International Centre for Radio Astronomy Research

ICRAR is a partnership between Curtin University of Technology and The University of Western Australia

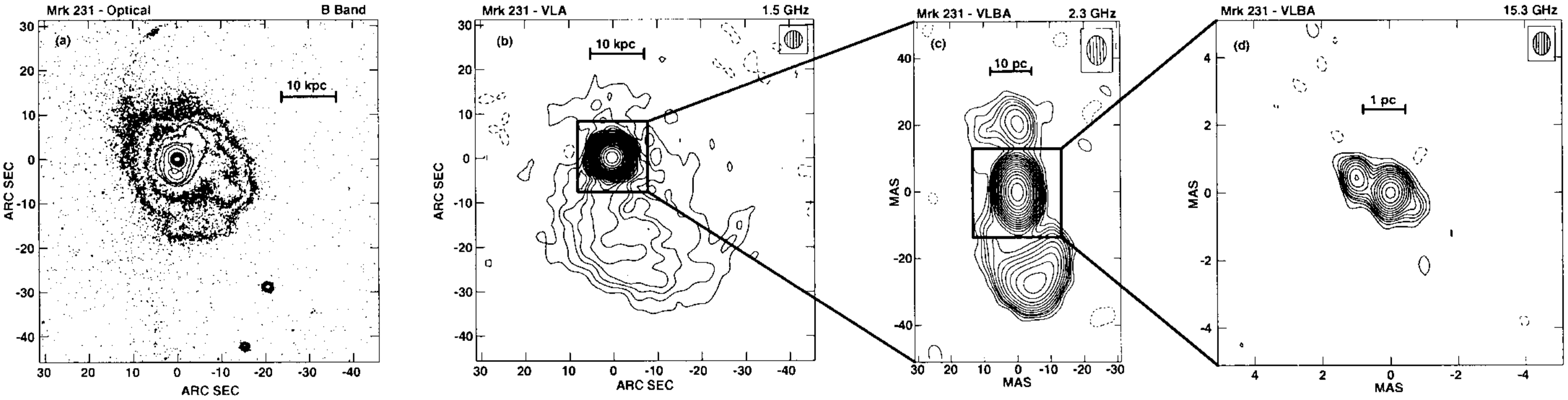
The High Frequency Flares in Mrk 231

Cormac Reynolds, Brian Punsly, Chris O'Dea, Joan Wrobel

Markarian 231

- Broad Absorption Line QSO
- Seyfert I optically
- ULIRG
- Closest radio quiet VLBI target (z=0.042) – 1 mas = 0.8 pc
  - Broad emission lines
  - High thermal luminosity
  - UV broad absorption lines
  - Radio jet
- “The Remarkable Seyfert Galaxy Markarian 231” - Boksenberg 1977

