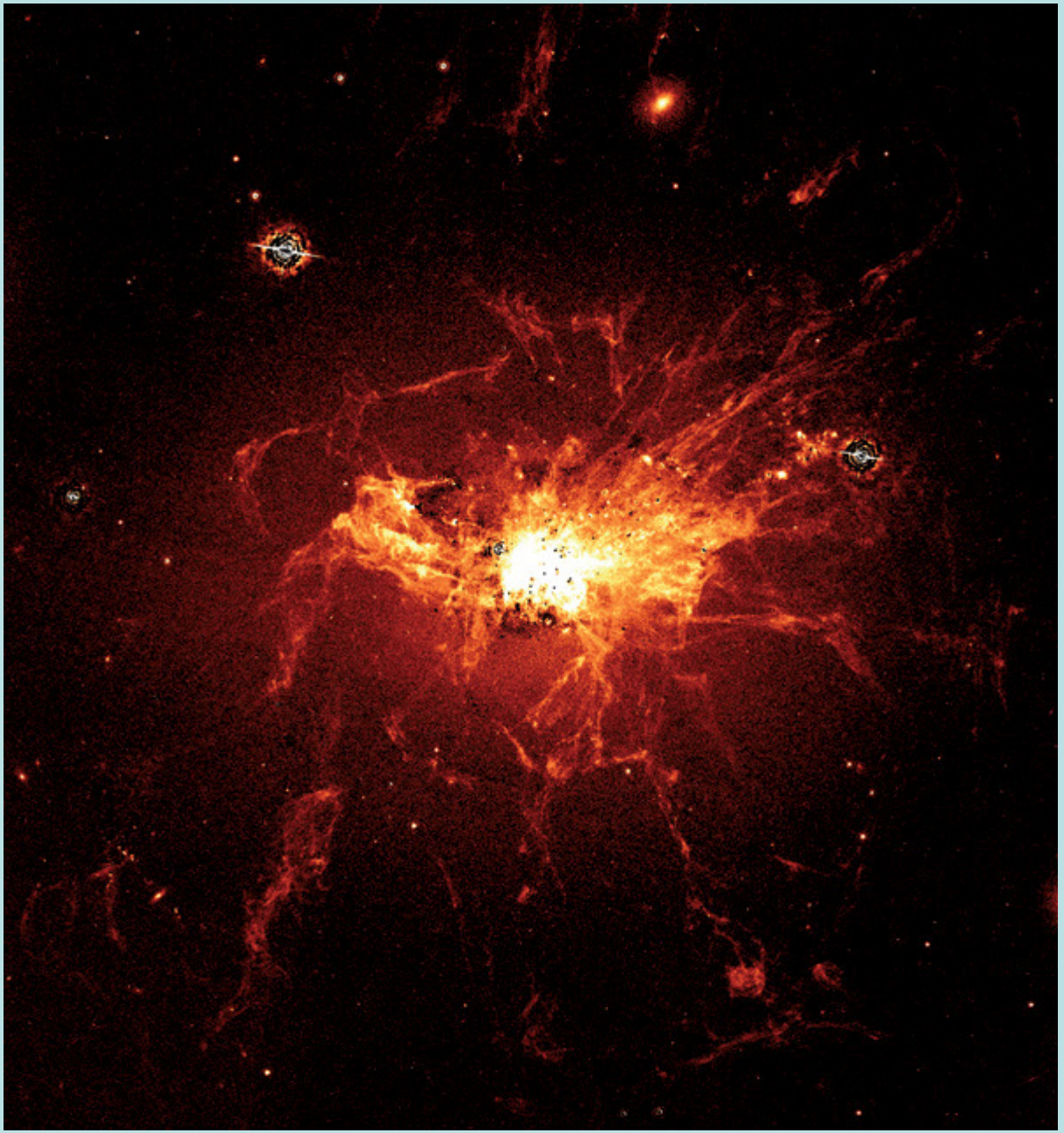
The nuclear structure of 3C 84 with Space VLBI (Radioastron) observations

Gabriele Giovannini
Physics and Astronomy Dept. – Bologna University
Radioastronomy Inst. - INAF

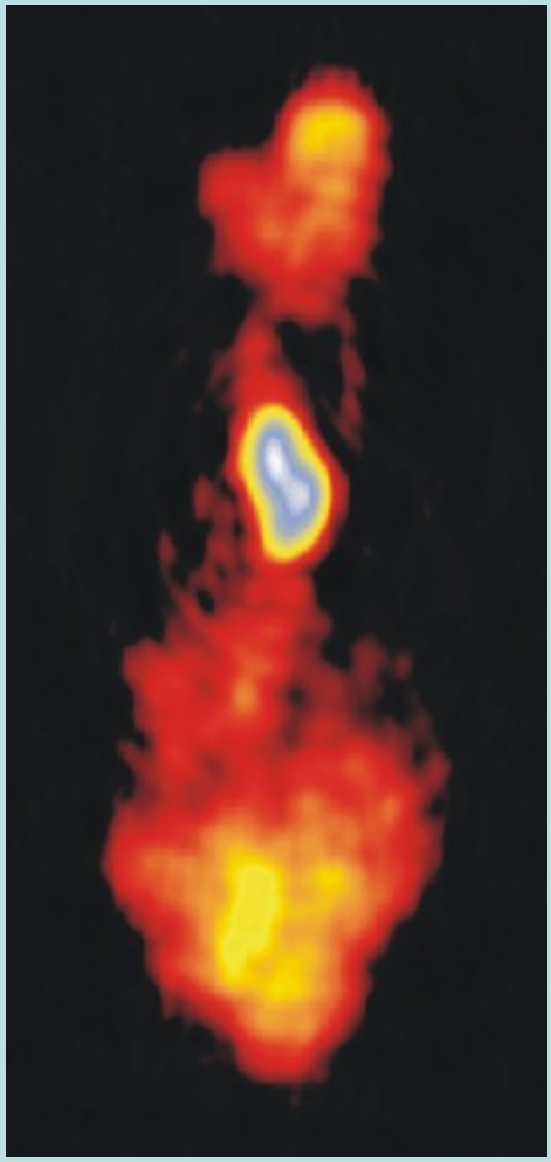
In collaboration with :
M. Giroletti, **M. Orienti**, R. Lico, K. Hada, F. D'Ammando **IRA-INAF**
H. Nagai , M. Honma **NAOJ**
M. Kino, B.W. Sohn, S-S. Lee **KASI**
T. Savolainen, A. Lobanov, T. Krichbaum, G. Bruni,
A. Zensus **MPIfR-Bonn**
Y. Kovalev **Astro Space Center Moscow**
et al.

HST image of NGC 1275 with the red filter (F625W) contains the H alpha line (Fabian etal 2008). The image measures 140x150 arcsec in size.



3C84: A gamma-ray bright misaligned AGN

- **BCG of the Perseus Cluster**
- **Prototypical cooling core cluster**
- **One of the strongest compact radio sources**
- **Extensively studied up to 87 GHz (radio)**
- **Nearby: z=0.0176 1 mas = 0.344 pc**
- **Central mass 3.4 x 10^8 solar masses**
- **0.1 mas = 10^3 r_g**

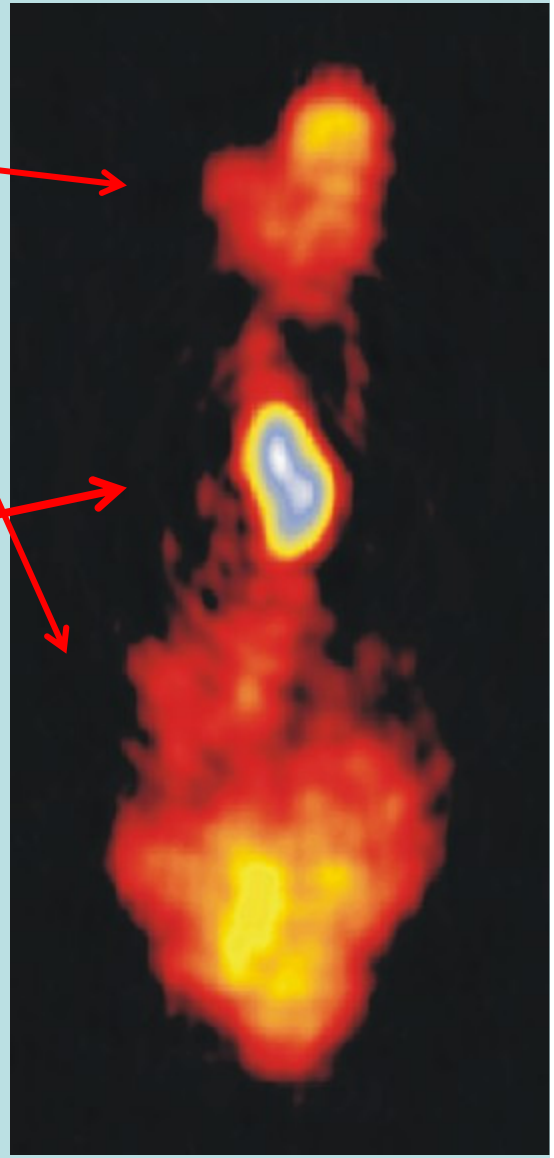


At mas resolution 3C84 shows two symmetric 'lobes' with evidence of absorption in the Northern one

