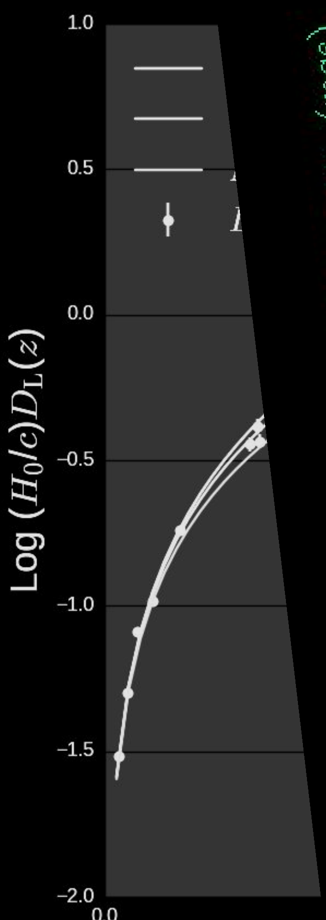
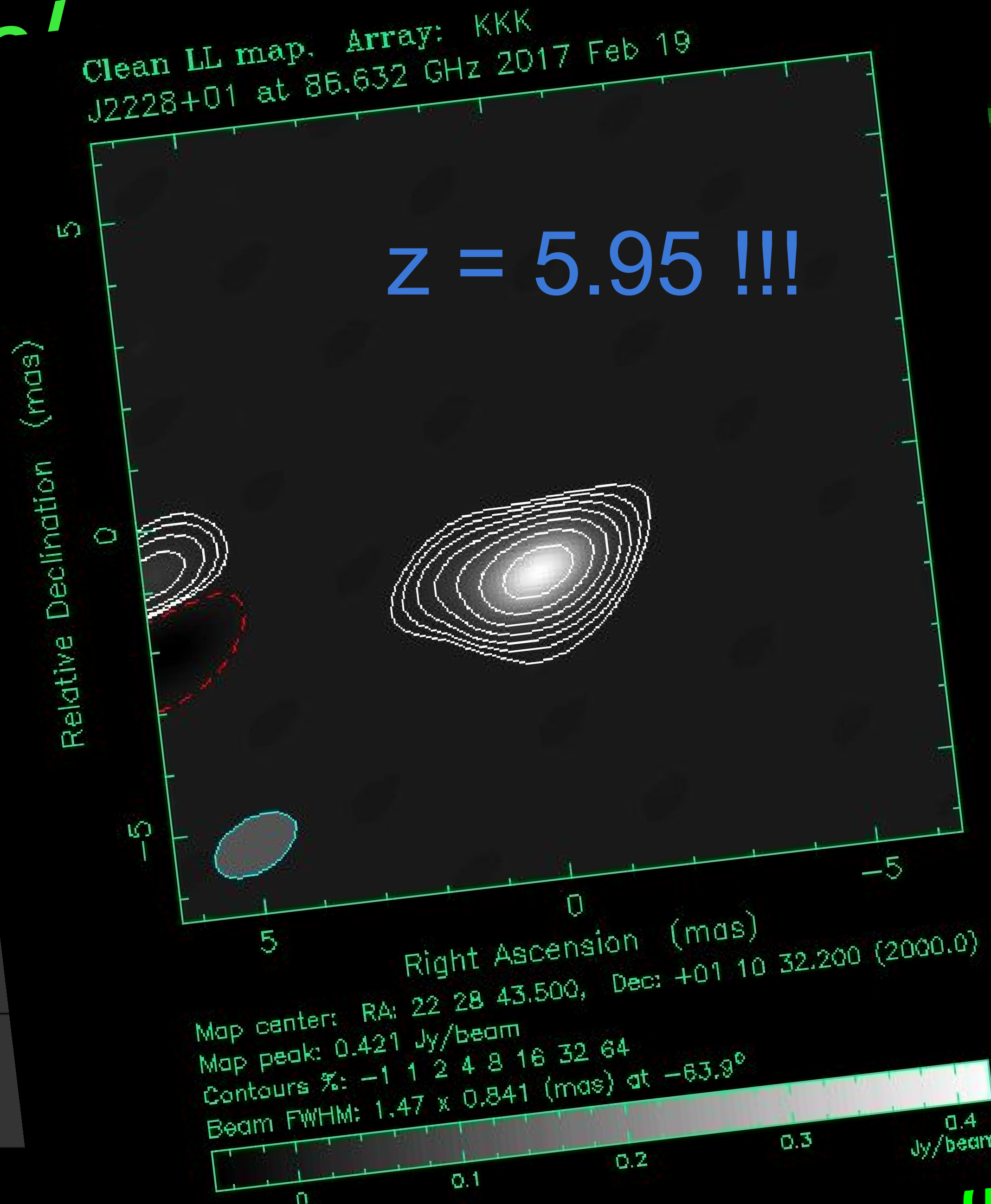
Cosm





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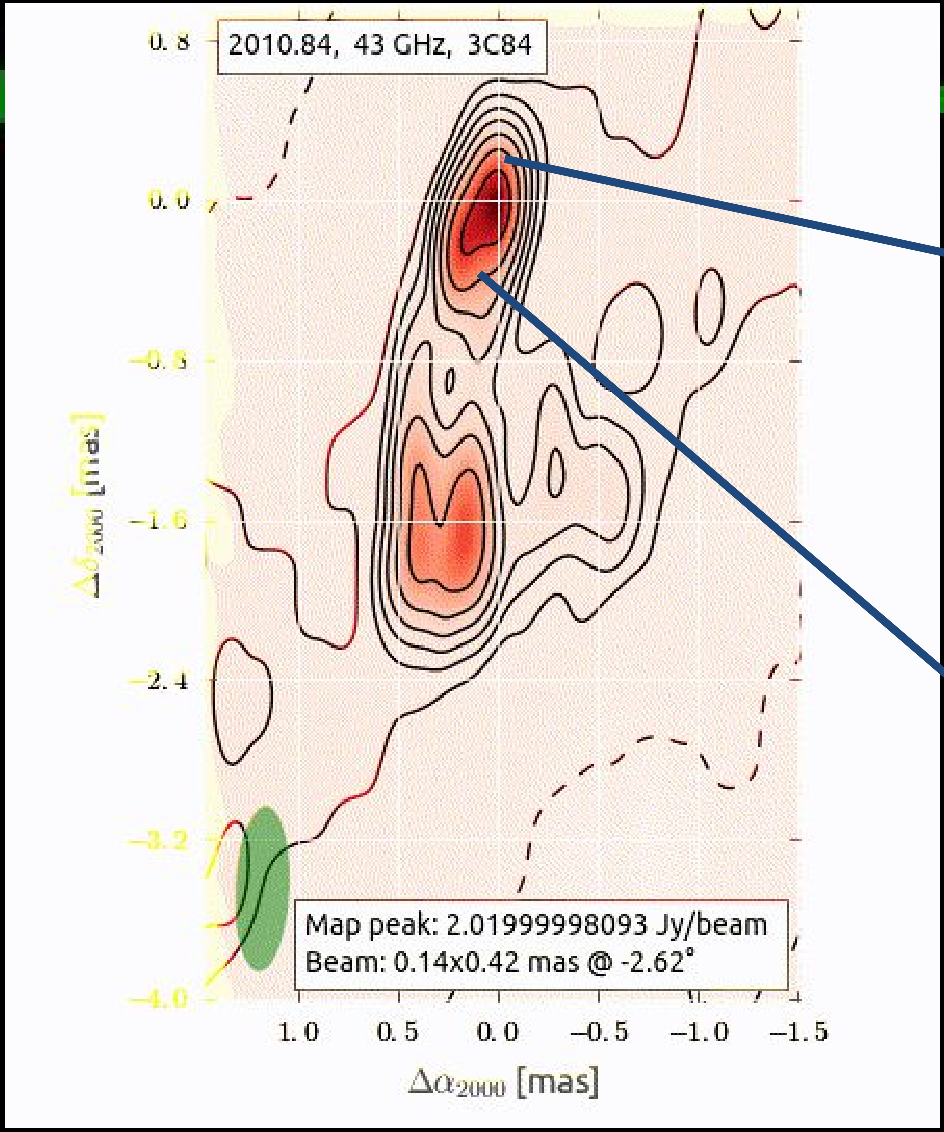
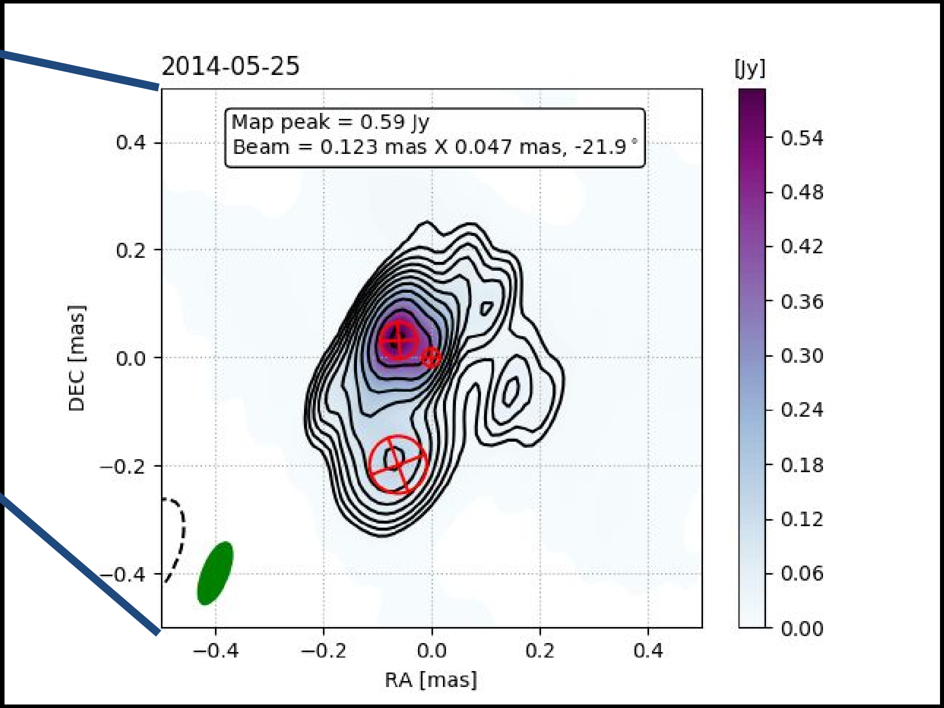
(!)

(Hodgson et. al. in prep)

3C 84 and AGN studies with KVN



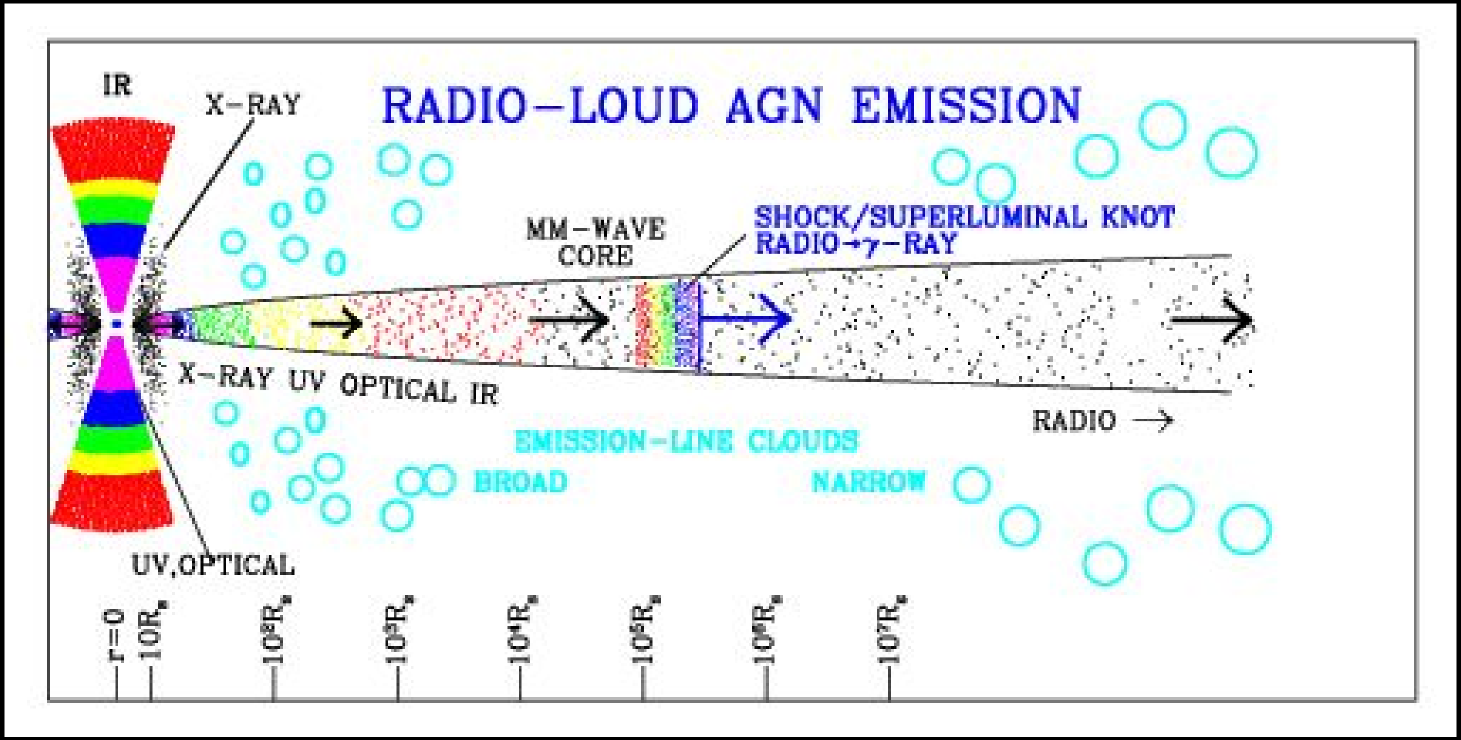


See J. Oh's poster!

