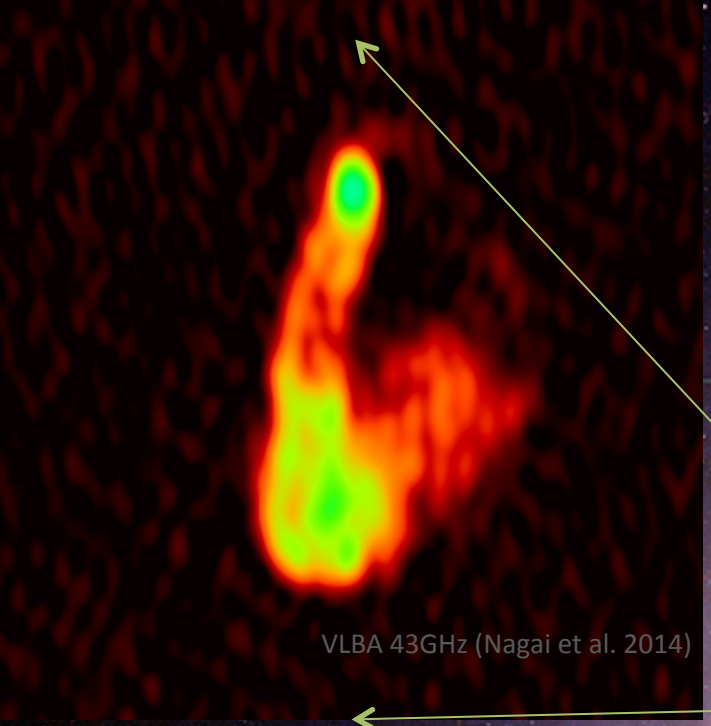

5th CSS-GPS workshop
Rimini, Italy

Long-term Radio and Gamma-ray Properties of 3C 84

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National Astronomical Observatory of Japan

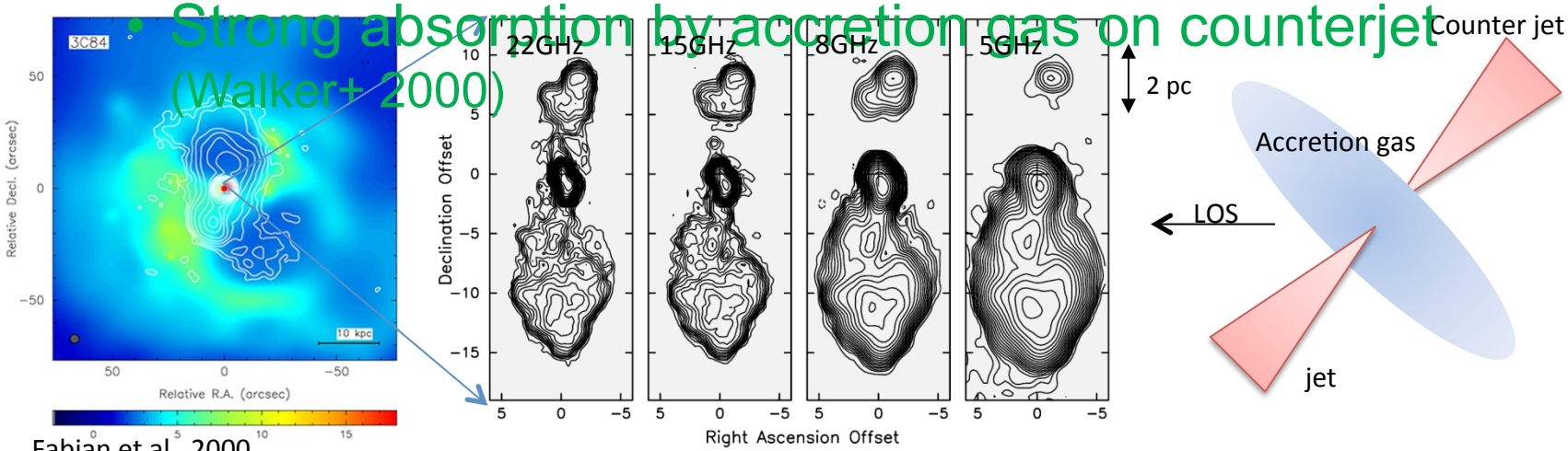
ESA/Hubble

Since last GPS-CSS workshop…

- Big change 1: re-started jet activity in 3C 84
  - New prominent component shows a monotonic flux increase and subluminal motion
    - Consistent with “mini-lobe”-like properties
- Big change 2: gamma-ray detection
  - No clear radio counterpart associated with short-term gamma-ray flares
    - Stratified jet or flare region embedded in optically-thick radio core
  - Correlation between radio and gamma-ray light curves on the timescale of years
    - Gamma-ray emission from young radio source?