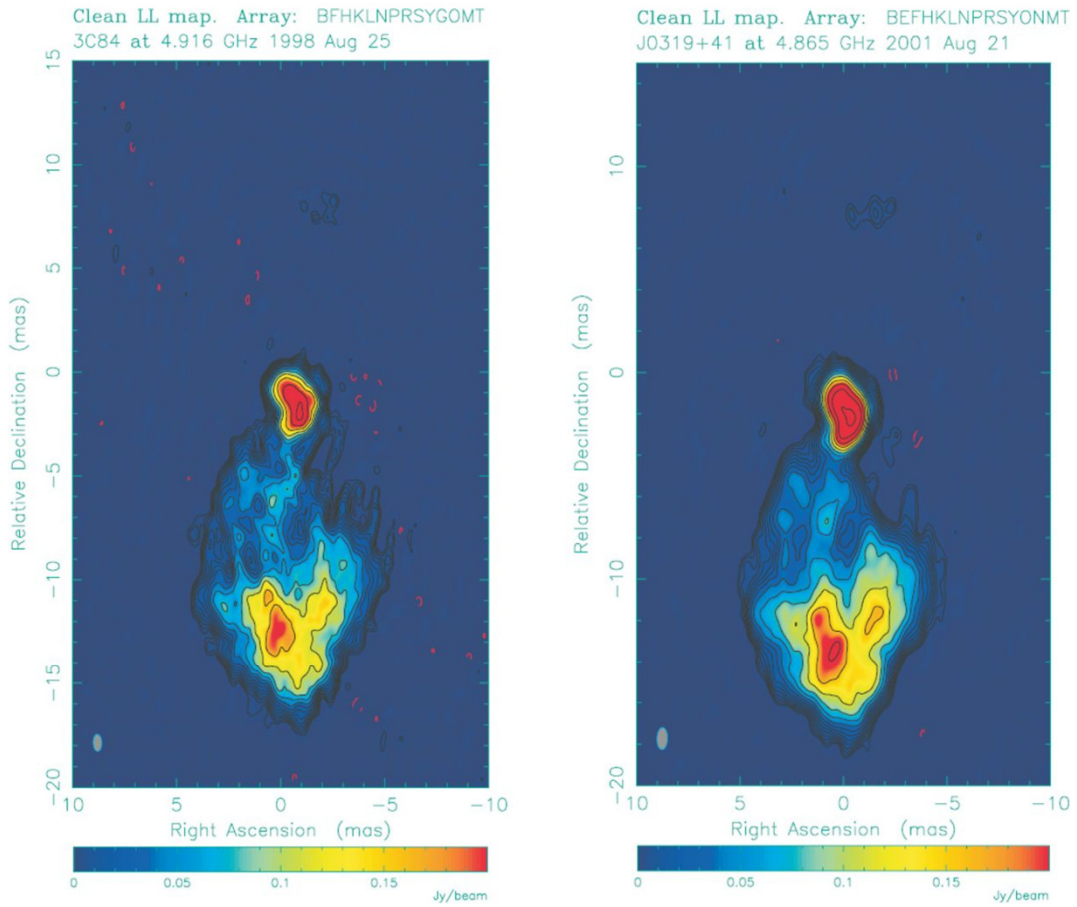
At sub-mas 3C84 appears one-sided with slow proper motion (sub-luminal) : 0.1 – 0.5 c in contrast with the sidness asymmetry
and the high jet velocity required by the gamma-ray emission

If the source is intrinsically symmetric it should have relativistic Jets: v = 0.9c if theta = 25 deg

➔large deceleration expected because of jet interaction with a dense ISM (cooling cluster, Liuzzo et a. 2010)



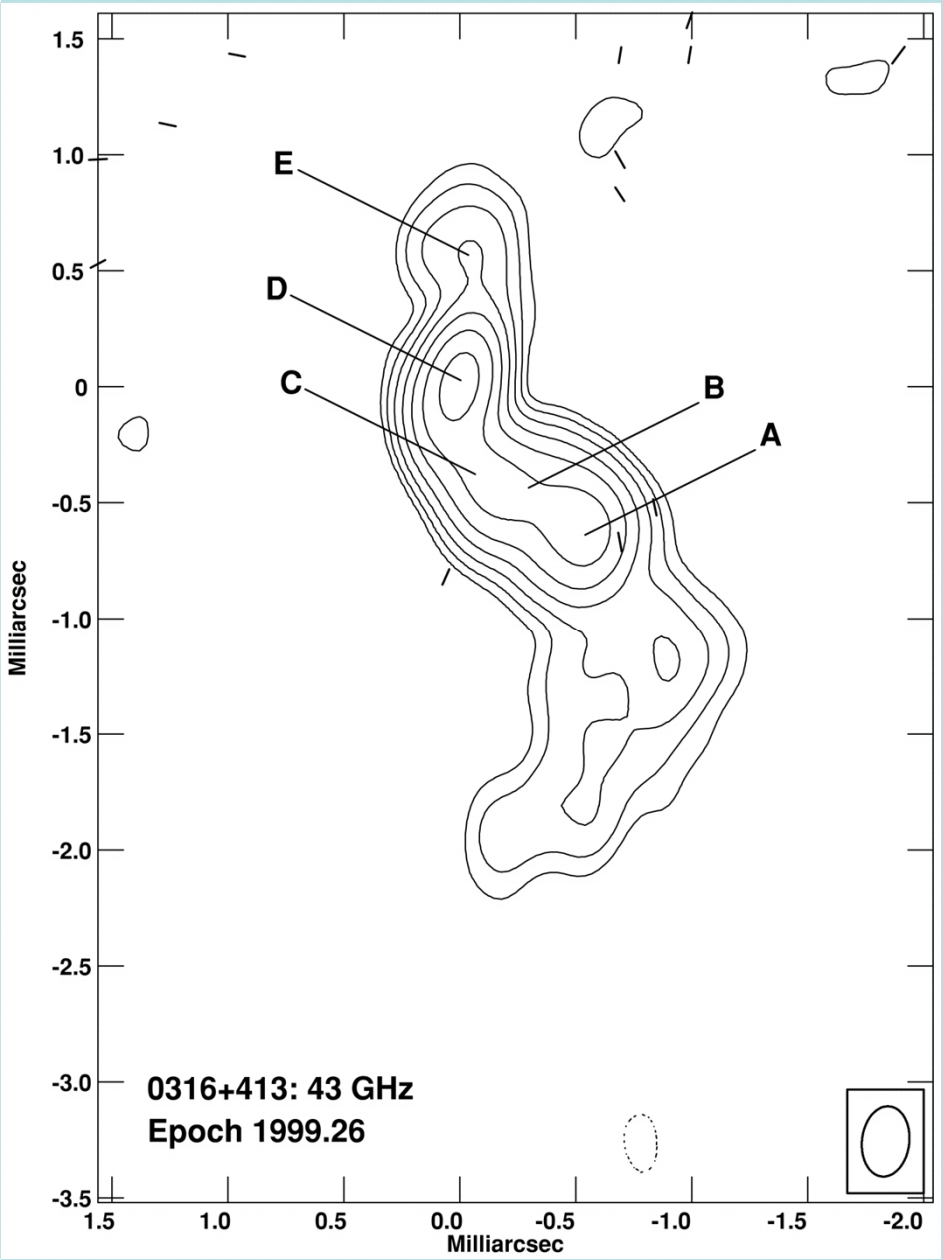
Contour images of the total intensities from the two VSOP observations.

