RadioAstron observations of the jet launch region in 3C 84

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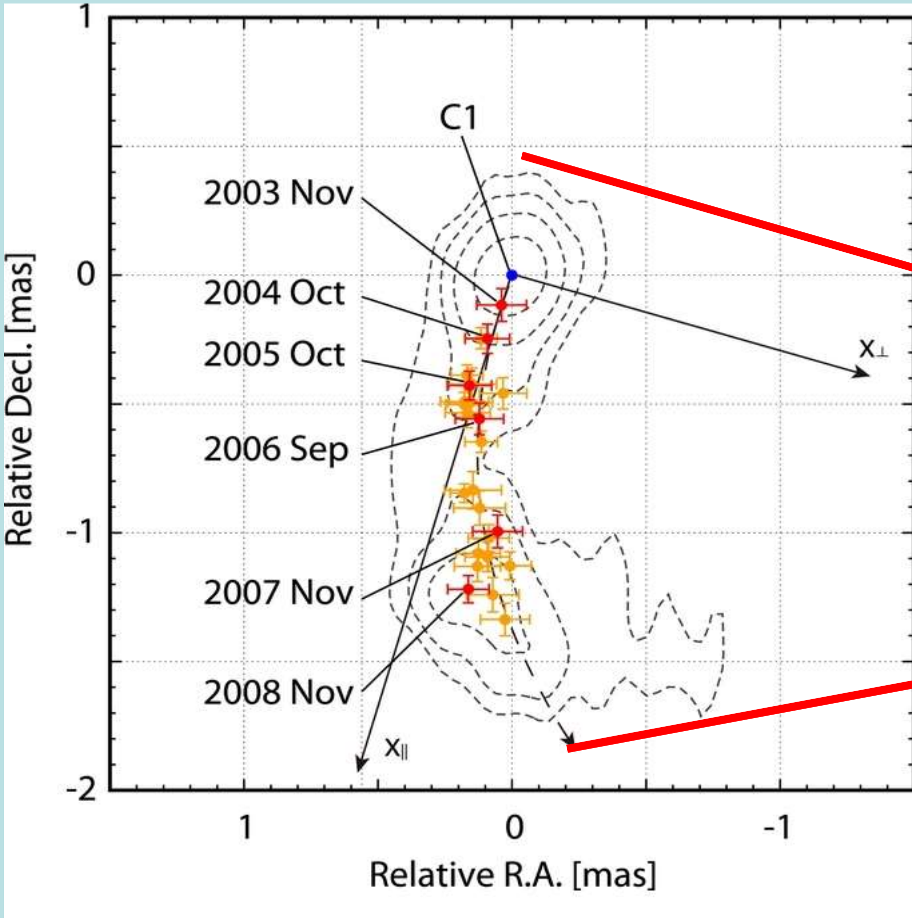
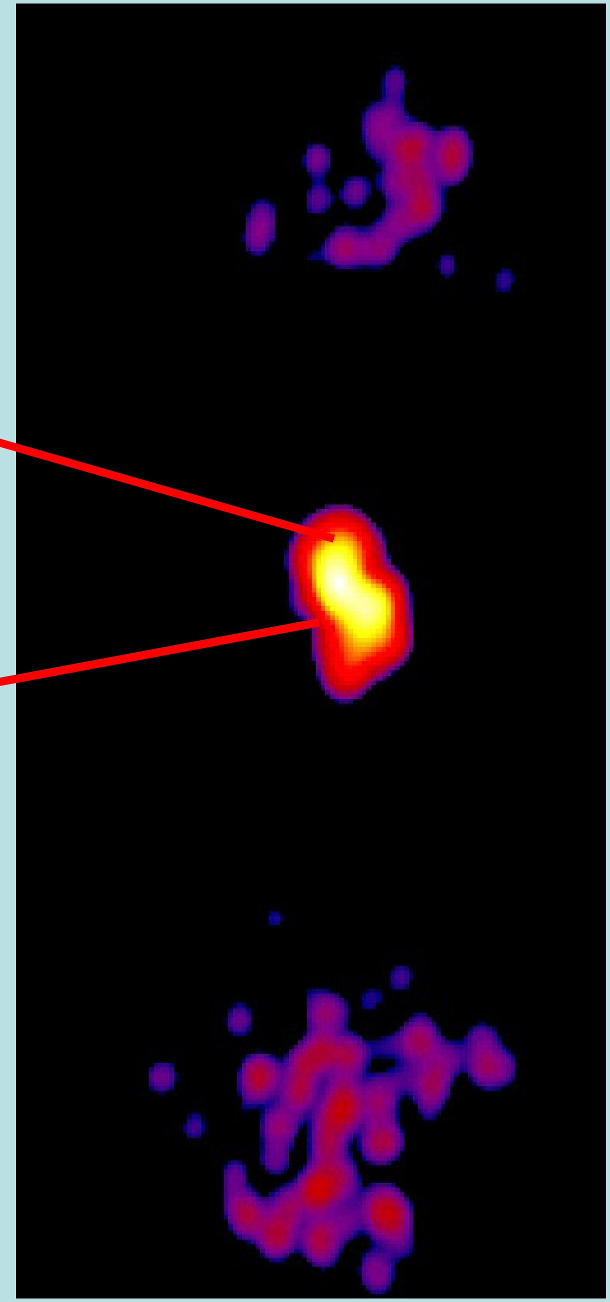
Main results published in Nature Astronomy 2018

Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

3C84 was observed by the RadioAstron SRT and an array of ground radio telescopes around the perigee passage of the SRT from 2013 September 21 15:00 ut to 2013 September 22 13:00 ut . In our experiment, projected space baselines from 0.2 to 10.4 Earth diameters