3C 84

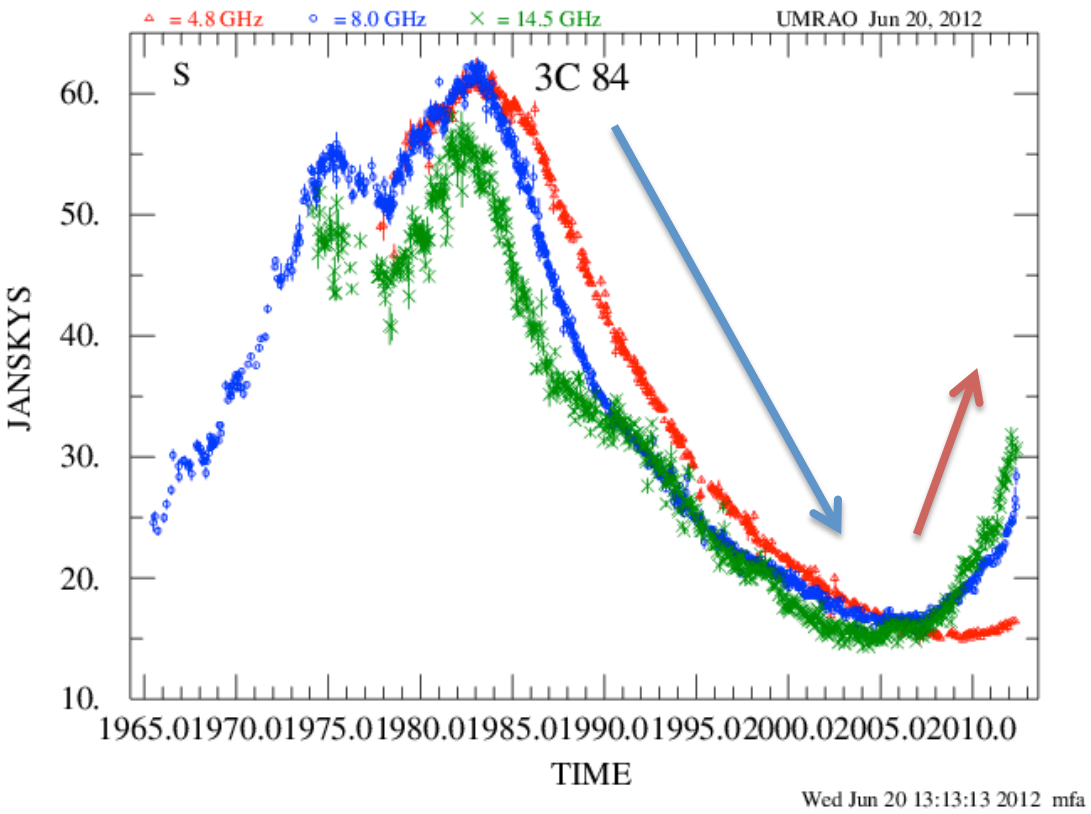
- Bright radio source associated with giant elliptical/radio galaxy NGC1275
- Not GPS/CSS
  - But, central parsec radio structure shows GPS/CSO-like properties (as mentioned by Kino. M)
    - mini-lobes formed by re-started jet since 1959 (O'Dea+ 1984)
    - Strong absorption by accretion gas on counterjet (Walker+ 2000)



Fabian et al. 2000

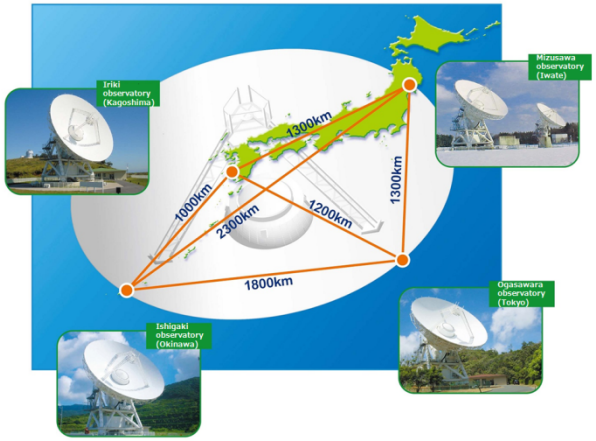
Walker et al. 2000

3C 84

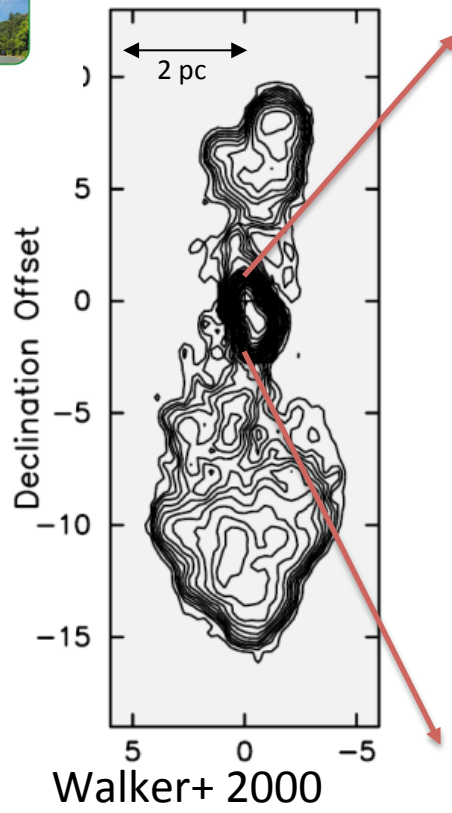


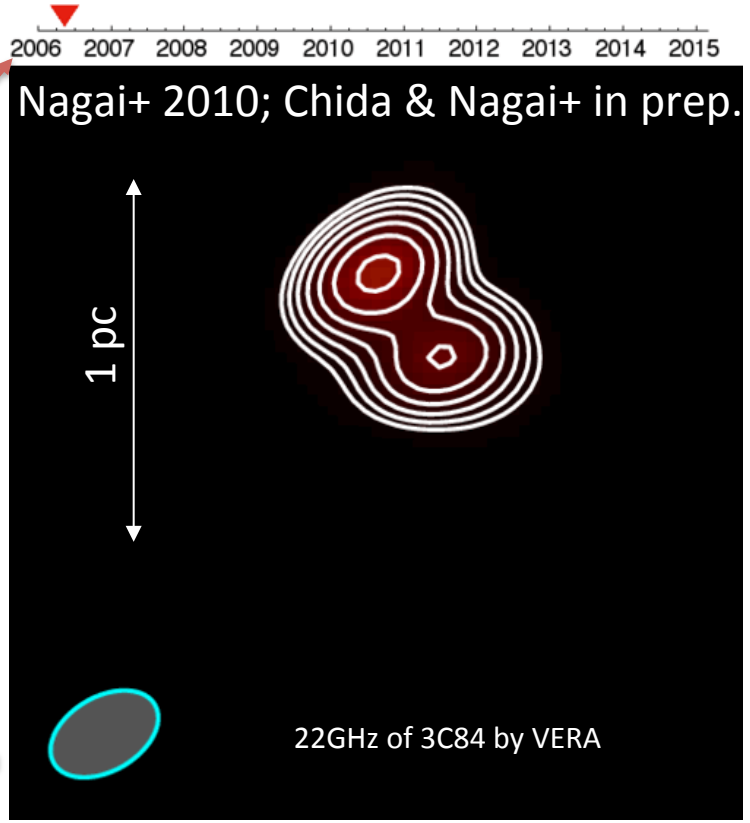
- Jet activity was decreasing after 1985
- Re-activated since ~2005
  - No one noticed this at the time of 4th GPS-CSS workshop!

