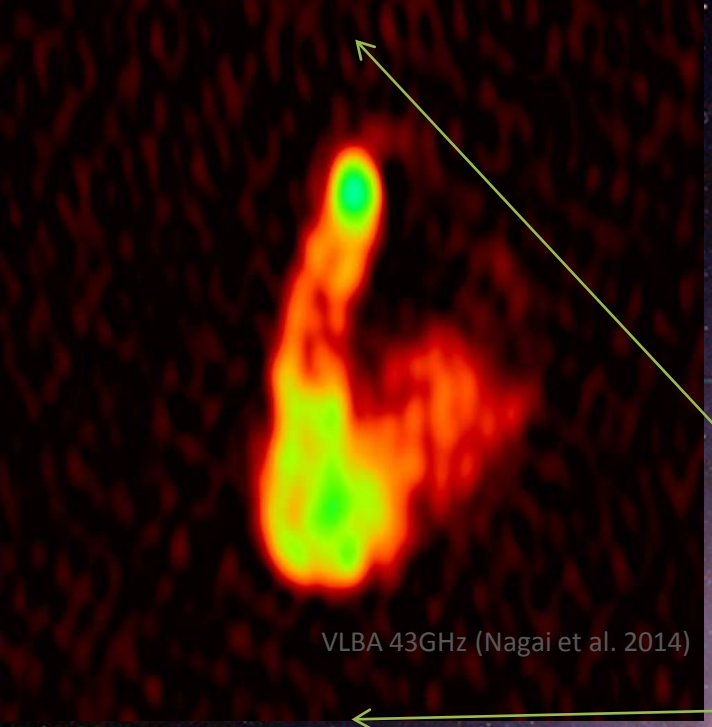

5th CSS-GPS workshop
Rimini, Italy

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

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National Astronomical Observatory of Japan

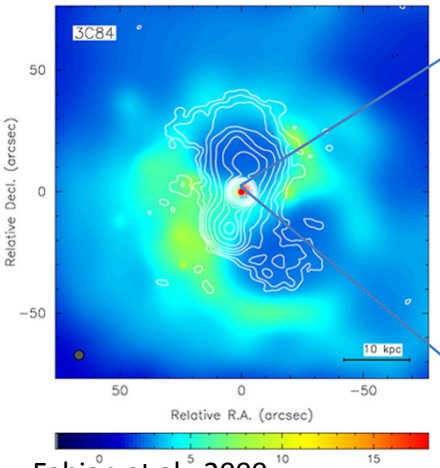
ESA/Hubble

Since last GPS-CSS workshop…

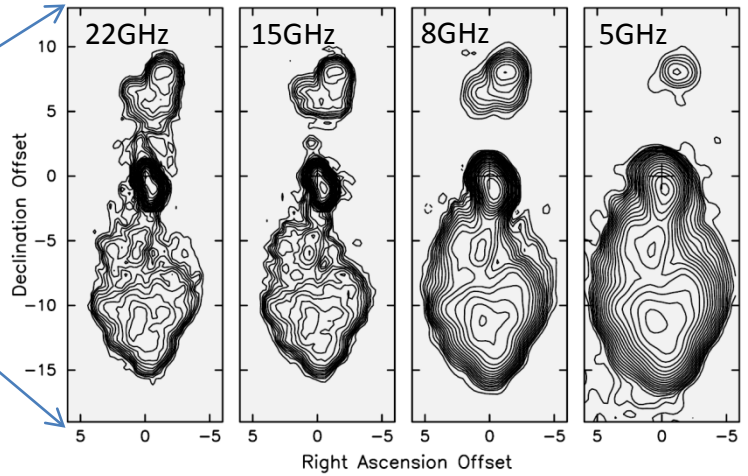
- **Big change 1: re-started jet activity in 3C 84**
  - **New prominent component shows a monotonic flux increase and subluminal motion**
    - **Consistent with "mini-lobe"-like properties**
- **Big change 2: gamma-ray detection**
  - **No clear radio counterpart associated with short-term gamma-ray 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

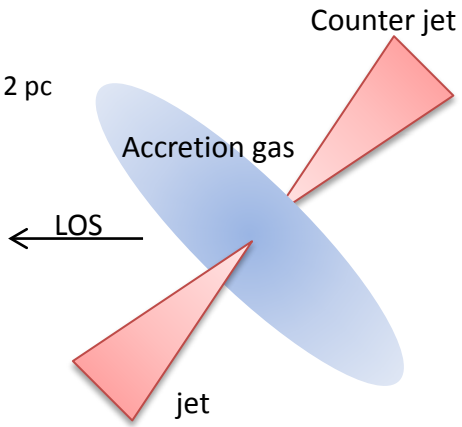
- **Bright radio source associated with giant elliptical/radio galaxy NGC1275**
- **Not GPS/CSS**
  - **But, central parsec radio structure shows GPS/CSO-like properties (as mentioned by Kino. M)**
    - **mini-lobes formed by re-started jet since 1959 (O'Dea+ 1984)**
    - **Strong absorption by accretion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