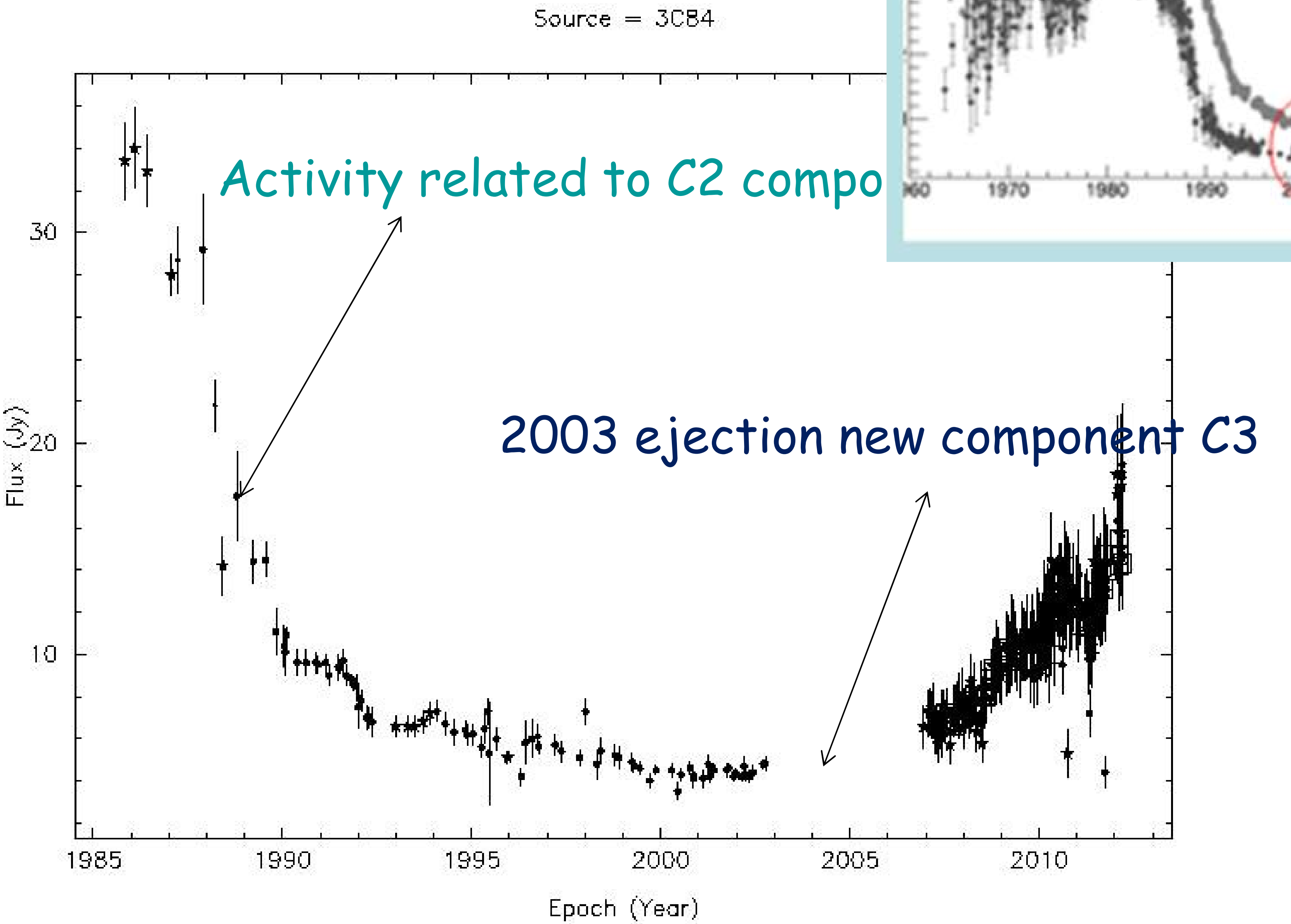
Recent activity



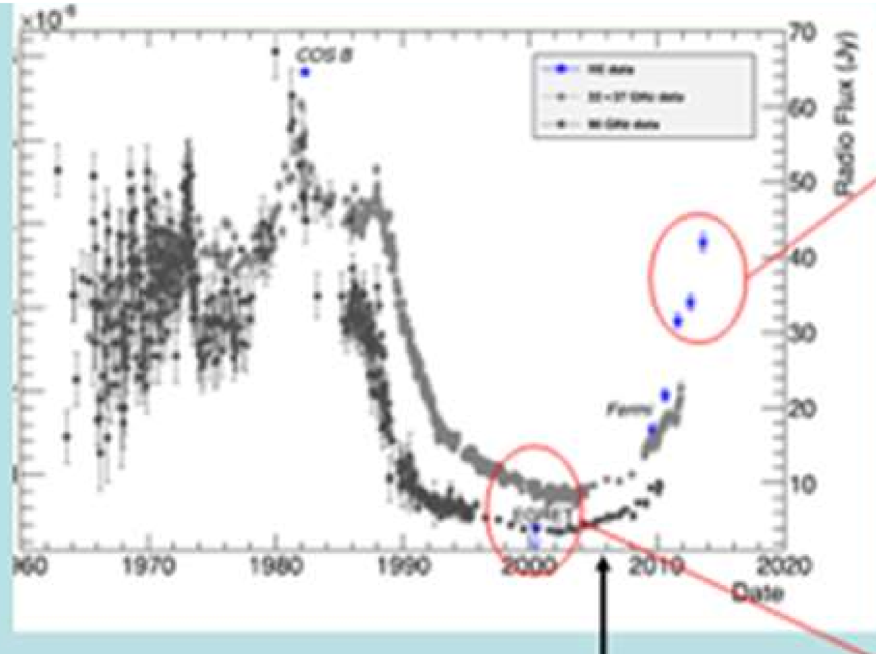


VLBA at 43 GHz in the period of 2003–2008. New component C3 (Kenta Suzuki et al. 2012).

