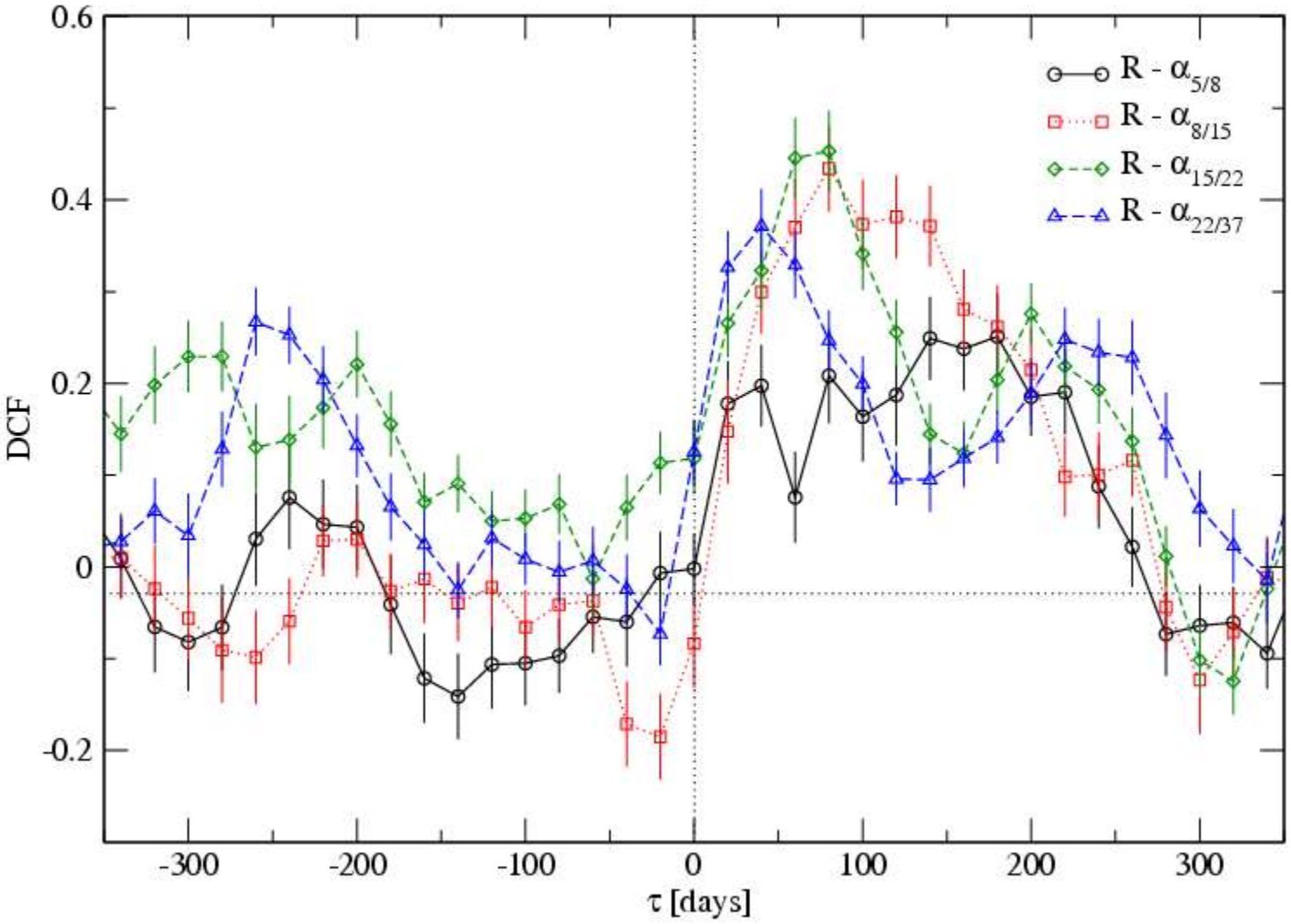


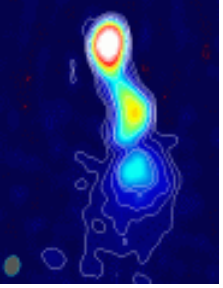
DCF: R-band-VLBI Core