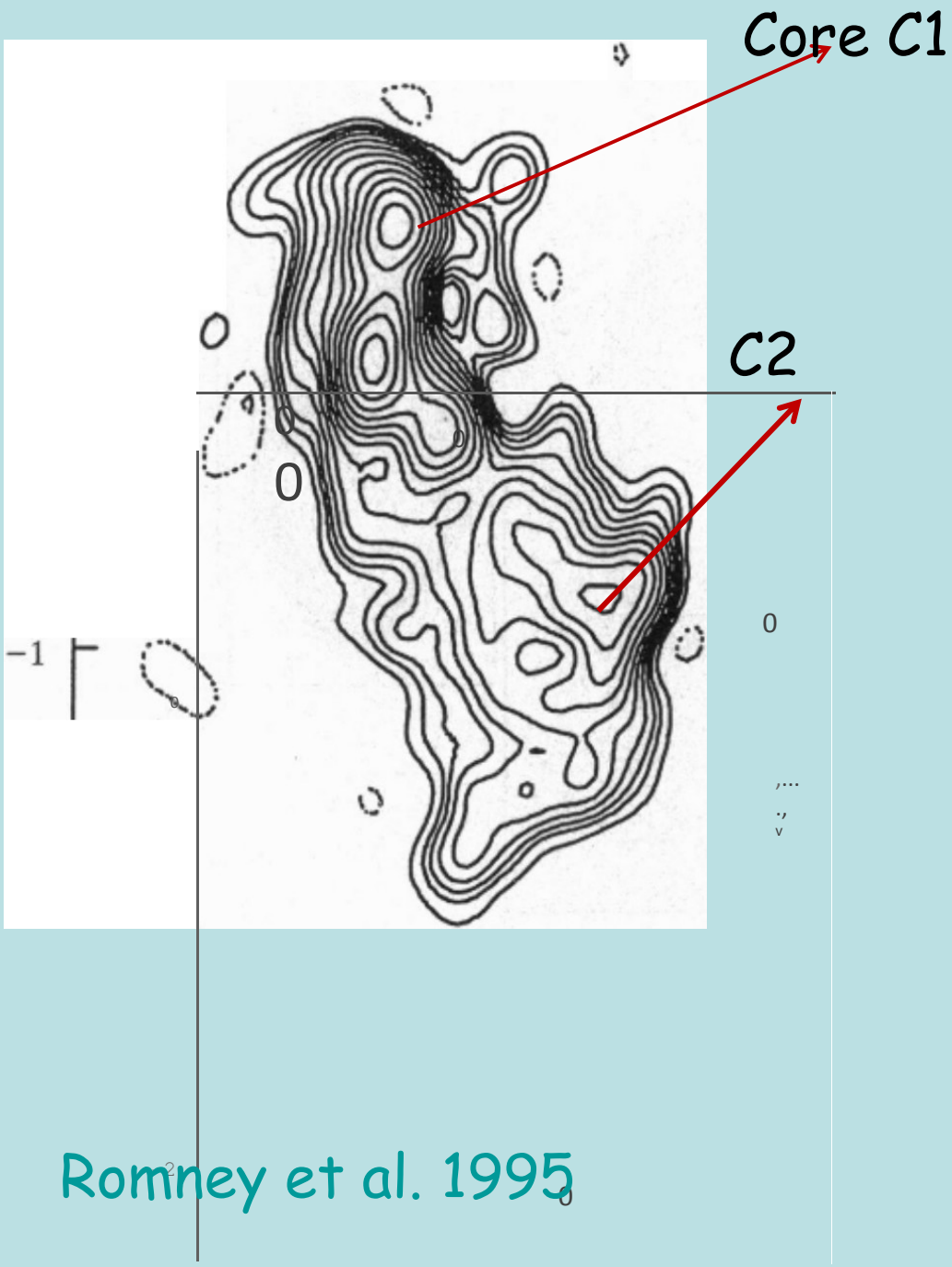


Asada K et al. Publ Astron Soc Jpn 2006;58:261-270

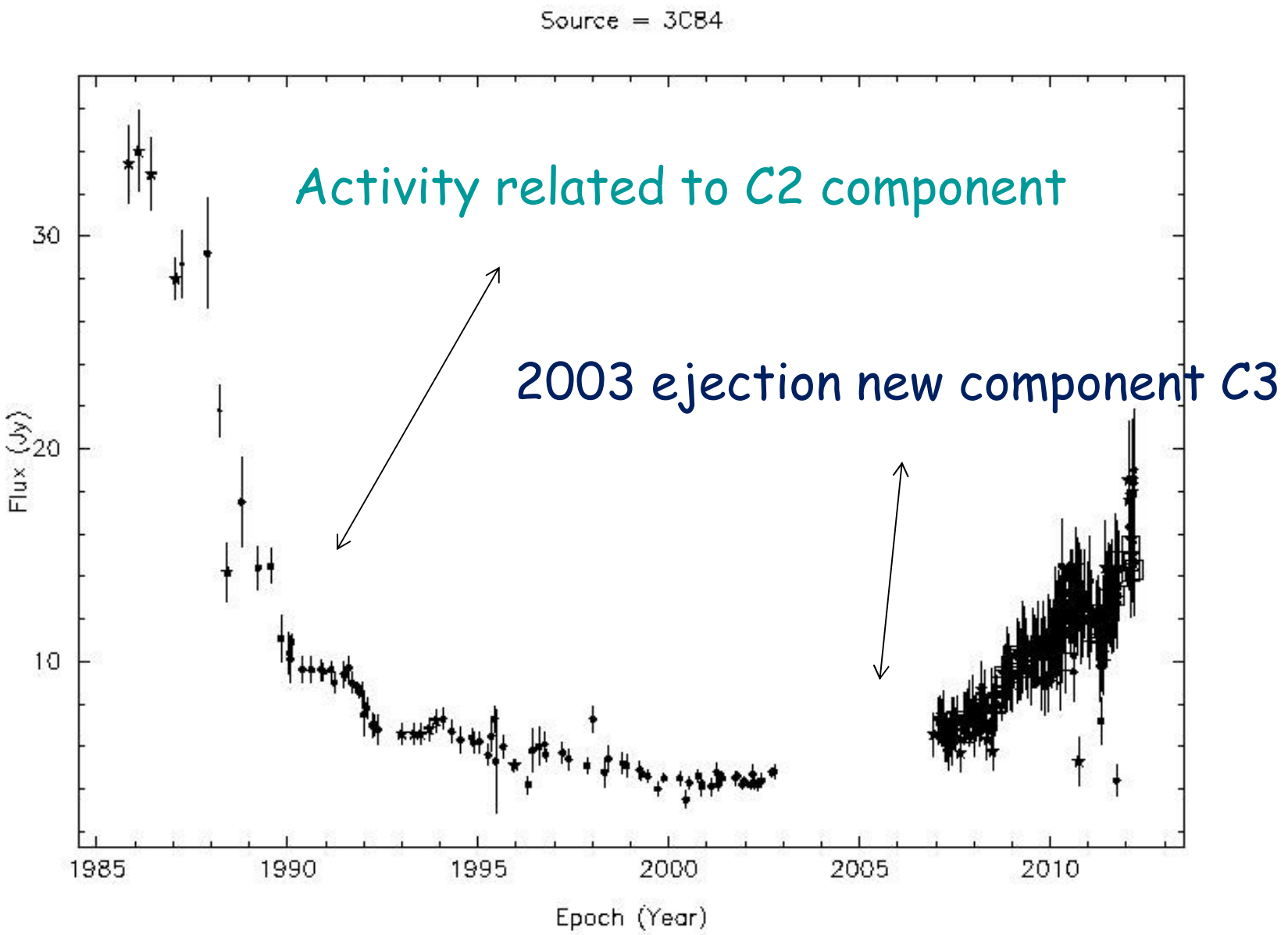
PASJ Publications of the Astronomical Society of Japan

From Asada et al. 2006, VSOP observations ➔ Lobe proper motion ➔ Lobe age: 1959 outburst