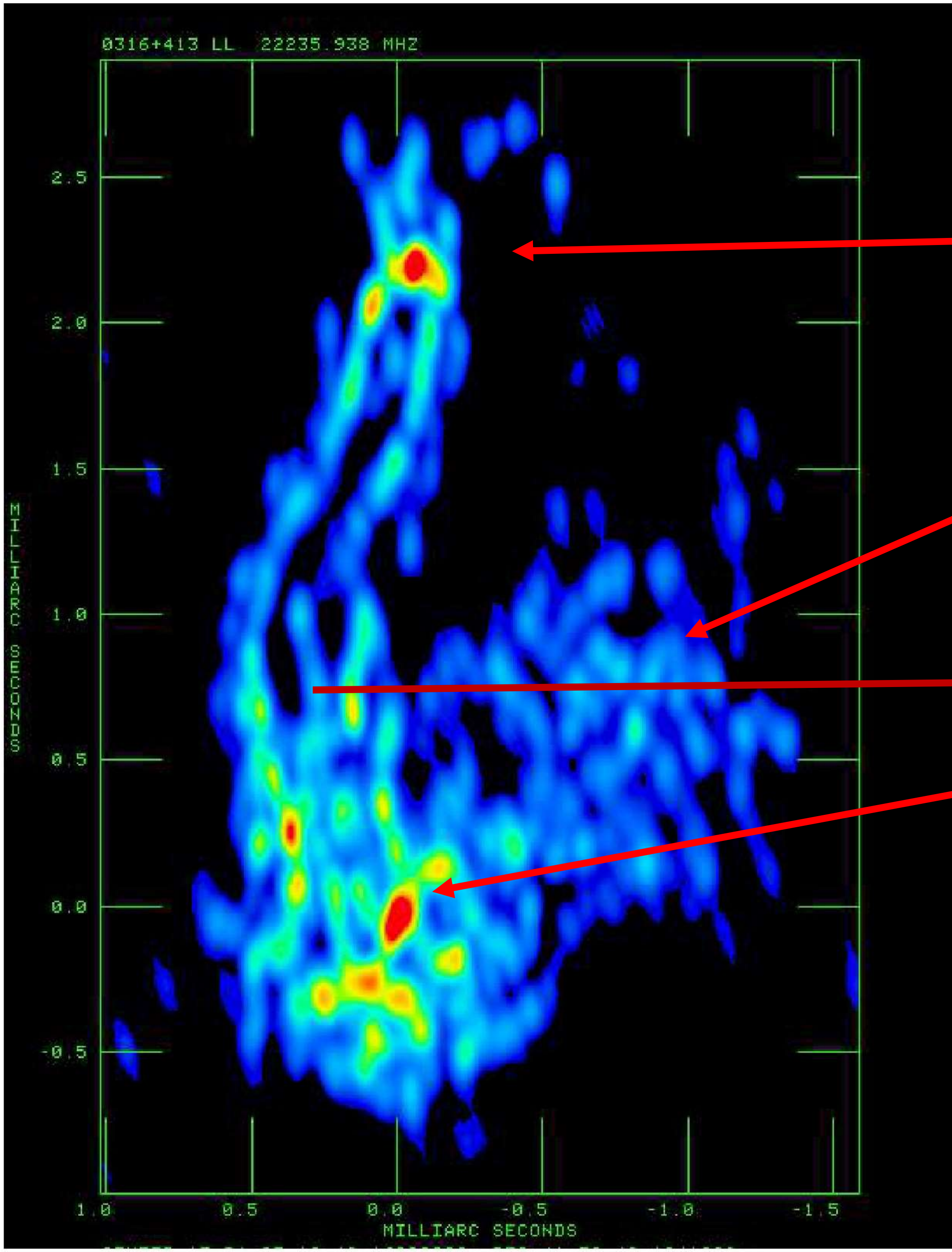
MOJAVE Program 2003-03 epoch



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



COS B
Fermi
EGRET
Radio Flux (Jy)
70
60
50
40
30
20
10
1970
1980
1990
2000
2010
2020
Date



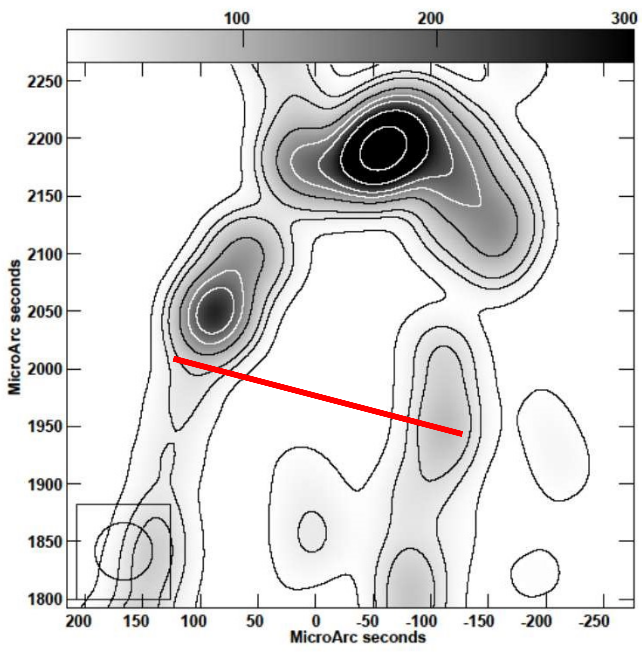
HPBW 0.10 x 0.05 mas

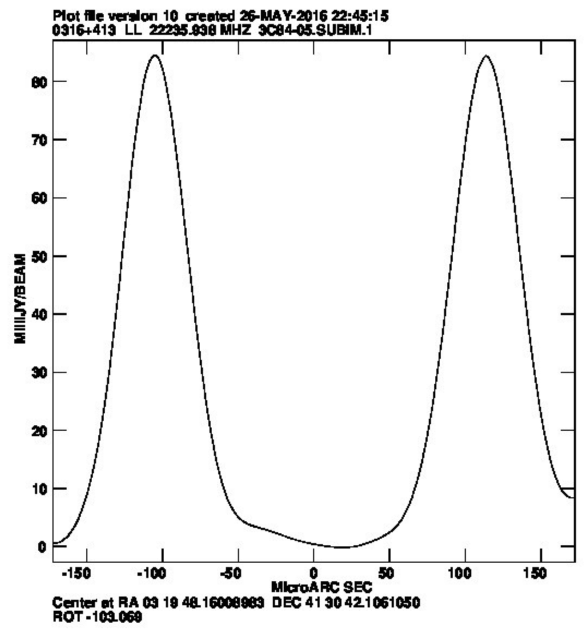
RadioAstron results at 22 GHz

See Giovannini et al. 2018 Nature Astr
arXiv: 1804.02198

1) Edge brightened jet at 30 microarcseconds from the core corresponding to 350 r_g de-projected