Jeffrey A. Hodgson, Junghwan Oh
KASI SNU

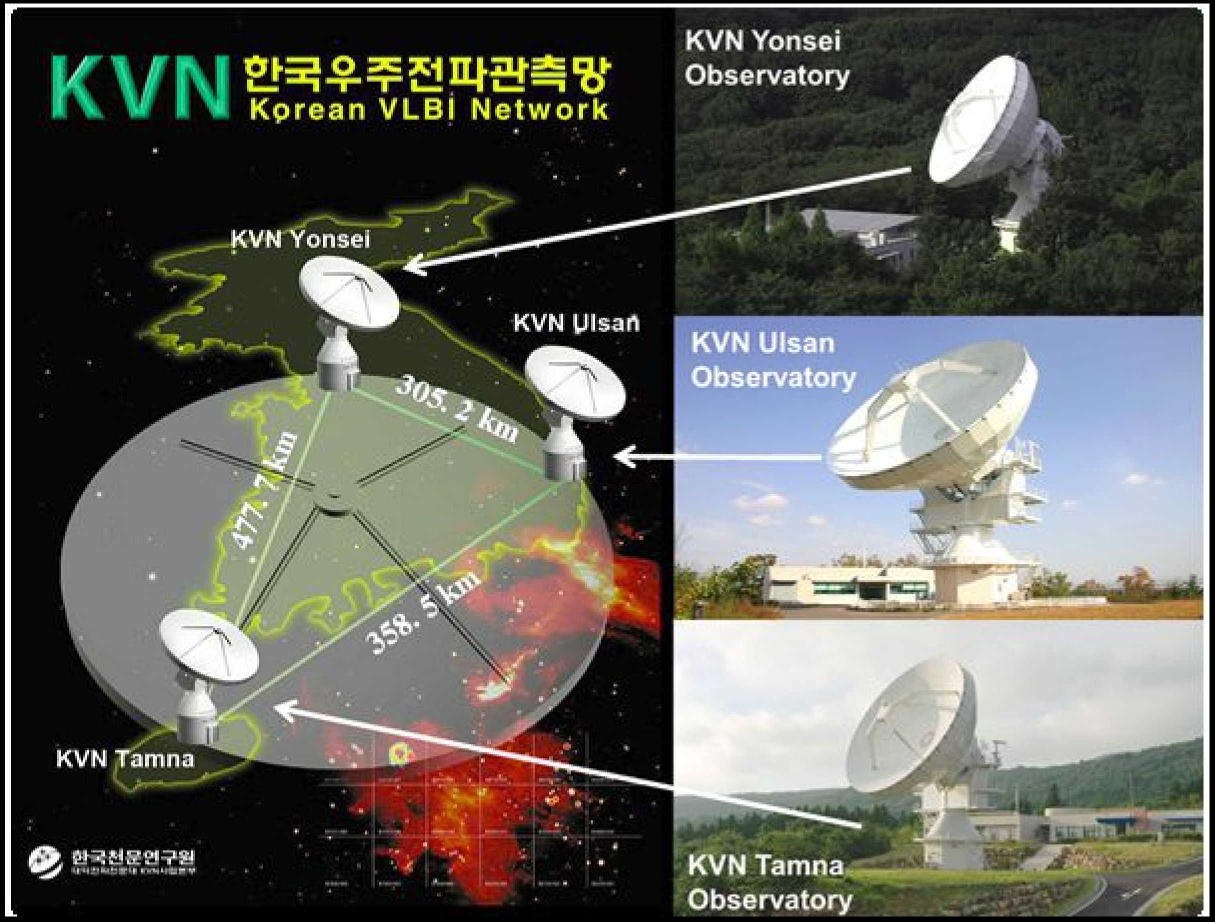
Where are G-rays made?

- Downstream of the BH? At the BH?
- BUT TeV in non relativistic sources.. why?



Korean VLBI Network (KVN)

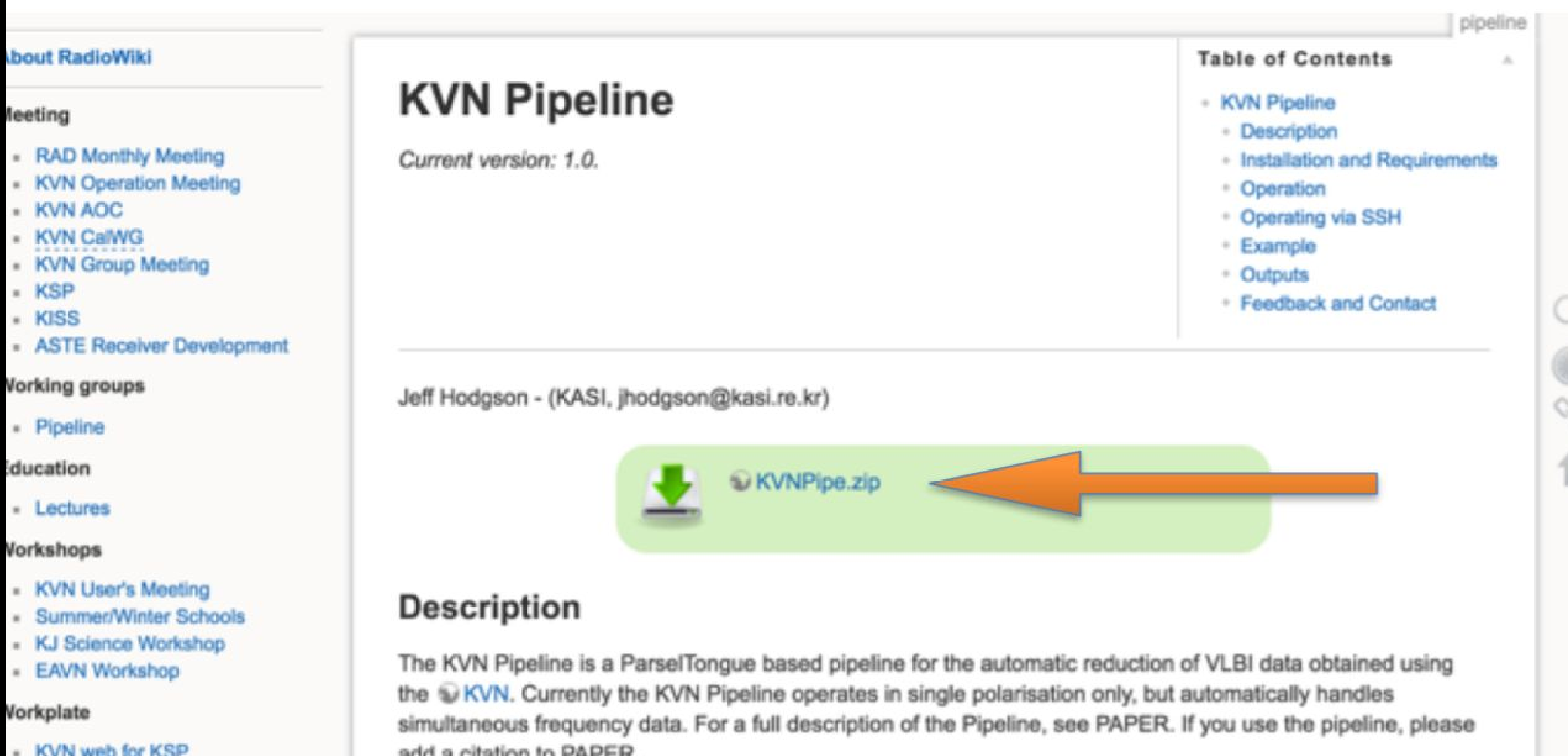
- 3 stations VLBI at 4 wavelengths (14, 7, 3, 2 mm)
- Frequency Phase Transfer: huge increase in mm-wave sensitivity! ~30 min integrations at 2 mm.



KVN Pipeline

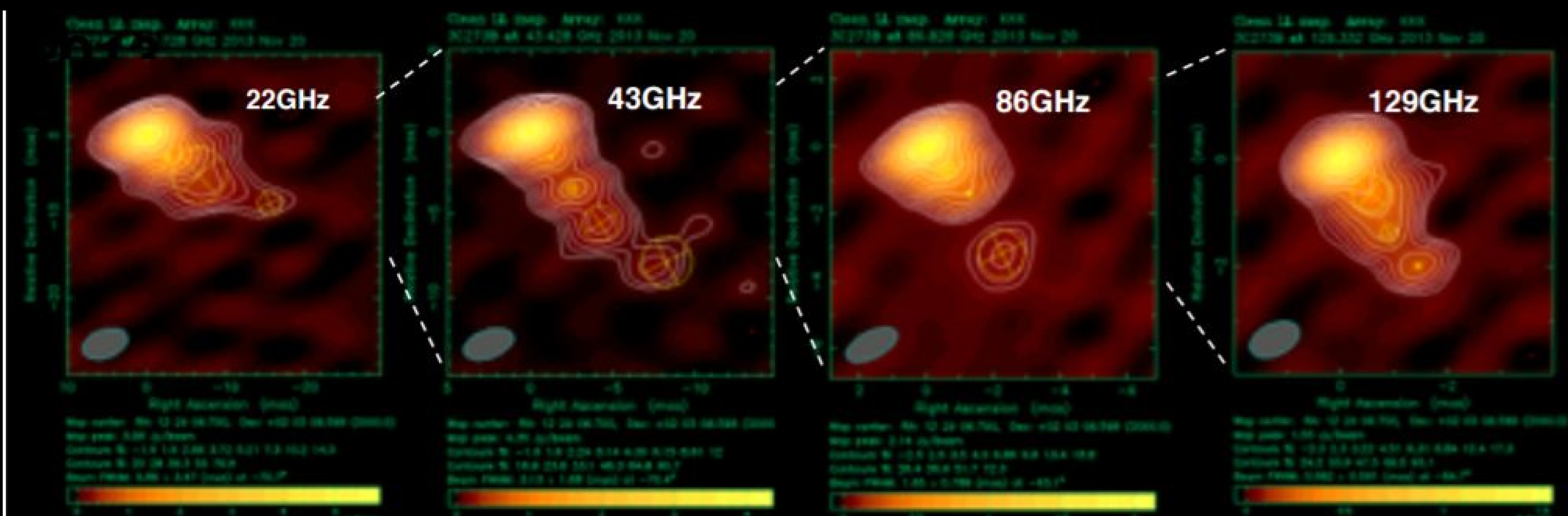
- Automatic calibration for single-pol continuum experiments
- VLBI for non VLBI people!   Hodgson+ 2016, JKAS

The KVN Pipeline radiowiki.kasi.re.kr



KVN KSP: iMOGABA

- interferometric MOnitoring of GAmma-ray Bright AGN
- 35 sources
- Monthly monitoring at 4 frequencies simultaneously:
  - 14mm 7mm 3mm and 2mm
- Check for correlations with radio, kinematics, turnover frequency



KVN KSP: iMOGABA

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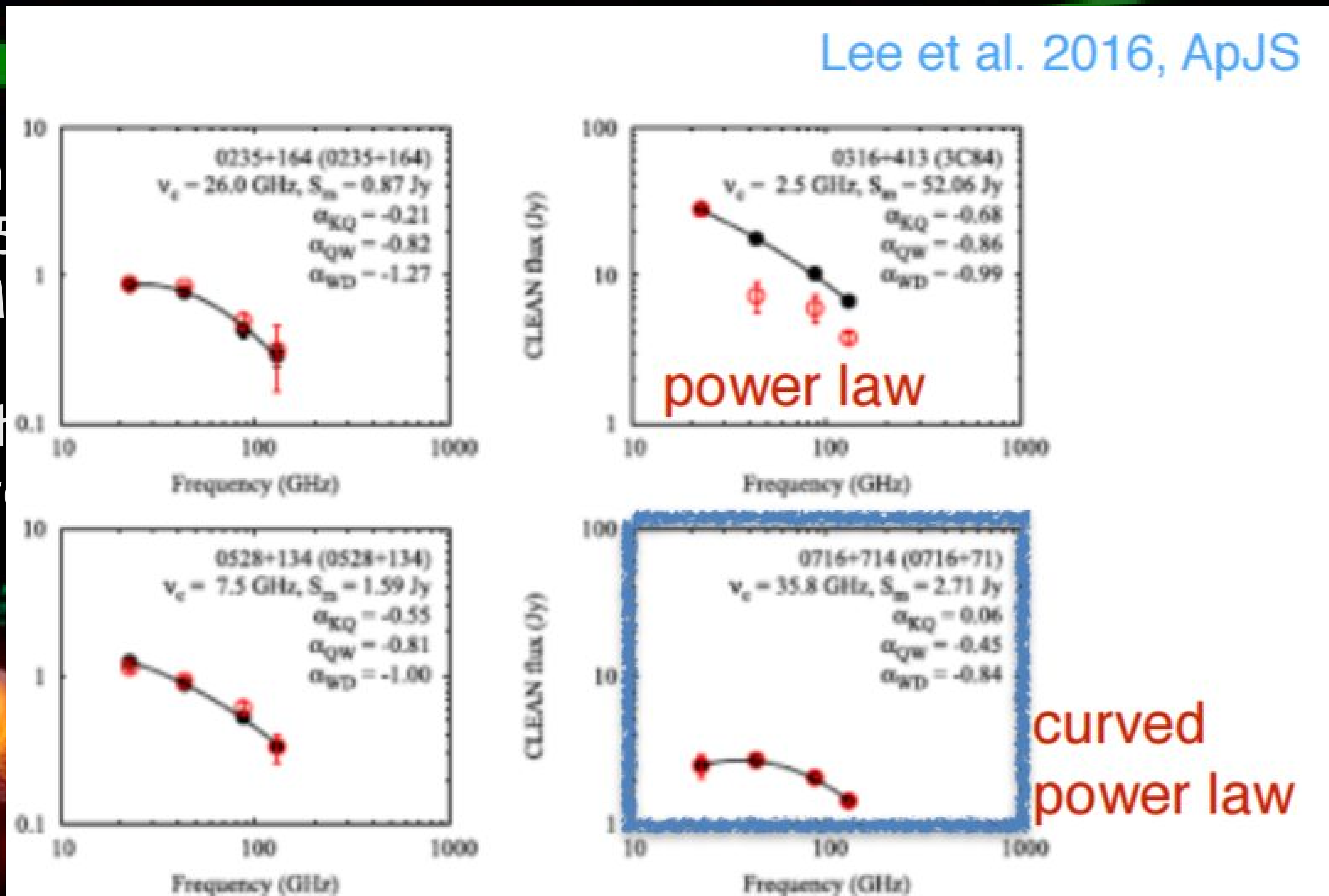
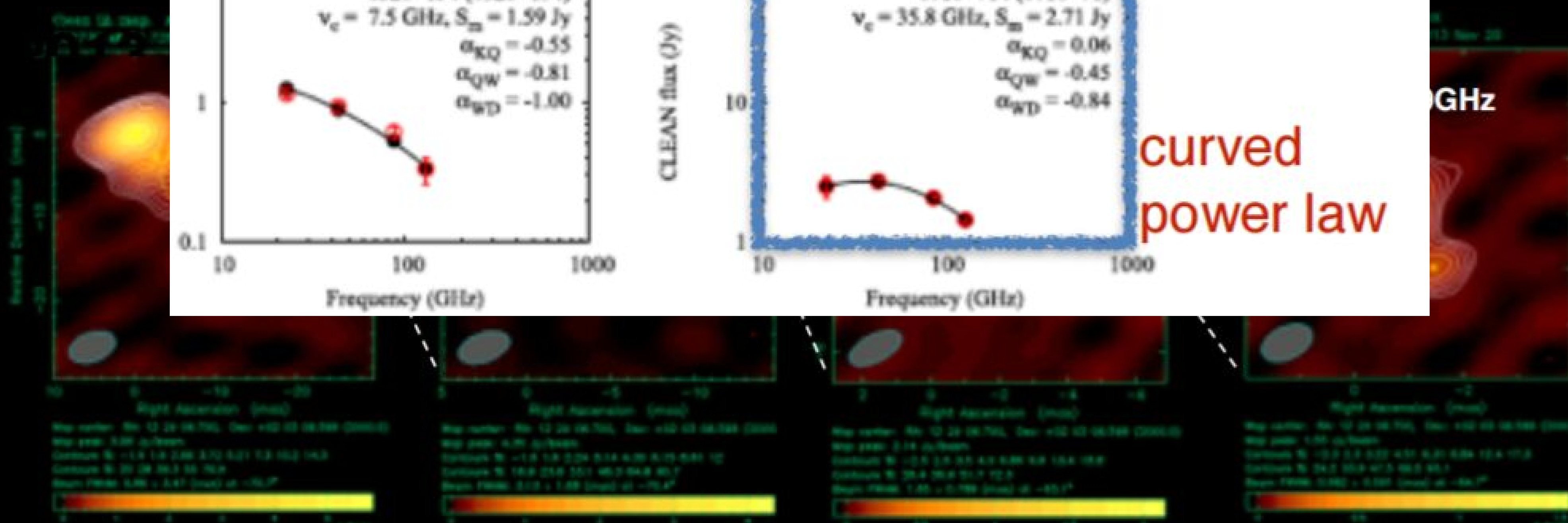
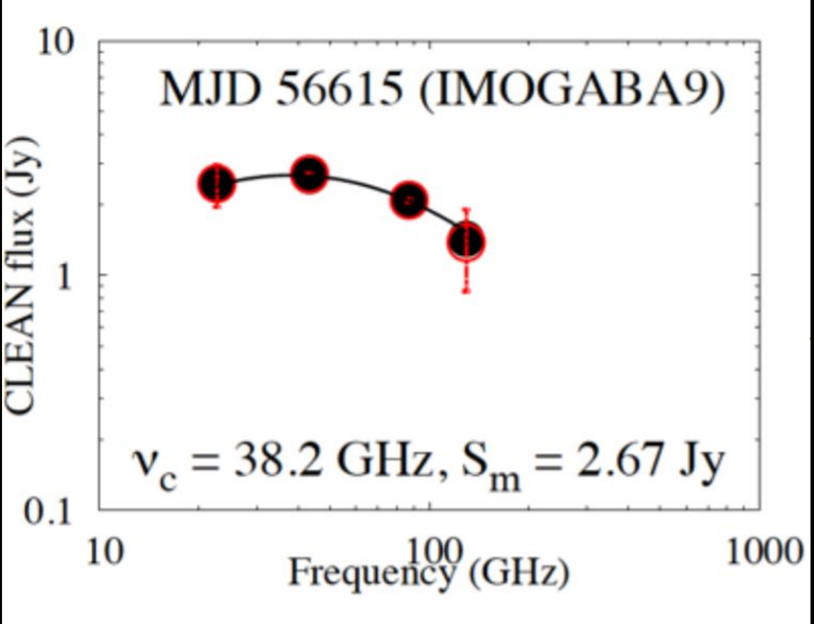