3C 84



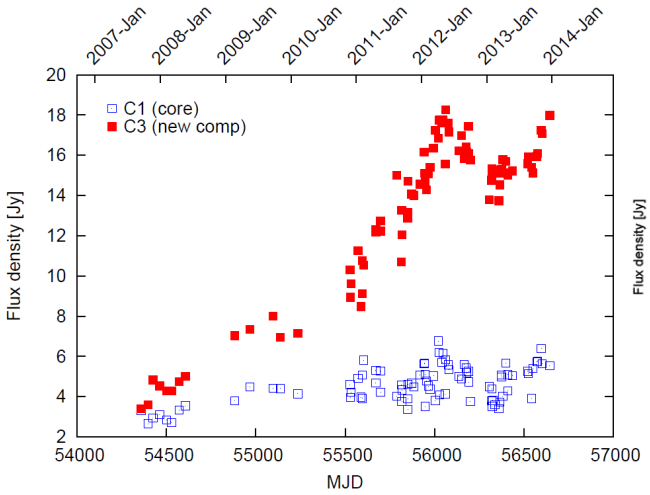
- VERA (Japanese VLBI array)
- AGN jet monitoring program: GENJI
  - by-weekly monitoring of 10 AGN jets (Nagai+ 2013)



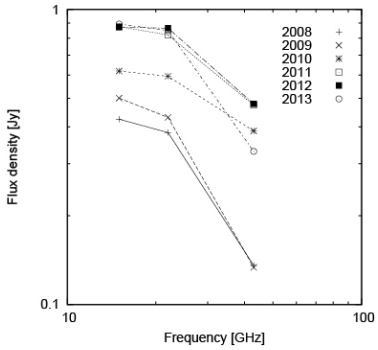


What is the nature of new component?

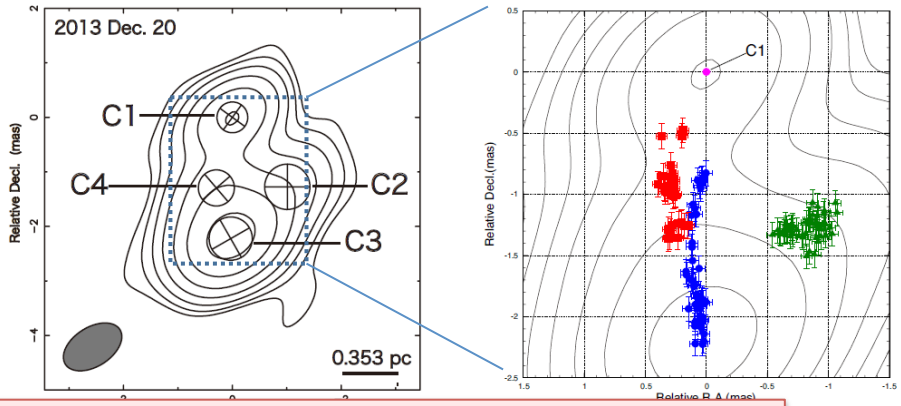
- Monotonic flux increase with optically thin spectrum
  - Need injection of fresh electrons
- Subluminal motion
  - Relative apparent speed ~0.3c
  - Comparable to CSO hotspot speed



Chida, Nagai+ in prep.

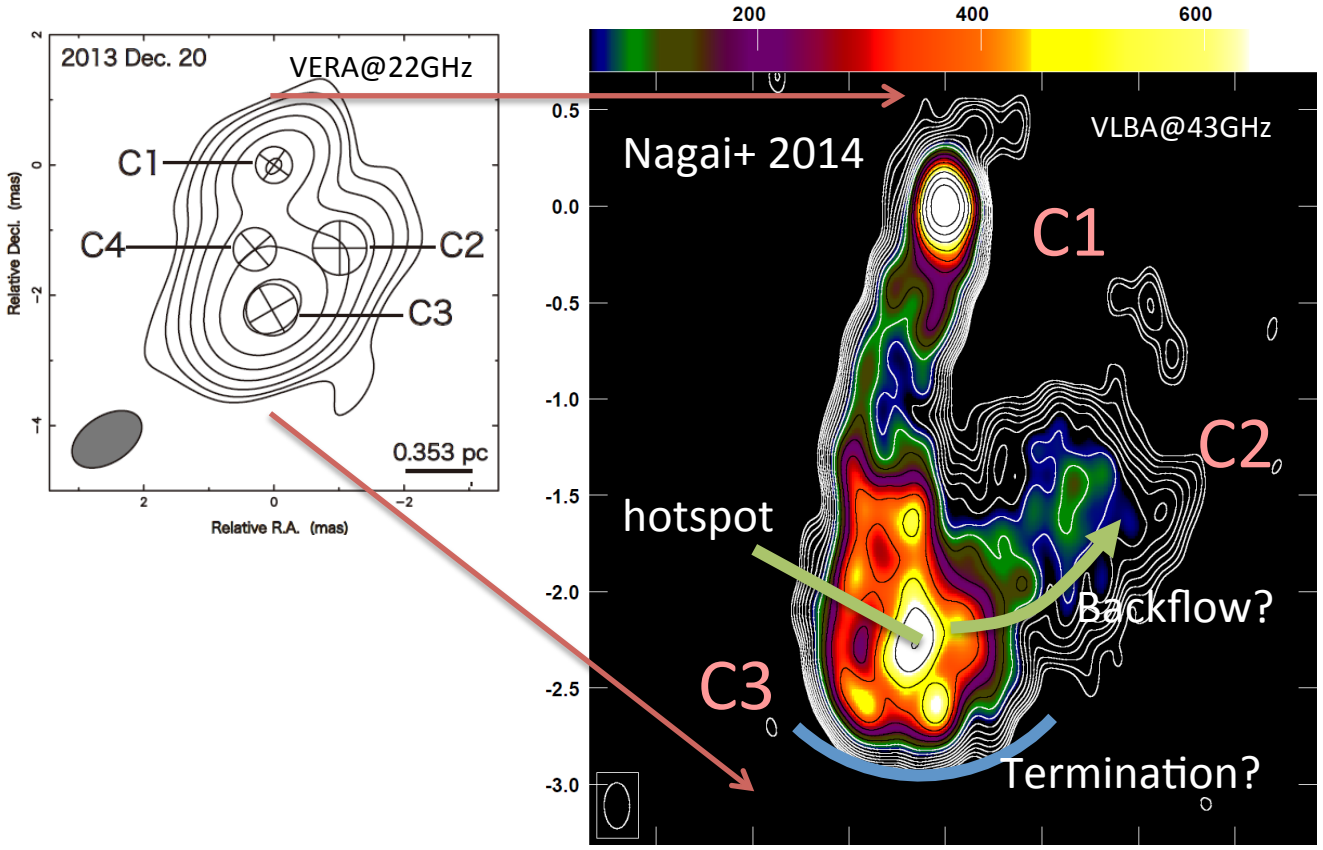


Hiura, Nagai+ in prep.