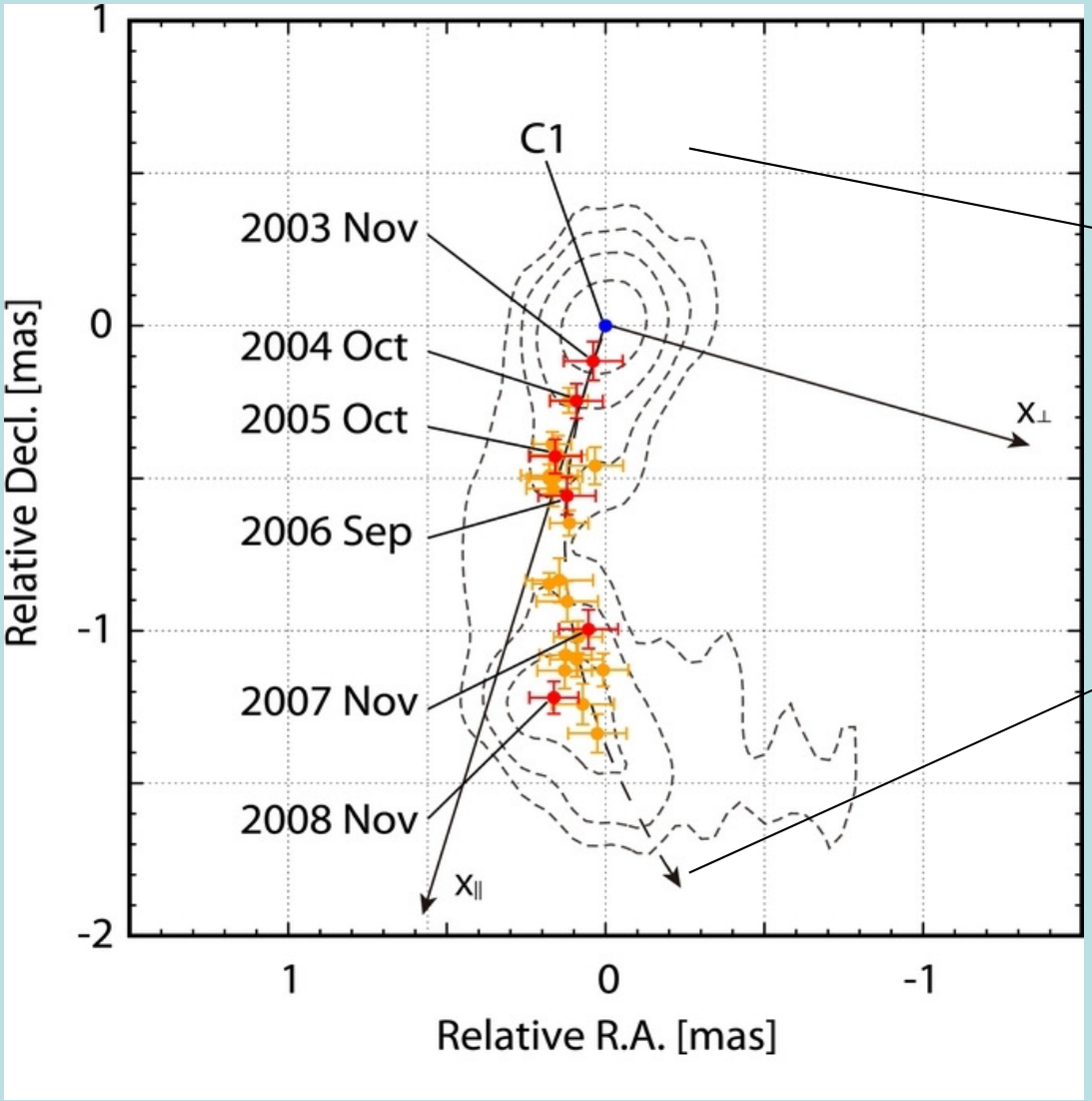


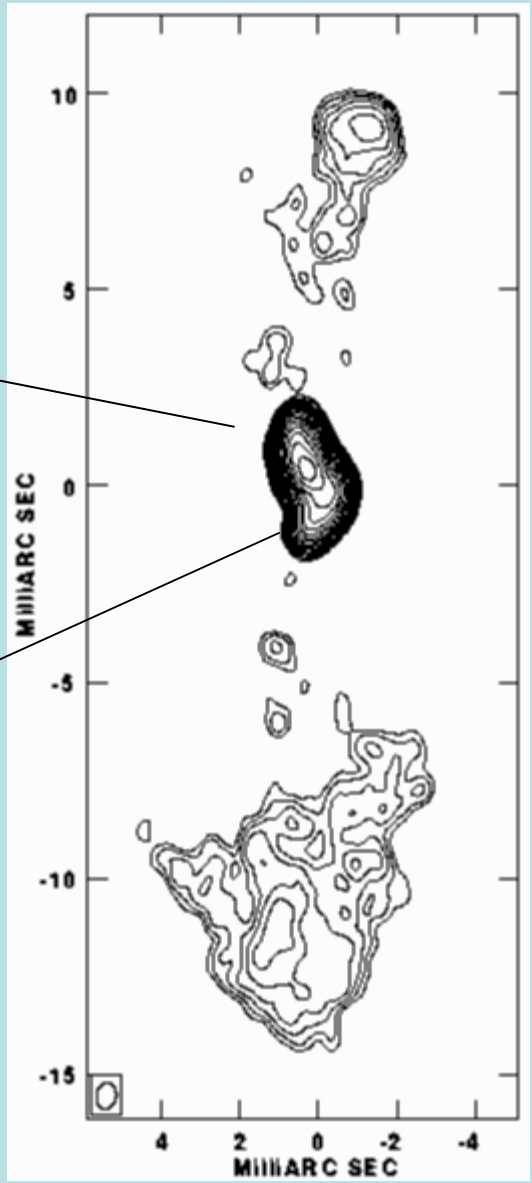


Romney et al. 1995

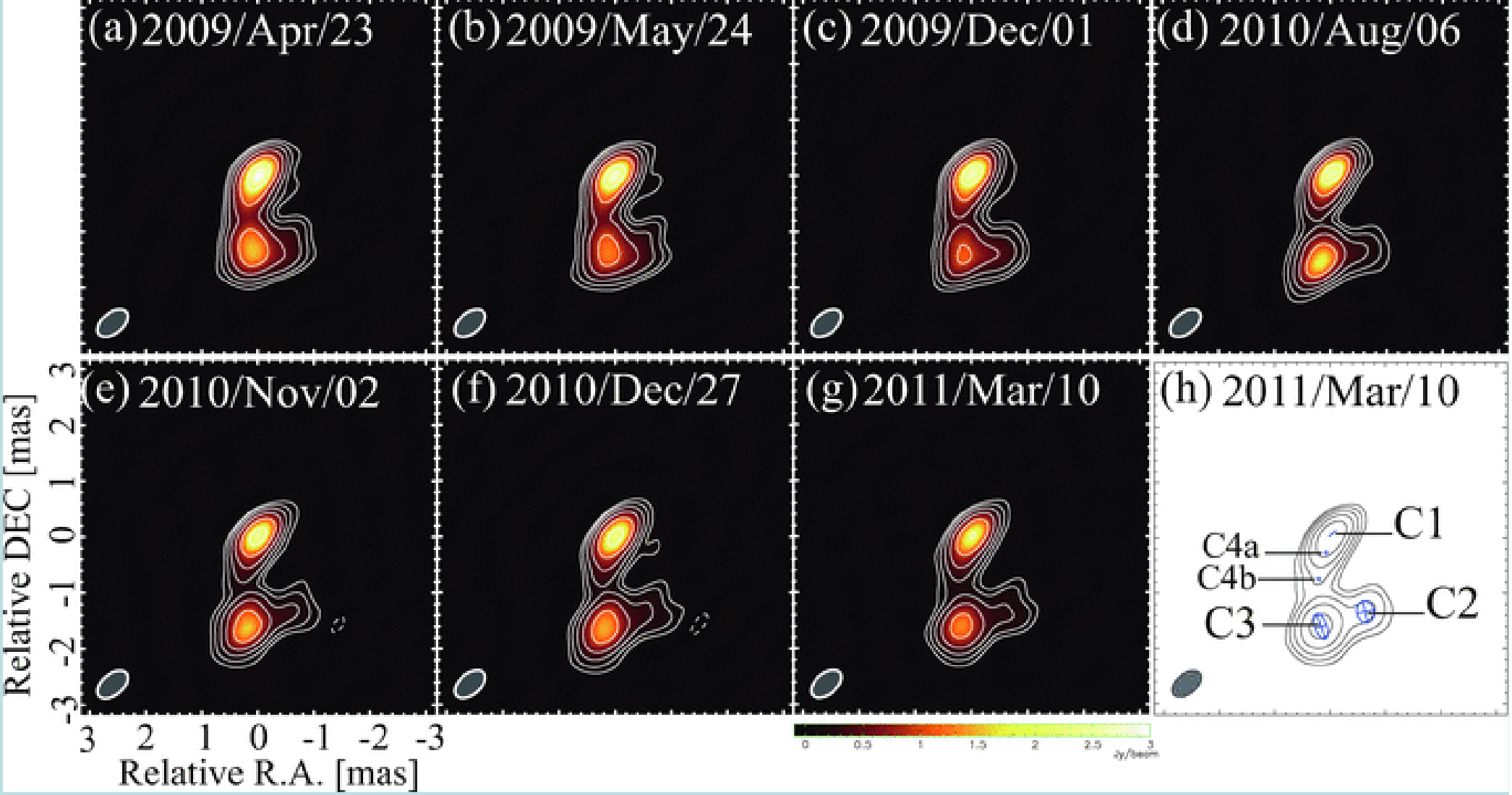

Source = 3C84
Activity related to C2 component
2003 ejection new component C3
Flux (Jy)
30
20
10
1985
1990
1995
2000
2005
2010
Epoch (Year)