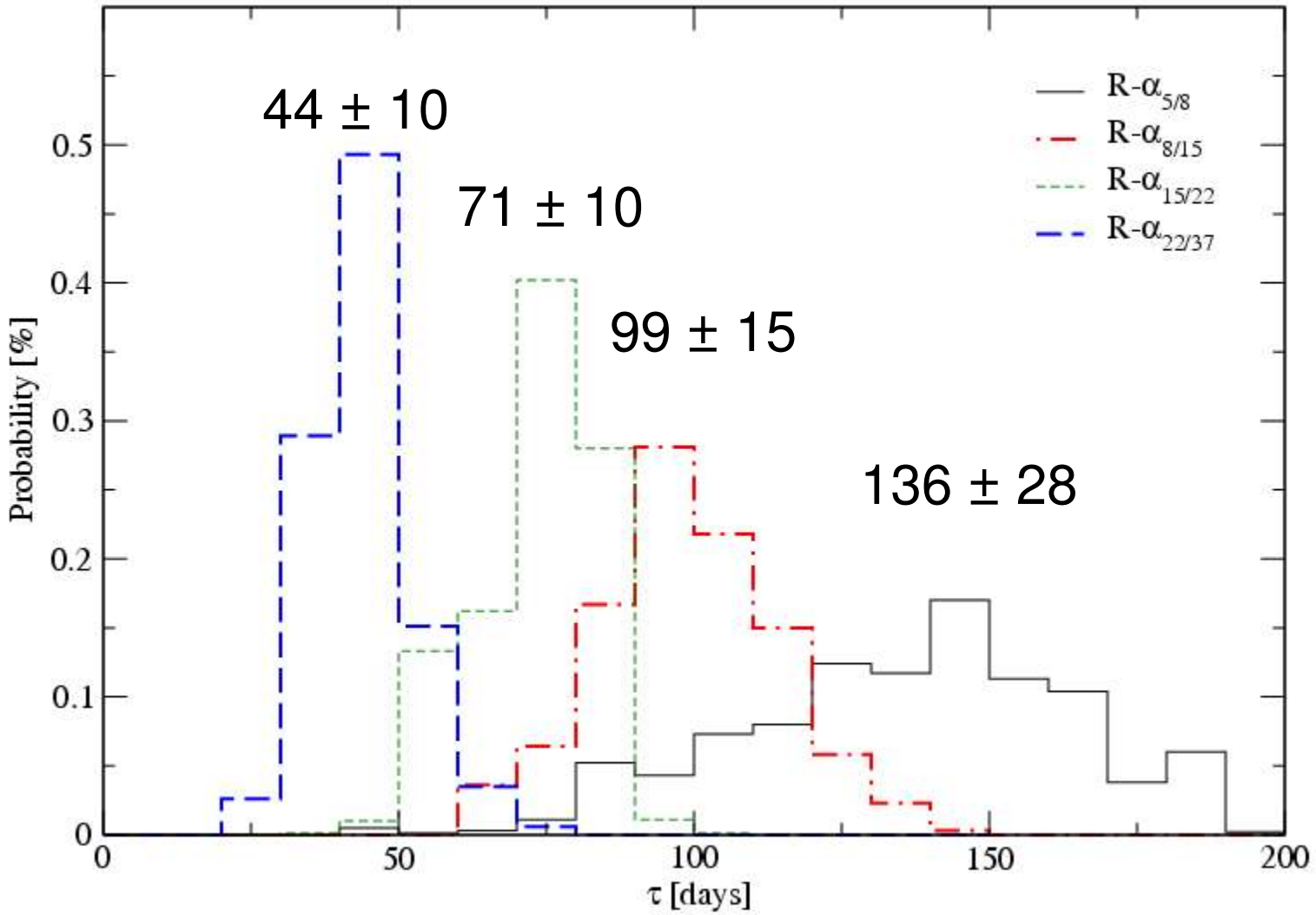


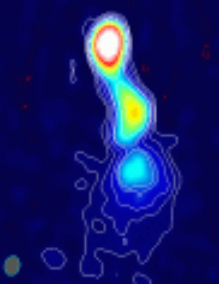
DCF: R band-Spectral Index



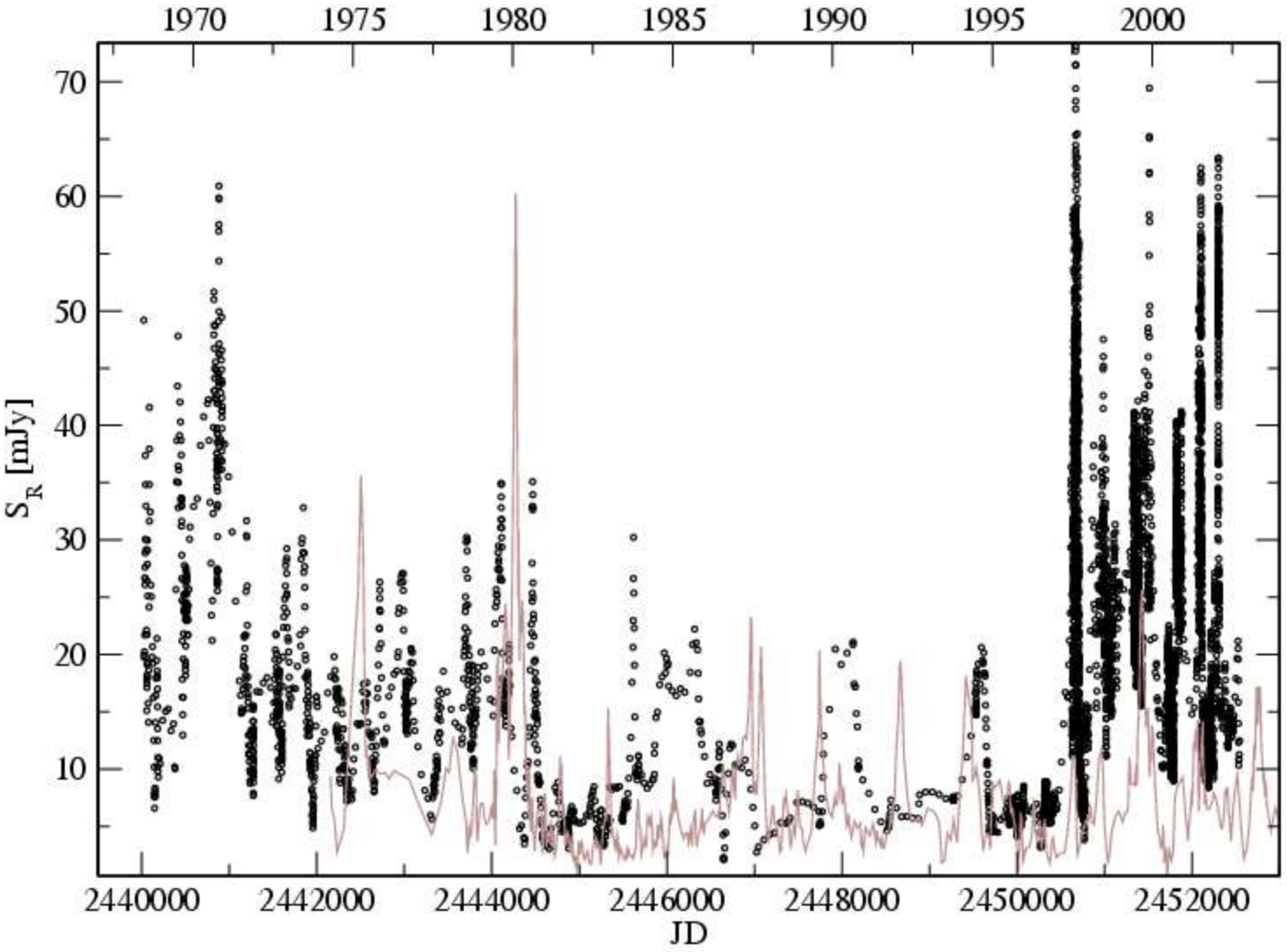


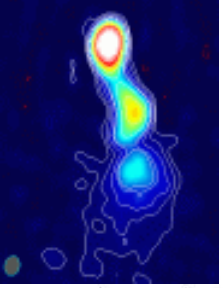
R band-Spectral Index DCF: 1000 Monte Carlo realizations