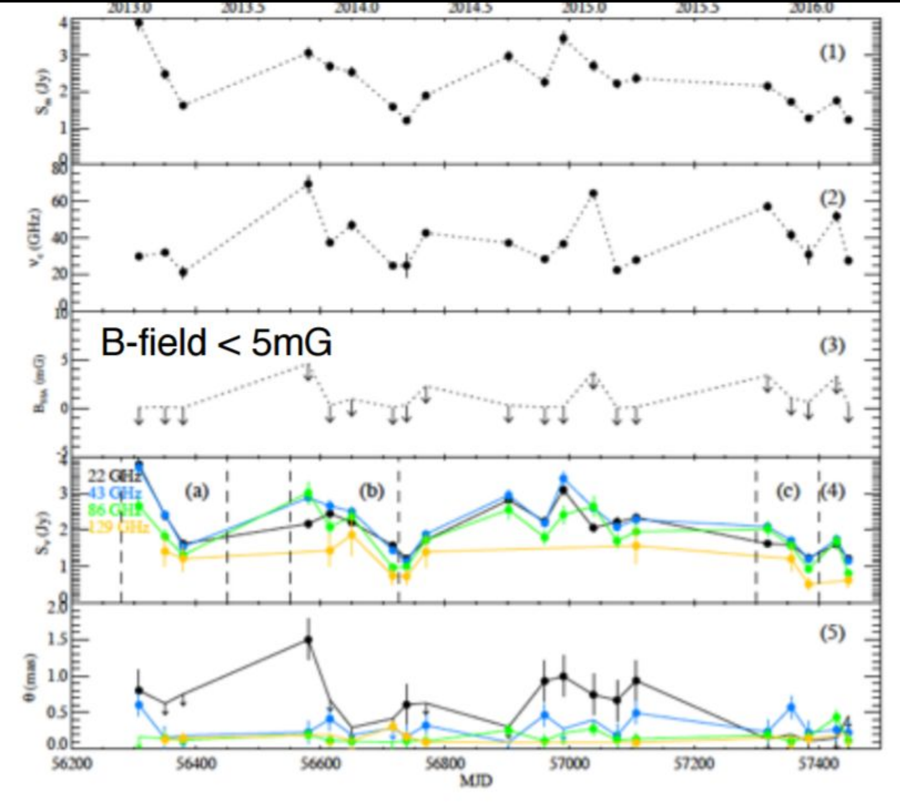


0716+714 (Lee+ 2017, ApJ)

- Turnover frequency changes with radio and Gamma-ray flaring
- Can estimate B-field from SSA - but strong assumptions using KVN (e.g. source size) B < 0.5mG



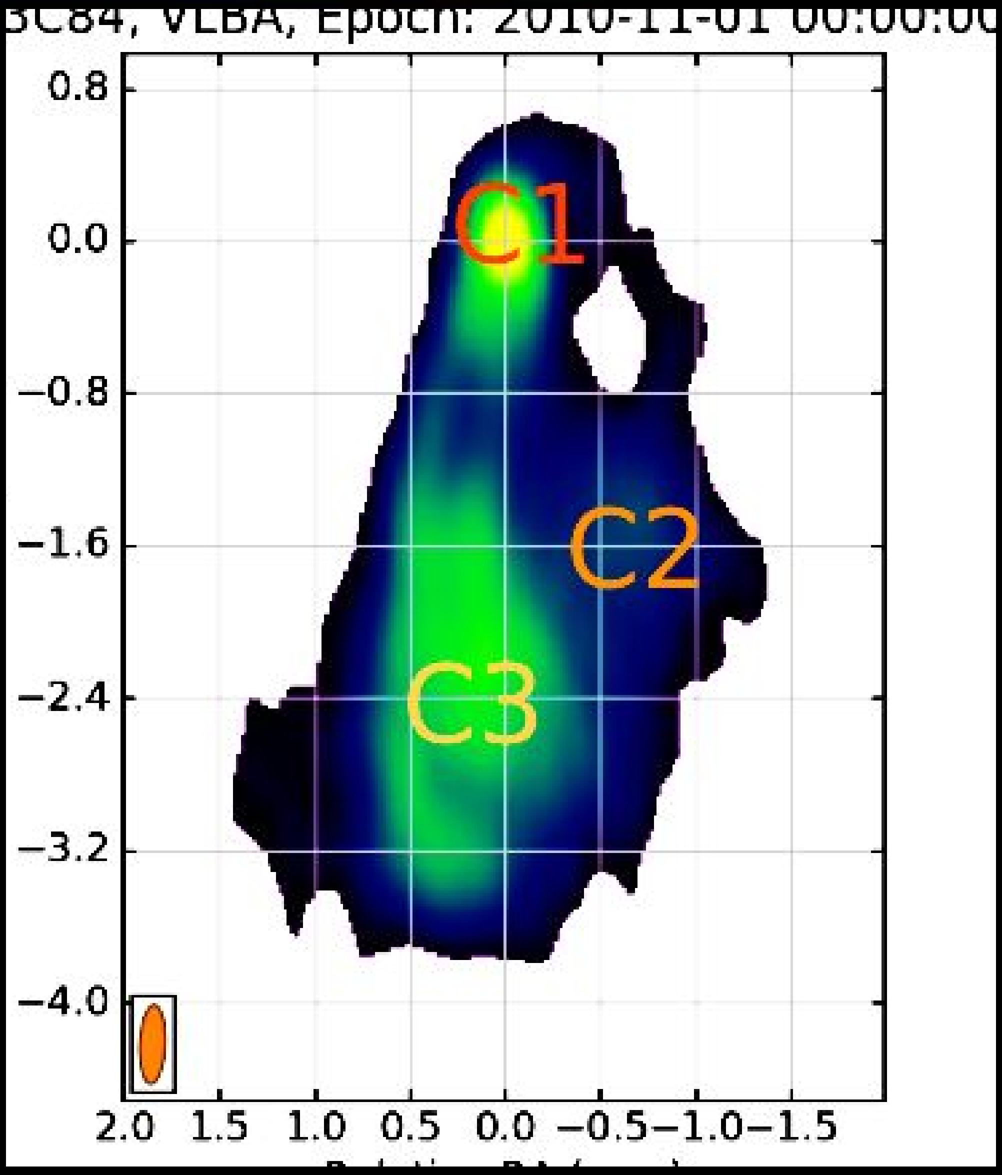
$$B \propto S_m^{-2}\theta^4\nu_c^5\left(\frac{\delta}{1+z}\right)^{-1}$$

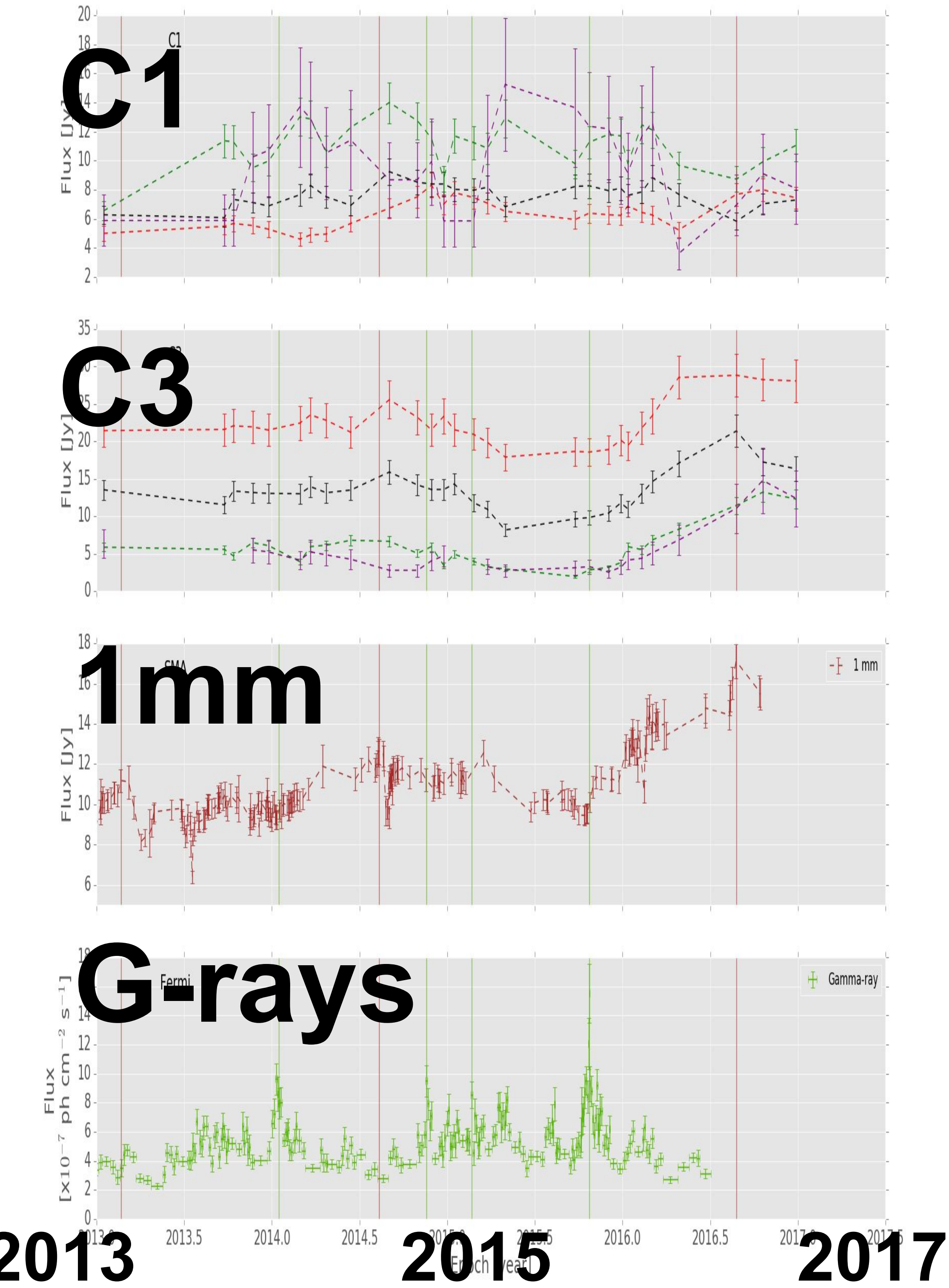


3C 84 in this talk

- Show G-ray emission from C1 and C3 regions
- WISE analysis of kinematics:
  - G-rays in C3 region are “GRB-like”
  - C3 crashes “through” C2
  - A solution to the “Doppler crisis”
    - why do low Doppler boosted sources produce TeV?
- C2 is a slow moving jet component ejected in early 1980s
- GMVA observations reveal double component nuclear structure
  - helical jet sheath