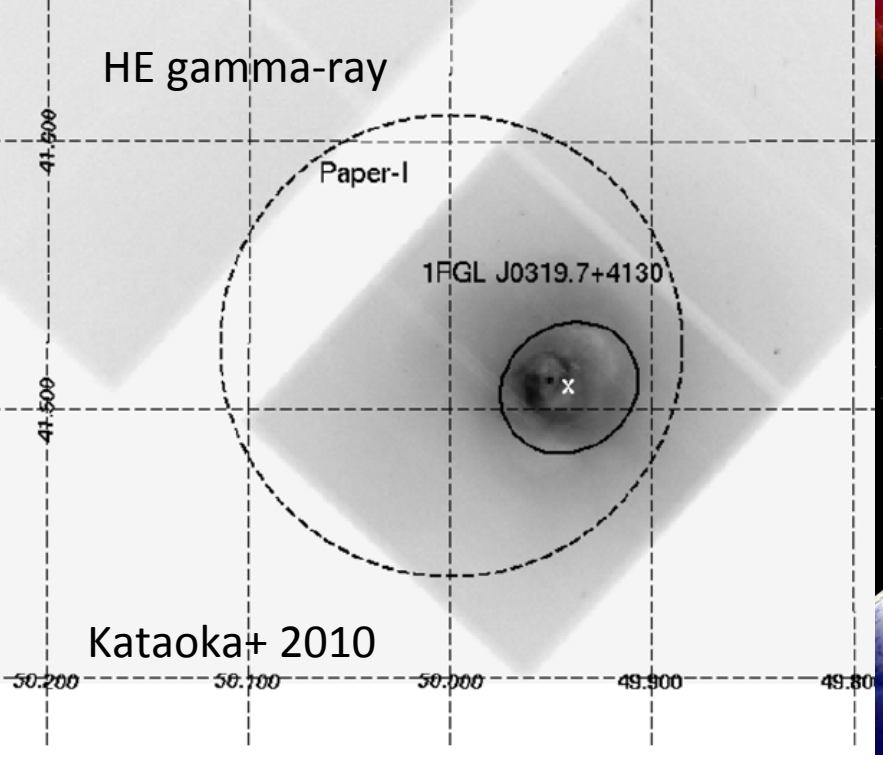


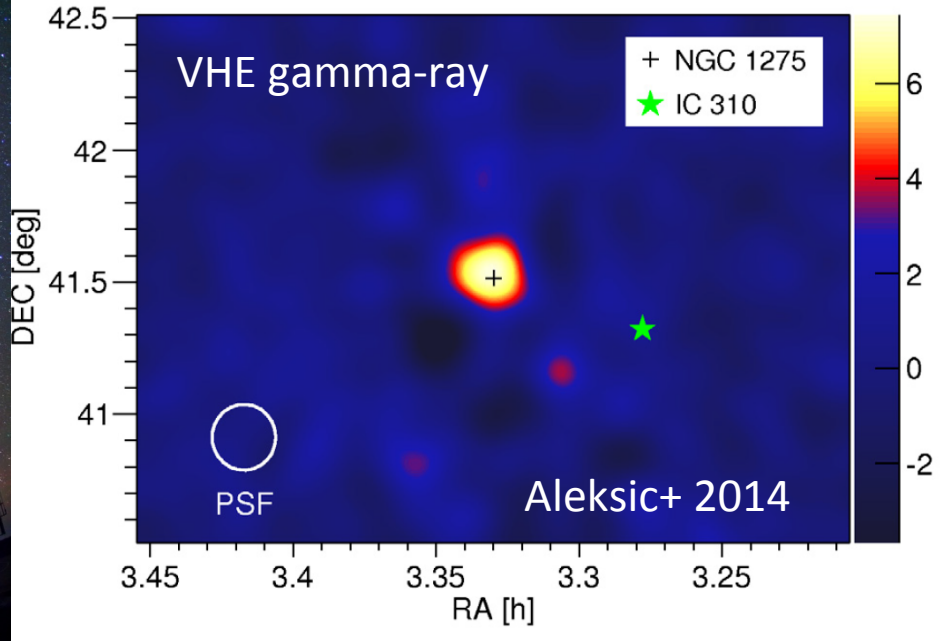
Not blazar-like component, but mini-lobe/hotspot