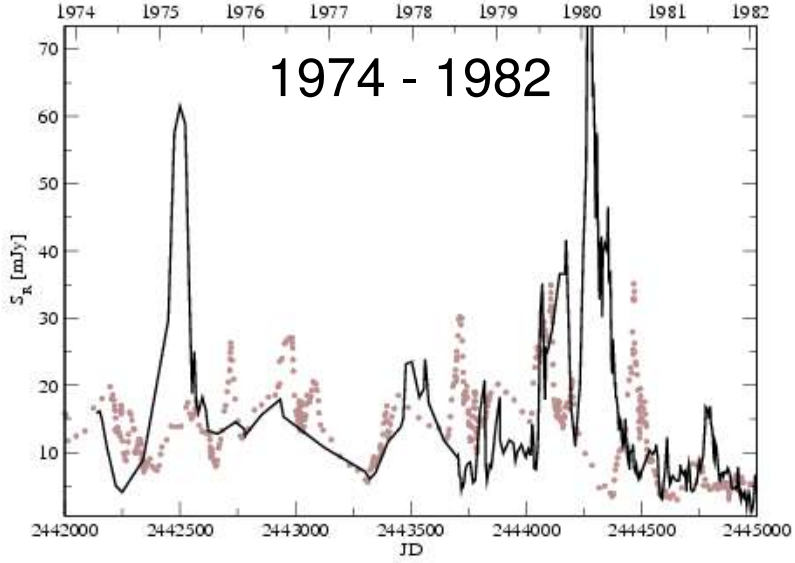


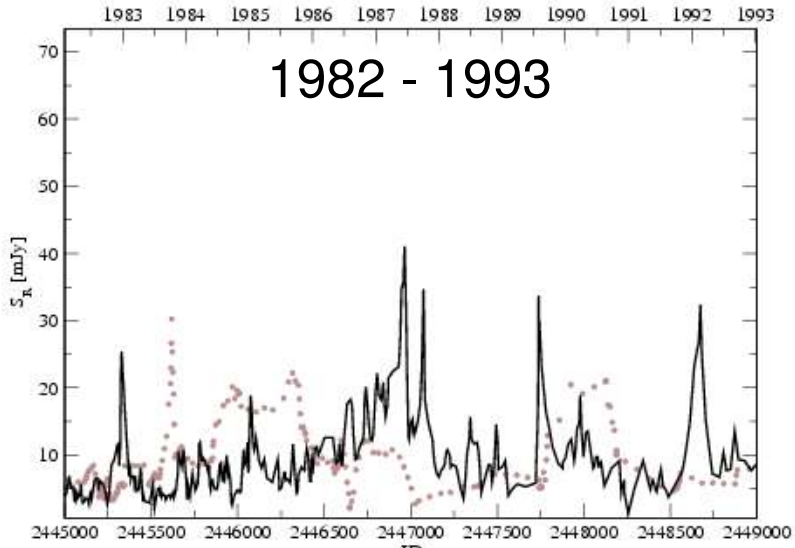
Optical Light Curve

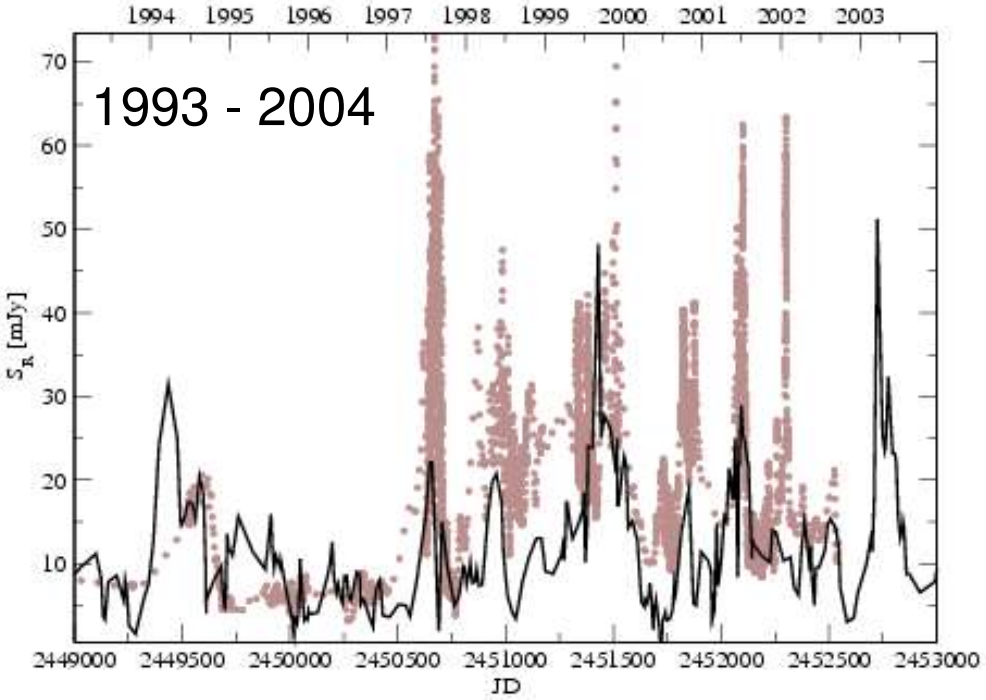