3C 84 in this talk





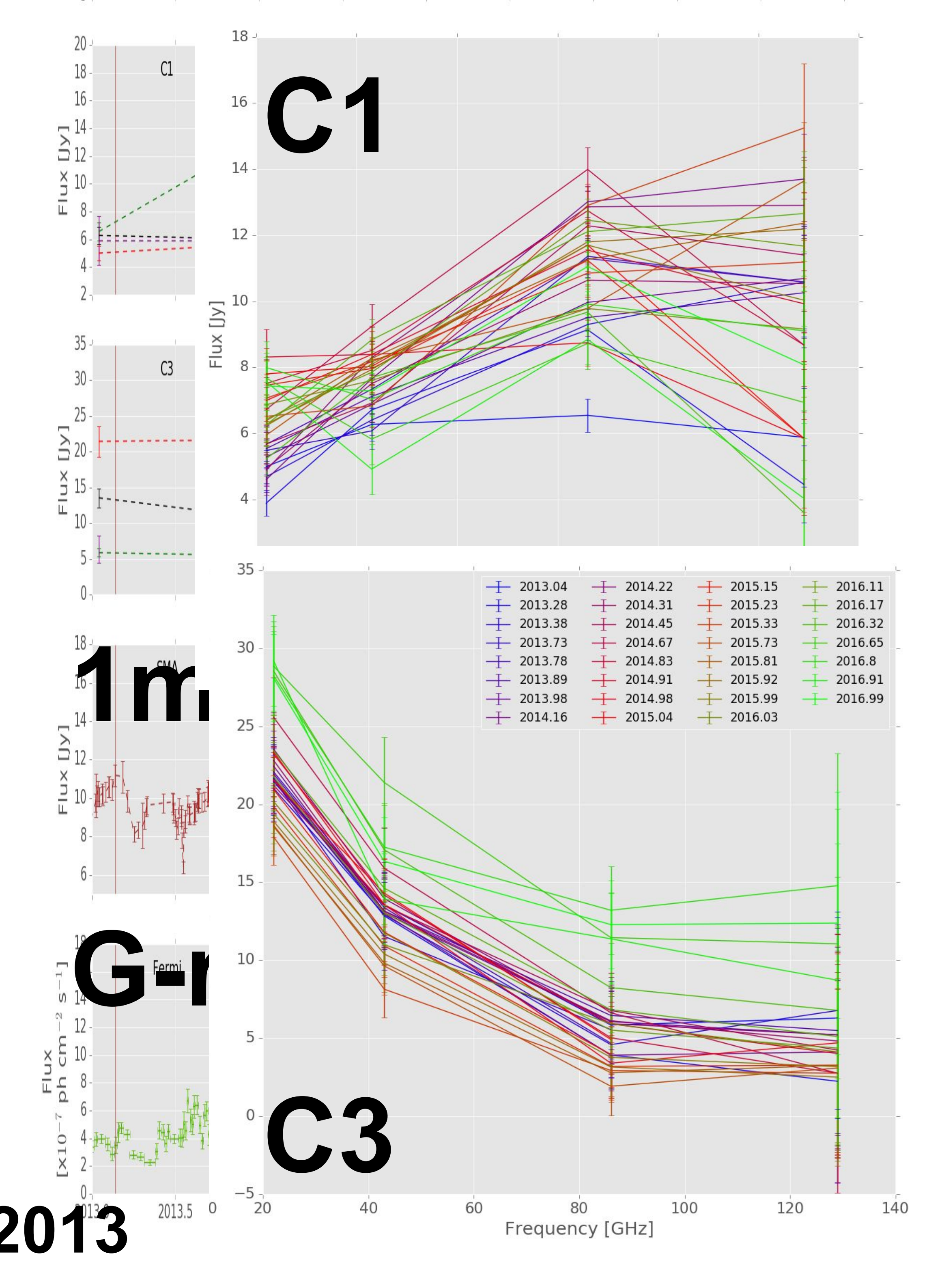
Short time-scale variability on top of slower rising trend

2mm more variable than 3mm and longer

Large flare in C3 beginning ~2015

G-ray flare at onset

(Hodgson et. al. MNRAS, accepted)



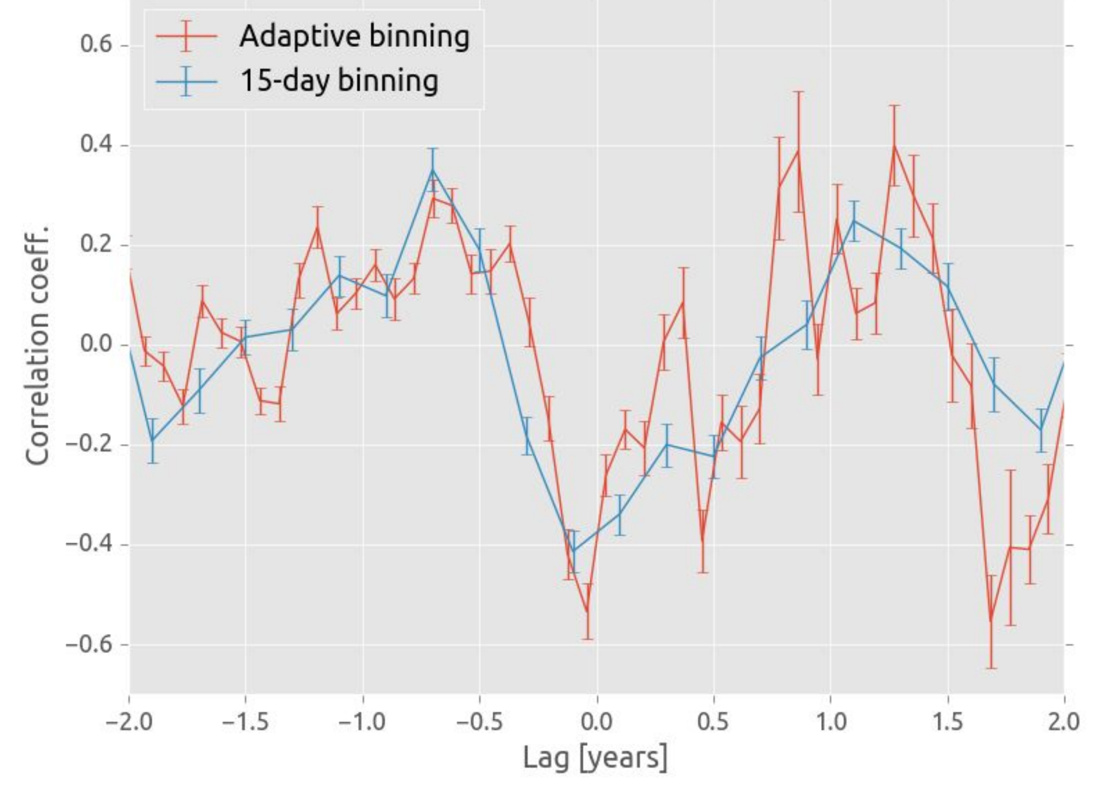
Short time-scale variability on top of slower rising trend

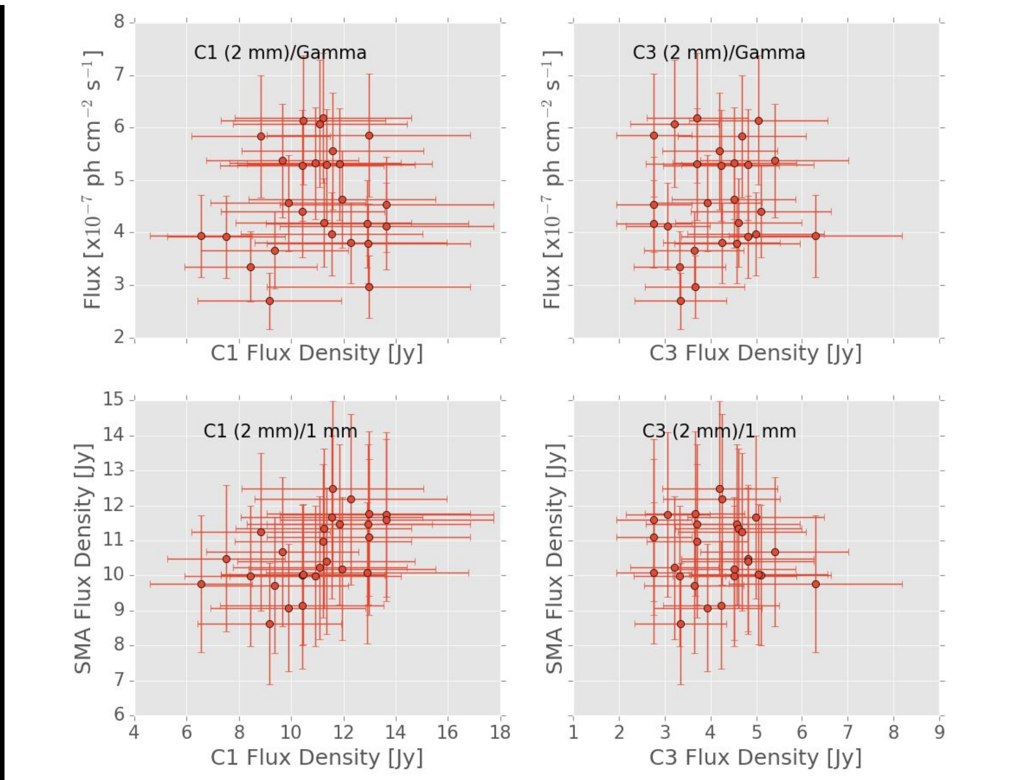
2mm more variable than 3mm and longer - only in C1!

Large flare in C3 beginning ~2015

G-ray flare at onset

(Hodgson et. al. MNRAS, accepted)





1mm and G-rays significantly correlated.

Short time-scale variability better correlated with C1 than C3.

>> G-rays in C1 and C3

Softer when brighter trend > different from blazar emission

(Hodgson et. al. MNRAS, basically accepted)

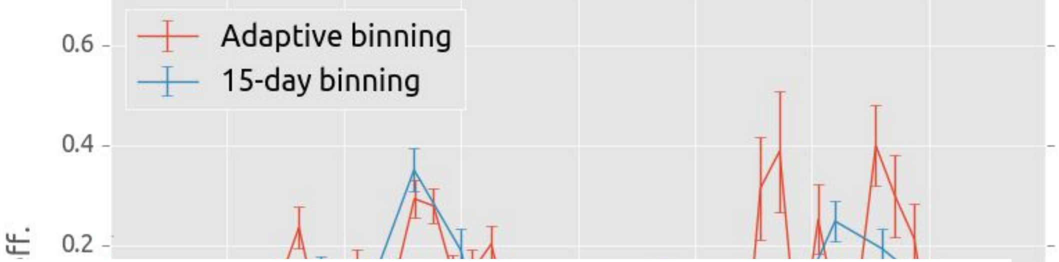
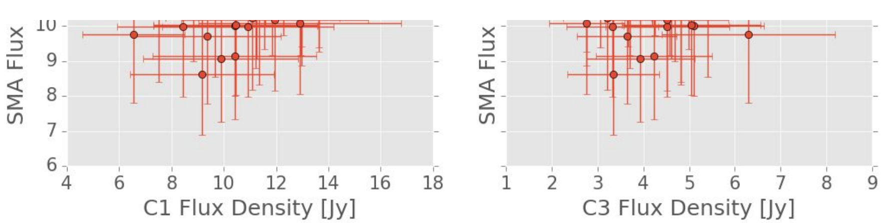


Table 6. Pearson correlation coefficients proceeding flare R3.

	Coeff.	Significance
C1/Gamma	0.16	0.43
C3/Gamma	0.13	0.52
C1/1 mm	0.49	0.01
C3/1 mm	−0.25	0.21

Table 7. Pearson correlation coefficients proceeding flare R3 with 8 month offset.

	Coeff.	Significance
C1/Gamma	0.60	0.006
C3/Gamma	−0.32	0.18
C1/1 mm	−0.11	0.63
C3/1 mm	−0.46	0.04



1mm and G-rays significantly correlated.

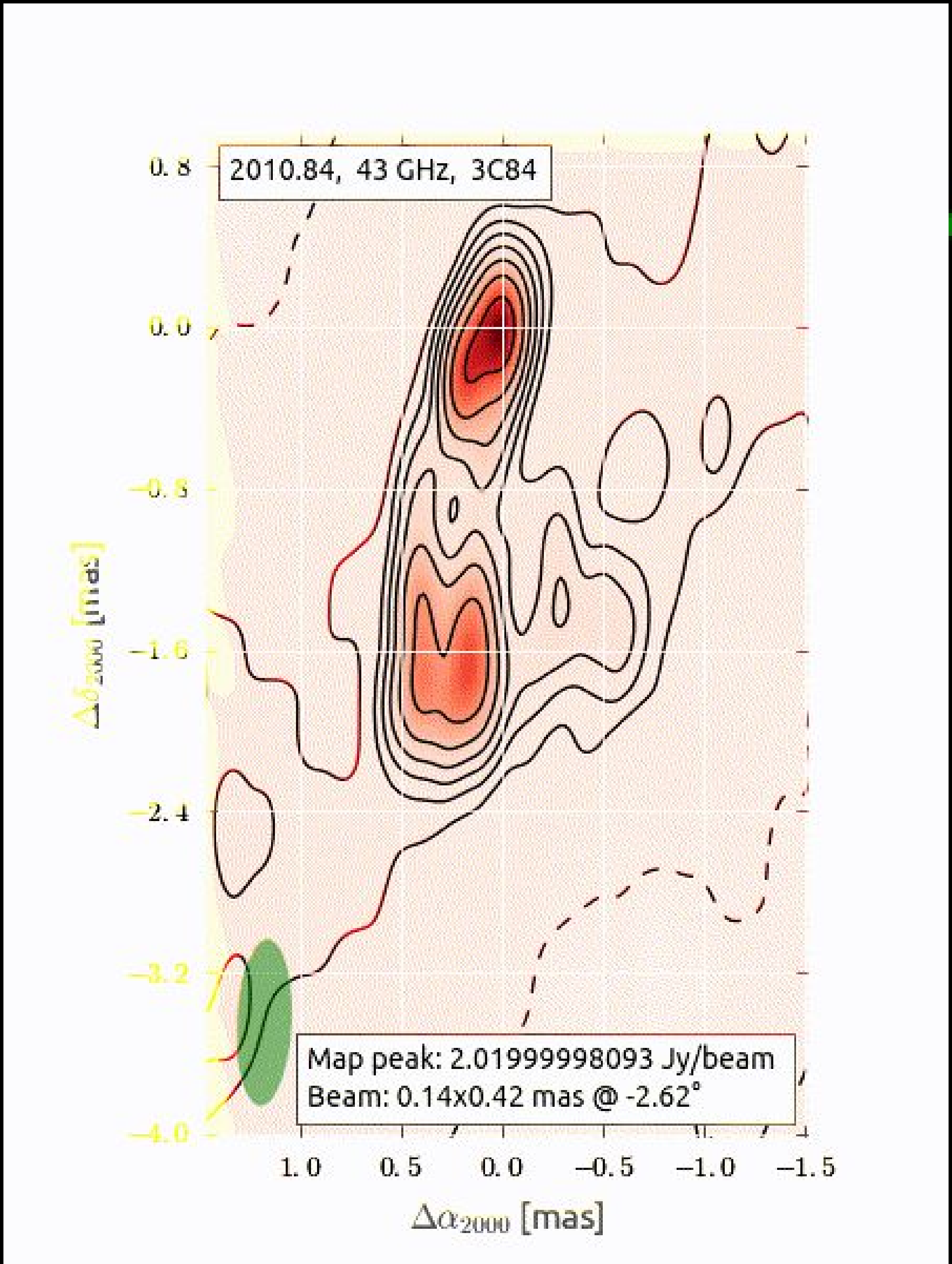
Short time-scale variability better correlated with C1 than C3.

>> G-rays in C1 and C3 Softer when brighter trend > different from blazar emission

Interpreted as due to random correlations of separated variable components

(Hodgson et. al. MNRAS, basically accepted)

What is happening in C3?