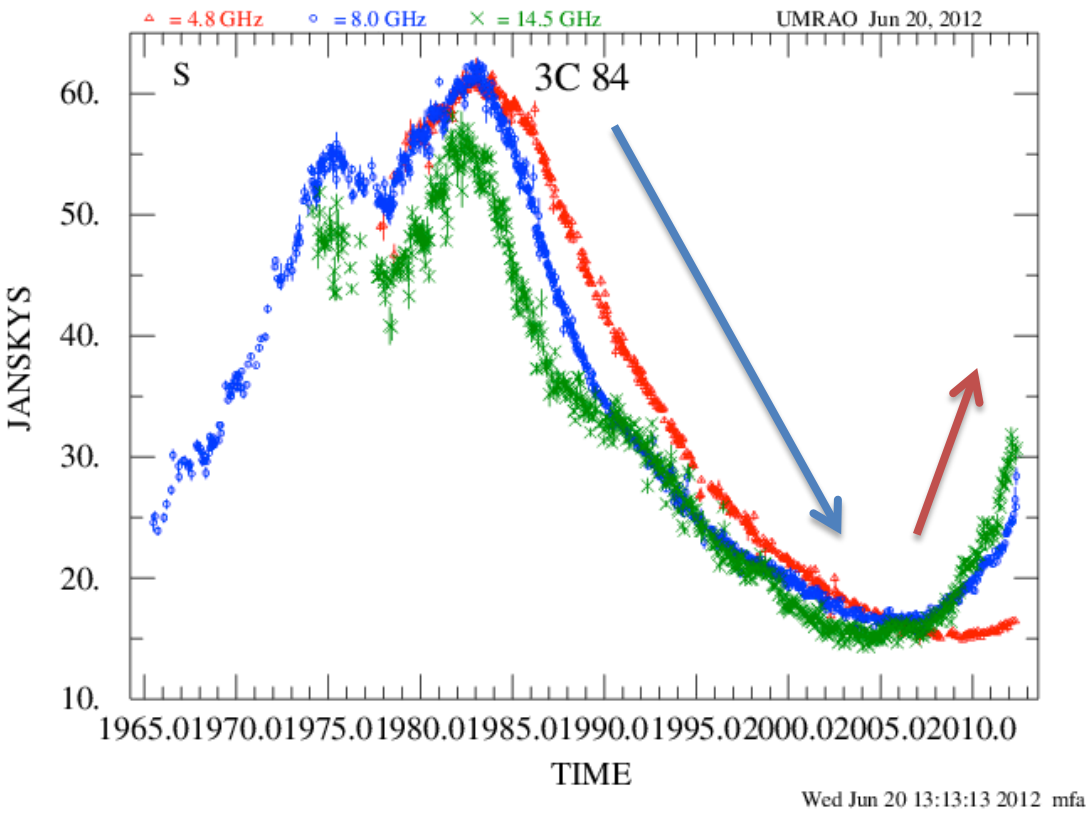
Fabian et al. 2000



Walker et al. 2000

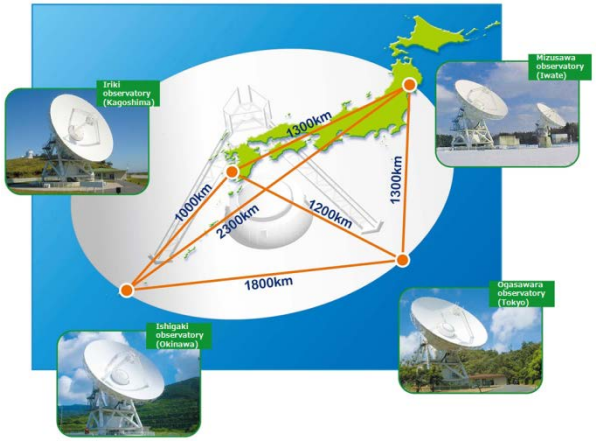


3C 84

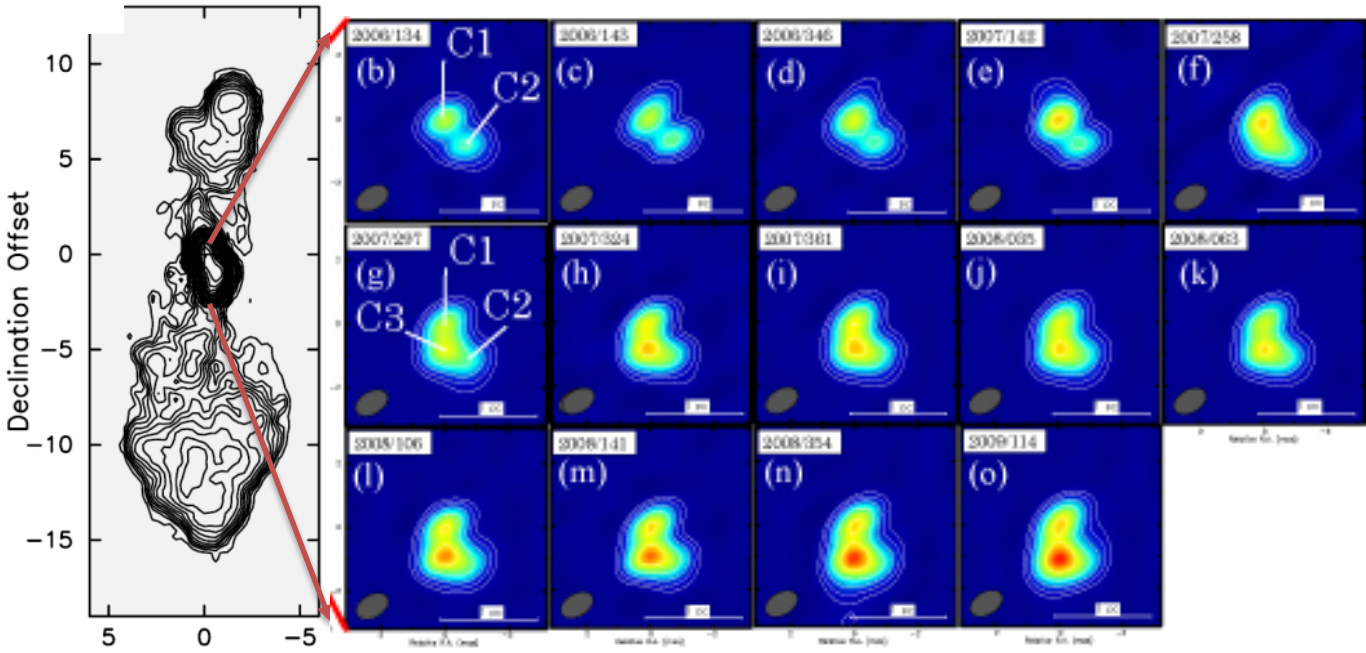


- **Jet activity was decreasing after 1985**
- **Re-activated since ~2005**
  - **No one noticed this at the time of 4th GPS-CSS workshop!**

3C 84



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