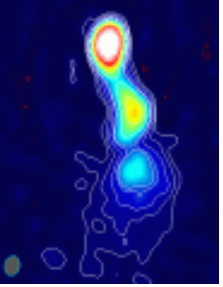


Optical Light Curve

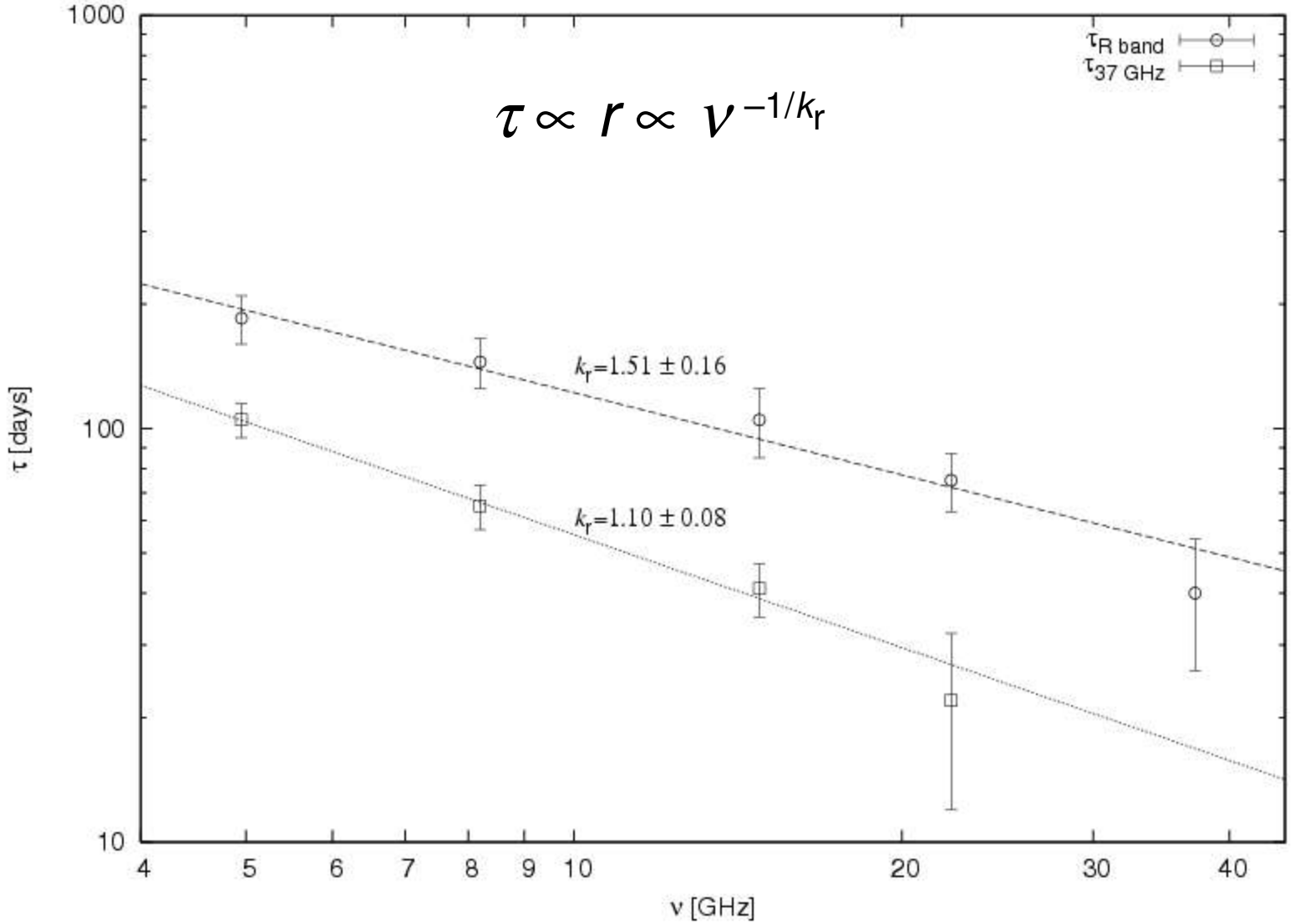


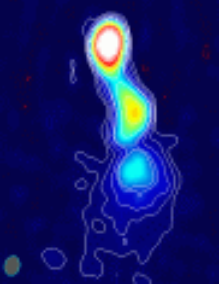