High Resolution Image of 3C84

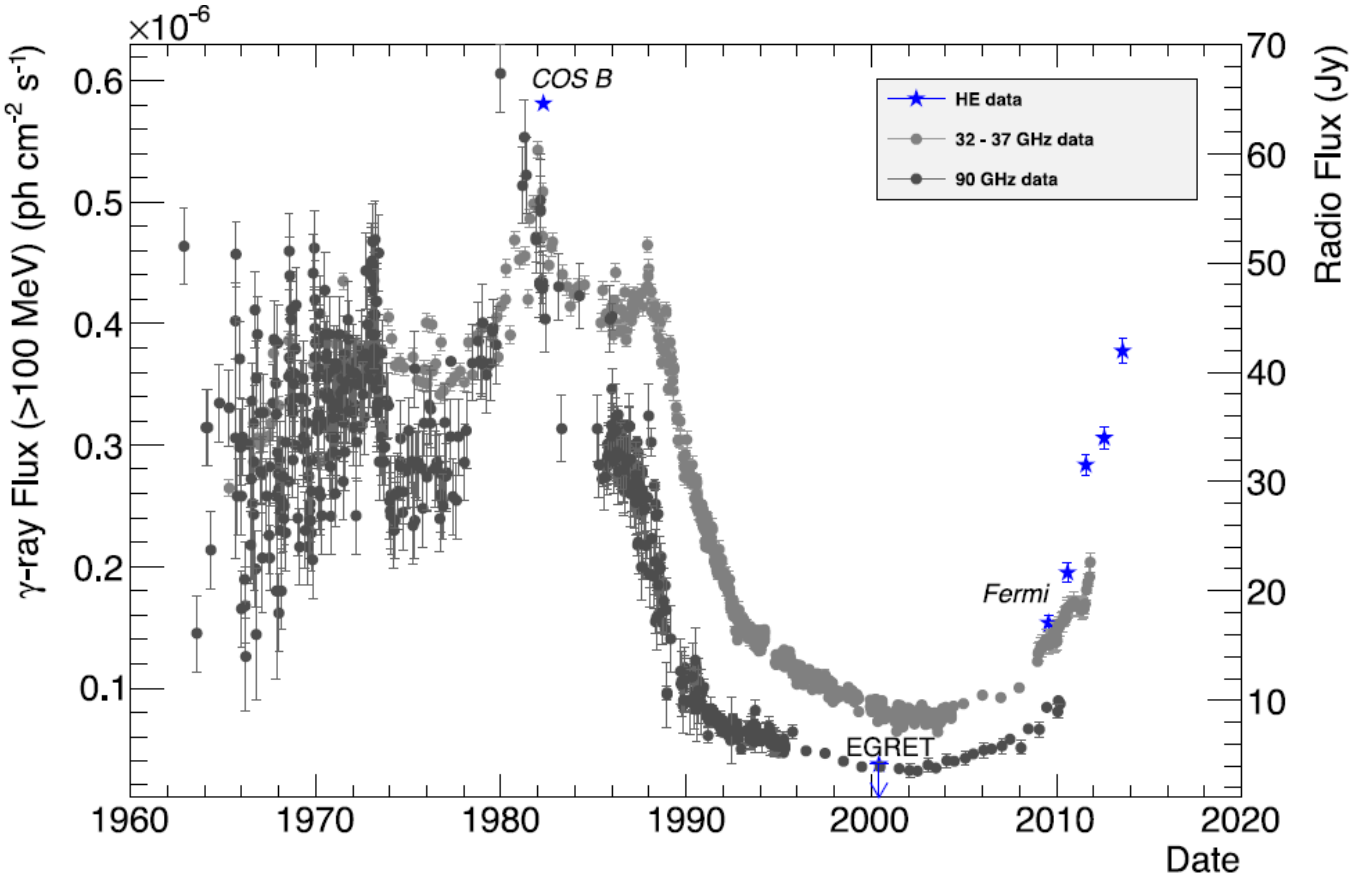


- Rare opportunity to study the lobe formation at very early stage (t_{dyn}~10 yr)
- Important to do further monitoring


HE gamma-ray
Paper-I
1FGL J0319.7+4130
41.500
41.500
50.200
50.100
50.000
49.900
Kataoka+ 2010


VHE gamma-ray
NGC 1275
IC 310
PSF
Aleksic+ 2014
42.5
42
41.5
41
DEC [deg]
3.45
3.4
3.35
3.3
3.25
RA [h]
6
4
2
0
-2

Radio – Gamma-ray connection

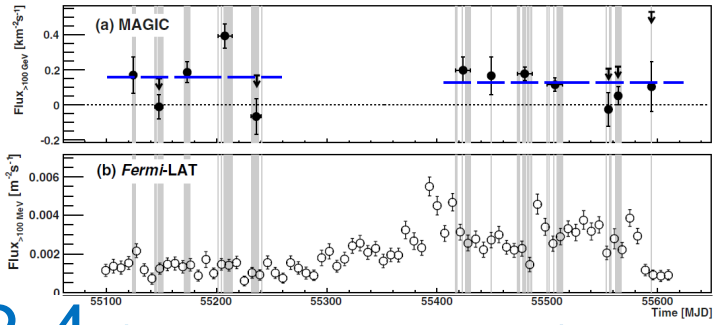


Dutson+ 2014

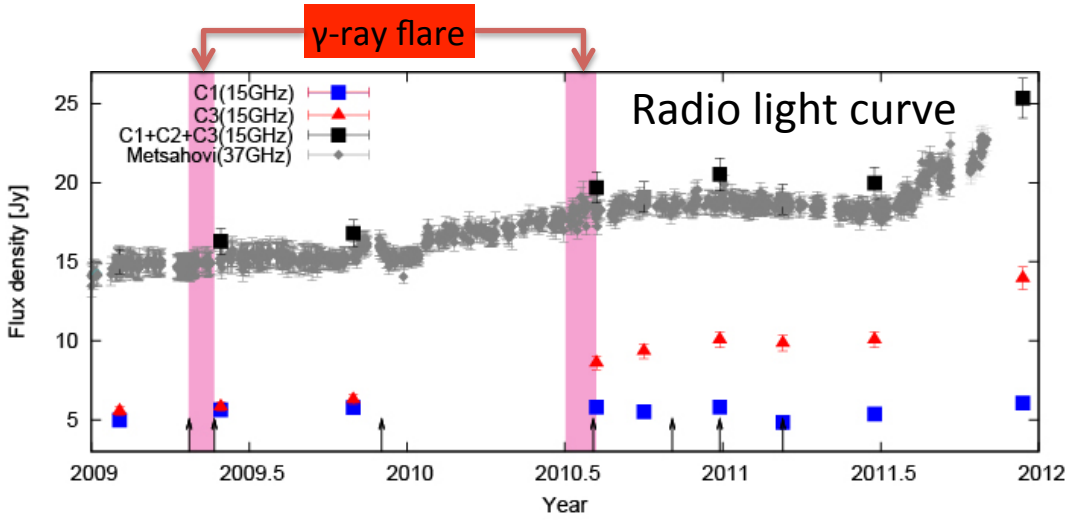
- Gamma-ray emitting region is likely to be associated with the site of radio brightening

Where is the gamma-ray emitting region?