BU 7mm data from 2010 until now

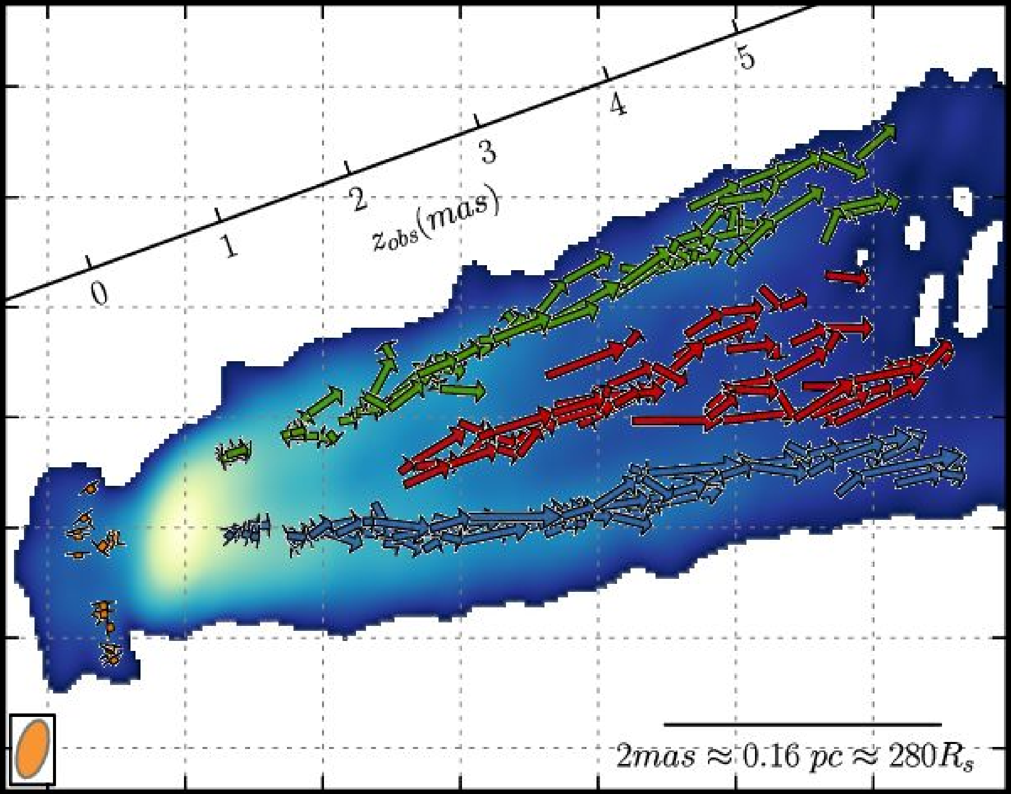
Looks like C3 crashing "through" C2

C3 has two hotspots that become bright and then dissipate to the west

Takes the appearance of also hitting an external medium.

(Hodgson et. al. in prep)

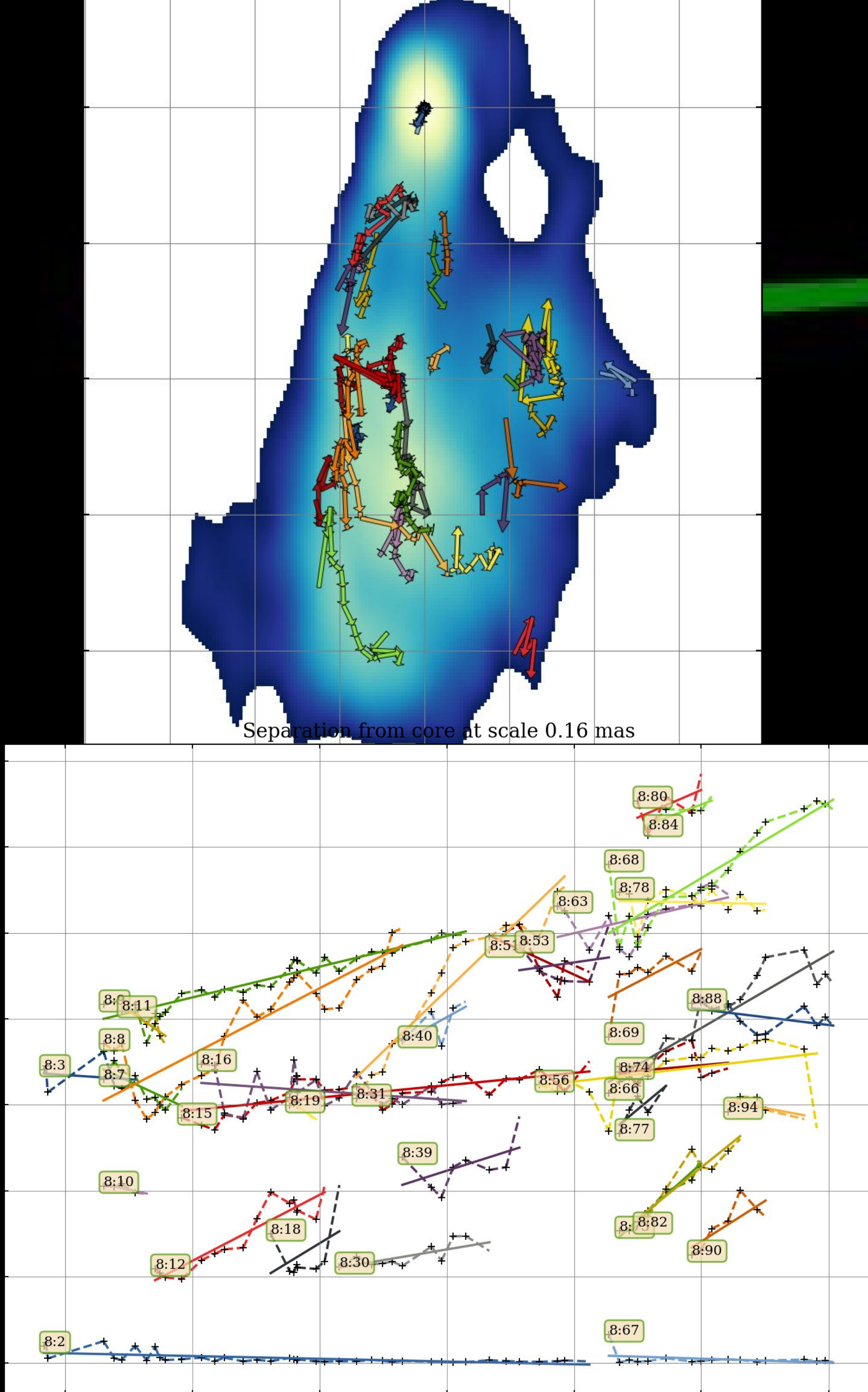
WISE: Wavelet Image Segmentation and Evalutation



Uses 2D cross correlations to *objectively* determine kinematics in high cadence datasets.

Has been used to detected spine-sheath and helical motions in M87 (Mertens16+)

Freely available to download



IS this what a GRB looks like?

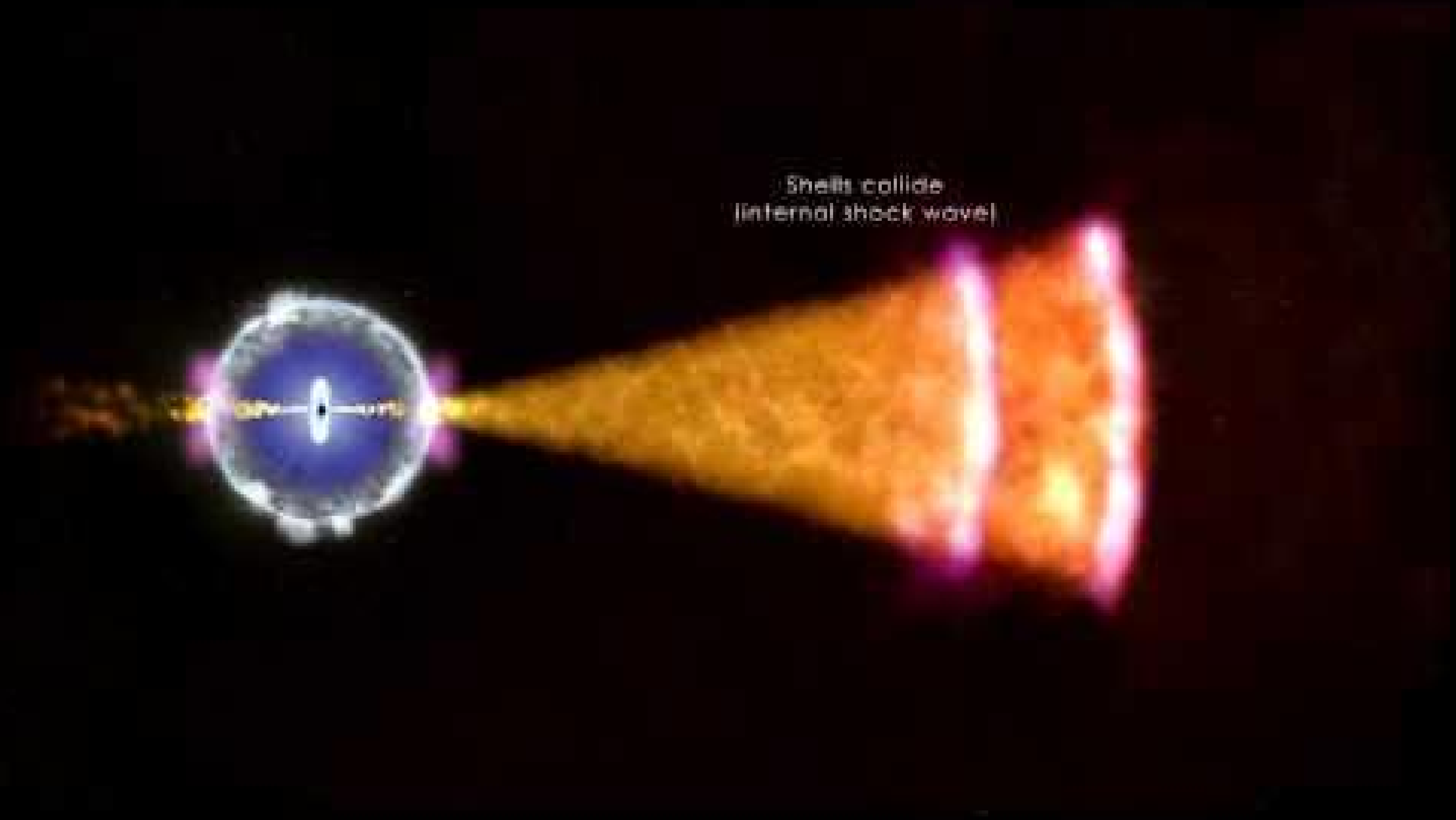
Helical motions

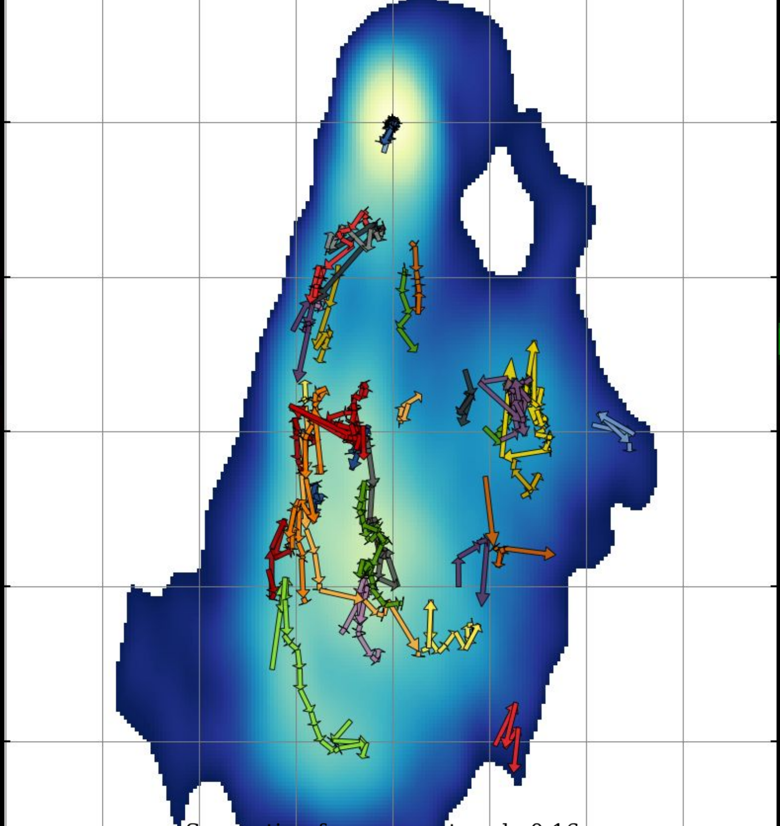
Super-luminal motion: fast shock catching up with slower shock > G-ray flare

Hits external medium > G-ray flare > dissipates west

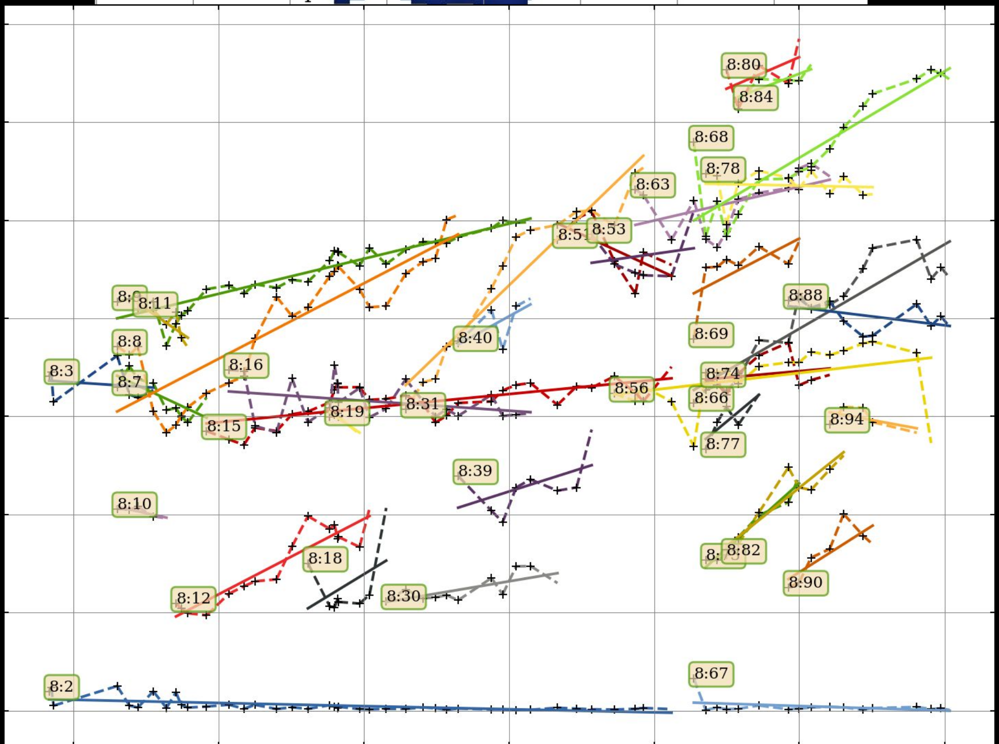
What does this look like?