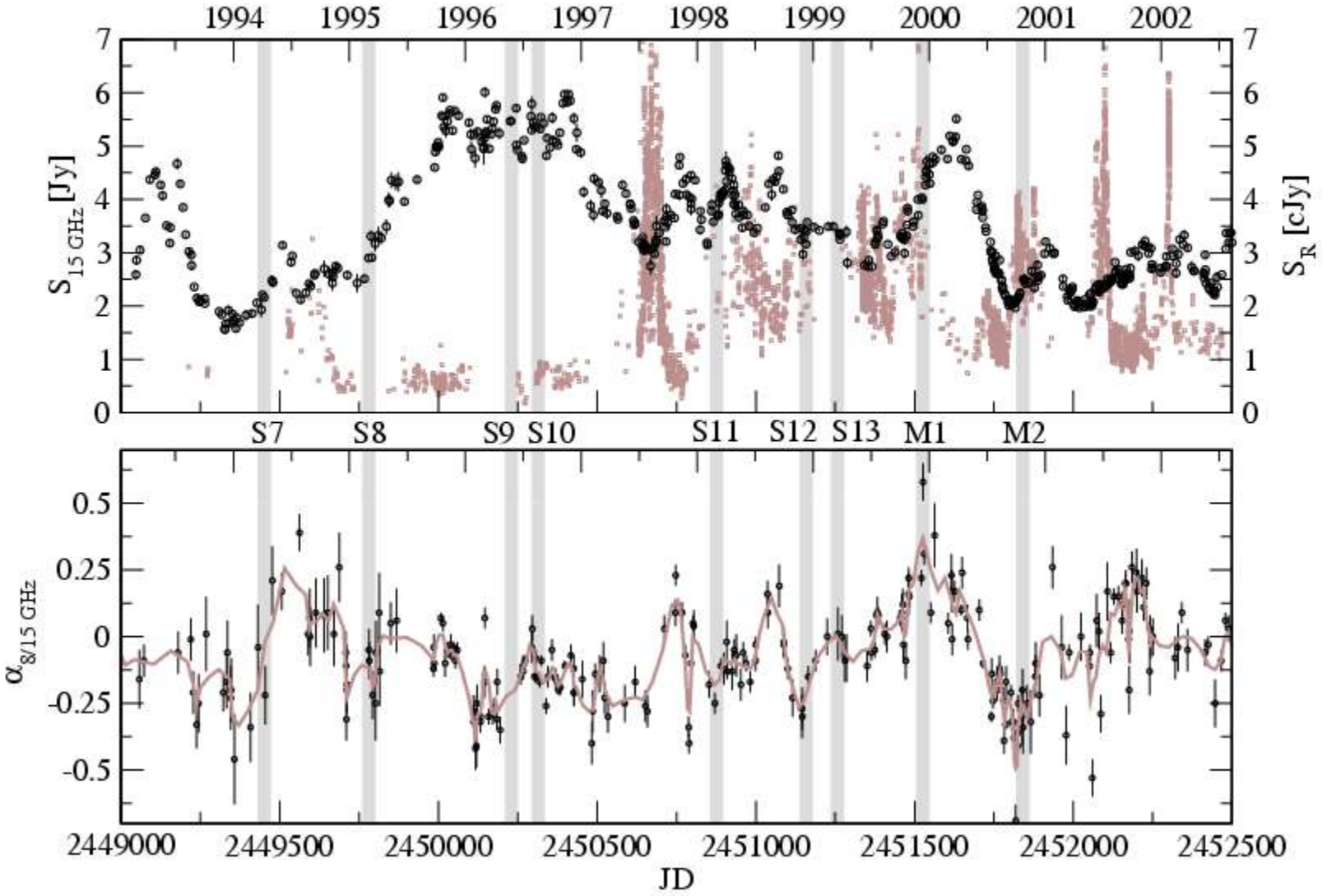


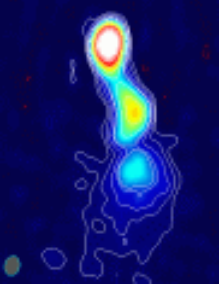
Time Delay vs. Frequency





New Jet Components?



