The (sub-) mm and γ-rays connection in blazars

J. León-Tavares

Metsähovi Radio Observatory (Finland)

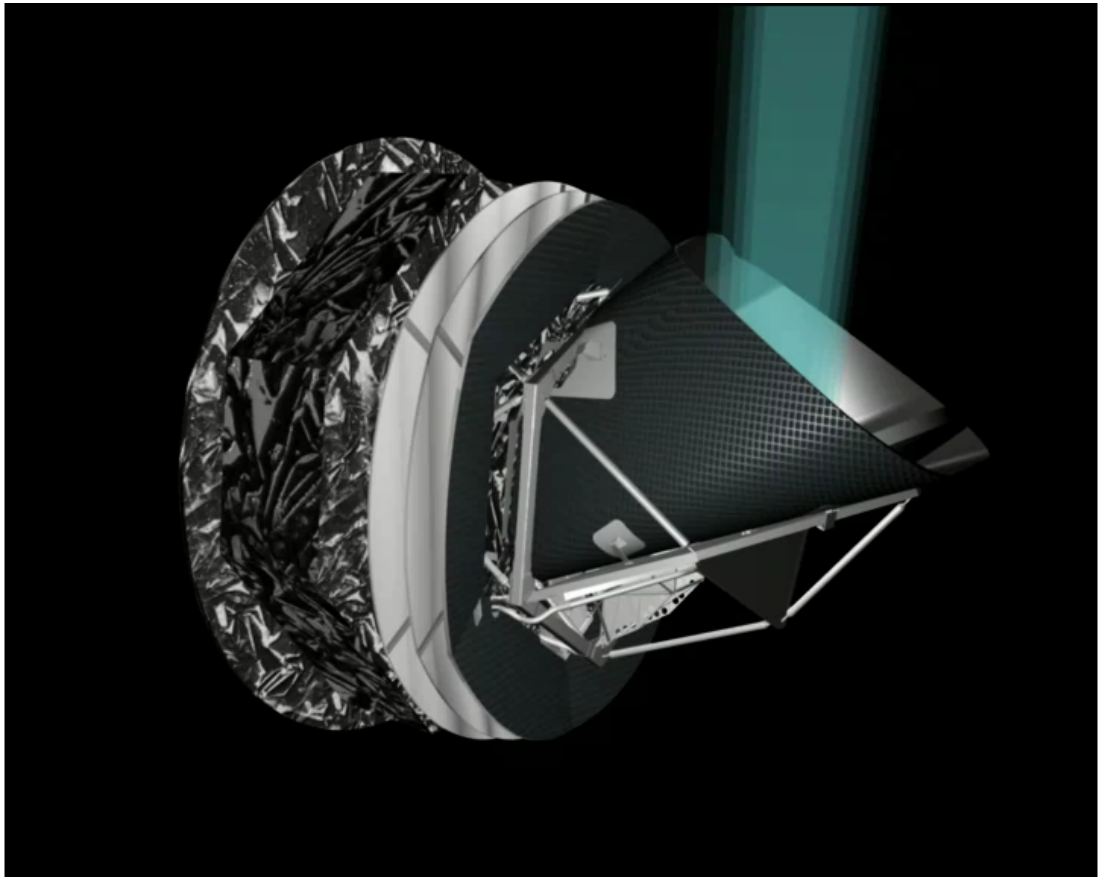
In collaboration with: E. Valtaoja, M. Tornikoski, A. Lähteenmäki, E. Nieppola