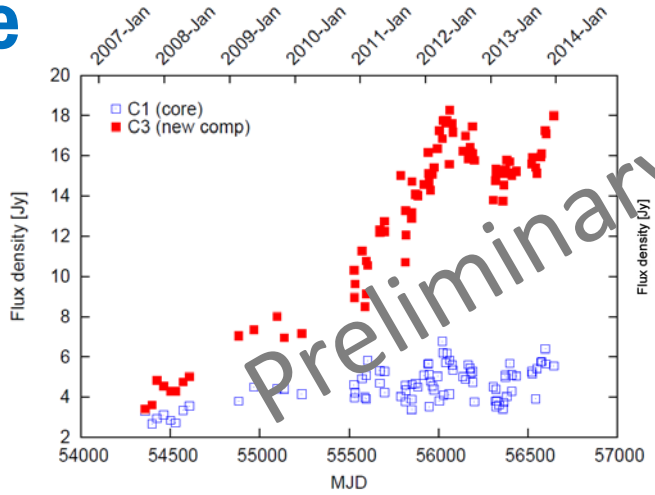


Walker+ 2000

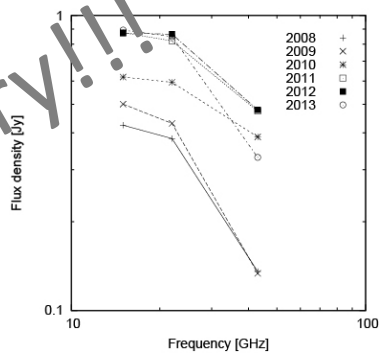
Nagai+ 2010

What is the nature of new component?

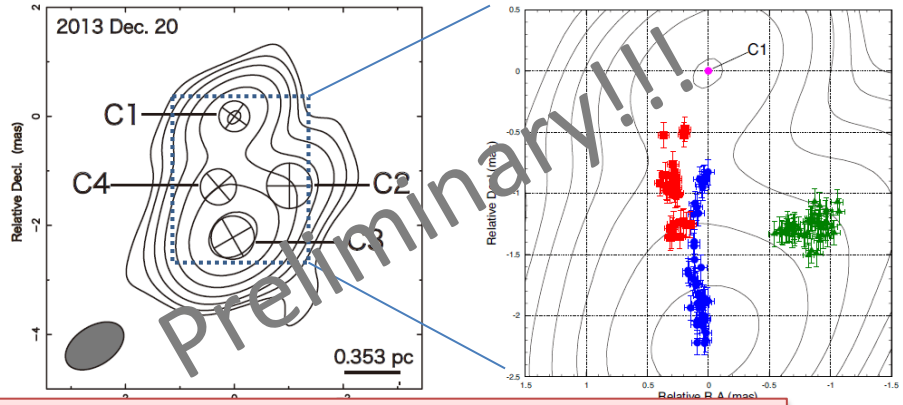
- **Monotonic flux increase with optically thin spectrum**
  - **Need injection of fresh electrons**
- **Subluminal motion**
  - **Relative apparent speed ~0.3c**
  - **Comparable to CSO hotspot speed**



Chida, Nagai+ in prep.