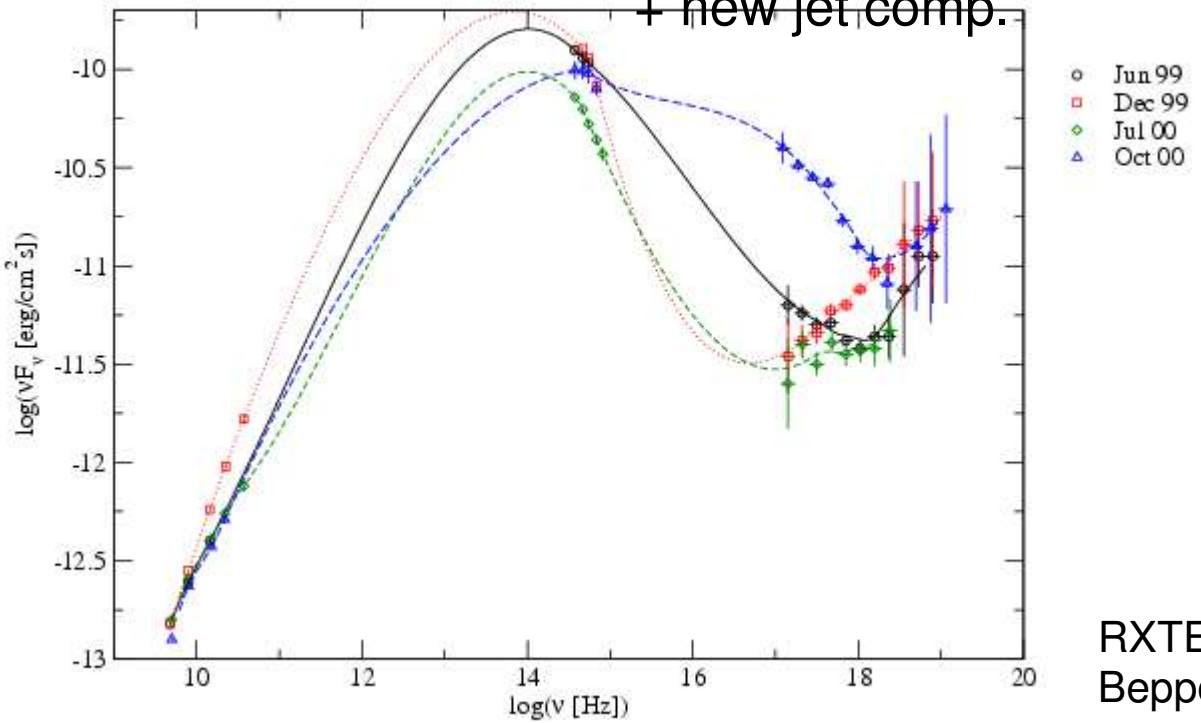


New Jet Components?

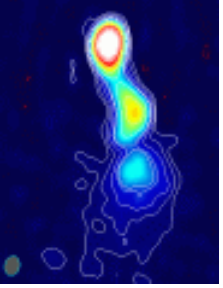
1999.5:
+ X-ray variability
+ soft x-ray spectrum
+ optical flare
+ small radio flare
– no new jet comp.

1999.9:
– no X-ray monit.
+ hard x-ray spectrum
+ optical flare
+ large radio flare
+ new jet comp.

2000.8:
+ X-ray variability
+ soft x-ray spectrum
+ optical flare
+ radio flare
+ new jet comp.