(Hodgson et. al. in prep)


Shells collide
(internal shock wave)



Separation from core at scale 0.16 mas



IS this what a GRB looks like?

Helical motions

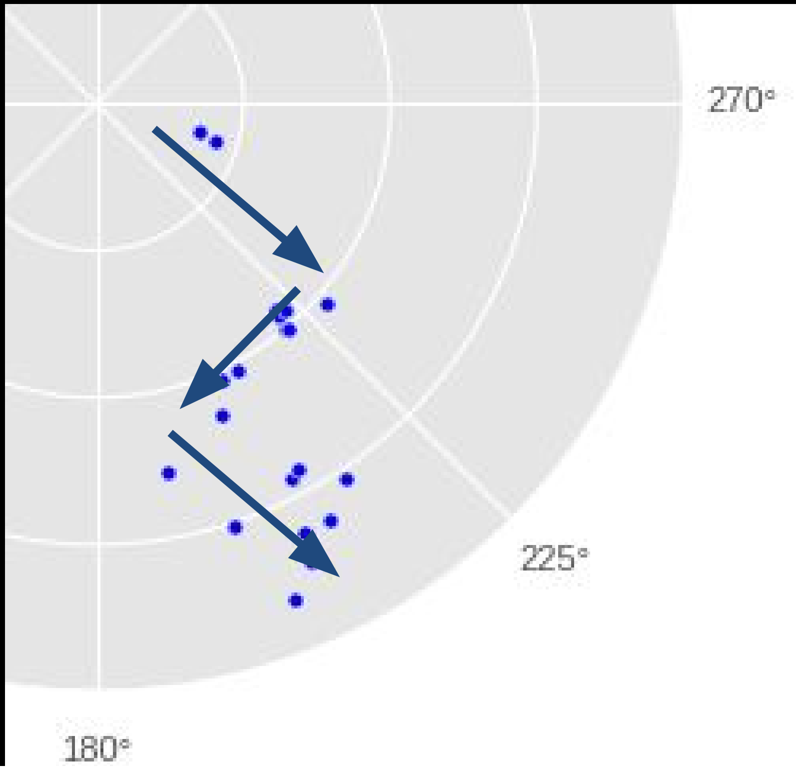
Super-luminal motion: fast shock catching up with slower shock > G-ray flare

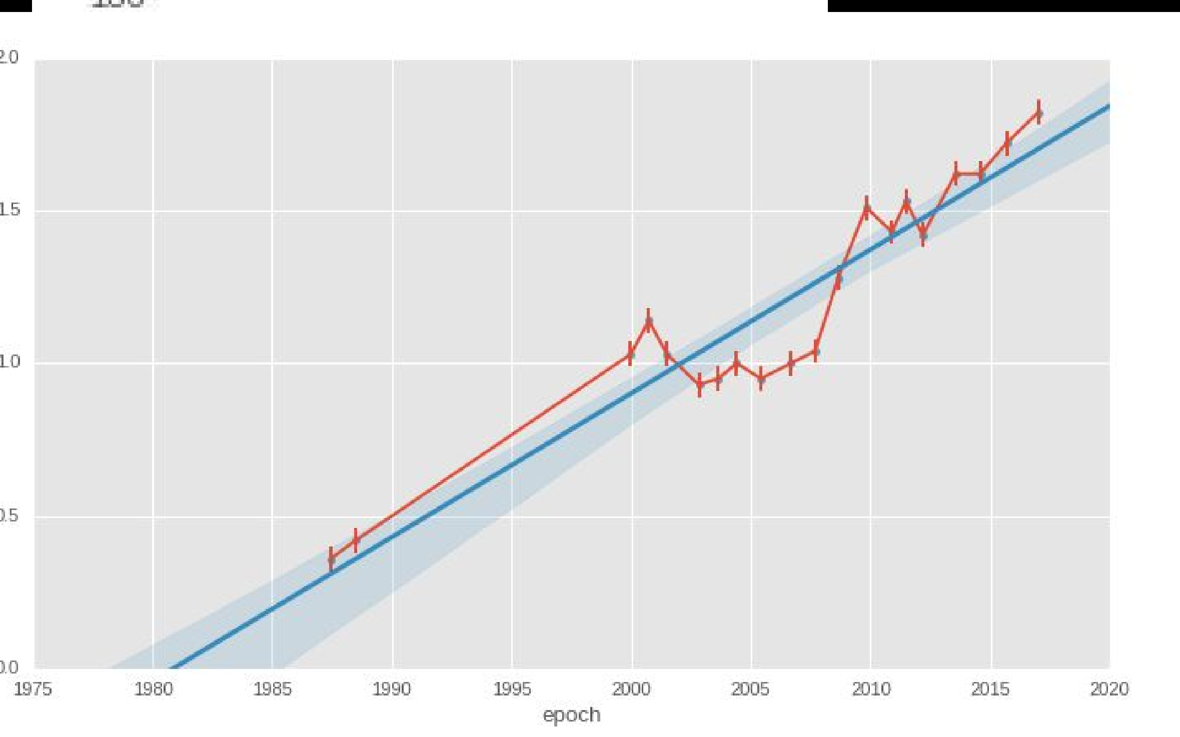
Hits external medium > G-ray flare > dissipates west

What does this look like?

A solution to the "Doppler crisis"?

What is C2?





Optically thin synchrotron emission

Very slow moving (0.09 mas/year ~0.1c)

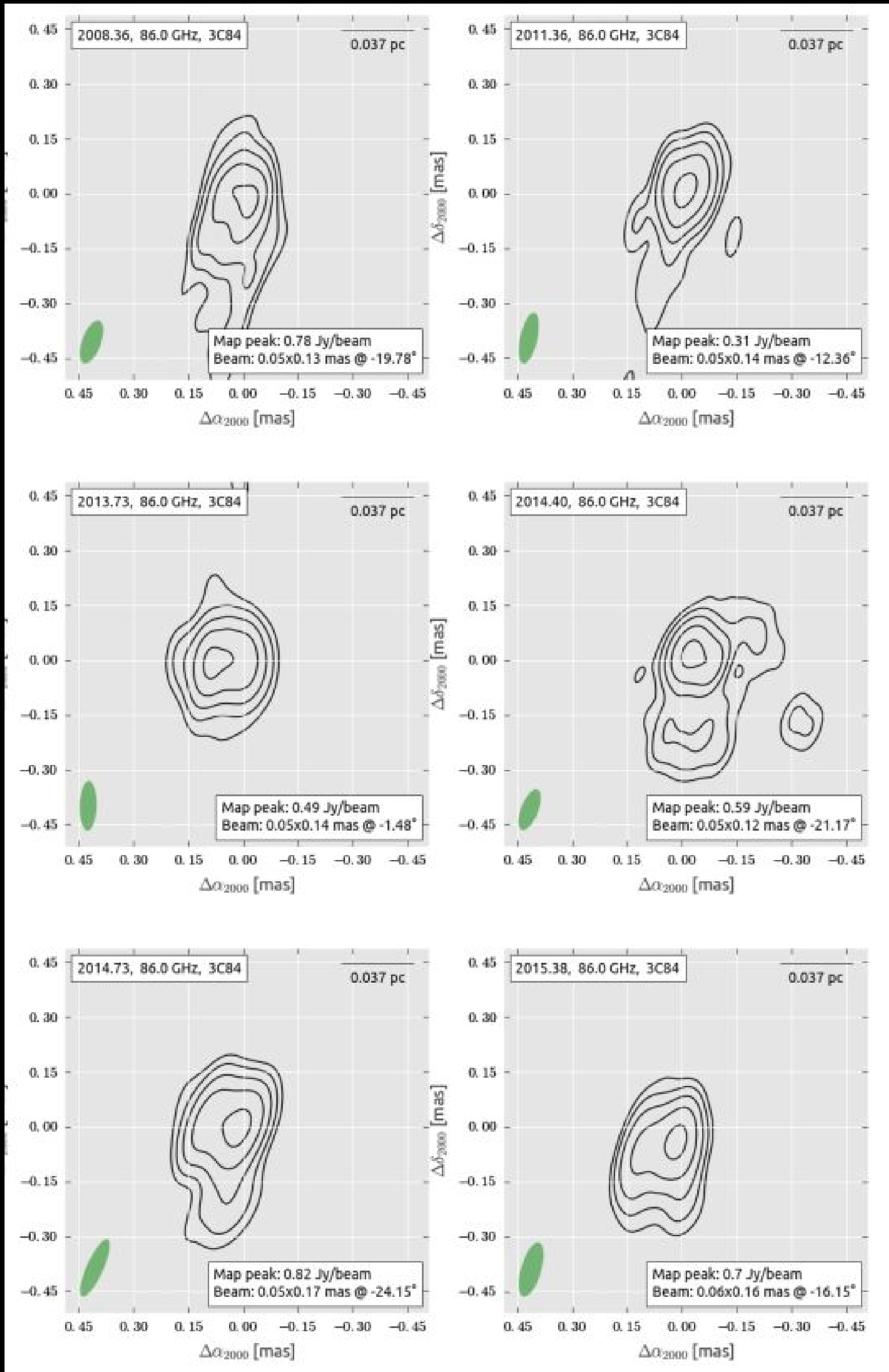
Ejected in ~1982 > at the peak of 1980s radio flare

Radically different PA

Stops moving in early 2000s > change in reference point?

(Hodgson et. al. in prep)

What is happening in C1 near the BH?



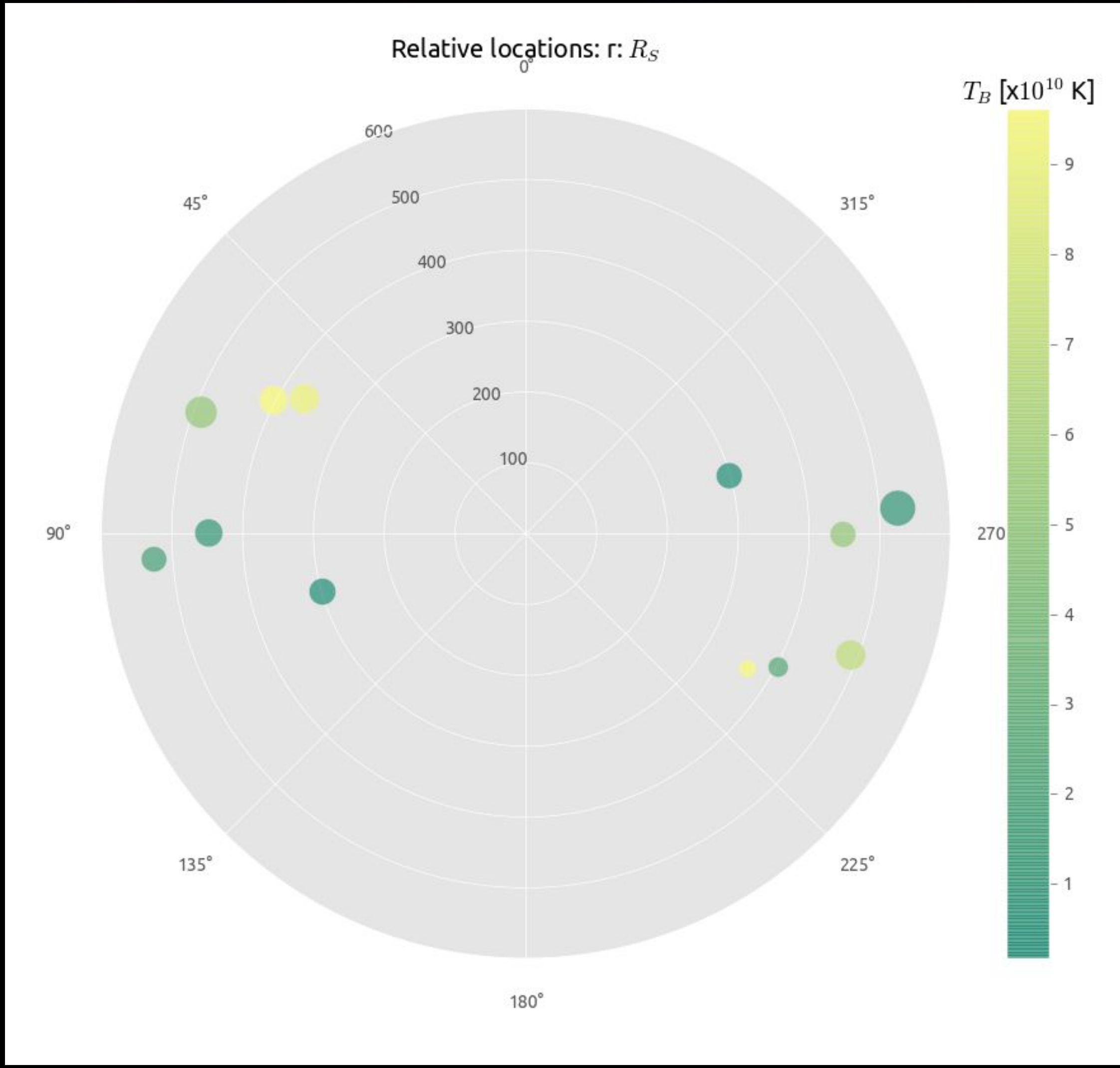
Double nuclear structure in all epochs since 2008.

East-west elongation

Western side on average brighter and higher TB

~700 R_S separation > too wide to be accretion disk > not location of SMBH

(Oh & Hodgson et. al. in prep) - See poster!