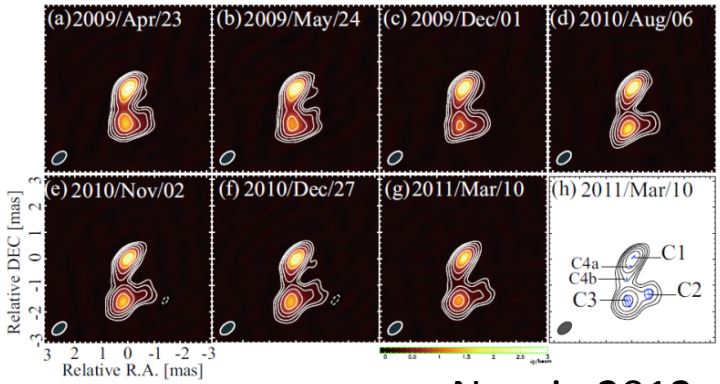
- Gamma-ray time variability
  - t_{var}~1 week at LAT band
  - $R<ct_{var}\delta \sim c\delta \times 10^{16}$ cm
- SED modeling suggests δ=2-4 (e.g., Aleksic+ 2014)
  - Mildly relativistic mini-jet required
- But, no core-brightening / jet ejection associated with short-term gamma-ray flares



Aleksic+ 2014



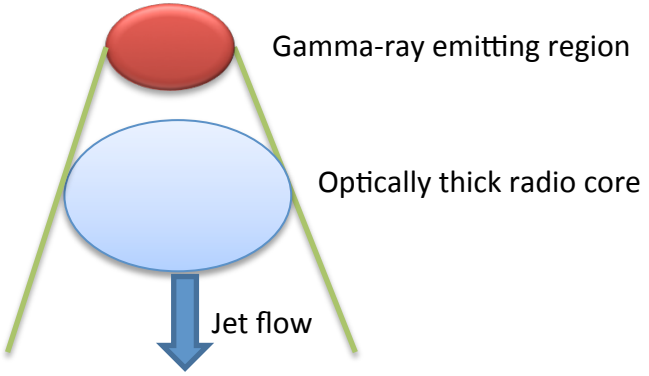
VERA at 43GHz



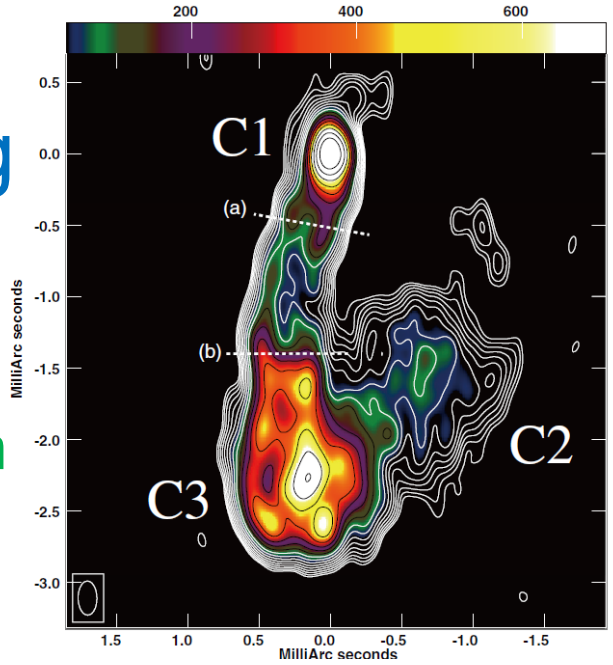
Nagai+ 2012

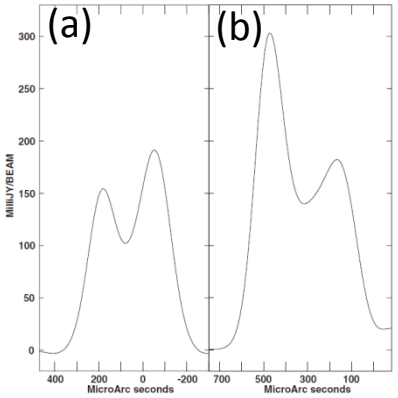
Why no radio counterpart of short-term flare?