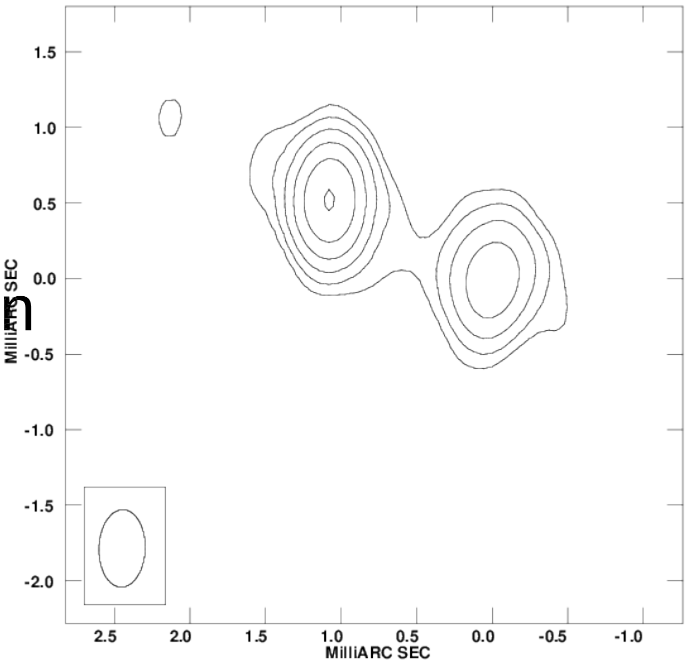
Mrk 231



From Ulvestad et al. 1999

Mrk 231 – The High Frequency VLBI Continuum Source

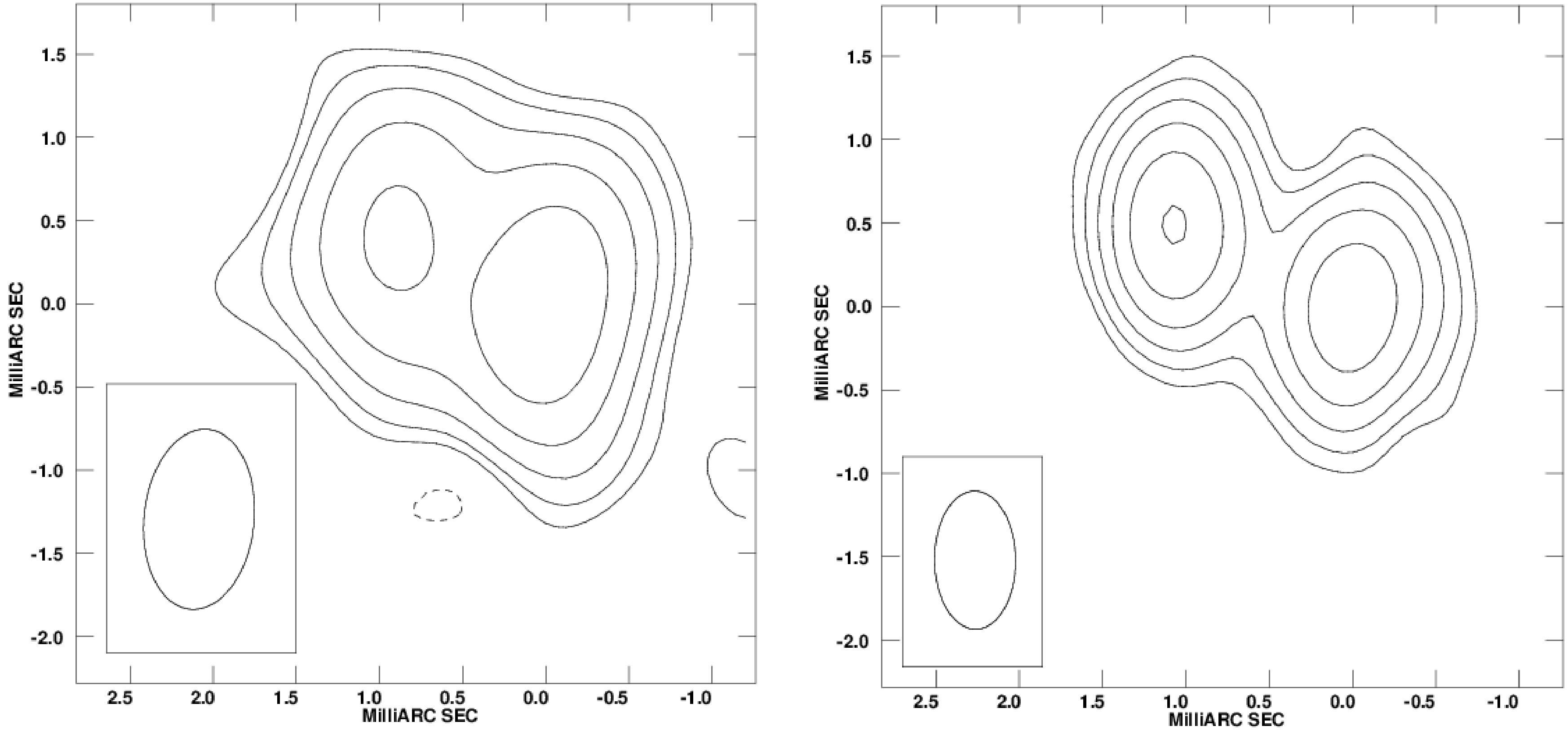
- Double radio source separated by 1 pc
- Apparently single-sided jet, Seyfert galaxy
  - High T_b implies synchrotron
- Good test-bed for testing intrinsic/environmental influences on RQQ
  - Possibility to detect motion of secondary
  - Secondary is slow moving
    - Jet not significantly Doppler boosted?
    - One-sided jet resulting from free-free absorption?