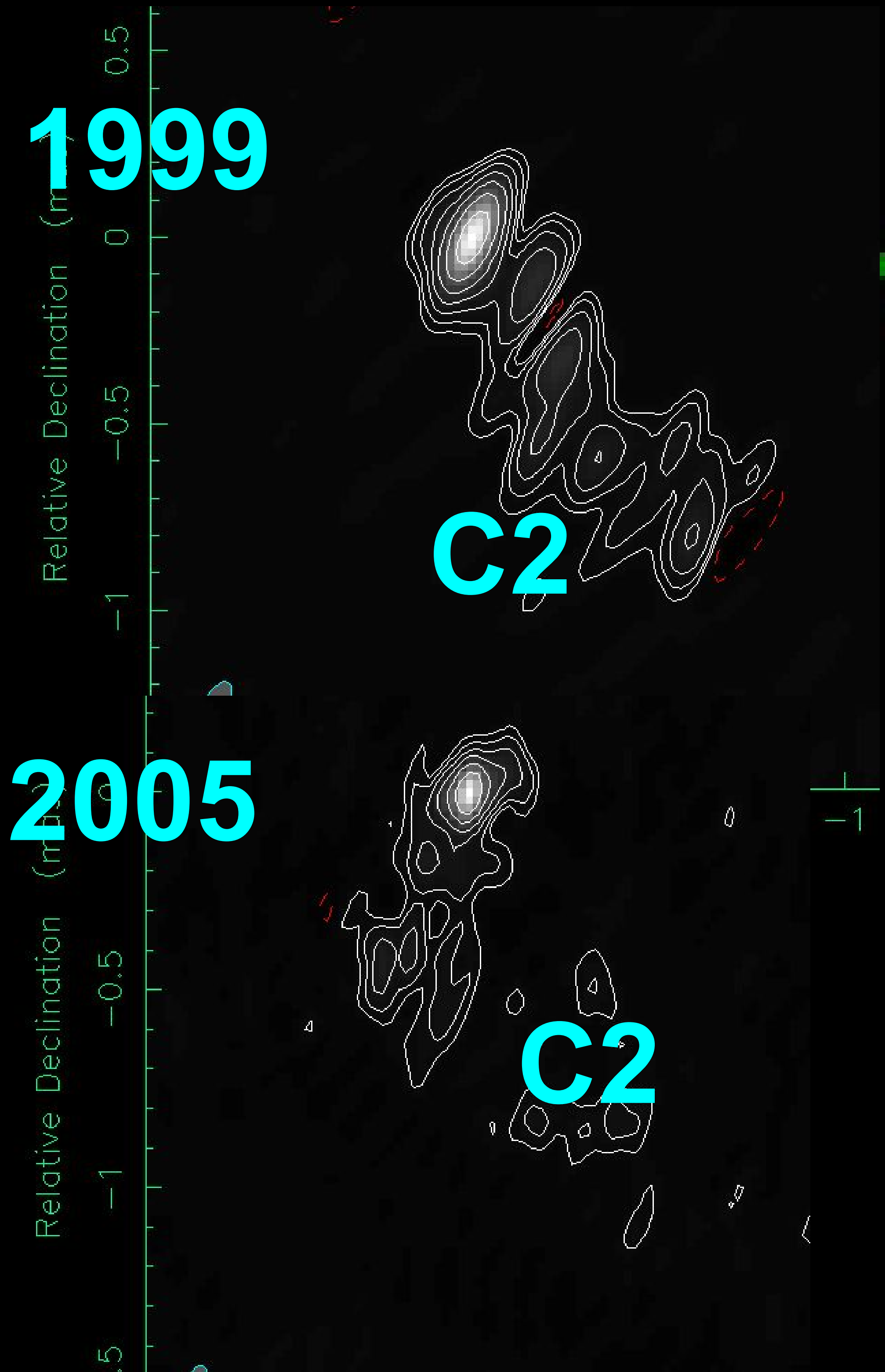


Northerly increasing TB trend in eastern component

Southerly increasing TB in western component

Consistent with helical motion in jet sheath

(Oh & Hodgson et. al. in prep) - See poster!

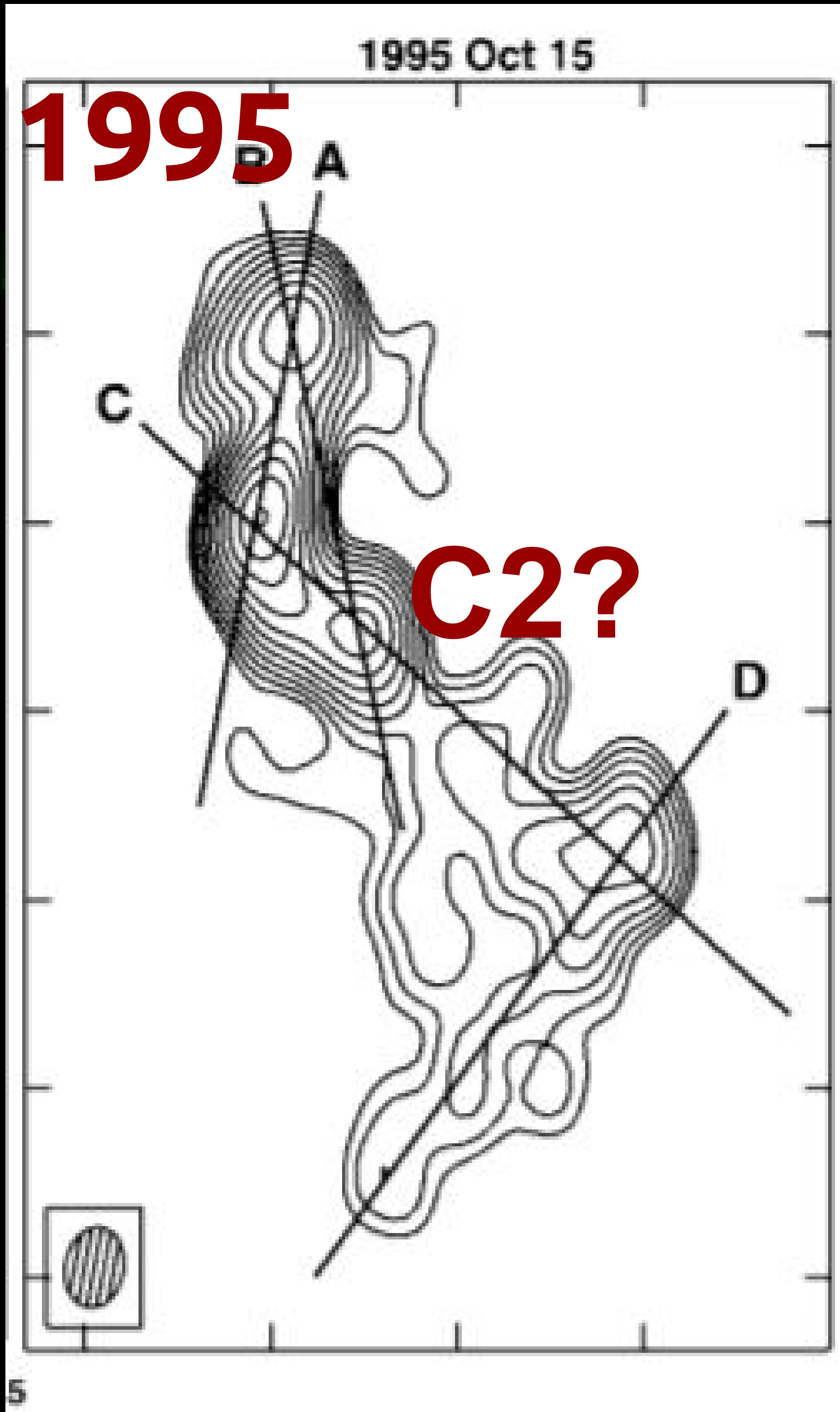


Change in PA of ~60 degrees in ~5 years.

Low Doppler boosting in 3C 84

Hard to imagine scenario where jet has physically changed that PA?

(Oh & Hodgson et. al. in prep)



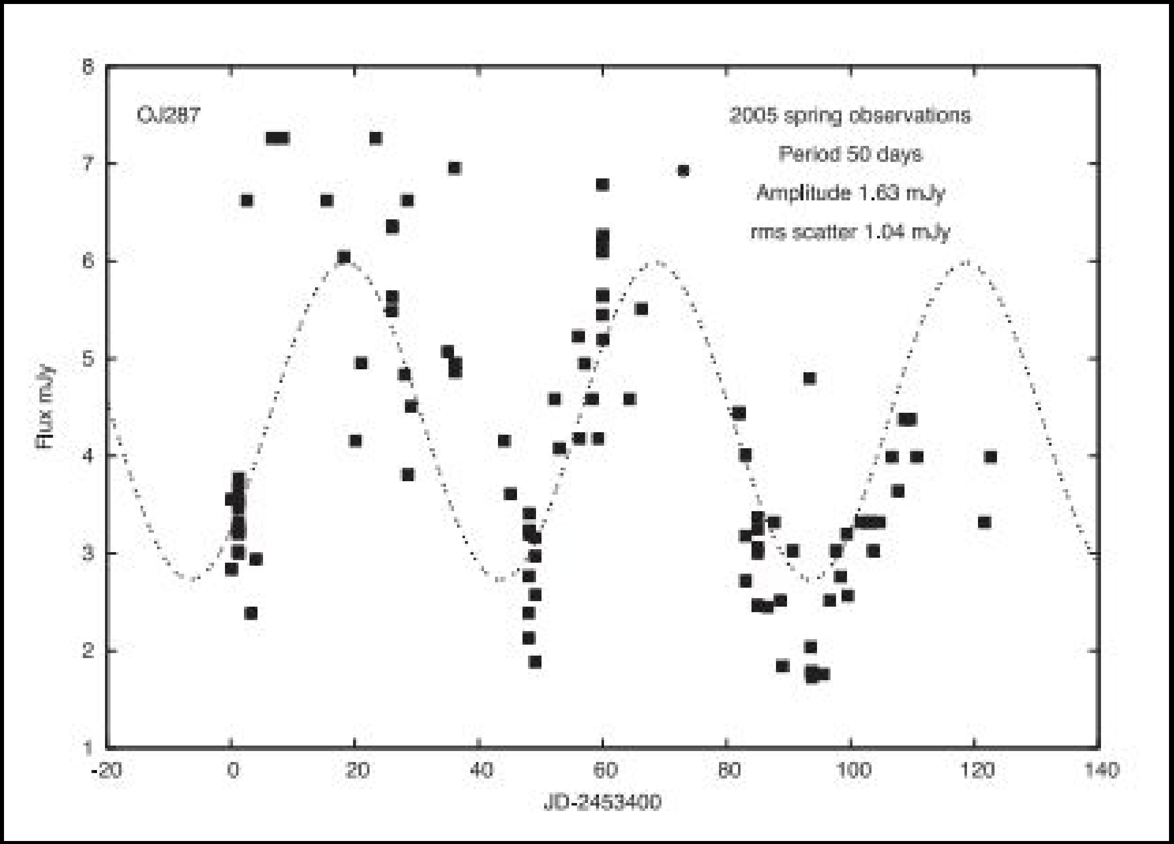
Is the “change in reference” seen in MOJAVE data occuring in data shown by Dhawan 1998?

Secondary black hole (and jet)?!?

(Oh & Hodgson et. al. in prep)

Is there any other sources that behave in similar ways?

OJ 287: a binary system

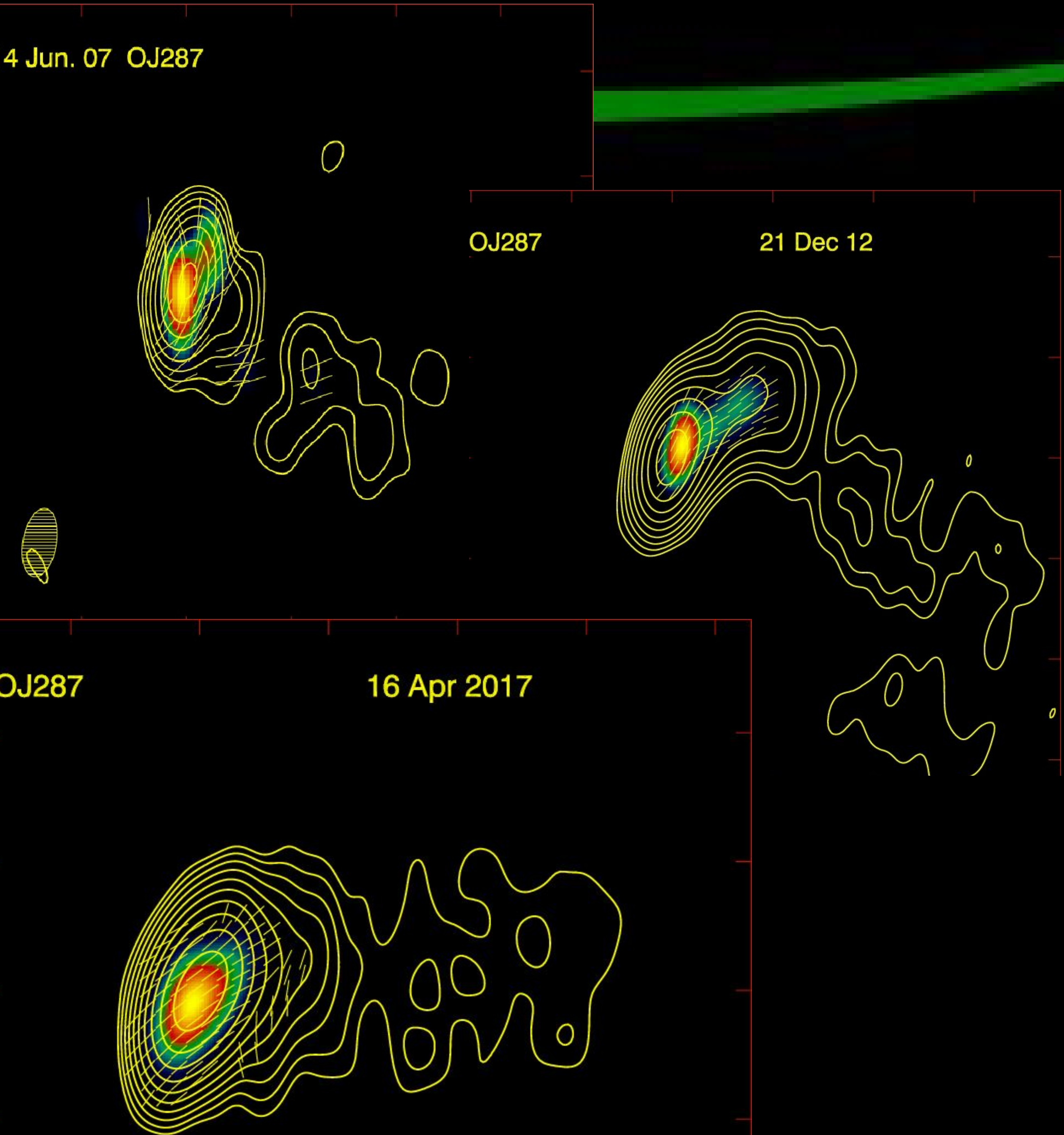


Modeling of optical light-curves, leads to very high (~10^10 M_sol) SMBH.

Smaller companion BH.

Predicted flaring very accurately.