1. Gamma-ray emitting region embedded in the optically thick core



2. Multi-zone emitting model
   - e.g., spine-sheath
     - Radio: slow sheath
     - Gamma: slow sheath+fast spine

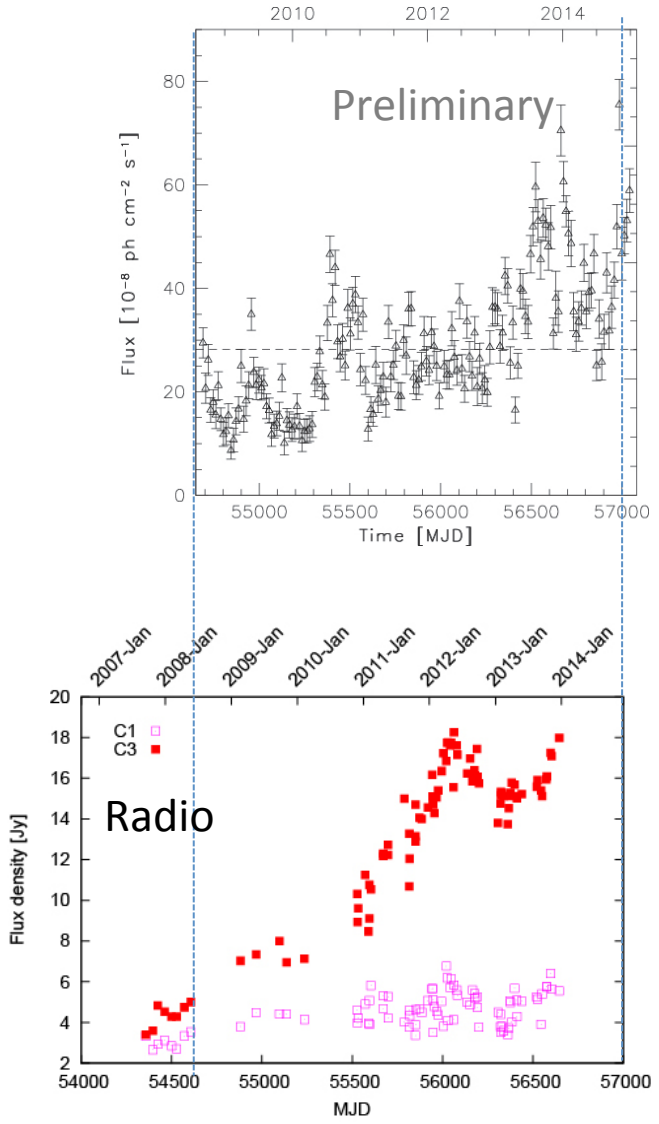




Long-term γ-ray variation

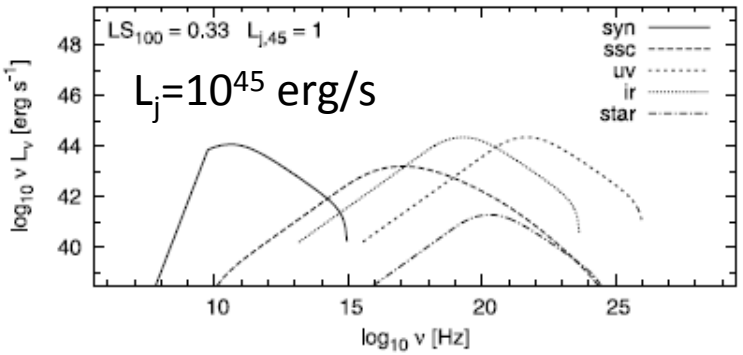
- Gamma-ray flux increases on the timescale of years
  - Composite of multiple mini-jet flares unlikely
  - Larger-sized emitting region favored
- C3 shows a radio flux increase on similar timescale
  - Signature of gamma-ray emission associated with

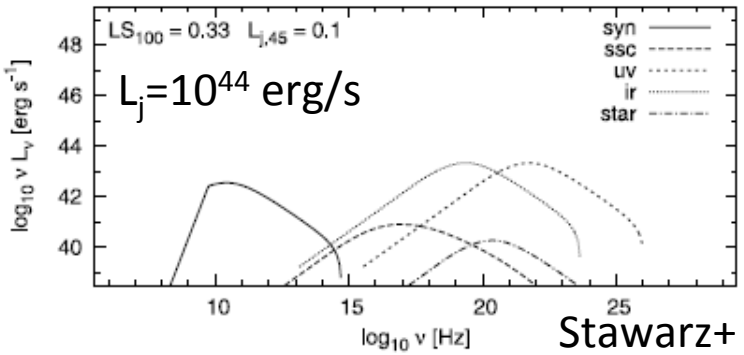
LAT light curve (Analysis by F. D'Ammando)



Gamma-ray emission model from YRS

- HE emission by IC of various surrounding photon fields by mini-lobes' electrons (Stawarz+ 2008)
  - LS=33pc, 100pc, 1kpc
- If $L_j=10^{45}$ erg/s, the model is accountable for the c 0^{44} ϵ

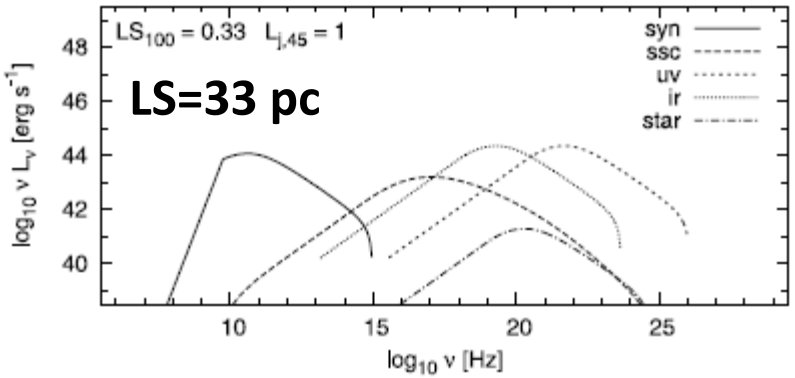


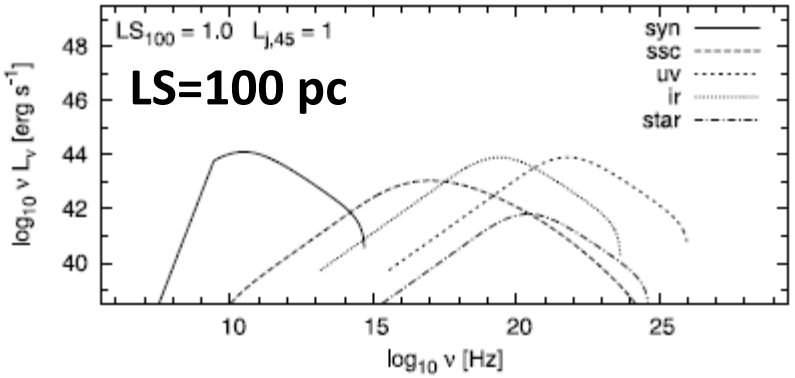


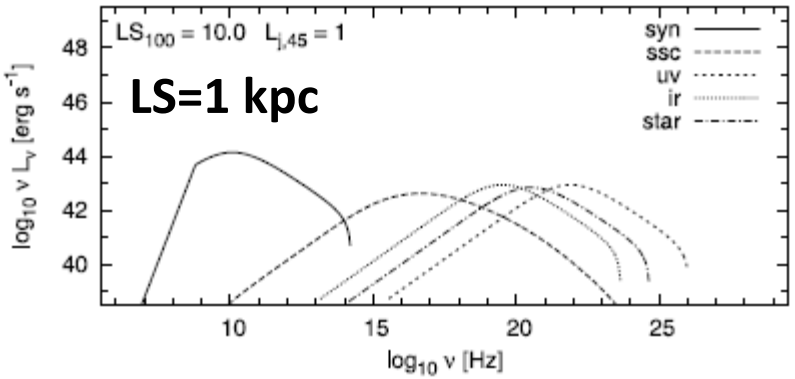
Stawarz+ 2008

  - ~10-times higher than L_j estimated from the kpc-scale radio bubble (Dunn & Fabian 2004)