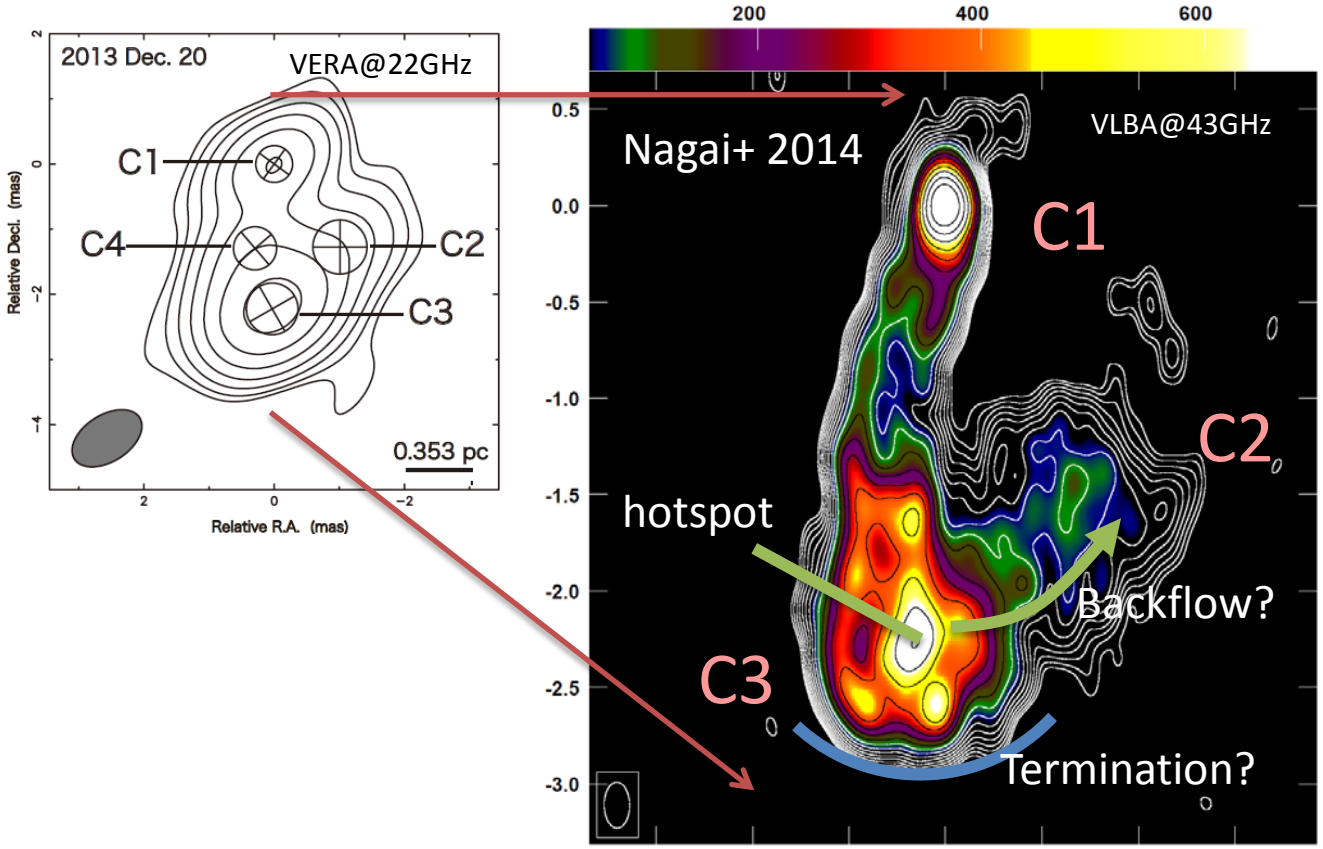


Hiura, Nagai+ in prep.