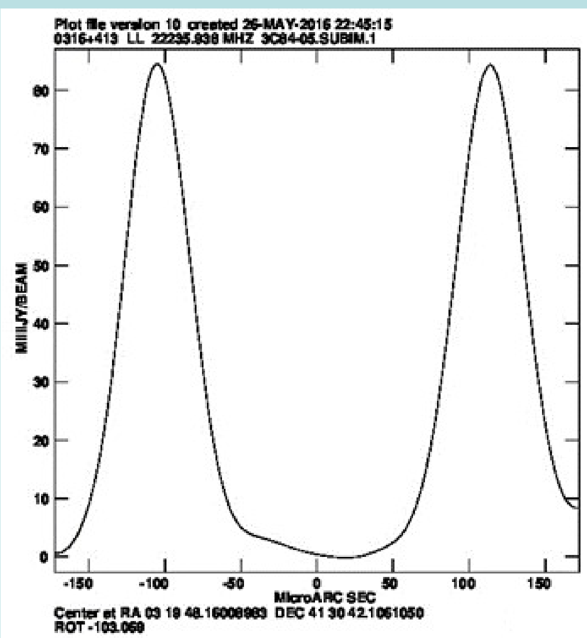
HPBW: 0.05 x 0.05

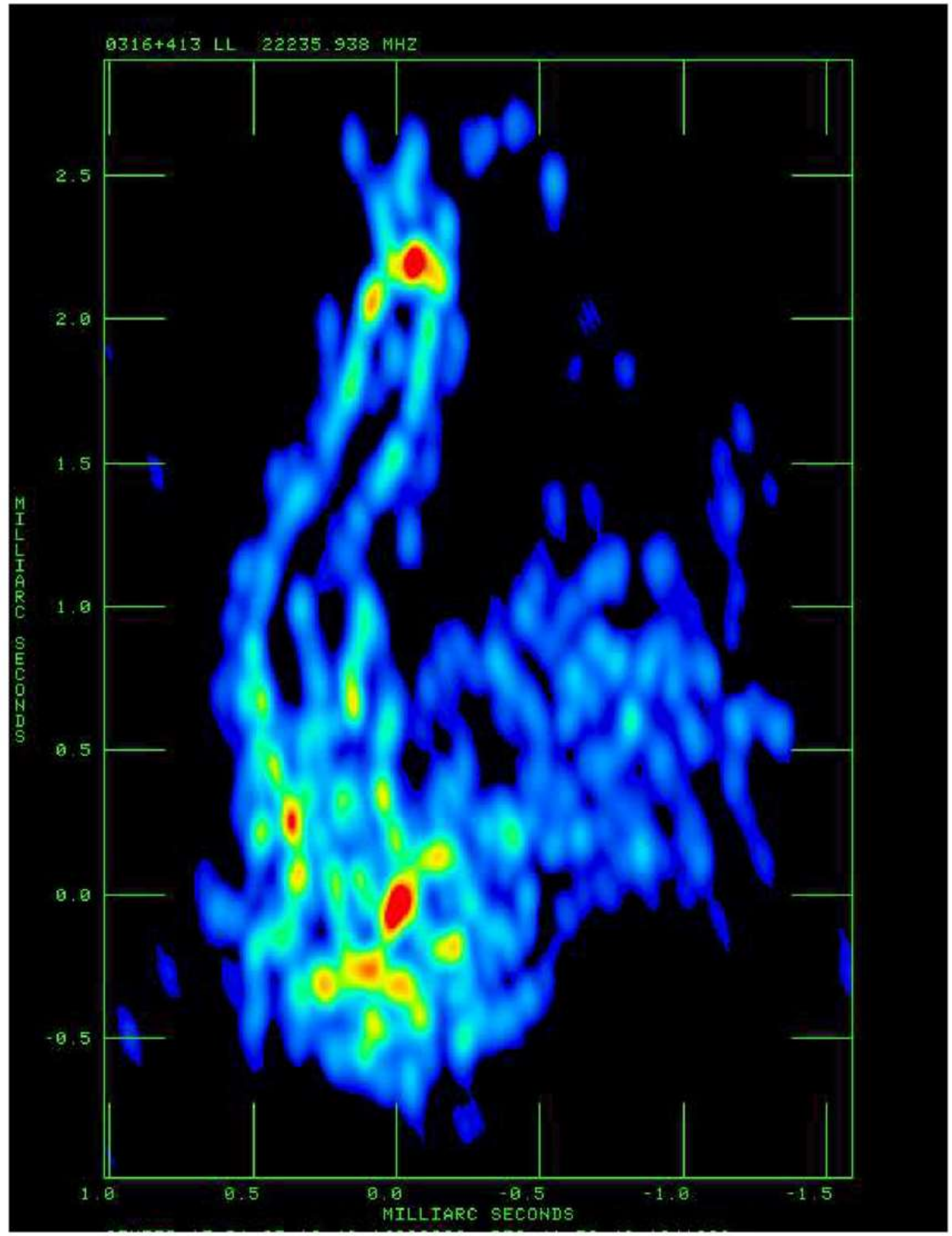


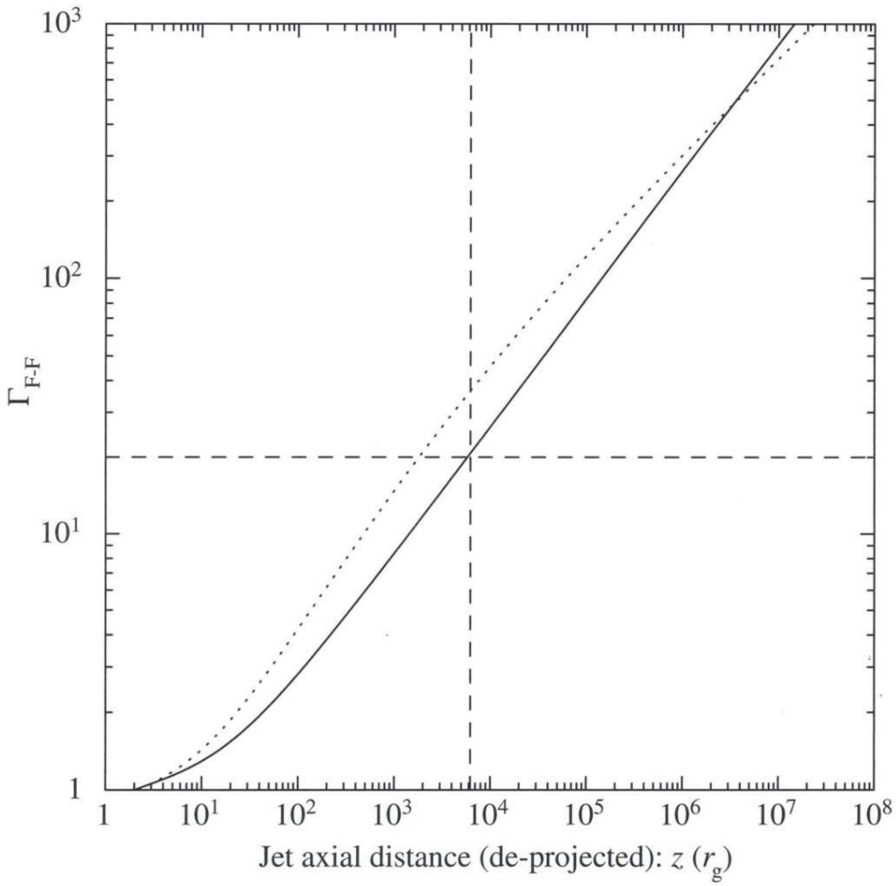


Hollow jet or velocity structure?
Brightness ratio between the shear and the spine is ≥ 20 ➔ transverse velocity structure or intrinsic emissivity differences or both