VLBA at 43 GHz in the period of 2002-2008
Kenta Suzuki et al. 2012



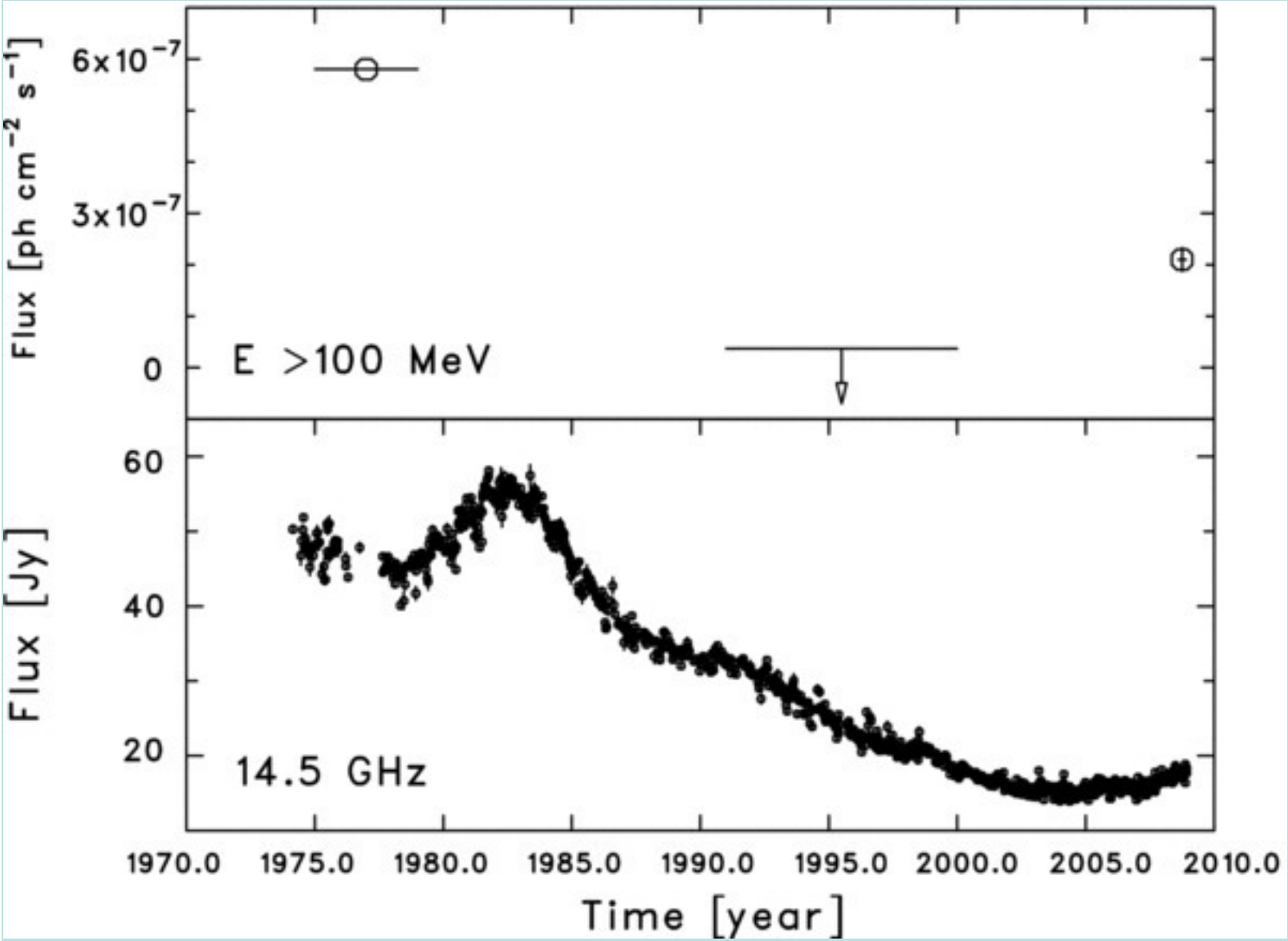


Peak position of C3

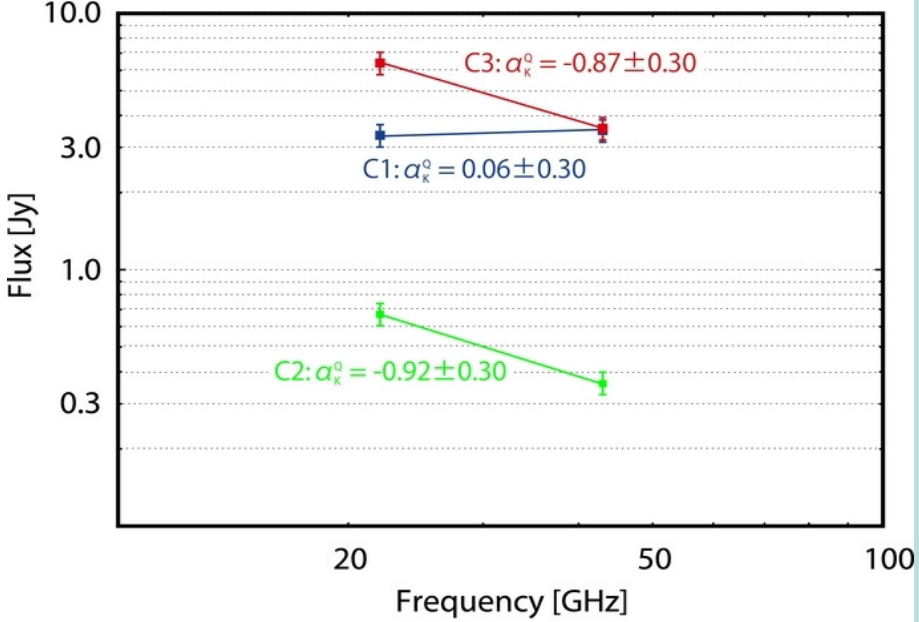


VERA 43 GHz images from Nagai et al. 2012

New ejection C3, flux density increase