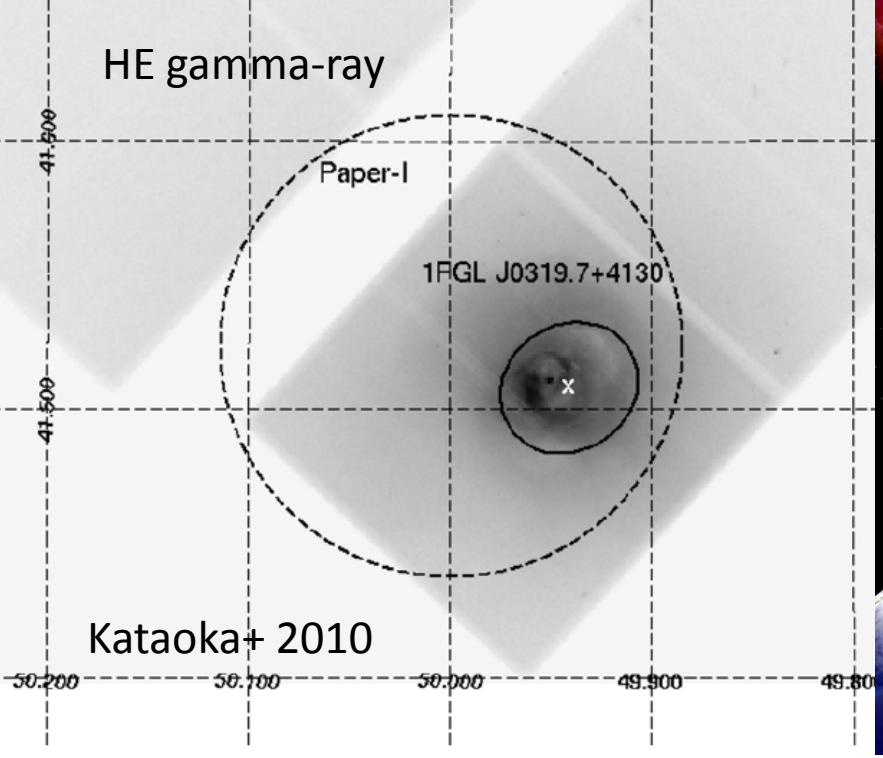


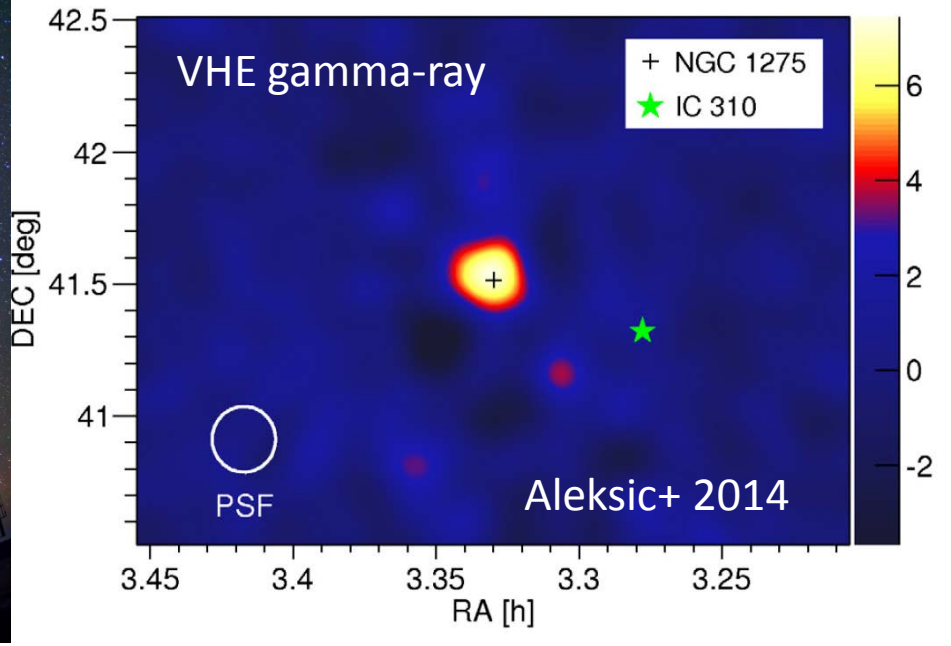
Not blazar-like component, but mini-lobe/hotspot

High Resolution Image of 3C84

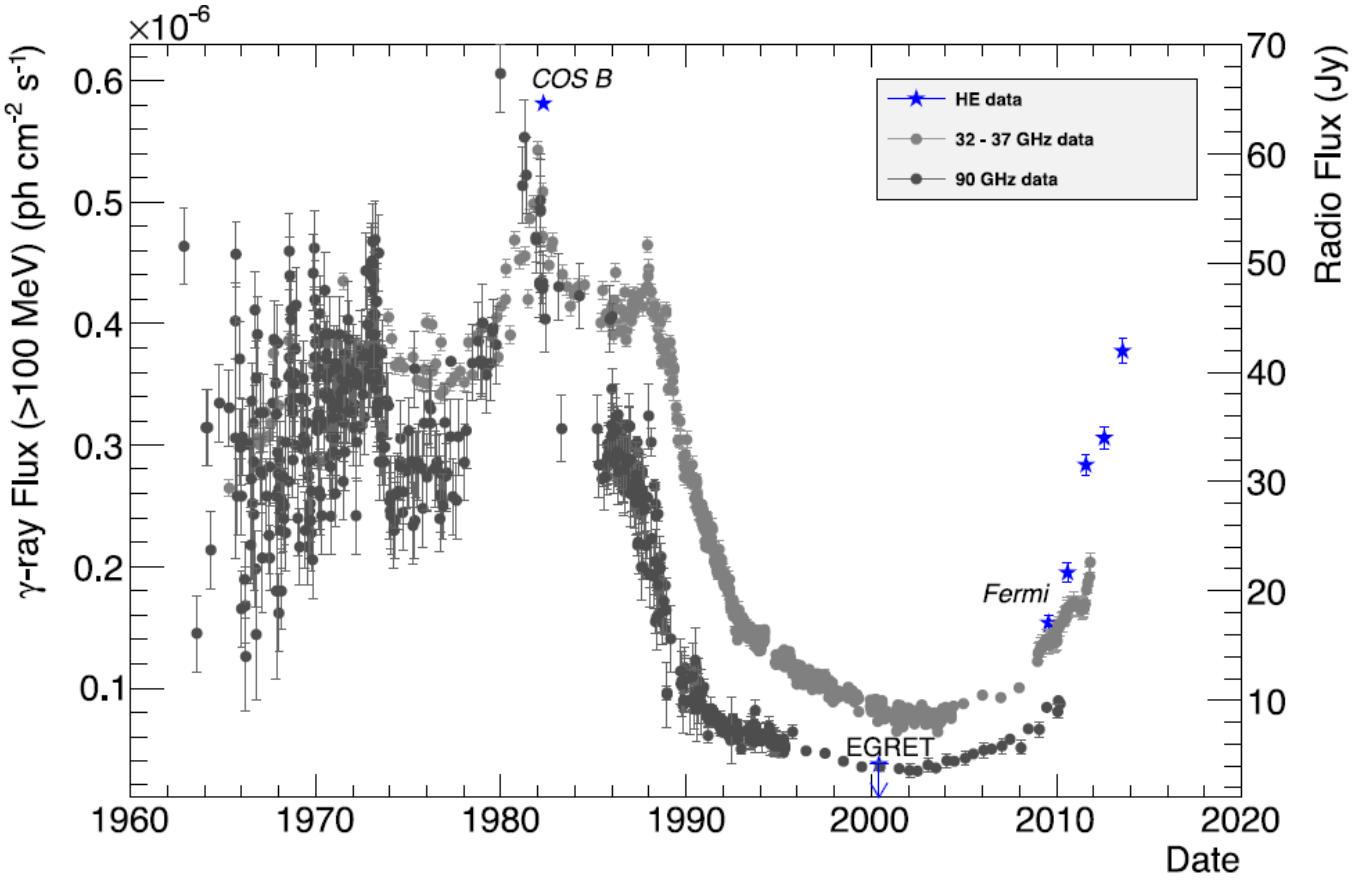


- Rare opportunity to study the lobe formation at very early stage (t_{dyn}~10 yr)
- Important to do further monitoring