We see the spine brightening as the jet approaches C3





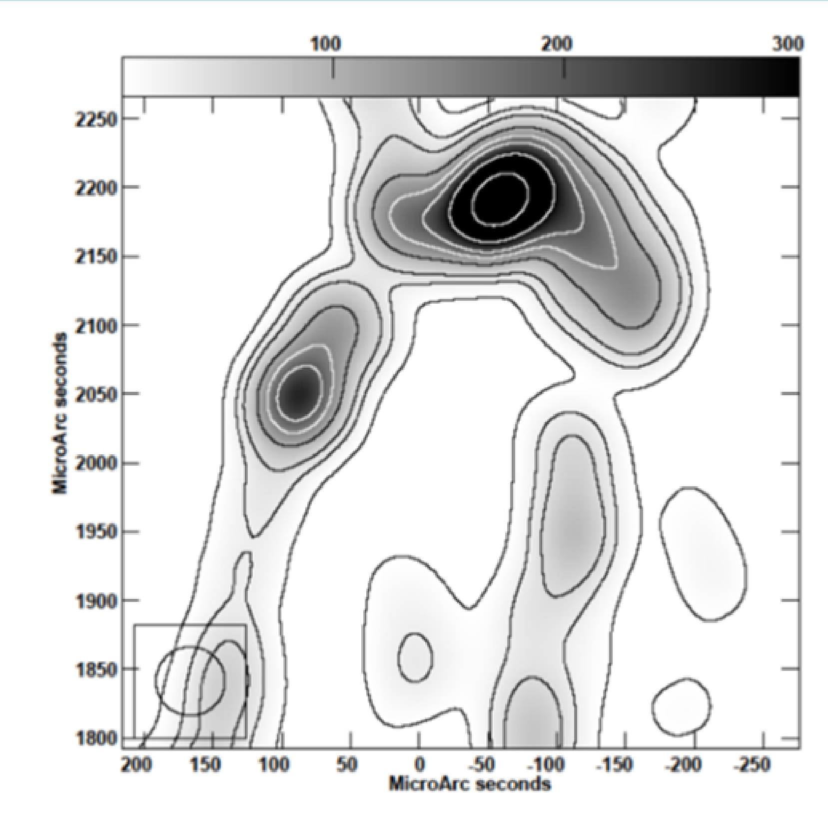


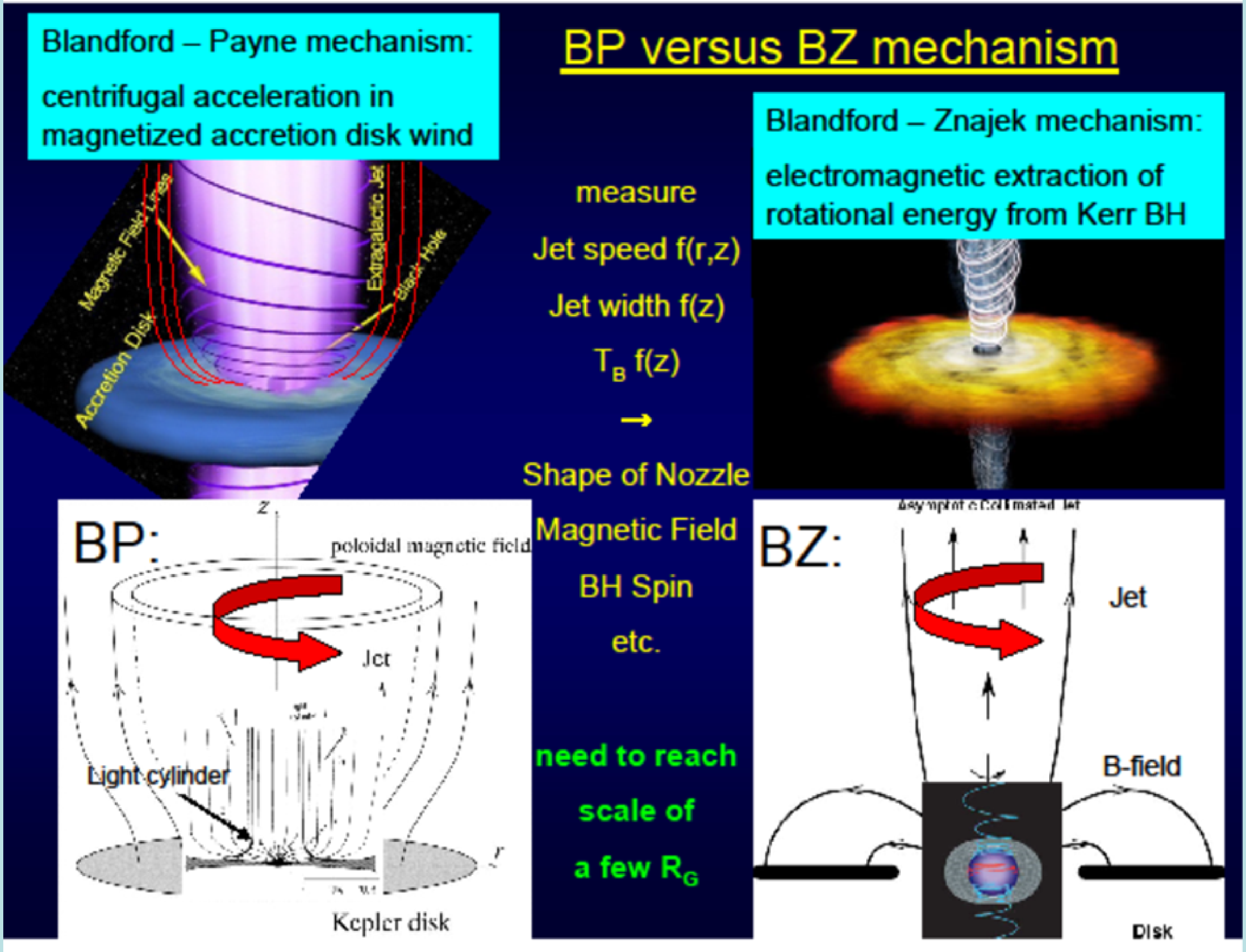
The shear velocity can be estimated by proper motion;
to have a spine with a brightness lower than a factor 20 we need a very fast spine.
Orientation angle from 18 to 30 and Γ > 20