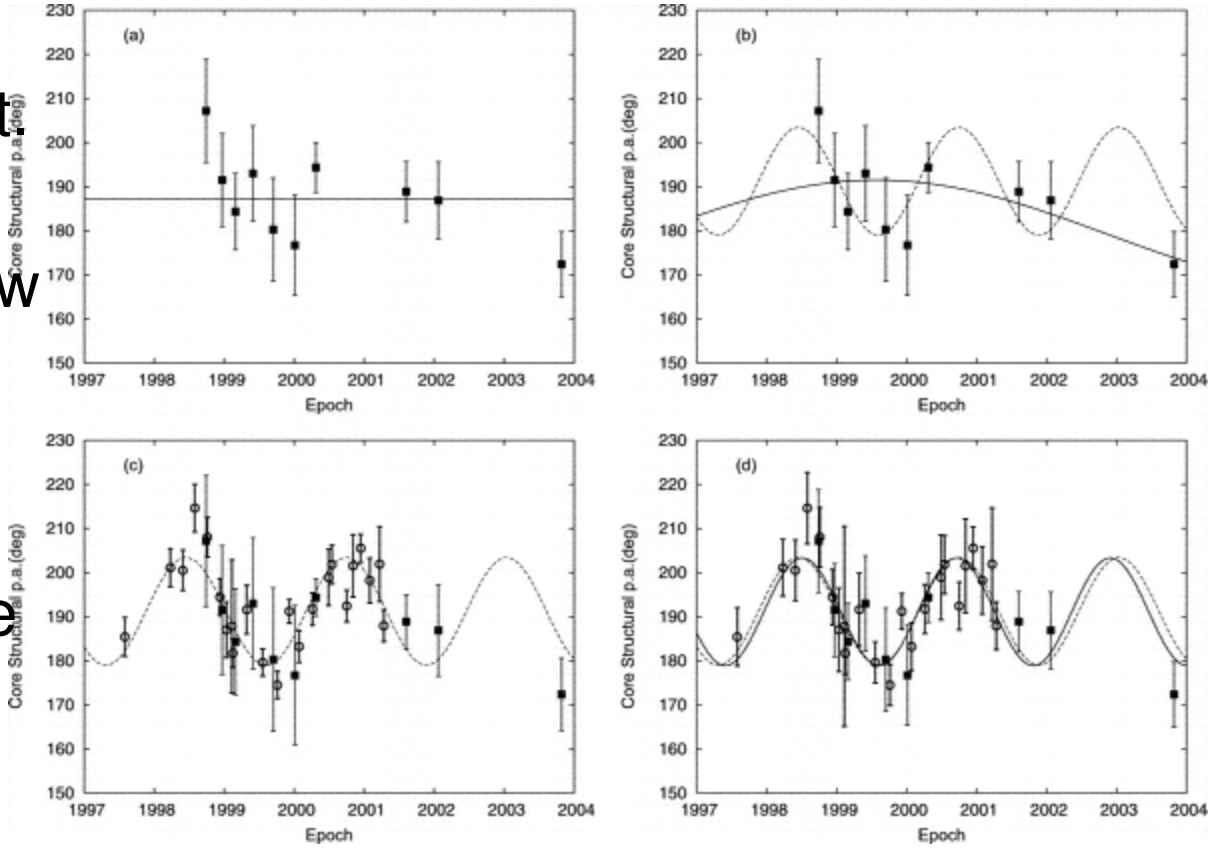


RXTE: Marscher et al. 2003
BeppoSax: Ravasio et al. 2003

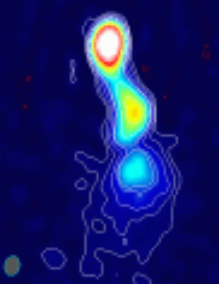


Precessing Jet?

- Sinusoidal variation at the base of the radio jet.
- EVPA at 7mm (VLBI) and at 1mm (HHT) show the same period .
- A precessing jet model with $\beta = 0.989\ c$ and $I = 9.2\ ^\circ$ can predict the component positions in the jet.

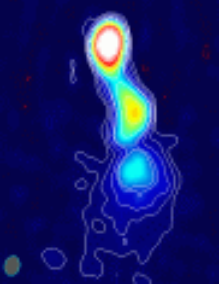


Stirling et al. 2003; Mutel & Denn 2005



Summary

- Single dish light curves are “contaminated” by the appearance of prominent jet components.
- Using only the VLBI core variations yields better correlations with the optical variability.
- Single dish spectral index variations are manly due to the VLBI core variability.
- Optical variations lead the radio ones by 40 to 170 days.
- Power law dependence of τ suggests that the jet is not freely expanding.
- Different time lags and optical variability characteristics can be explained by a precessing helical jet structure.
- Some contemporaneous events from X-ray to radio suggest a connection with newly emerging jet components.



Outlook

Many blazars exhibit similar pc-scale jet structures like BL Lac (e.g., 3C 454.3, 3C 345, OJ287…) and a lot of VLBI data exists on them.

It might be worth to look at this!