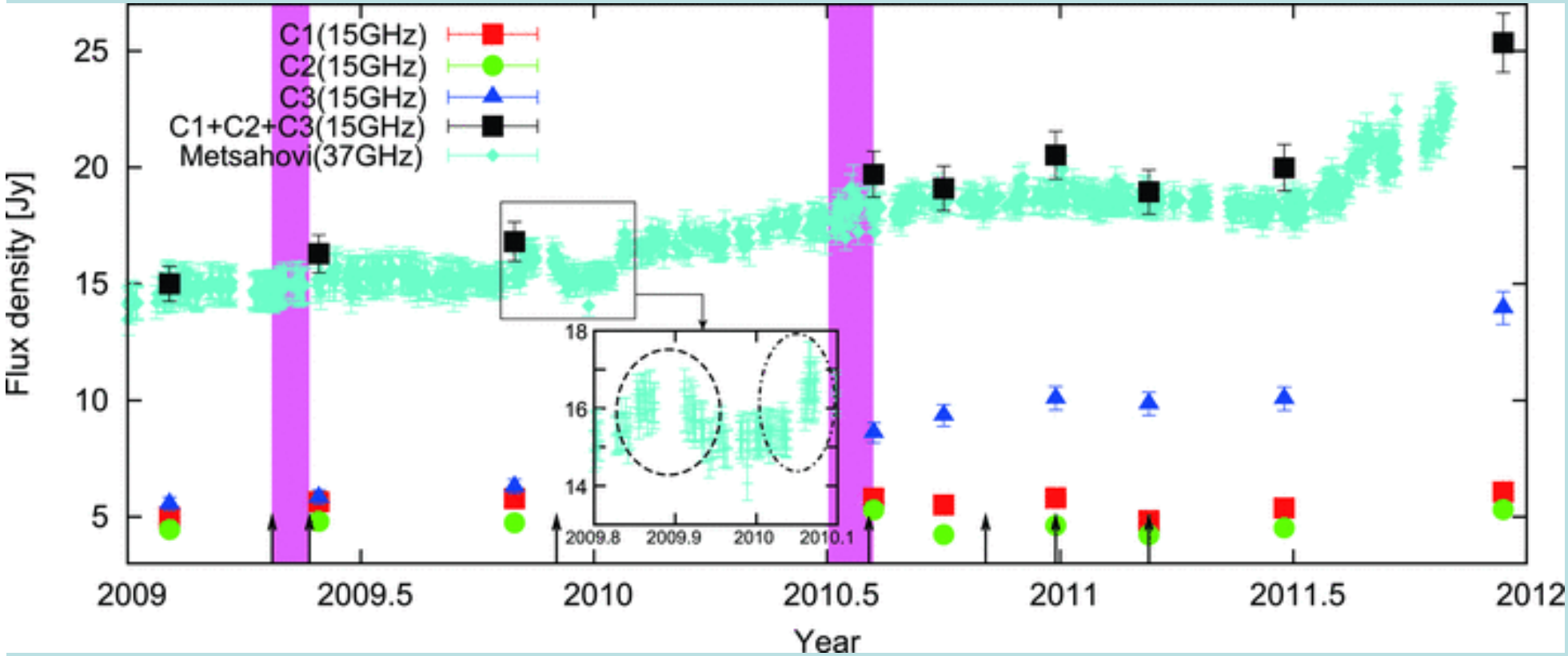


2009 August detected by Fermi-LAT
Abdo et al. 2009

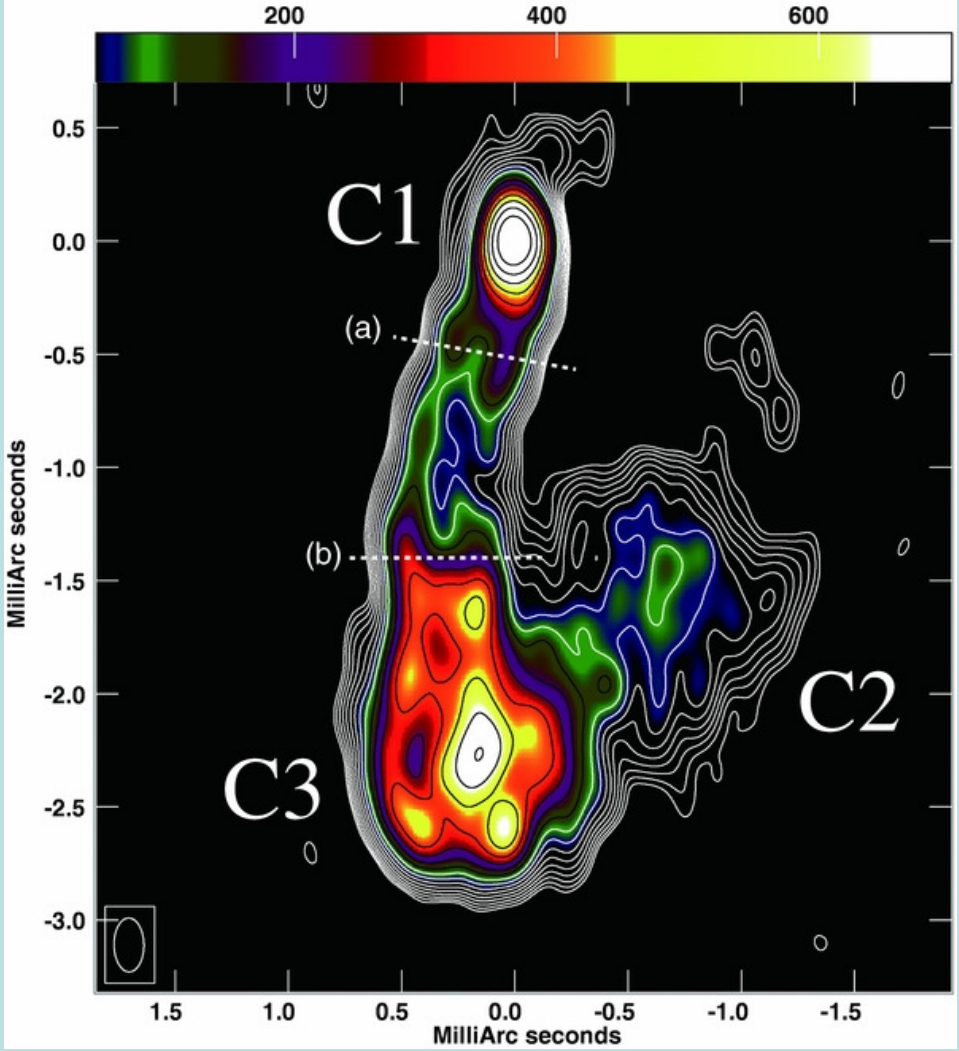


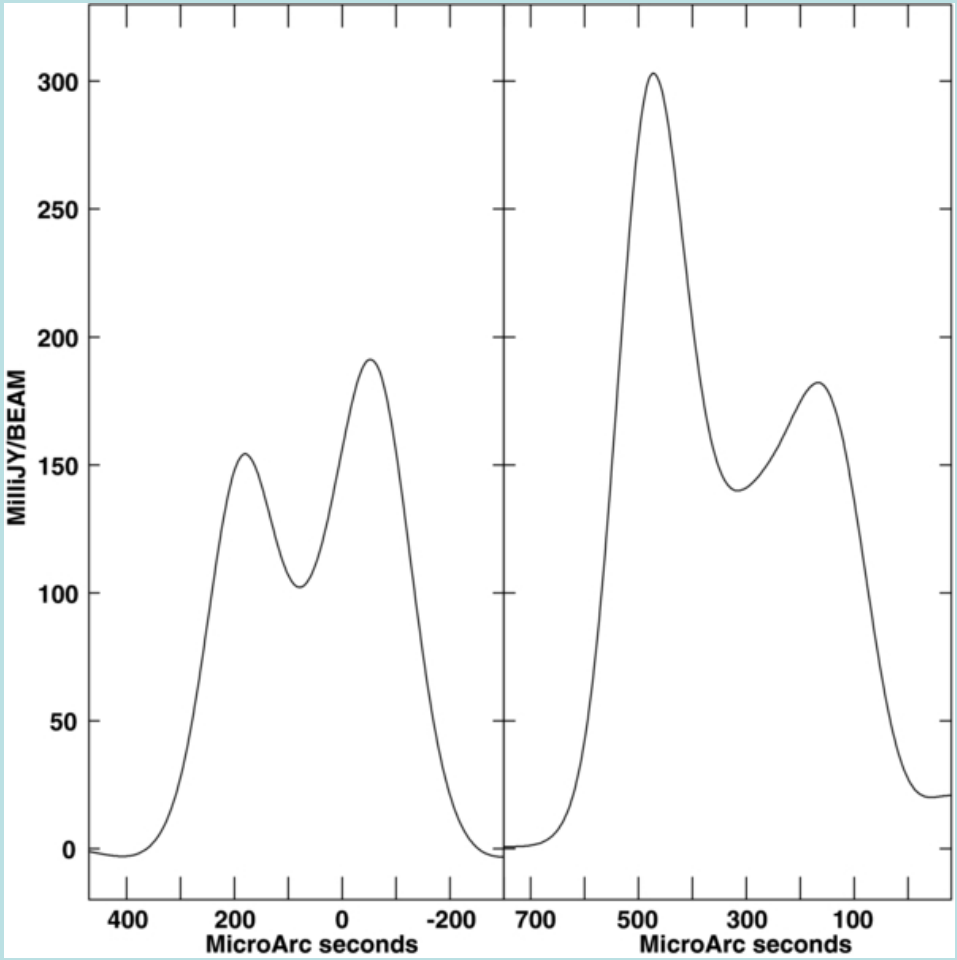
Spectral index information suggest C1 as the radio core