Problem: we are very near to the core. Even with an efficient acceleration we expect at a deprojected distance of 500 rg Γ = 10, we need at least Γ = 20.
A rapid more efficient acceleration (semi-parabolic spine –dotted line) is better but at z = 500 we have Γ = 10 too low.
We need also an intrinsic brightness difference.

2) Large opening angle followed by almost cylindrical jet profile

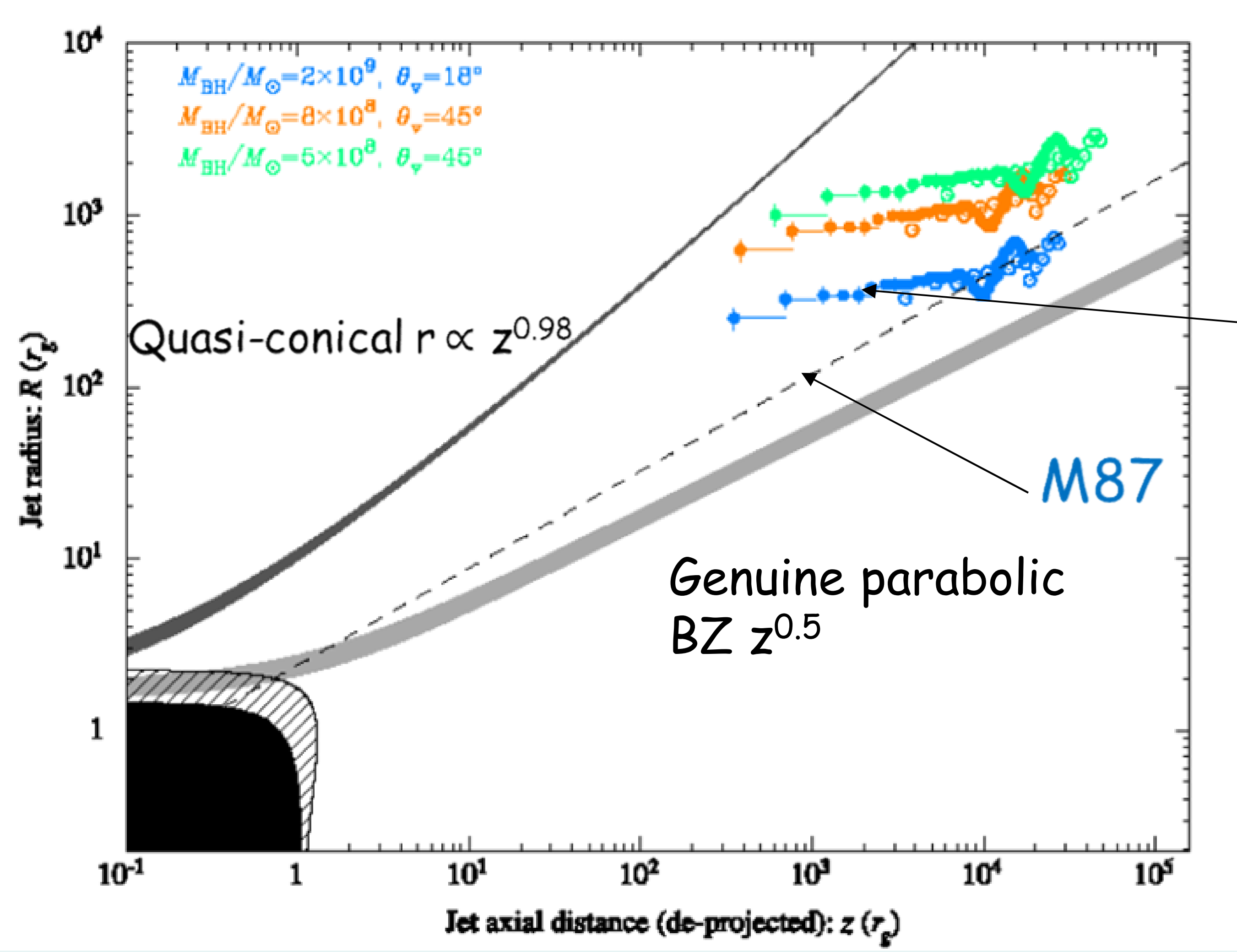
We find a broad jet with a tranverse radius ≥ $250 r_g$ at only $350\ r_g$ from the core.
If the bright outer jet layer is launched by the BH ergosphere, it has to rapidly expand laterally followed by an almost cylindrical collimation. If this is not the case ➔ the jet sheath is likely launched from the accretion disk.





From Krichbaum, 2014

Theoretical arguments and computer simulations favour BZ model especially in thick radiatively inefficient accretion flows (RIAFs) as is considered 3C84.