First Epoch High Frequency Observations

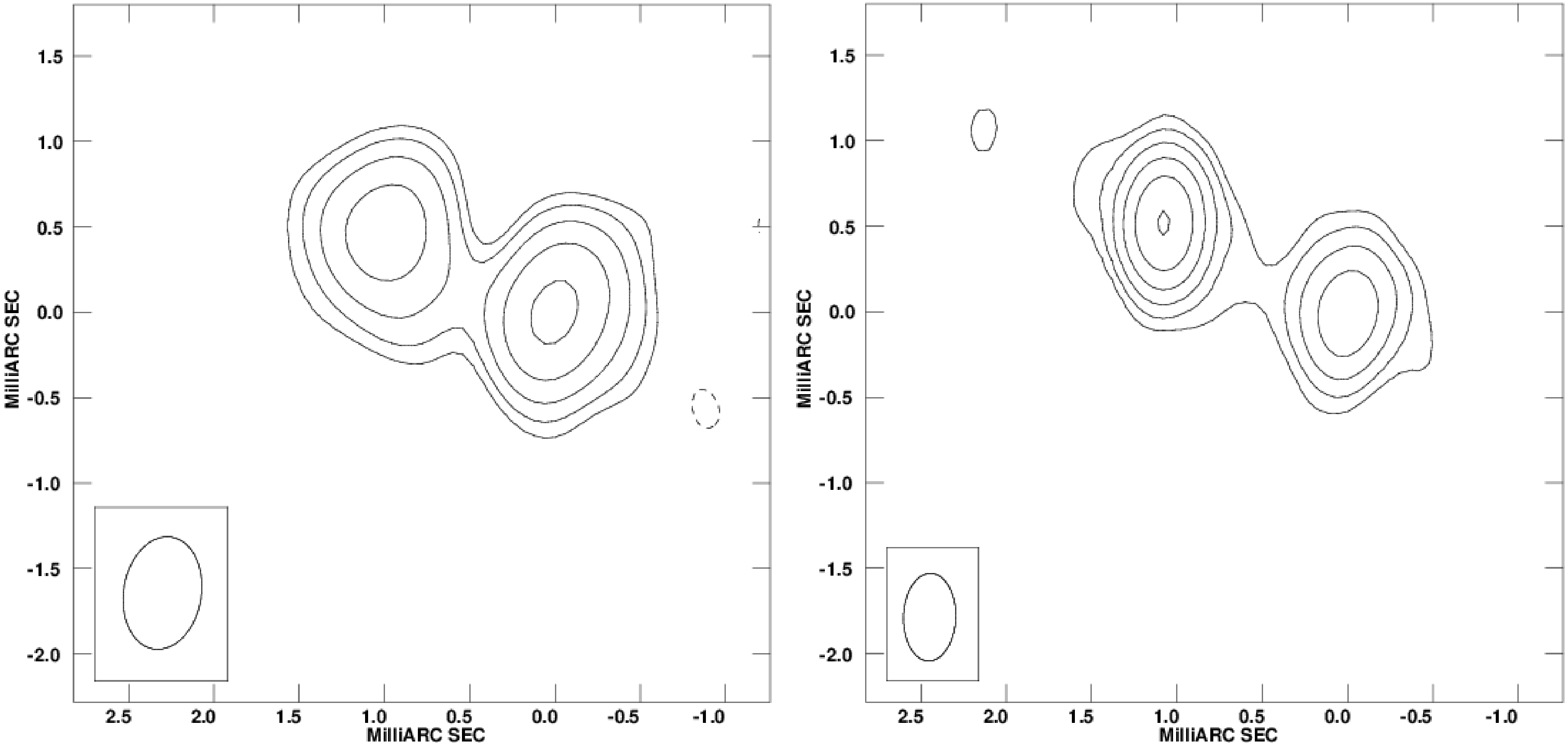
- 15, 22, 43 GHz observations separated by 3 months.
- Phase referenced to J1302+5748
  - Further self-cal possible at all but 43 GHz
- Archival data at 8, 15 and 22 GHz retrieved from the VLBA public archive – 6.6 years
  - Provide additional constraints on long term variability and proper motion
- Calibration and imaging in AIPS, model-fitting in Difmap.