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


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

Radio – Gamma-ray connection

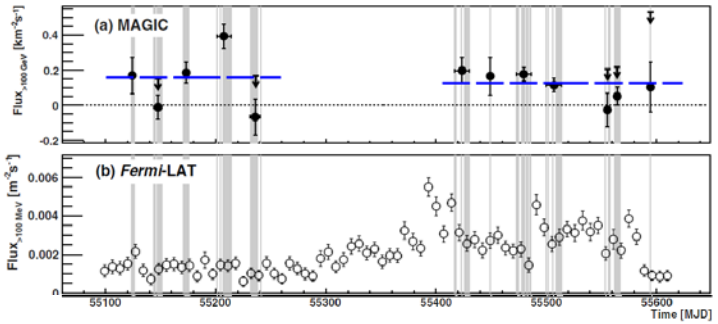


Dutson+ 2014

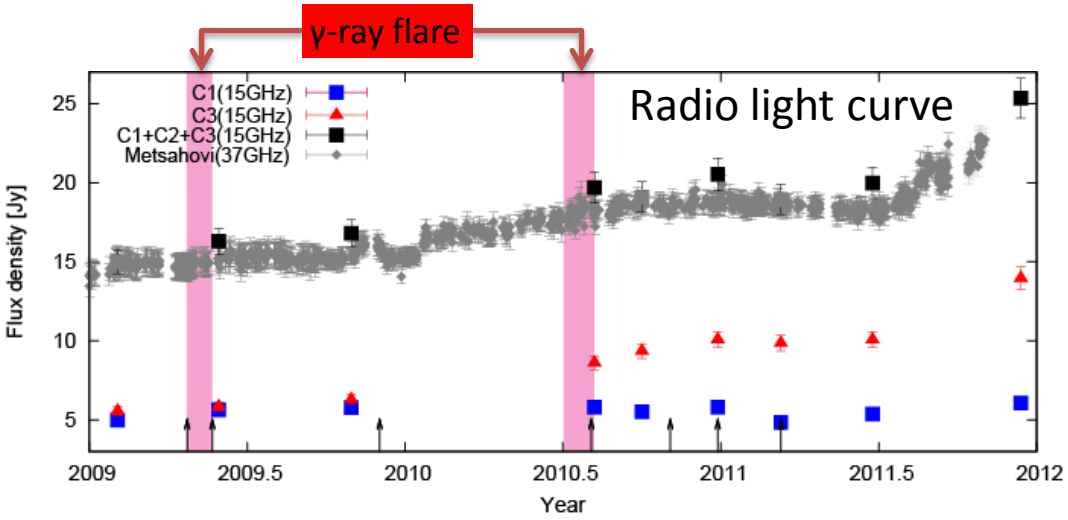
- **Gamma-ray emitting region is likely to be associated with the site of radio brightening**

Where is the gamma-ray emitting region?

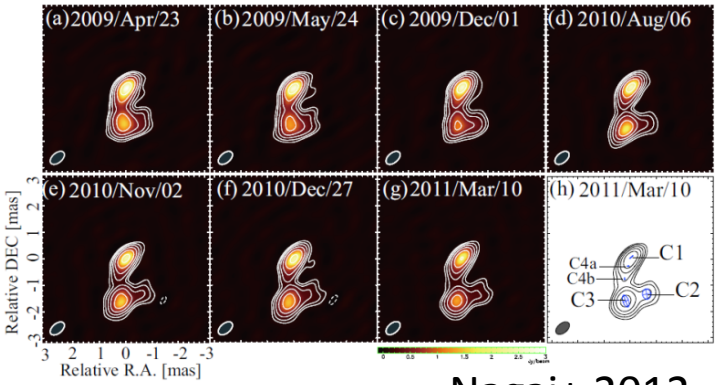
- **Gamma-ray time variability**
  - t_{var} ~ 1 week at LAT band
  - $R < ct_{var}\delta \sim c\delta \times 10^{16}$ cm
- **SED modeling suggests δ=2-4 (e.g., Aleksic+ 2014)**
  - Mildly relativistic mini-jet required
- **But, no core-brightening / jet ejection associated with short-term gamma-ray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