Measured jet width is between 2 streamlines hence an ergosphere-launched jet is possible

Almost cylindrical flow with $r \propto z^{0.17}$

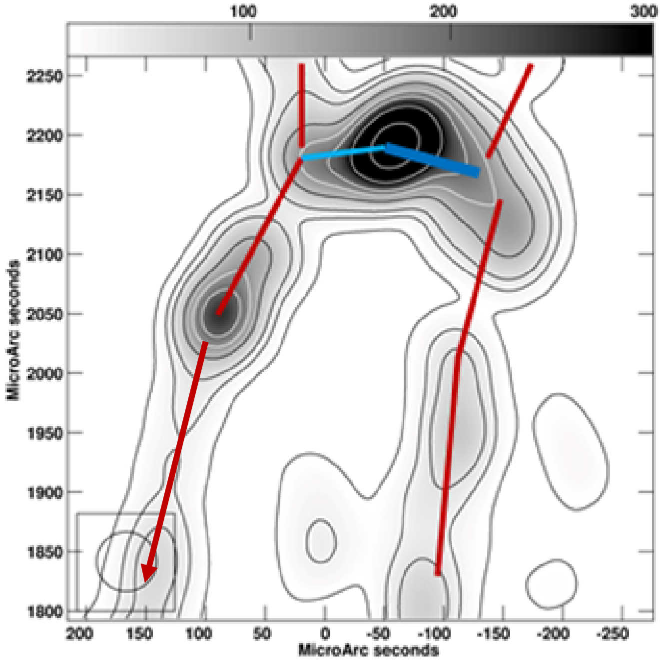
$r \propto z^{0.56}$

Problems.

1) Core shift

2) BH mass: Scharwachter + 2013 Using different orientation angle

Streamlines of the jet sheath may in principle to connect to the horizon if a rapid lateral expansion is present. If such a rapid expansion does not occur on scales below 100 r_g the jets sheath is launched from the accretion disk.



We see a rapid collimation at ≤ 400 r_g followed by a quasi-cylindrical jet.

Flat density profile up to $\sim 10^4 r_g \sim 0.8$ pc.

- What kind of medium?
  - Gas in nearly free fall has $\rho \propto z^{-3/2}$ Excluded.
  - Inner edge of thick disk or torus? Possible
  - Hot cocoon of shocked gas?

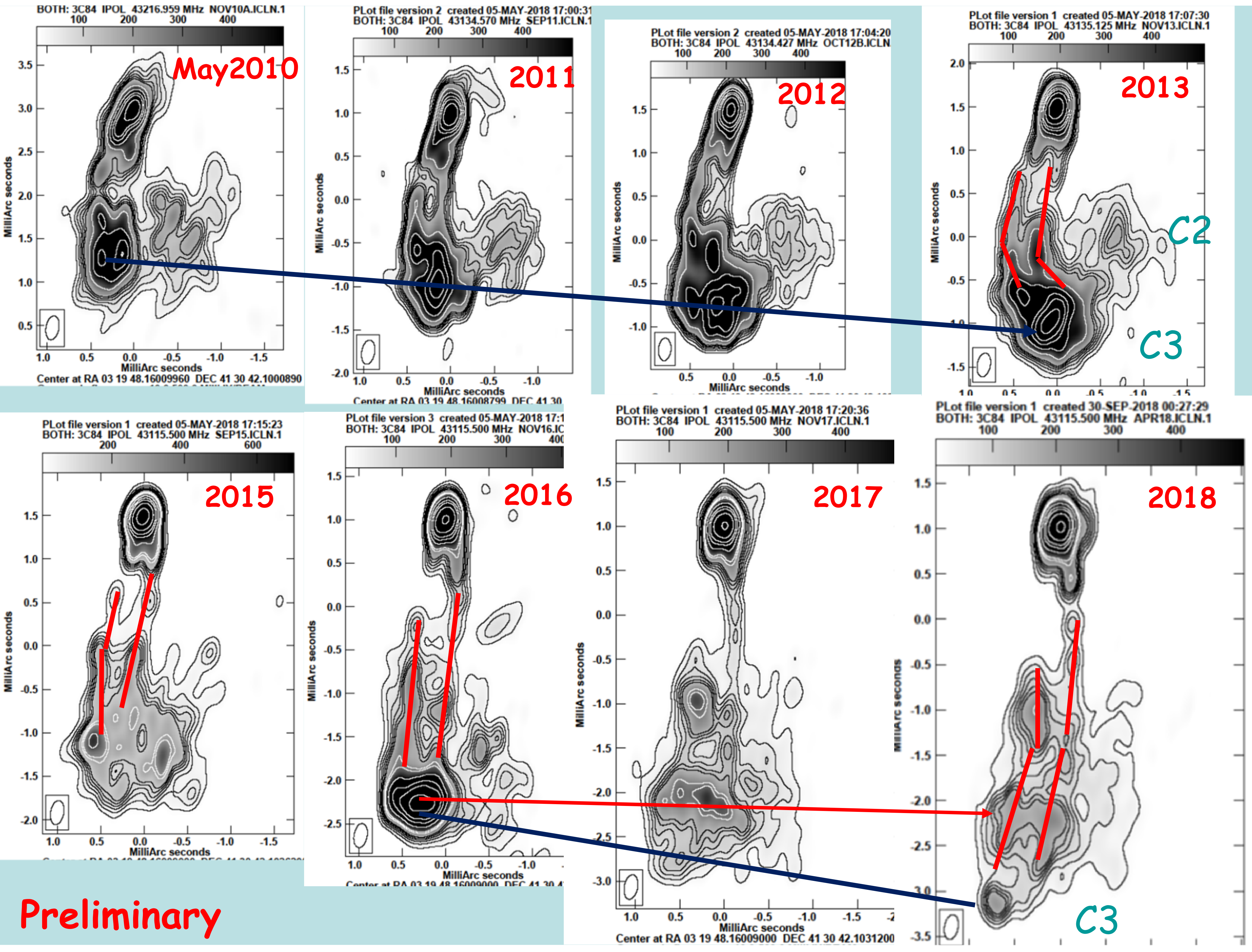
See Savolainen previous talk, Savolainen + in preparation

3) A still in evolution scenarium is supported by the C3 properties:

- Nagai et al. 2013 discussed C3 polarization and interaction with the ambient

- Kino + 2018 discussed the flip of the jet head position (C3) of 3C 84 in 2015 as an evidence of a jet propagation in clumpy ambient

- Hiura et al. 2018 present VERA monitoring of the radio jet in 3C 84 during 2007-2013 with a strong evidence of a non linear motion.