Tuorla Observatory, University of Turku

FINCA — Finnish Centre for Astronomy with ESO

Aalto University School of Science and Technology

Planck



- launched in August 2009

- all-sky survey in 6 months

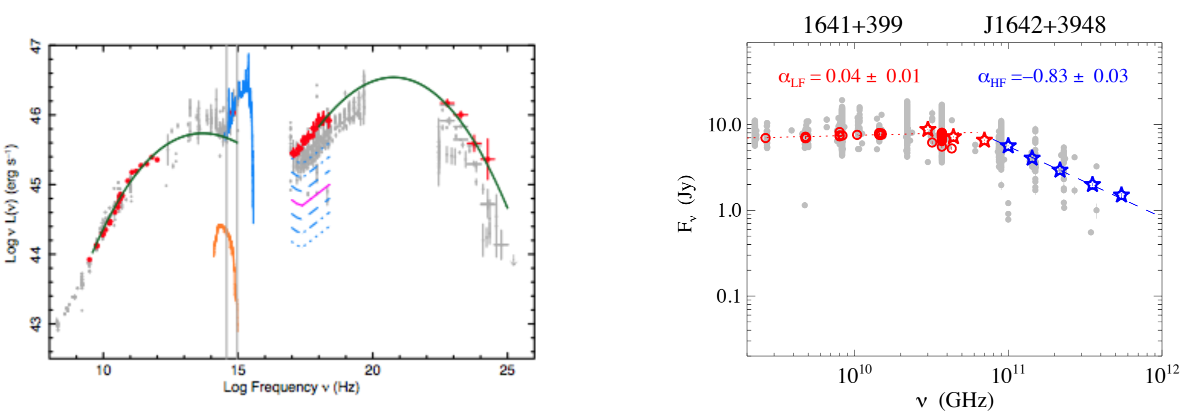
- 9 months catalog of compact sources (ERCSC) at 9 frequencies:
30, 44, 70, 100, 143, 217, 353, 545, 860 GHz

Planck Early Results

Planck Early Results 15: Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources

Planck Collaboration: J. Aatrokoski[1], P. A. R. Ade[82], N. Aghanim[53], H. D. Aller[4], M. F. Aller[4], E. Angelakis[75], M. Arnaud[69], M. Ashdown[66,7], J. Aumont[53], C. Baccigalupi[80], A. Balbi[33], A. J. Banday[87,11,74], R. B. Barreiro[60], J. G. Bartlett[6,64], E. Battaner[89], K. Benabed[54], A. Benoît[52],

A&A accepted, arXiv:1101.2047



Observatories involved: APEX, ATCA, Effelsberg, IRAM, Medicina, Metsahovi, MRO, OVRO, RATAN, VLA, KVA, Xinglong, SWIFT, Fermi/LAT

Simultaneous *Planck*, *Swift*, and *Fermi* observations of X-ray and γ-ray selected blazars

P. Giommi[2,3], G. Polenta[2,23], A. Lähteenmäki[1,19], D. J. Thompson[5], M. Capalbi[2], S. Cutini[2], D. Gasparrini[2], J. González-Nuevo[42], J. León-Tavares[1], M. López-Caniego[32], M. N. Mazziotta[33], C. Monte[14,33], M. Perri[2], S. Rainò[14,33], G. Tosti[35,15], A. Tramacere[28], F. Verrecchia[2],