Images – 15 GHz



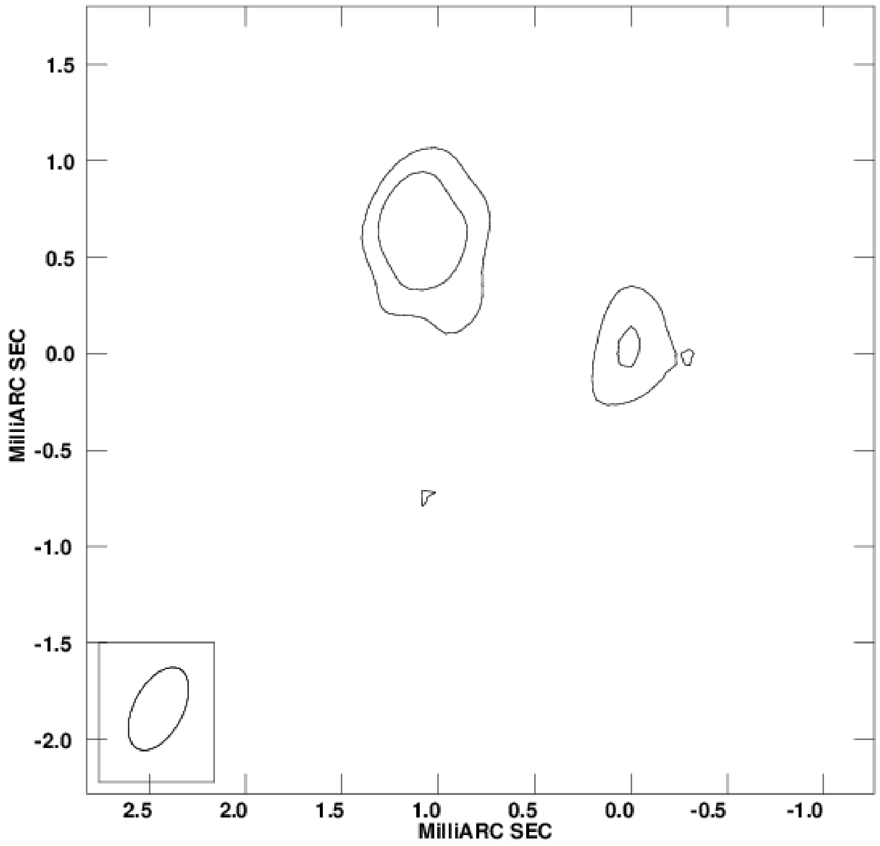
Peak ~ 60 mJy/beam

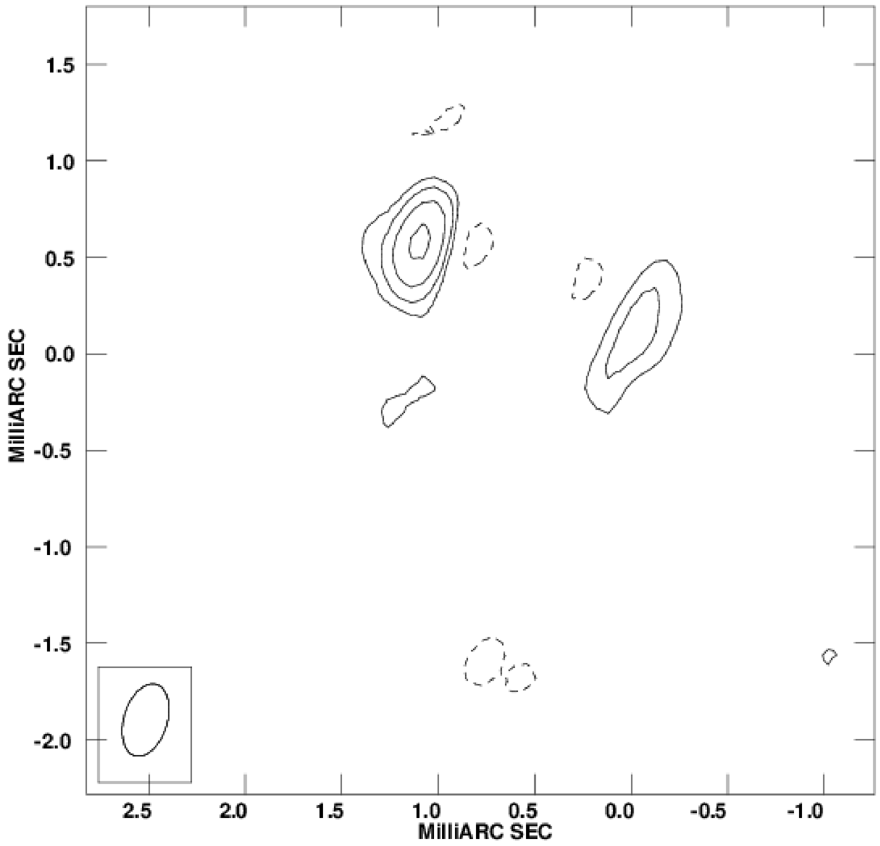
Images – 22 GHz



Peak ~ 60 mJy/beam

Images – 43 GHz





Peak ~ 120 mJy/beam

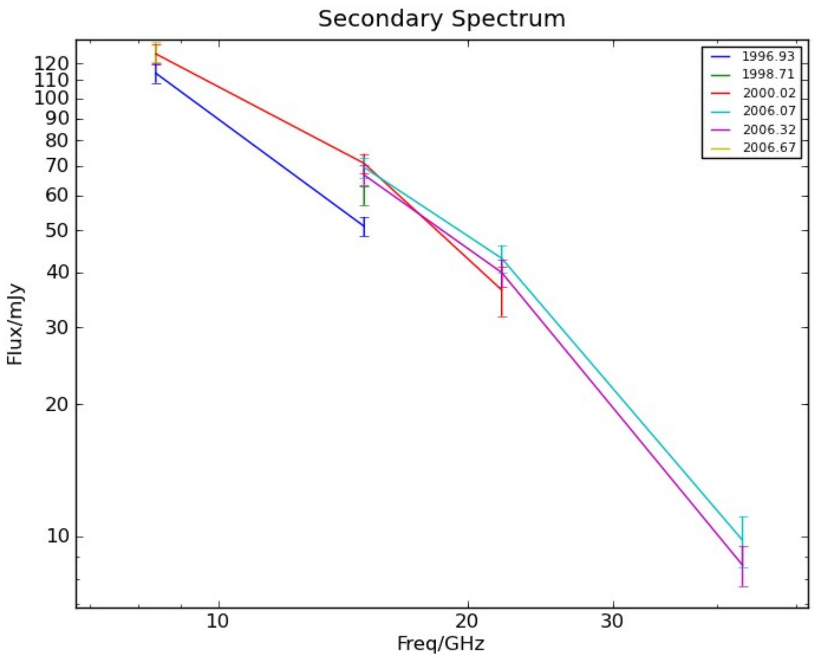
Core – Secondary separation

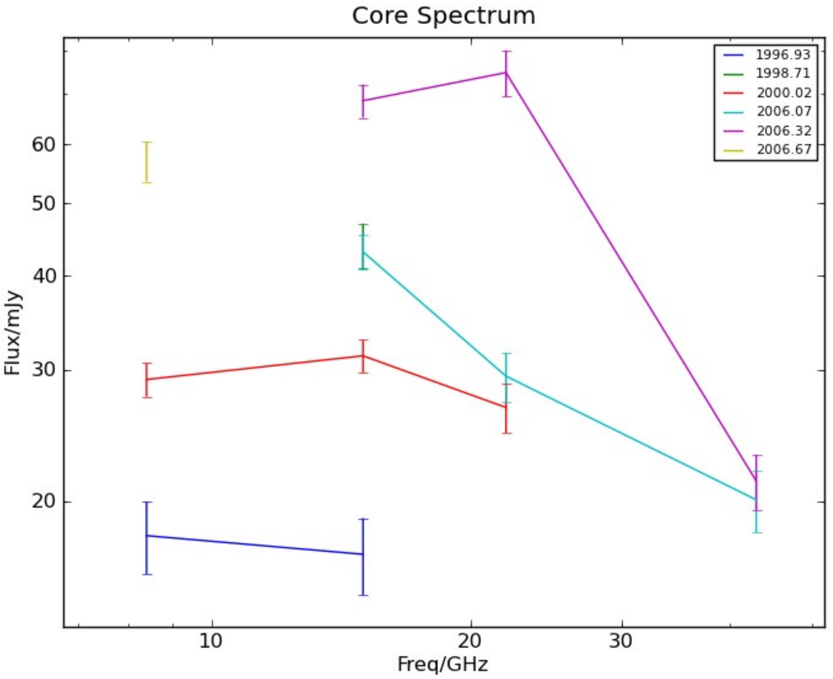