Aleksic+ 2014



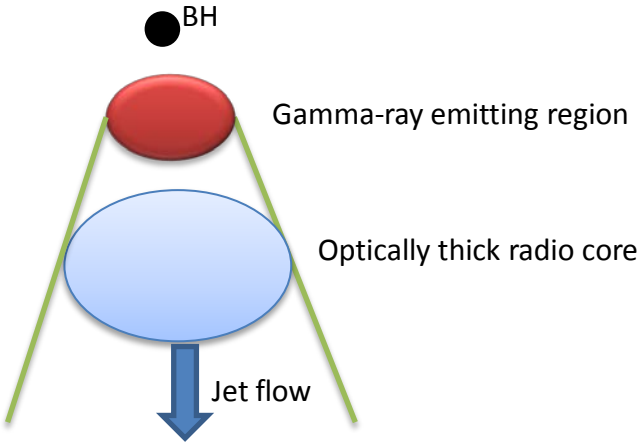
VERA at 43GHz



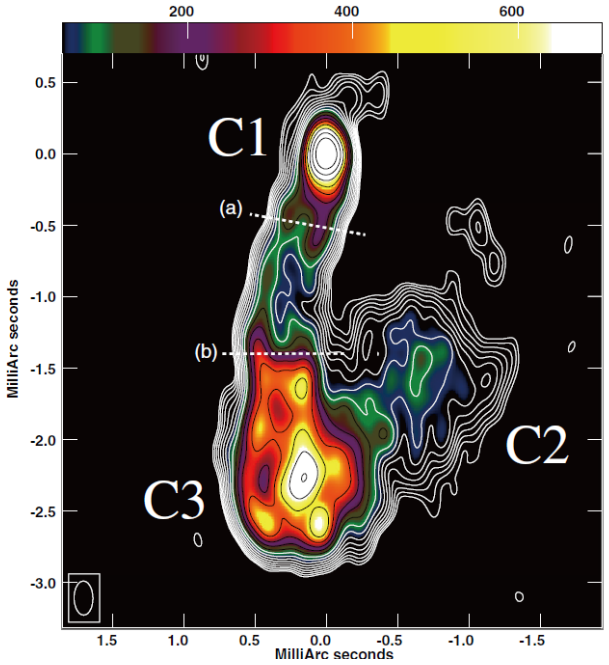
Nagai+ 2012

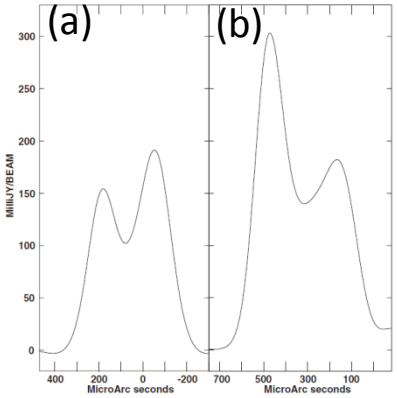
Why no radio counterpart of short-term flare?

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**

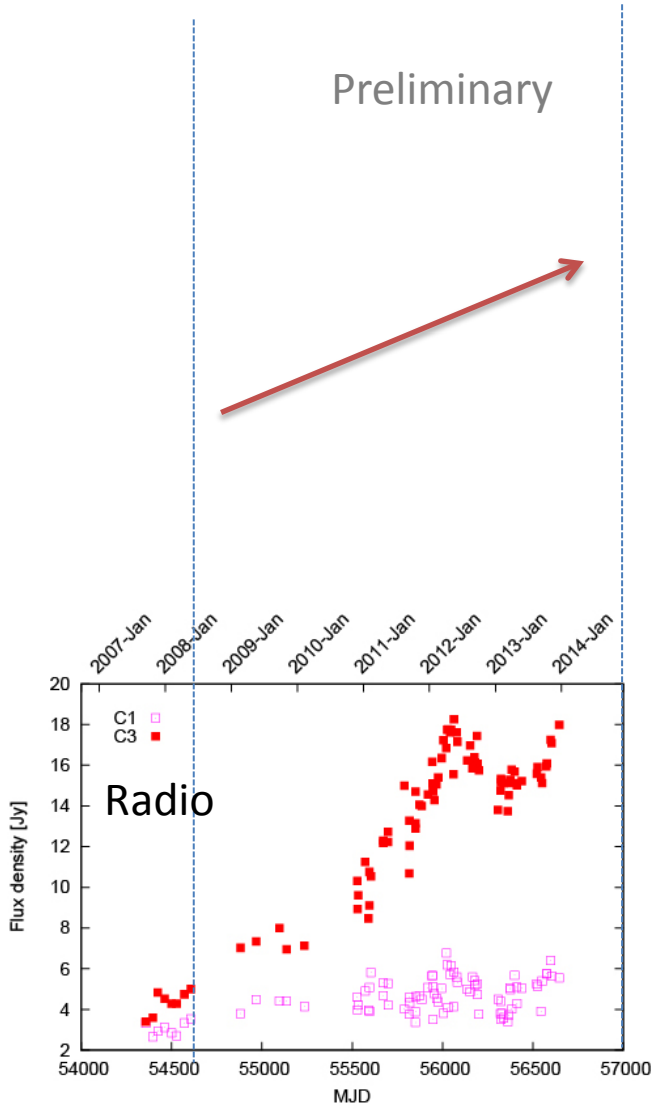




Long-term γ-ray variation

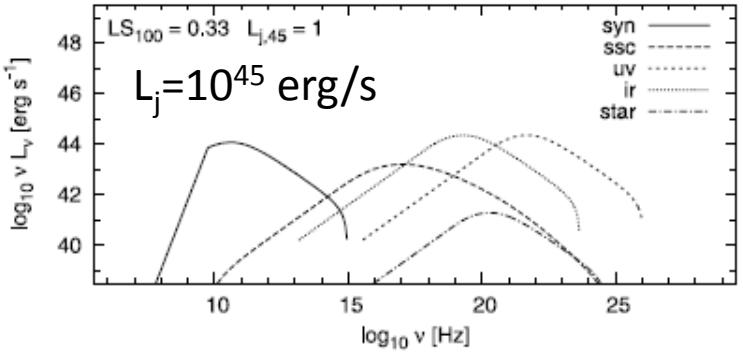
- **Gamma-ray flux increases on the timescale of years**
  - **Composite of multiple mini-jet flares unlikely**
  - **Larger-sized emitting region favored**
- **C3 shows a radio flux increase on similar timescale**
  - **Signature of gamma-ray emission associated with C3 (mini-lobe/hotspot)**