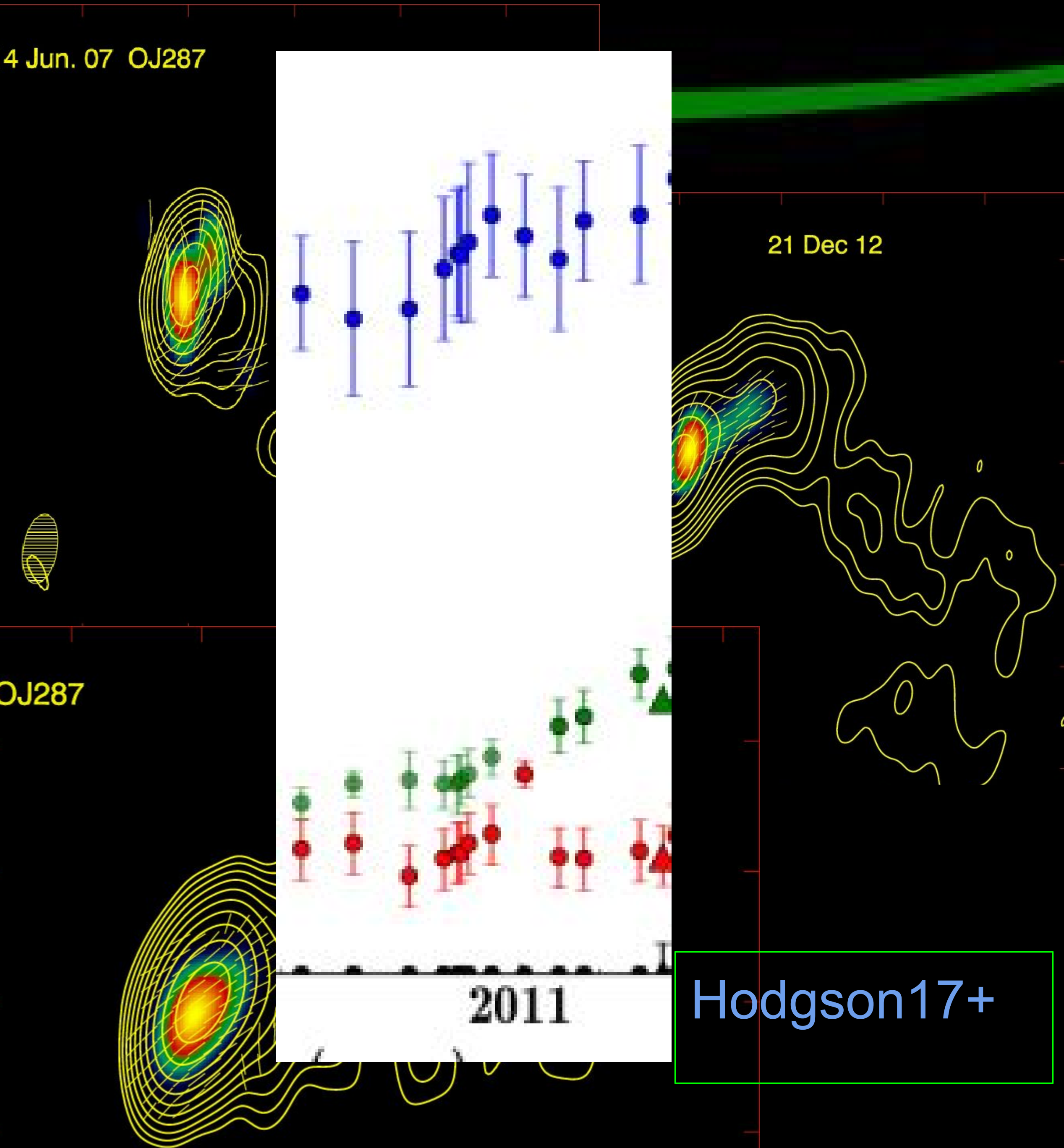
OJ 287: the VLBI view



Radical change in jet direction

G-ray (and TeV!) flaring seen in *downstream* quasi stationary feature

OJ 287: the VLBI view



Hodgson17+

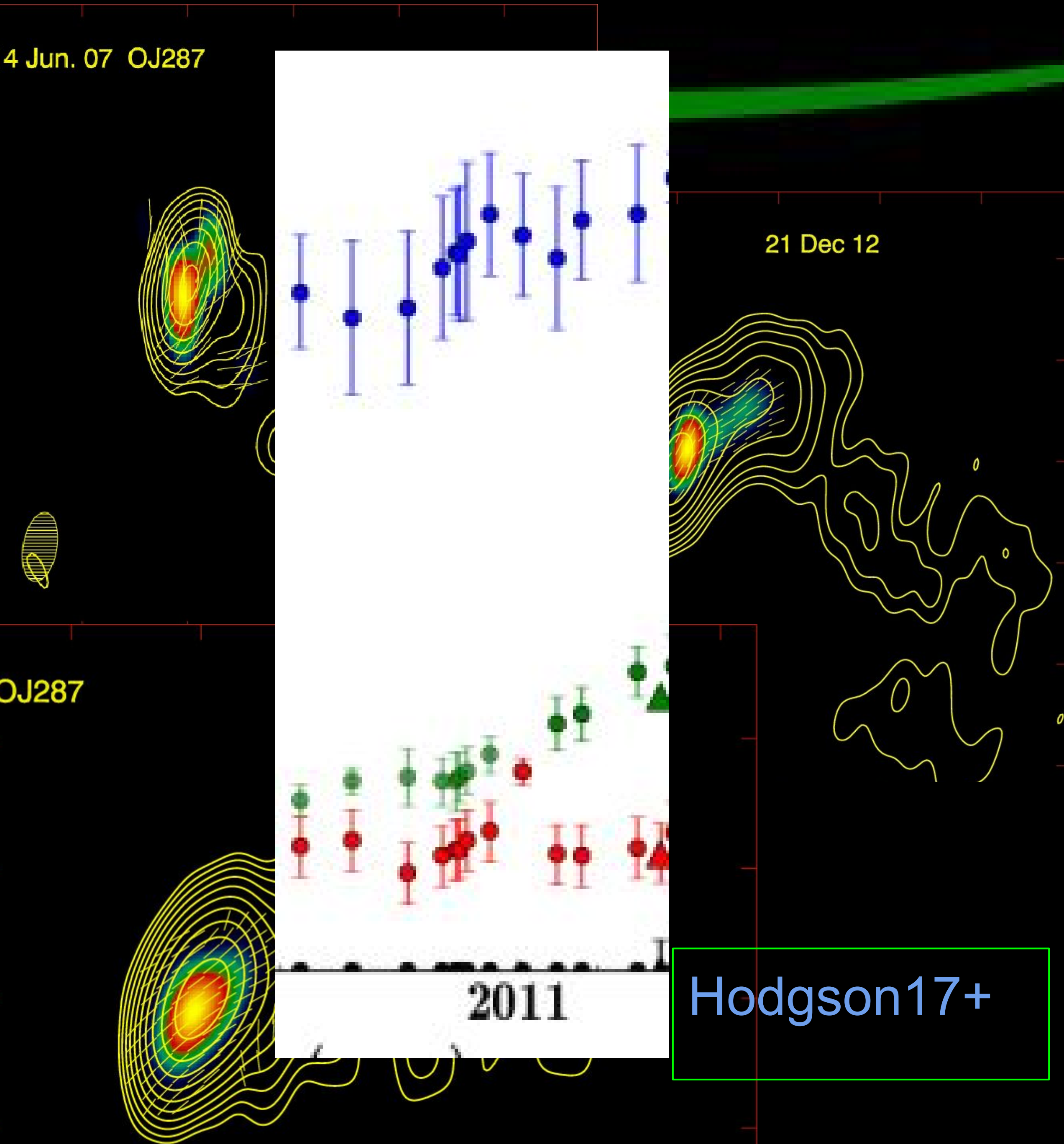
Radical change in jet direction

G-ray (and TeV!) flaring seen in *downstream* quasi stationary feature

Change in reference point?

Changes in reference points, off-axis jet emission in Mrk 501 (Koyama16+) (also a TeV source)

OJ 287: the VLBI view

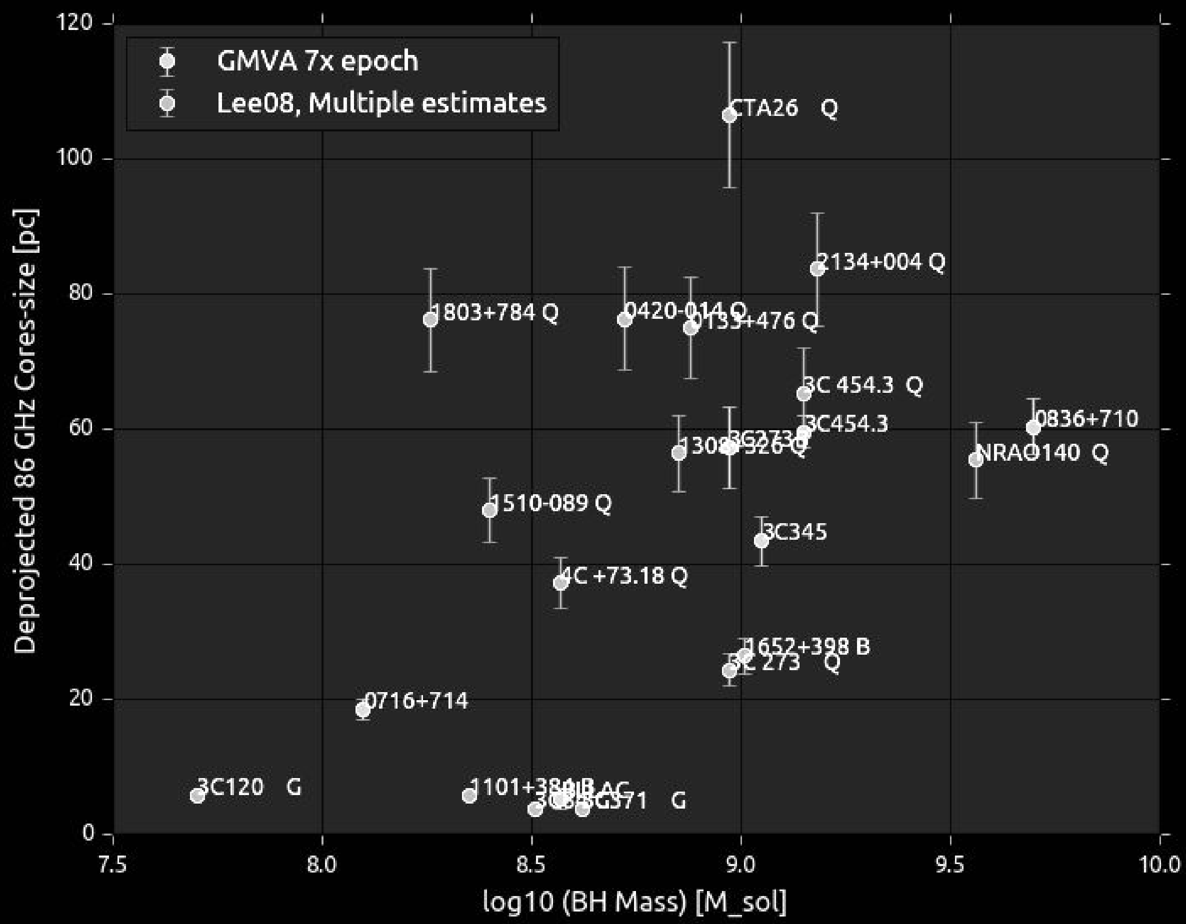


Hodgson17+

Is there a connection between "swinging jets", shifting reference points, binary BHs, GRB-like emission,TeV emission and the Doppler crisis?

A quick intro to AGN as a standard candle

BH Mass evolution



Possible (order of magnitude) tracer of BH mass using 3mm Core-sizes

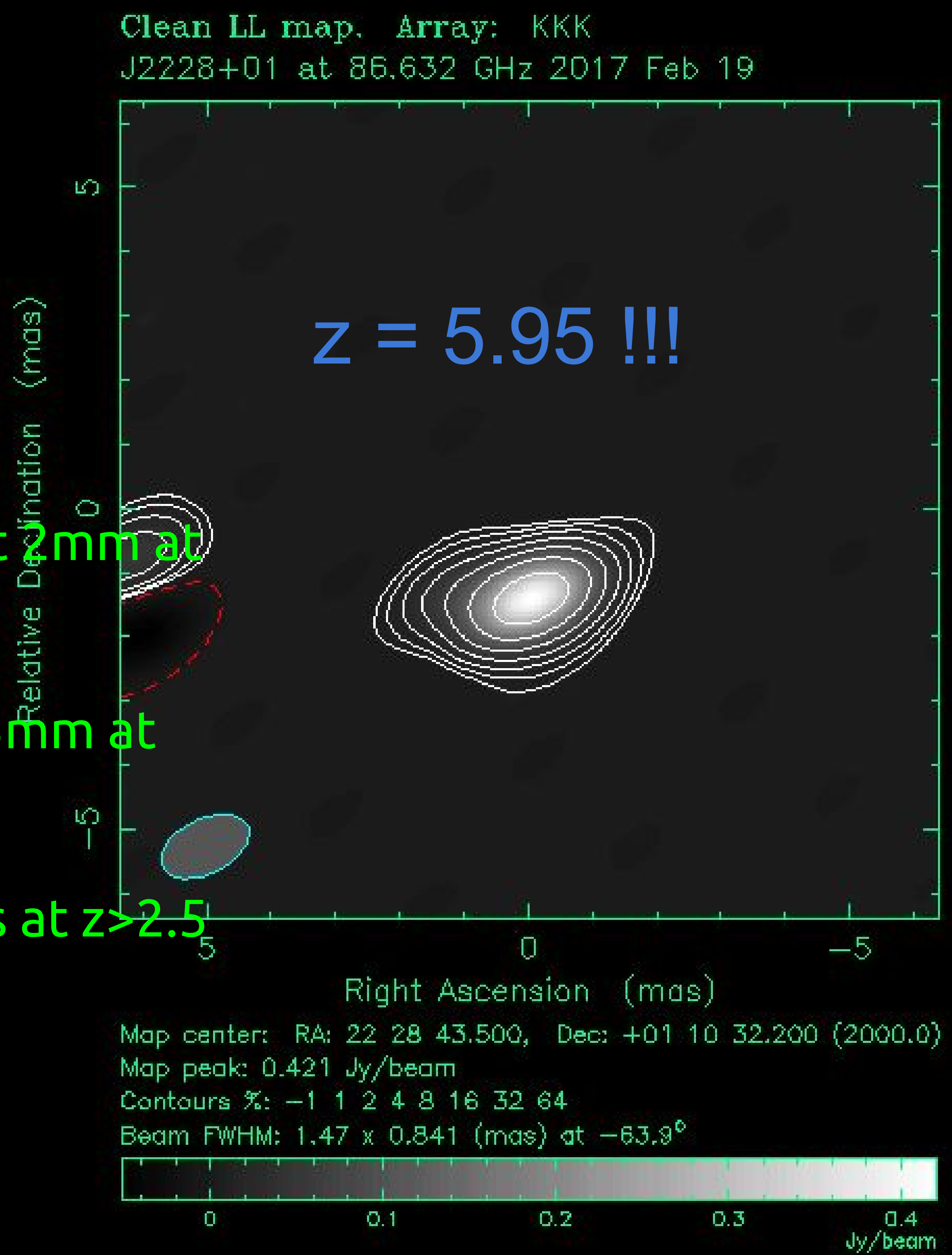
How do AGN BH masses evolve over time?

How did such big SMBHs exist at z>5?

What do we need?

- Cosmology methods are still a secret (for now)
  - Require high-cadence (2-weekly>Monthly)
  - High resolution - need to resolve components
  - Imaging capability less important
- Multi-frequency is not necessary, but desirable
  - Not clear which frequency works best for this
  -

Cosm



Detected at 2mm at z=6.2

Imaged at 3mm at 5.95

150 sources at z>2.5 at 22 GHz

Conclusions

- Why is the location of G-rays so hard to pin down in AGN?
  - Because they occur everywhere for all sorts of reasons
- Differing shock wave speeds, hitting external medium causing G-rays > like a GRB
- Double nuclear structure of 3C84 consistent with a helical jet
  -