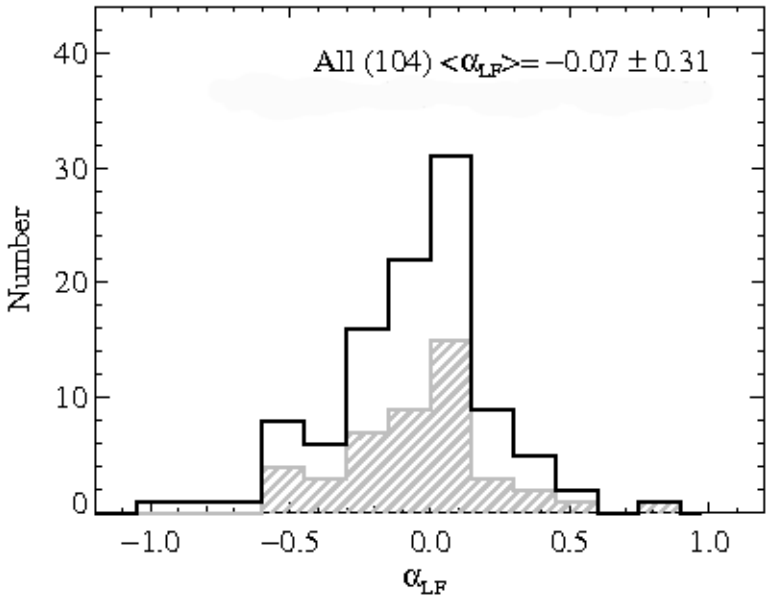
A&A accepted, arXiv:1108.1114

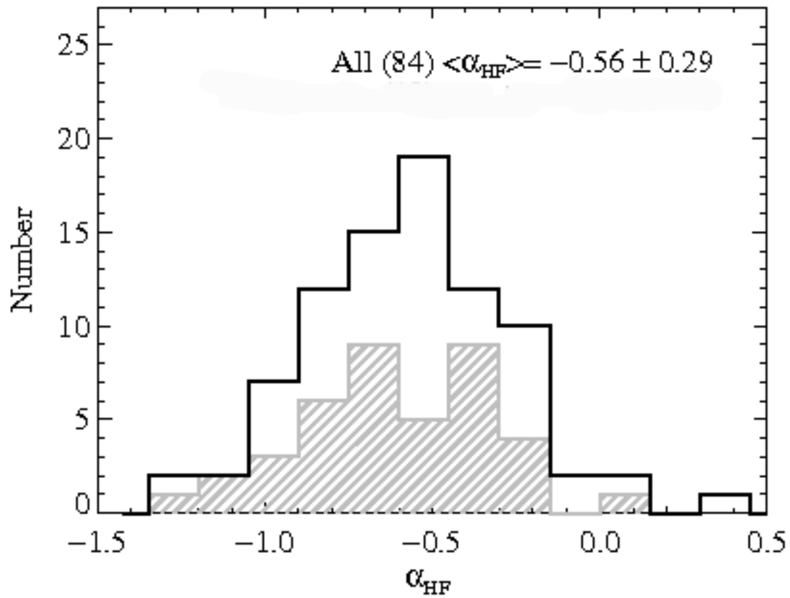
Planck Early Results

Planck Early Results 15: Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources

Planck Collaboration: J. Aatrokoski[1], P. A. R. Ade[82], N. Aghanim[53], H. D. Aller[4], M. F. Aller[4], E. Angelakis[75], M. Arnaud[69], M. Ashdown[66,7], J. Aumont[53], C. Baccigalupi[80], A. Balbi[33], A. J. Banday[87,11,74], R. B. Barreiro[60], J. G. Bartlett[6,64], E. Battaner[89], K. Benabed[54], A. Benoît[52],

A&A accepted,
arXiv:1101.2047

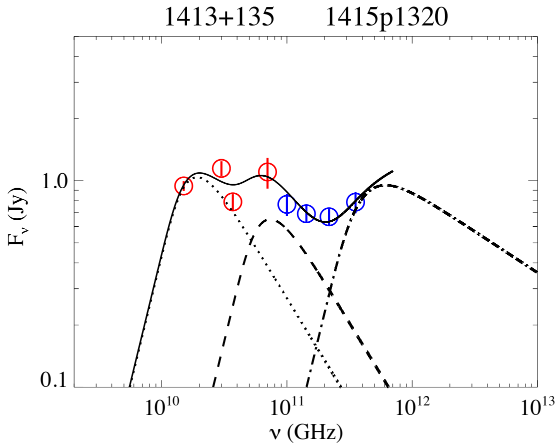


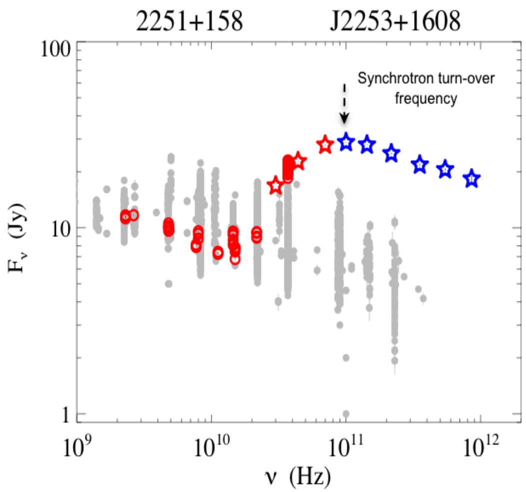


α_{LF} (< 70 GHz)