No strong connection between gamma-ray flares and radio activity



C3 flux density is increasing -- it is the brightest component





January 2013 image VLBA at 43 GHz

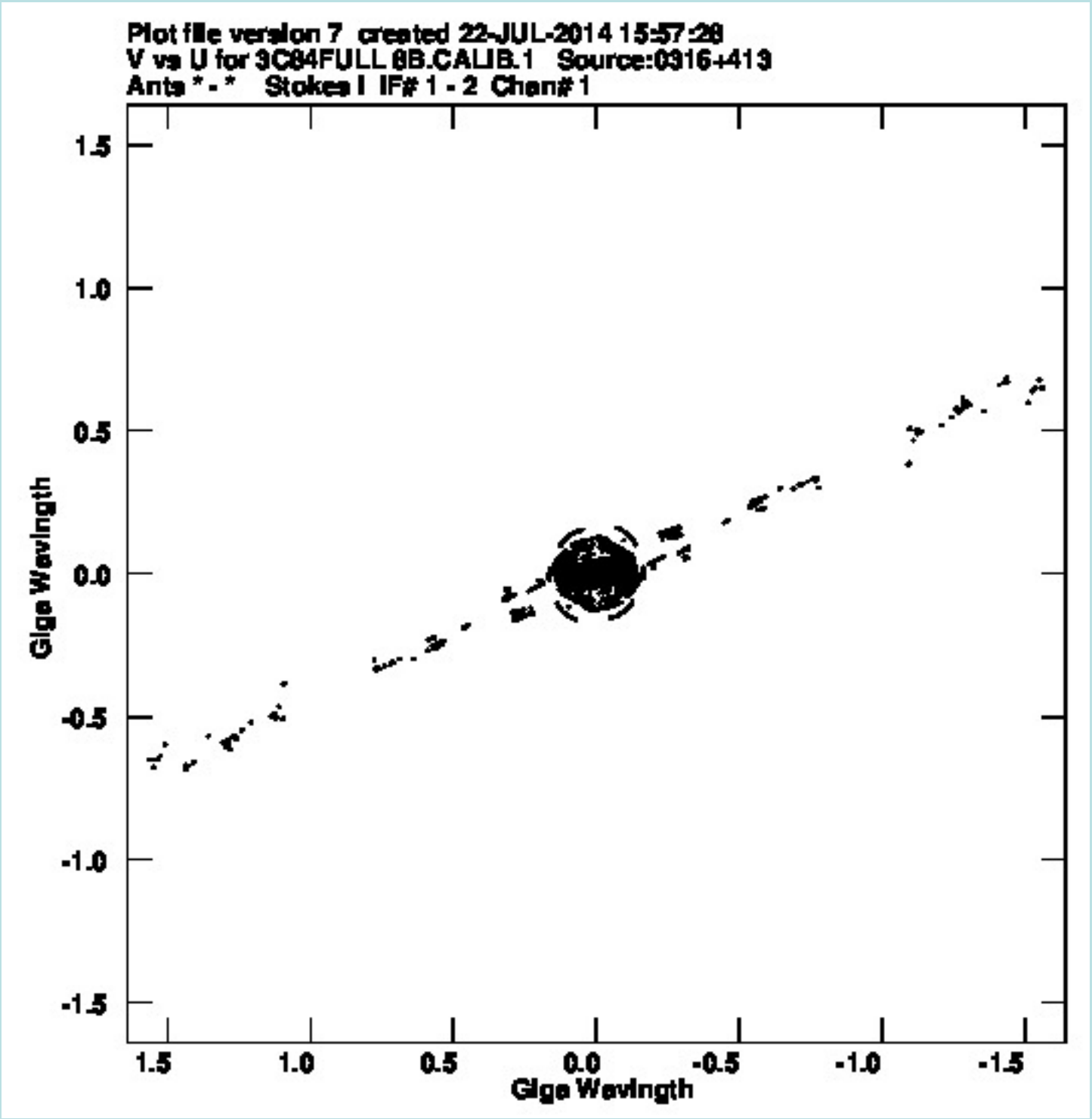
Nagai et al. 2014

Radioastron: September 21, 2013

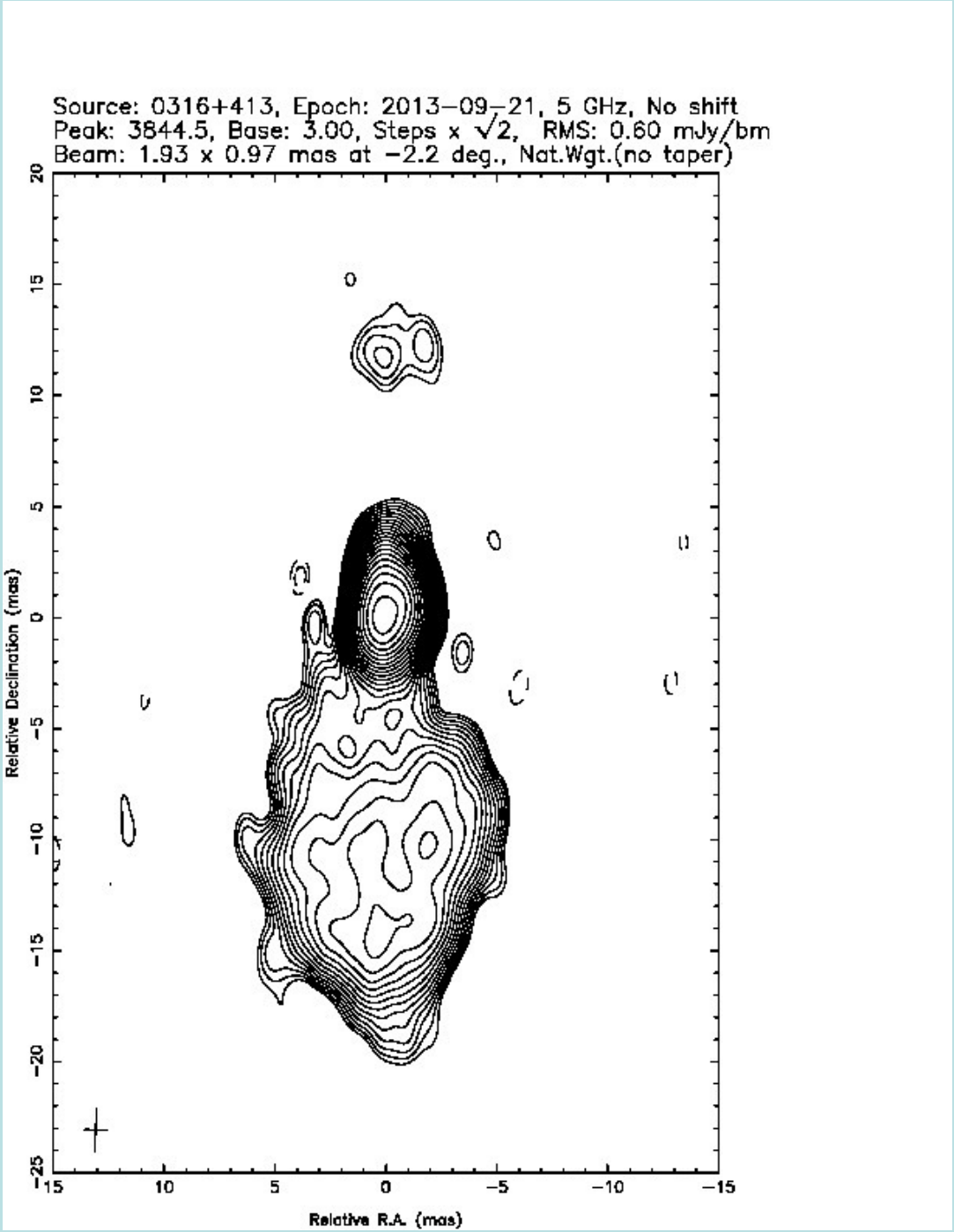
JVLA – phased array at 22 GHz, but observations also at different Frequencies:

JVLA only: unresolved nuclear structure:

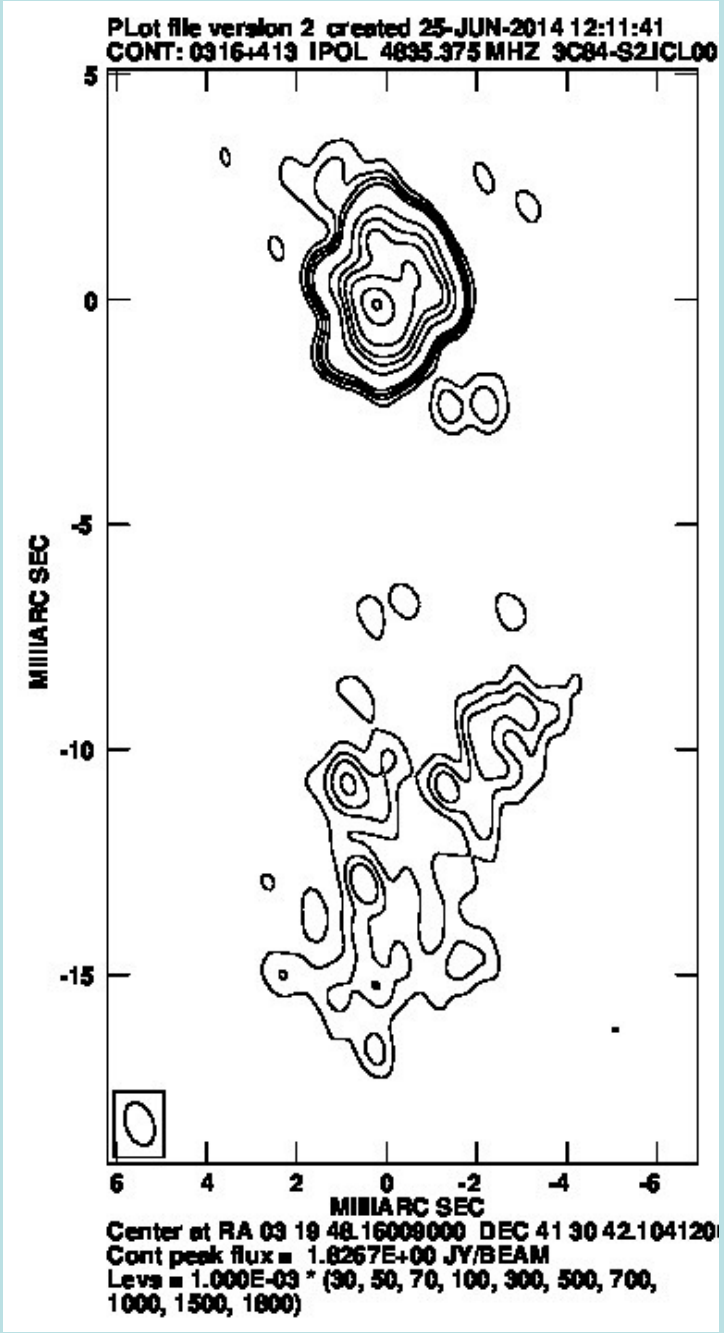
5 GHz	17.5 Jy			
15 GHz	35.9 Jy	5-15 GHz spectral index	-0.65	self abs.
22 GHz	42.3 Jy	15-22 GHz	-0.43	self. Abs.
43 GHz	29.3 Jy	22-43	0.55	



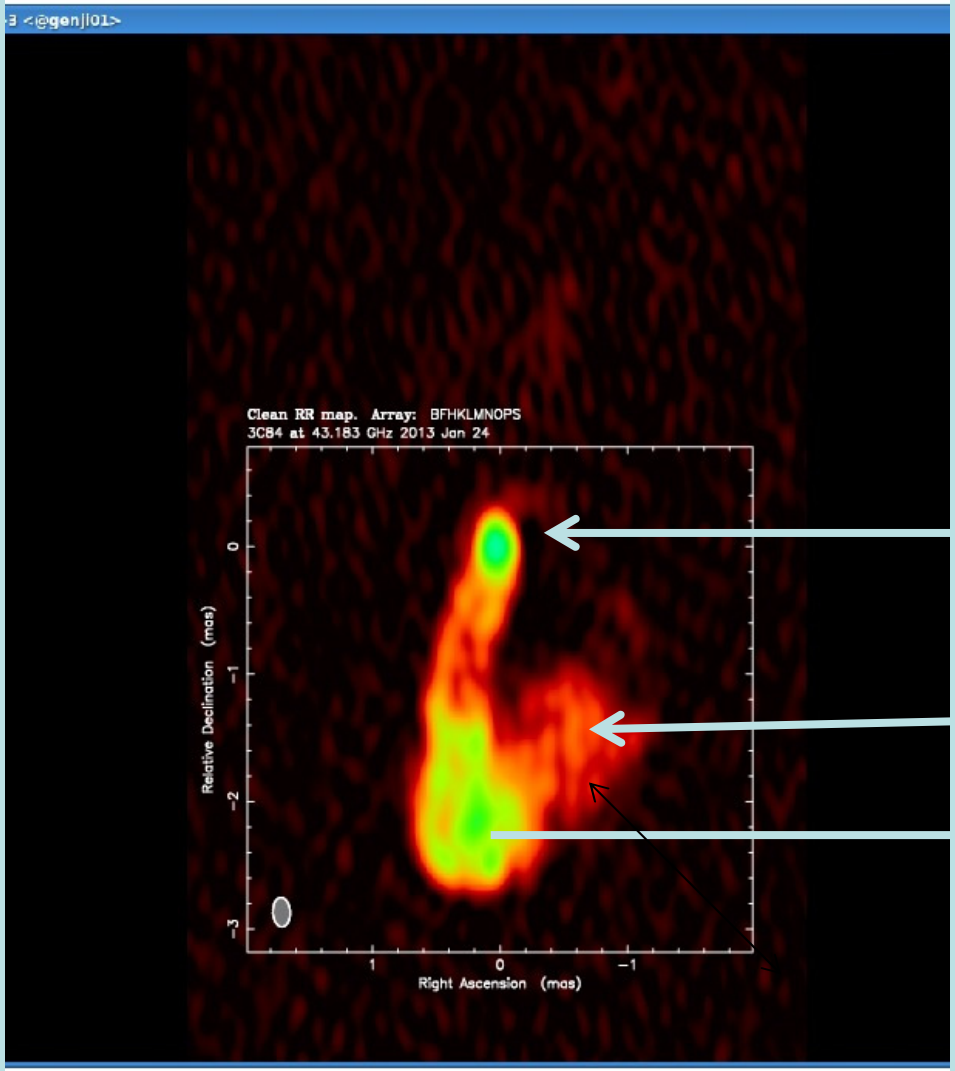
UV coverage Radioastron at 5 GHz after data editing and calibration