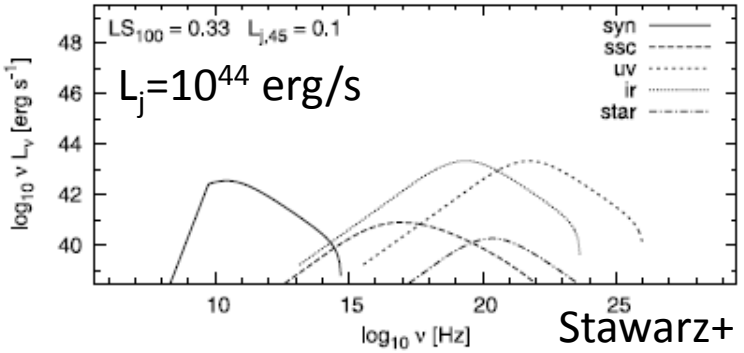
LAT light curve (Analysis by F. D'Ammando)



Gamma-ray emission model from YRS

- **HE emission by IC of various surrounding photon fields by lobes' electrons (Stawarz+ 2008)**
  - **LS=33pc, 100pc, 1kpc**
- **If $L_j=10^{45}$ erg/s, the model is accountable for the observed gamma-ray luminosity of 3C 84 (~10^{44} erg/s)**

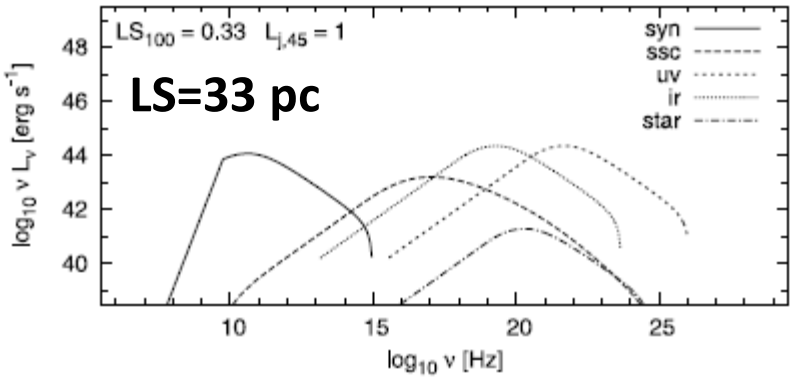


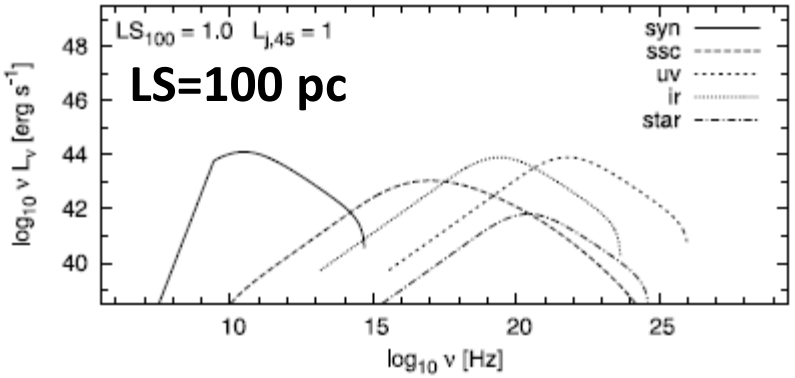


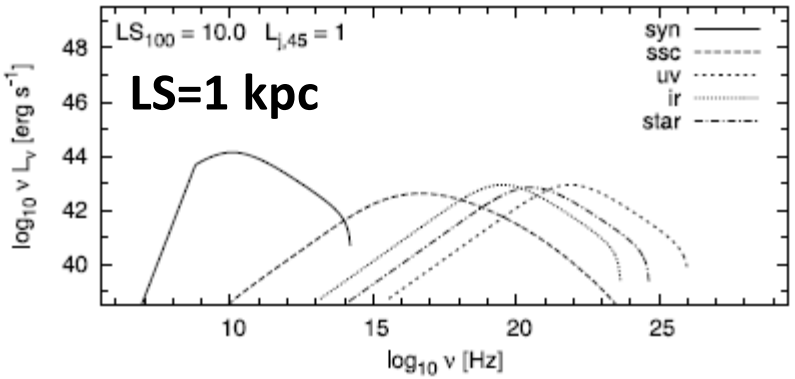
Stawarz+ 2008

  - **~10-times higher than L_j estimated from the kpc-scale radio bubble (Dunn & Fabian 2004)**
  - **Past jet power could be lower than at present?**

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
  - $V_{app} \sim 0.3c$
- 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?