- 10 years of VLBI imaging

Change in Separation:
0.091+/- 0.094 mas
0.026 +/- 0.027 c

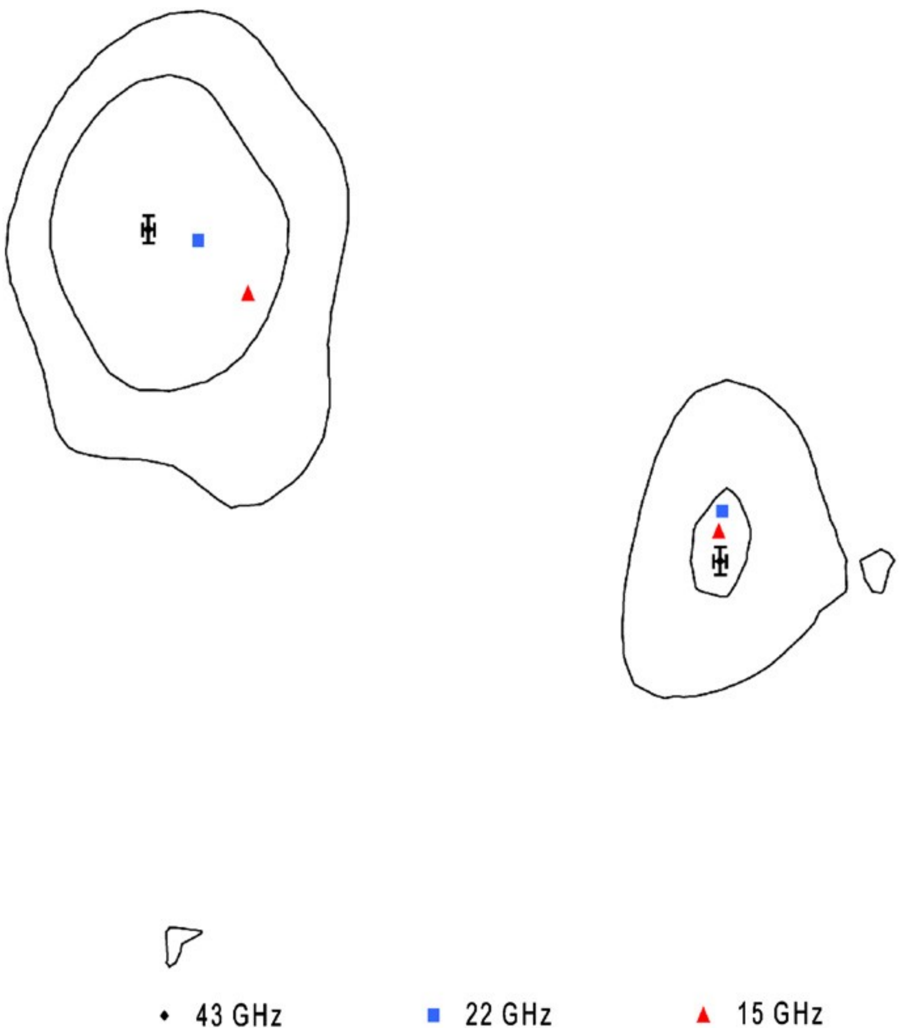
- No evidence for relativistic motion

Core and Secondary Spectra



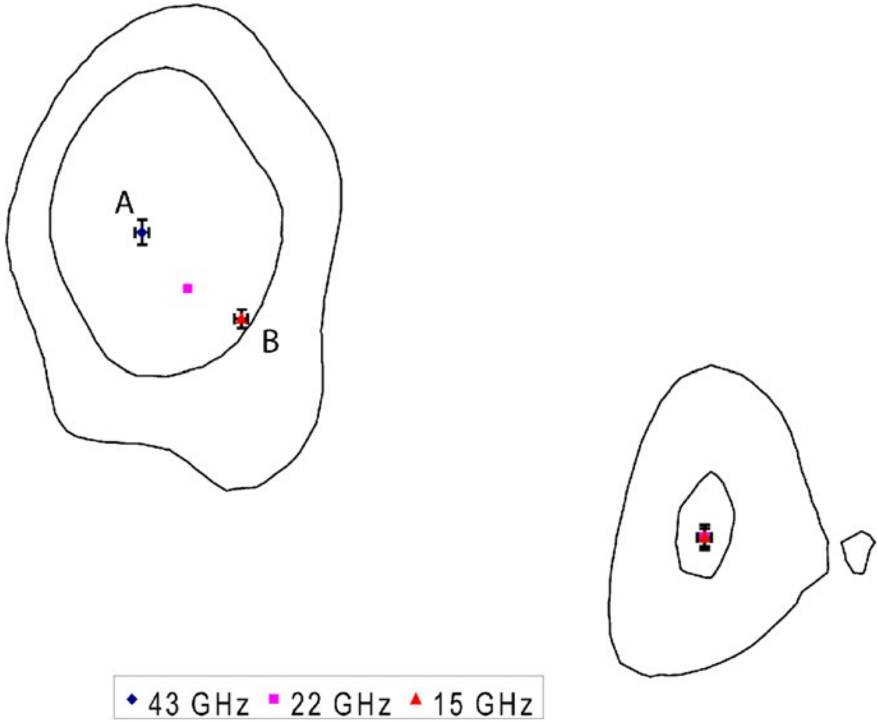


Core Shift (Phase referenced)



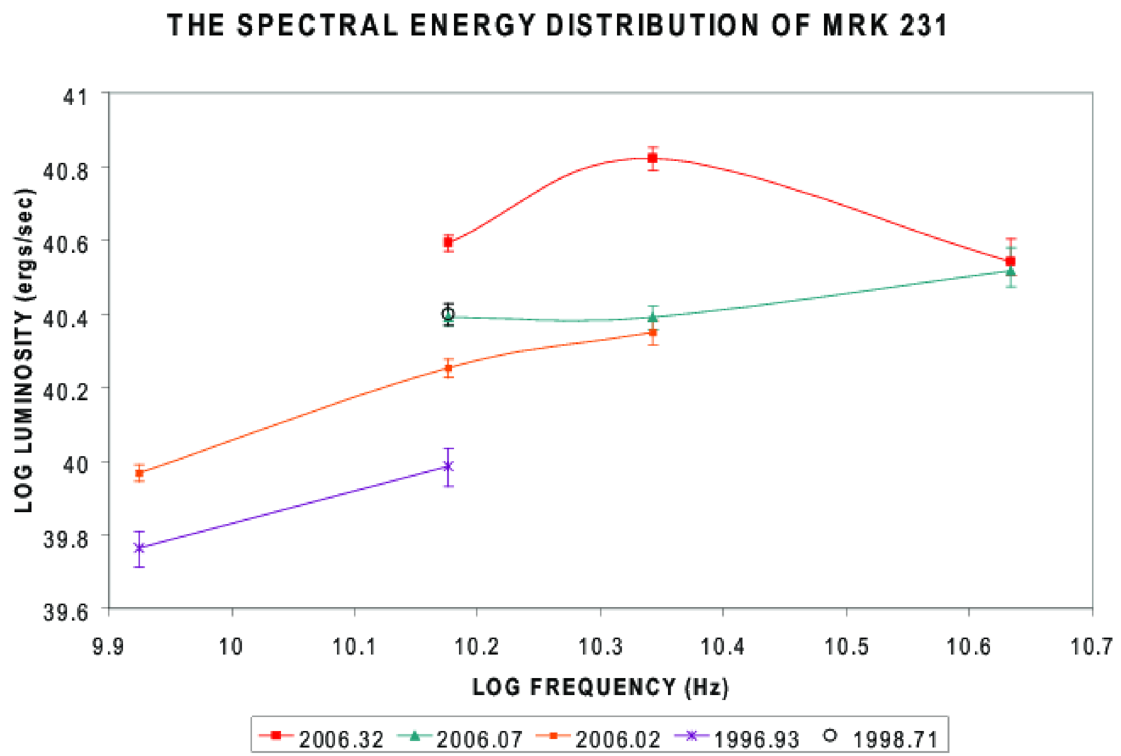
Core Shift (Aligned on Secondary)

- Linear core shift, 15 – 43 GHz (2006.02)
  - But 22 GHz is optically thin
- Interpret as substructure in core
  - Optically thick + very steep spectrum component
- Extremely efficient cooling mechanism required to produce the very steep spectrum component.