Dependence of LS



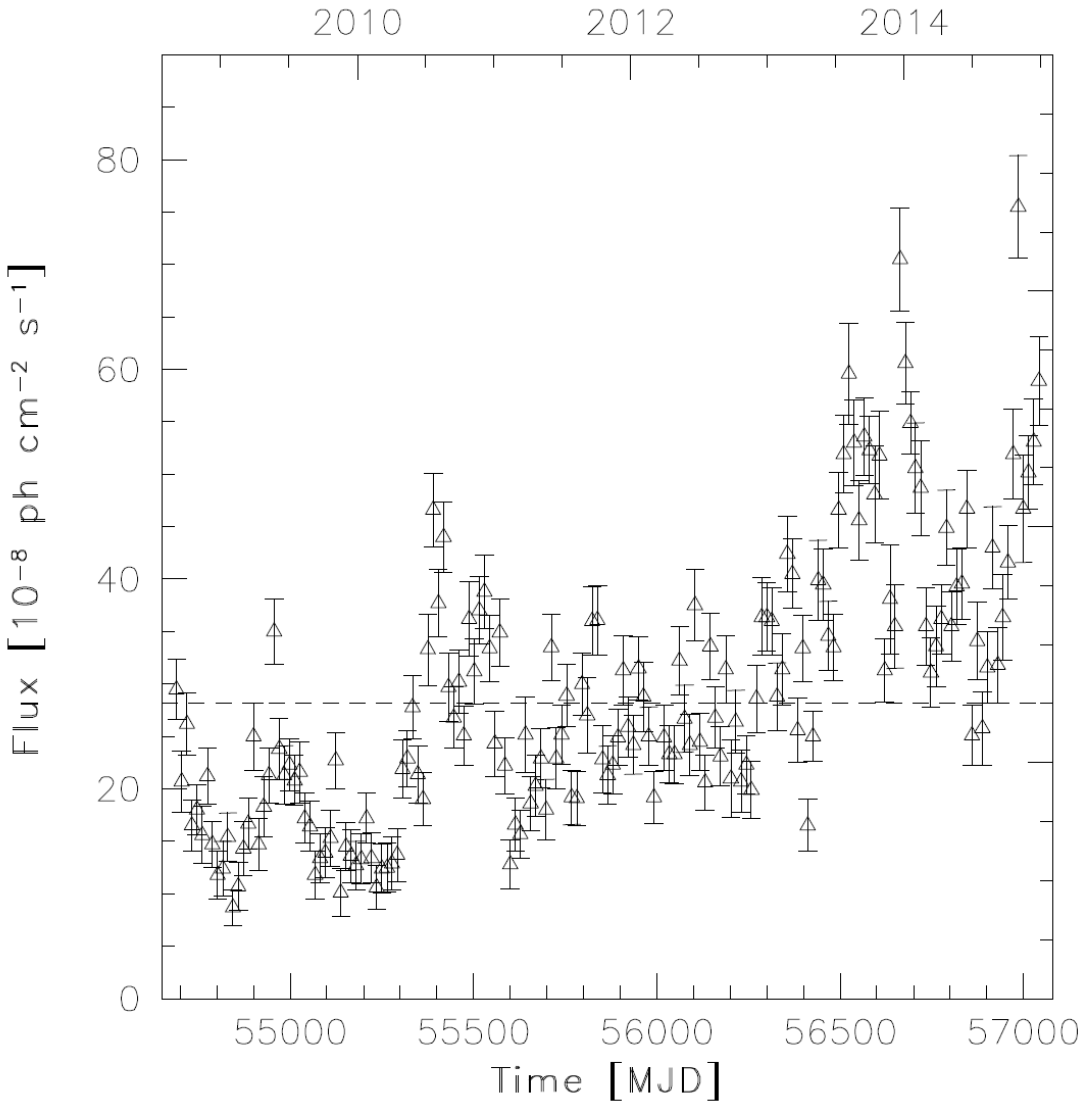


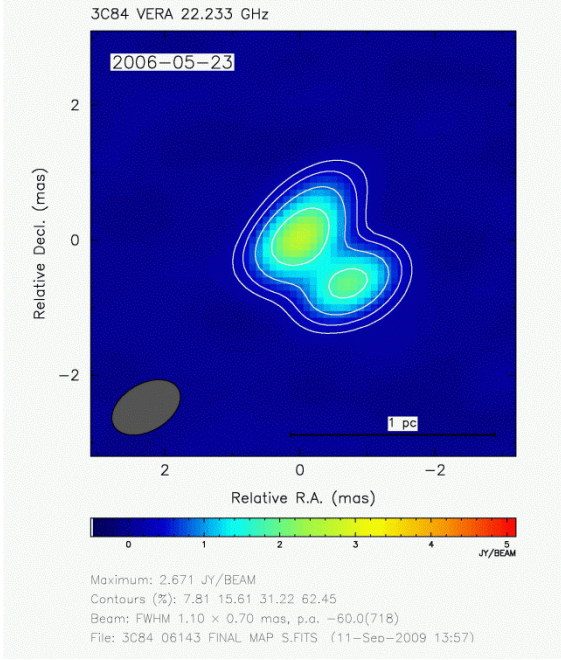


Stawarz+ 2008

Summary

- New radio component (C3) associated with recent restarted activity of 3C 84 shows mini-lobe/hotspot properties
  - Monotonic flux increase with optically-thin spectrum over 6 years
  - V_{app}~0.3c
- Short-term and long-term gamma-ray variations are different origin
  - Short-term flare: probably blazar-like component, but no radio counterpart
  - Long-term flux variation: possibly associated with new component C3
    - 1st clear evidence of gamma-ray emission from YRS?


2010
2012
2014
80
60
40
20
0
Flux [10⁻⁸ ph cm⁻² s⁻¹]
55000
55500
56000
56500
57000
Time [MJD]


3C84 VERA 22.233 GHz
2006−05−23
2
0
−2
Relative Decl. (mas)
1 pc
2
0
−2
Relative R.A. (mas)
0
1
2
3
4
5
JY/BEAM
Maximum: 2.671 JY/BEAM
Contours (%): 7.81 15.61 31.22 62.45
Beam: FWHM 1.10 × 0.70 mas, p.a. −60.0(718)
File: 3C84 06143 FINAL MAP S.FITS (11−Sep−2009 13:57)