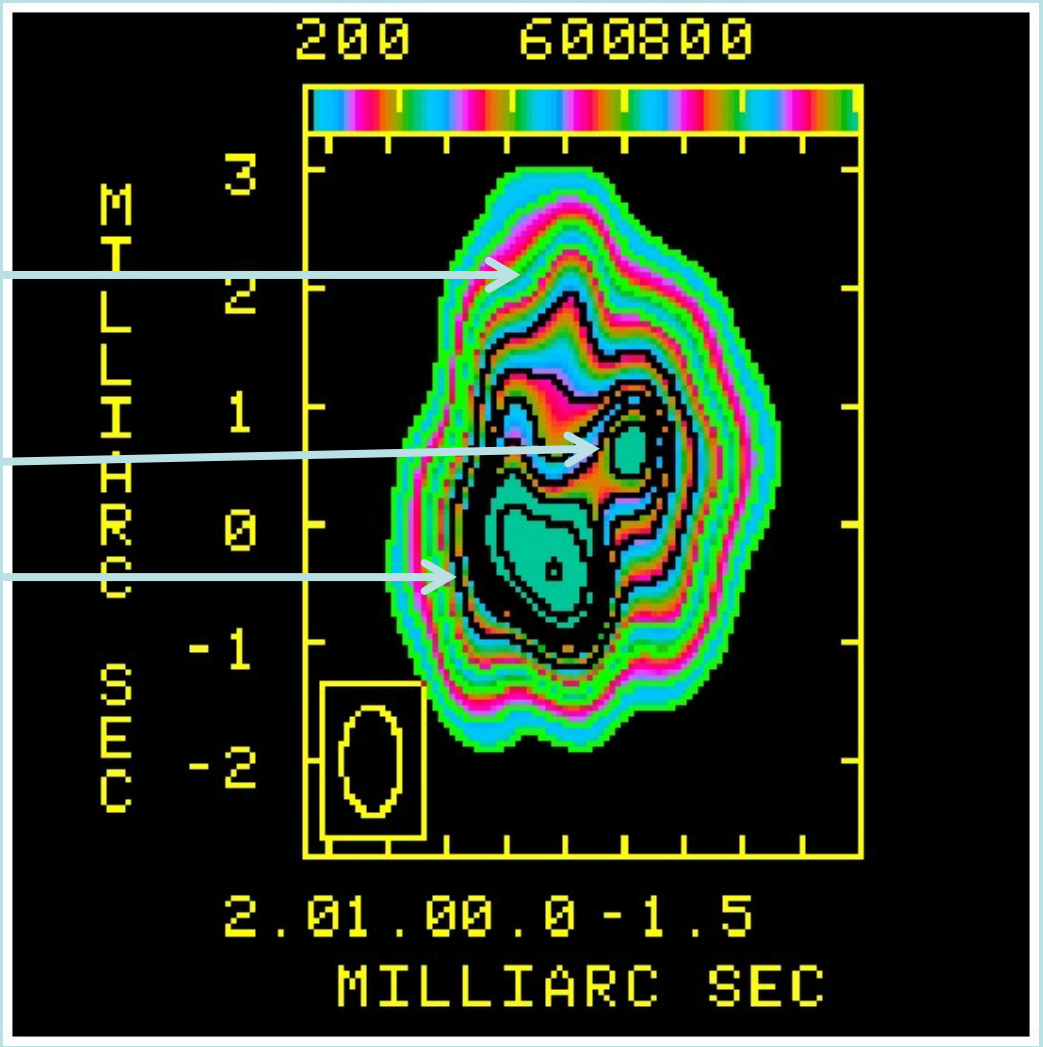


Ground only baselines



Ground + a few space bas.
2 ED





43 GHz image from Nagai et al. 2014 - HPBW: 0.24x0.13

5 GHz Radioastron image 0.9 x 0.5 mas

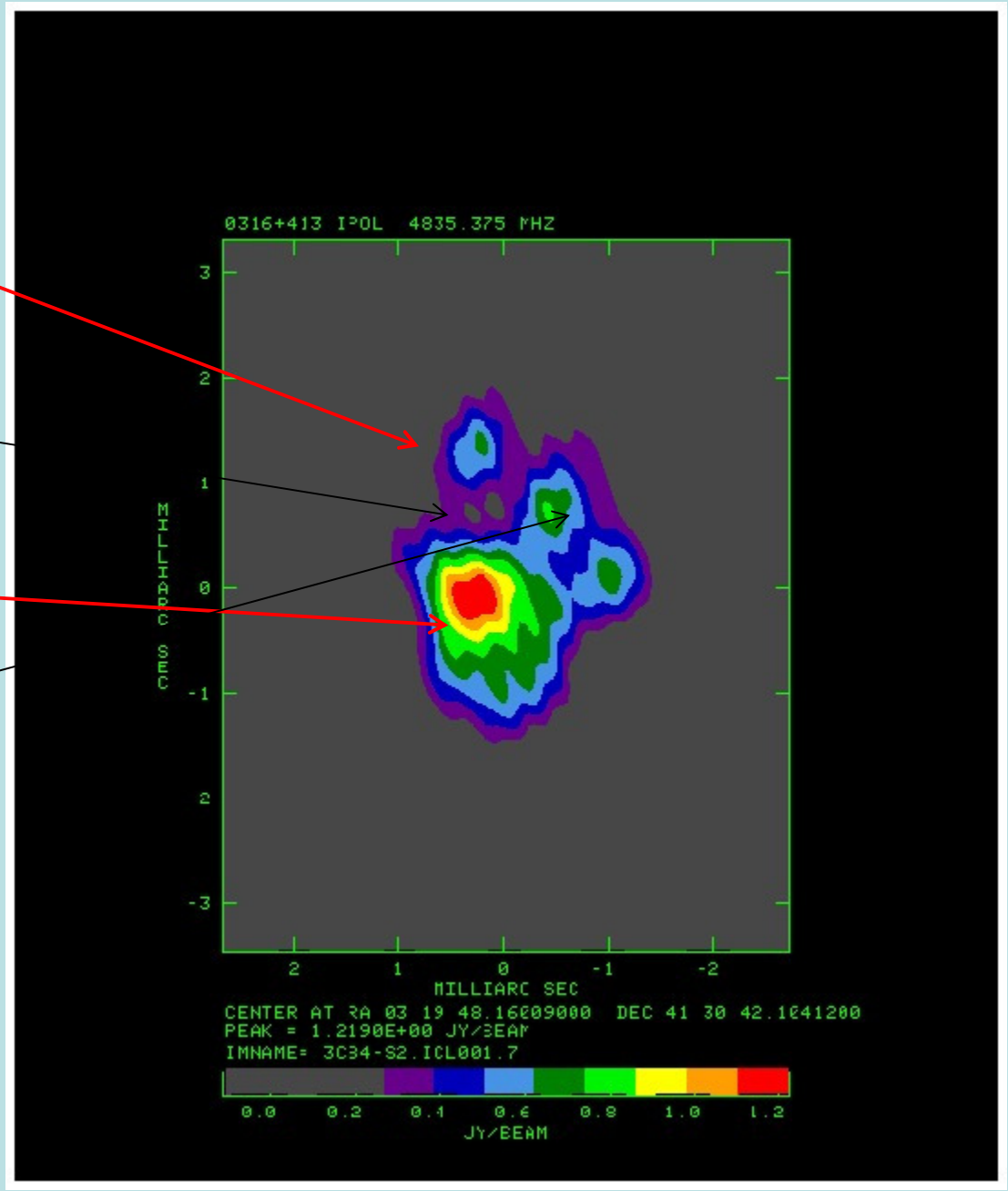
Spectral index between
5 and 43 GHz

-1.4

0.2

-0.7

1.1



HPBW=0.70x0.45
uv max 70×10^4
4.7 ED

1990 – 2000: source in a low flux density phase
centrally peaked jet
no VHE emission
C2 now relatively steep spectrum: 1990 – 2000 activity
connection with 1959 lobes?

After 2005: nuclear activity + C3 ➔ increasing flux density
new jet orientation
limb-brightened jet
VHE activity: 2009, 2010, 2013 Jan. (GeV)

C3 self-absorbed – new ejection - connection with 1959 lobes?
C1 core self-absorbed

Tavecchio and Ghisellini 2014: the overall SED of 3C84 can be reproduced in the framework of the «spine-shear» model.

Radioastron results (only from 5 GHz data):

1) 3C 84 core self-absorbed – unresolved at about 0.4 – 0.3 mas

2) One-sided jet resolved in agreement with limb-brightened structure spectral index = 0.2

3) C3 compact and bright component surrounded by a diffuse emission

4) C2 emission diffuse and steep spectrum (1.1 = old emission)
➔Previous activity misaligned by IGM not connected to lobes?

We need a better insight of the core and the C3 region
➔ **radioastron 22 GHz data**


Radioastron jet
Thank You
18/07/2011 04:48