Radio SED

- 2006.32 flare has unusual spectrum
  - Cannot model as FFA for reasonable gas temperatures
- SSA models can be found with plausible physical parameters
  - B ~ a few Gauss



Synchrotron Cooling Models

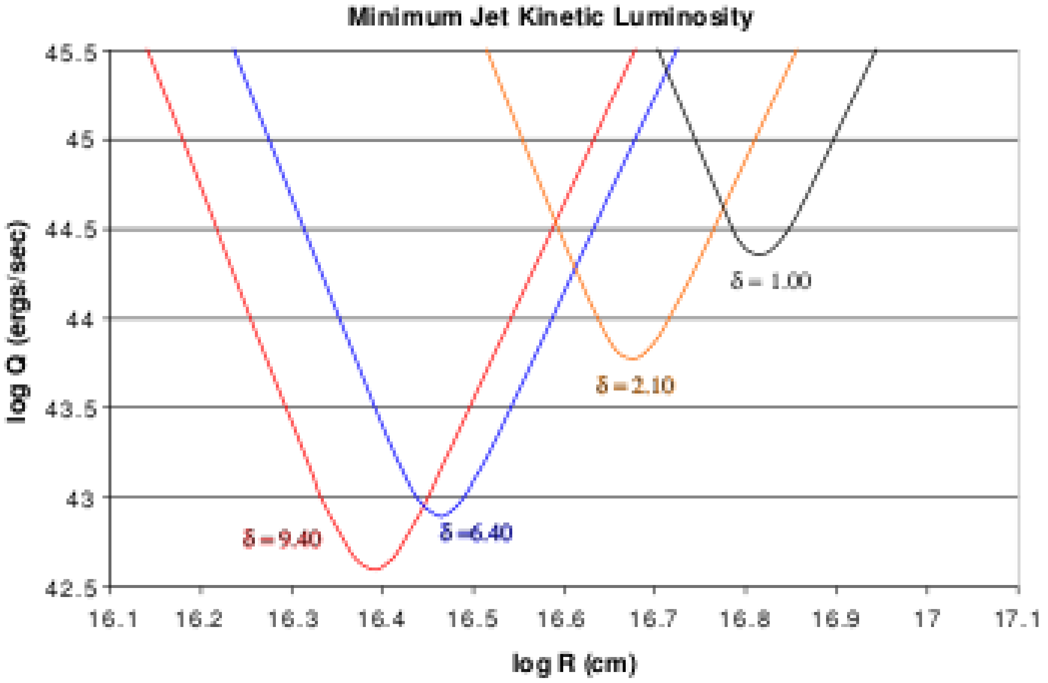
$$\frac{L_{\rm ic}}{L_{\rm synch}} \sim \frac{10^{44}\ {\rm erg\ s^{-1}}}{10^{41}\ {\rm erg\ s^{-1}}} = 10^3\ .$$

$$\frac{L_{\rm ic}}{L_{\rm synch}} = \left(\frac{T_b G(\alpha, z)^{1/5}}{10^{12.22}}\right)^5 \left[1 + \left(\frac{T_b G(\alpha\ , \ z)^{1/5}}{10^{12.22}}\right)^5\right]$$