BOTH: 3C84 IPOL 43216.959 MHz NOV10A.ICLN.1
May2010
MilliArc seconds
Center at RA 03 19 48.16009960 DEC 41 30 42.1000890
PLot file version 2 created 05-MAY-2018 17:00:31
BOTH: 3C84 IPOL 43134.570 MHz SEP11.ICLN.1
2011
PLot file version 2 created 05-MAY-2018 17:04:20
BOTH: 3C84 IPOL 43134.427 MHz OCT12B.ICLN
2012
PLot file version 1 created 05-MAY-2018 17:07:30
BOTH: 3C84 IPOL 43135.125 MHz NOV13.ICLN.1
2013
C2
C3
PLot file version 1 created 05-MAY-2018 17:15:23
BOTH: 3C84 IPOL 43115.500 MHz SEP15.ICLN.1
2015
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2016
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BOTH: 3C84 IPOL 43115.500 MHz NOV17.ICLN.1
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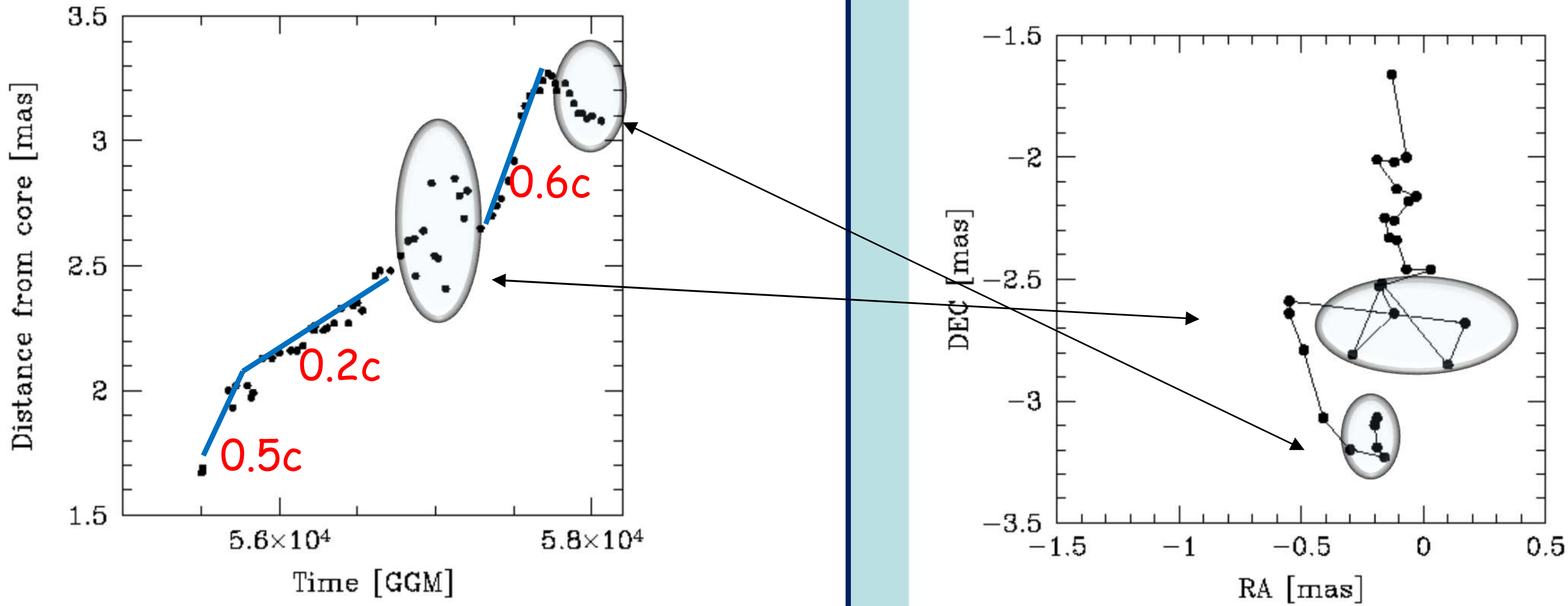
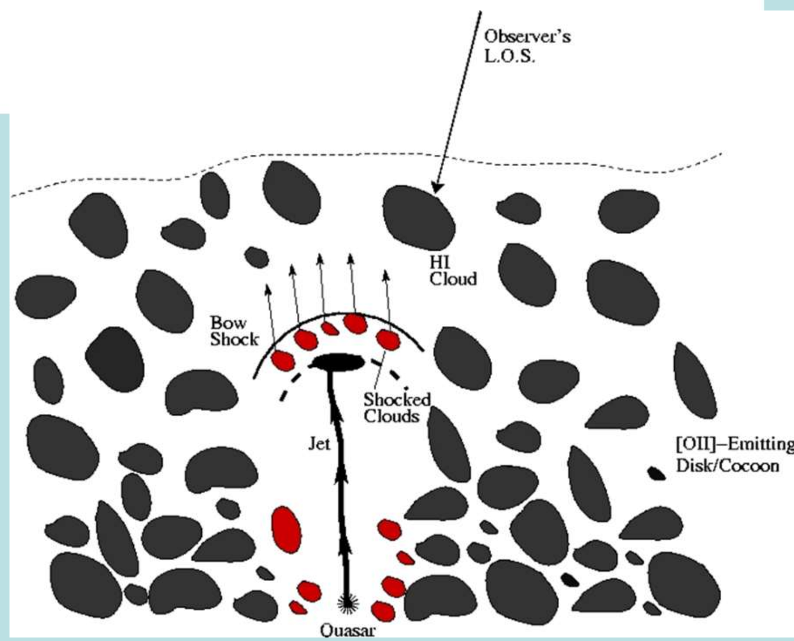
2018
C3
Preliminary



43 GHz VLBA data from the VLBA-BU Blazar Monitoring Program from November 2010 to November 2017

3C 84 jet still evolving: unique opportunity to study early evolution of a restarted jet in an active rich gas galaxy



conclusions

1) 3C 84 core: complex edge brightened jet with large opening angle near the core

2) Large difference in brightness between the jet shear and spine ➔ different Doppler factor and/or electron density problem: too near to the core

3) The shear is well defined and collimated: strong confinment by the external medium

4) An ergosphere launched jet is possible but we cannot exclude that the jet sheath is launched from the accretion disk

5) Unique opportunity to study in detail the evolution of a young jet


Thank You
18/07/2011 04:48