$T_b \sim T_{max}$ for $\delta = 1$

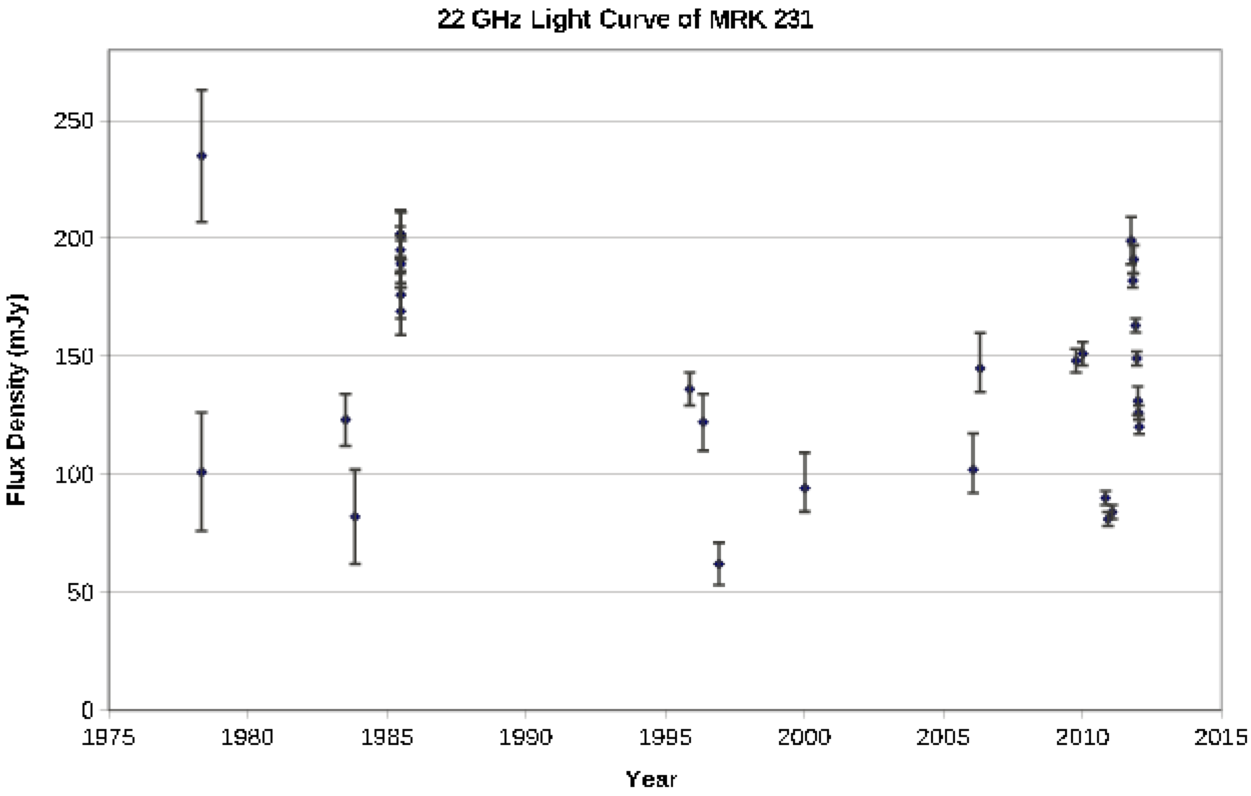
Mrk 231 not strong X-ray source

$L_{ic}/L_{synch} = 10e8$ at Q_{min}

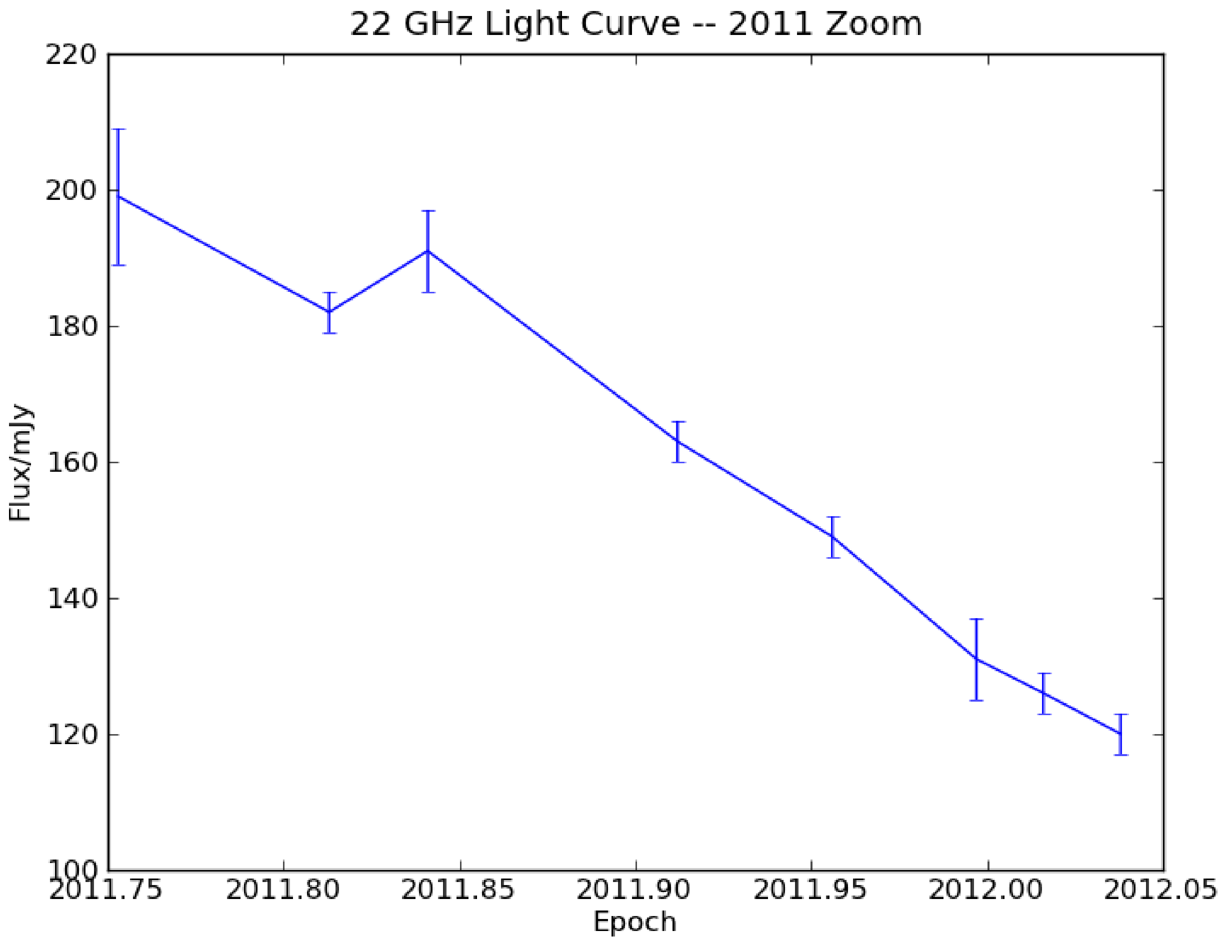


How Common Are These Flares?

VLA – Historical plus recent monitoring campaign



VLA Light Curve – 2011 Flare



Summary

- Emission from Mrk 231 is significantly Doppler boosted
  - Relativistic jet viewed pole on
  - Another RQQ displaying outflow with high kinetic luminosity
- Rapidly evolving flares, with no obvious structural changes
- Rapid cooling, consistent with synchrotron ageing, with strong B field
- Flares are frequent, and VLBI monitoring will allow us to test the cooling models
- Potential probe of the X-ray emitting gas, X-ray absorbing gas and Broad Absorption Line wind in an RQQ