α_{HF} (> 70 GHz)

Planck Early Results





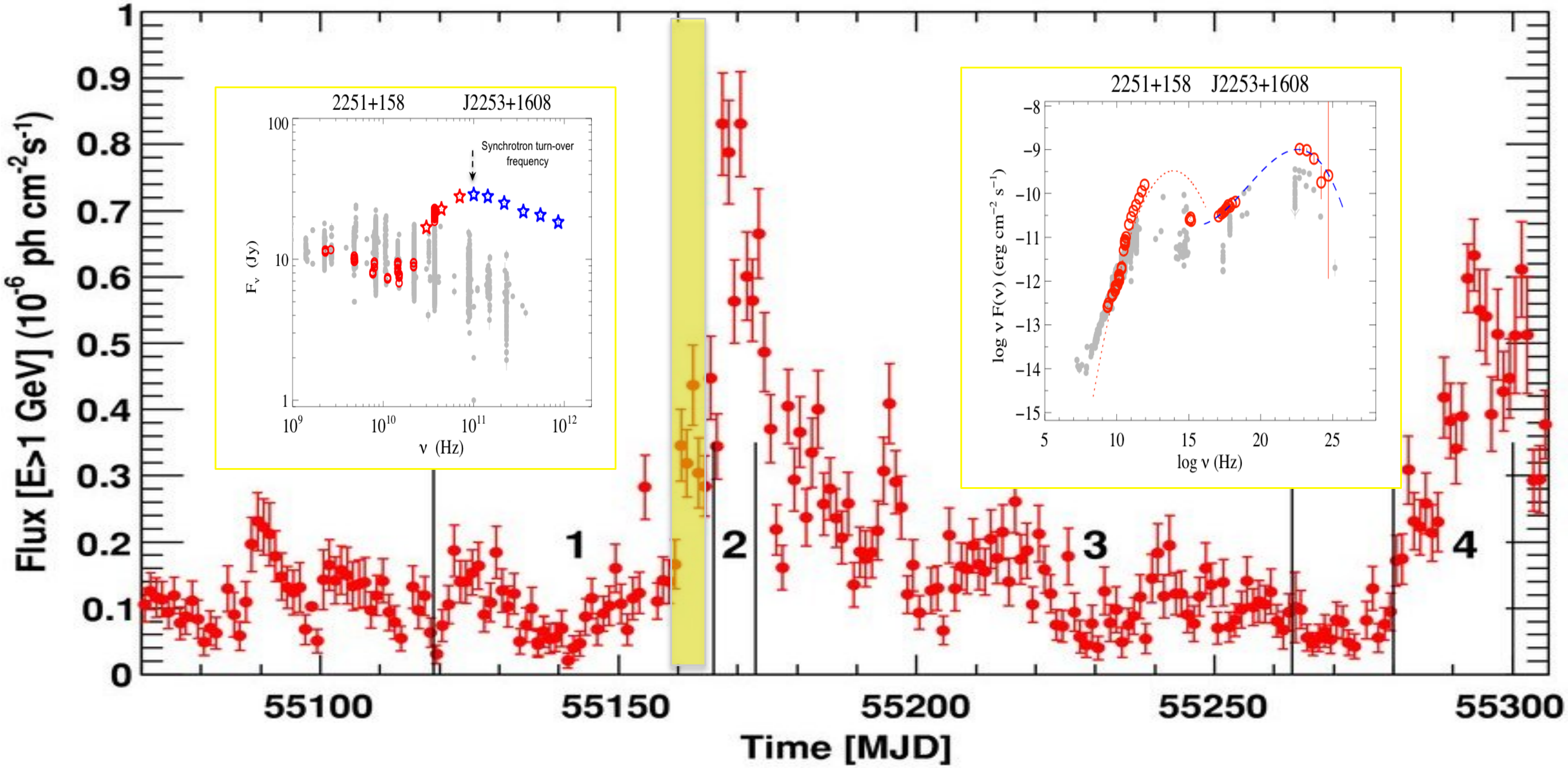
A flat α_{HF} has two possible explanations:

- either the total HF spectra are defined by several underlying components or,

- the energy spectrum of the electron population is much harder than generally assumed (s ≈ 1.5)

Planck collaboration et al. 2011, A&A, arXiv:1101.2047

Planck Early Results



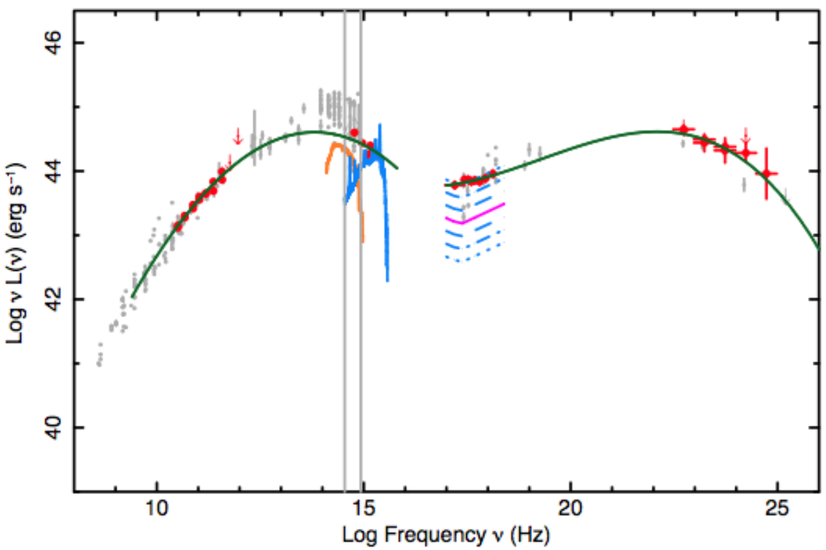
Ackermann + 2010

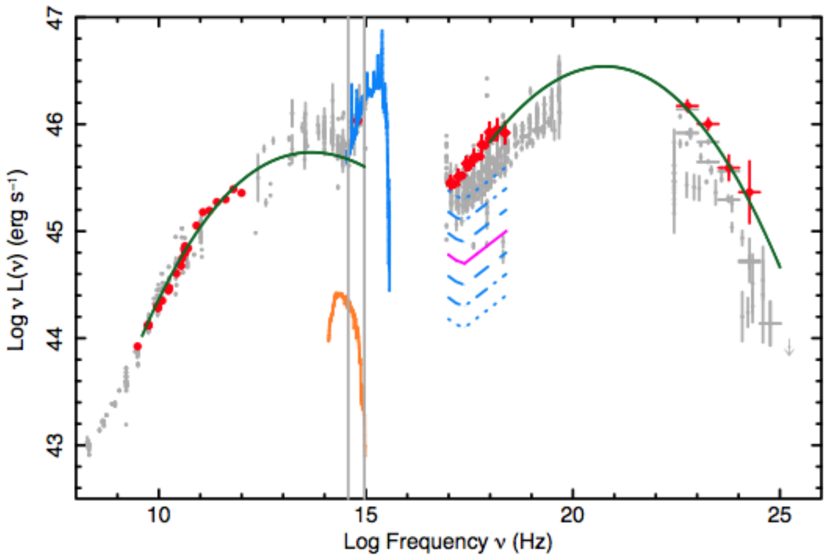
Planck Early Results

Simultaneous *Planck*, *Swift*, and *Fermi* observations of X-ray and γ-ray selected blazars

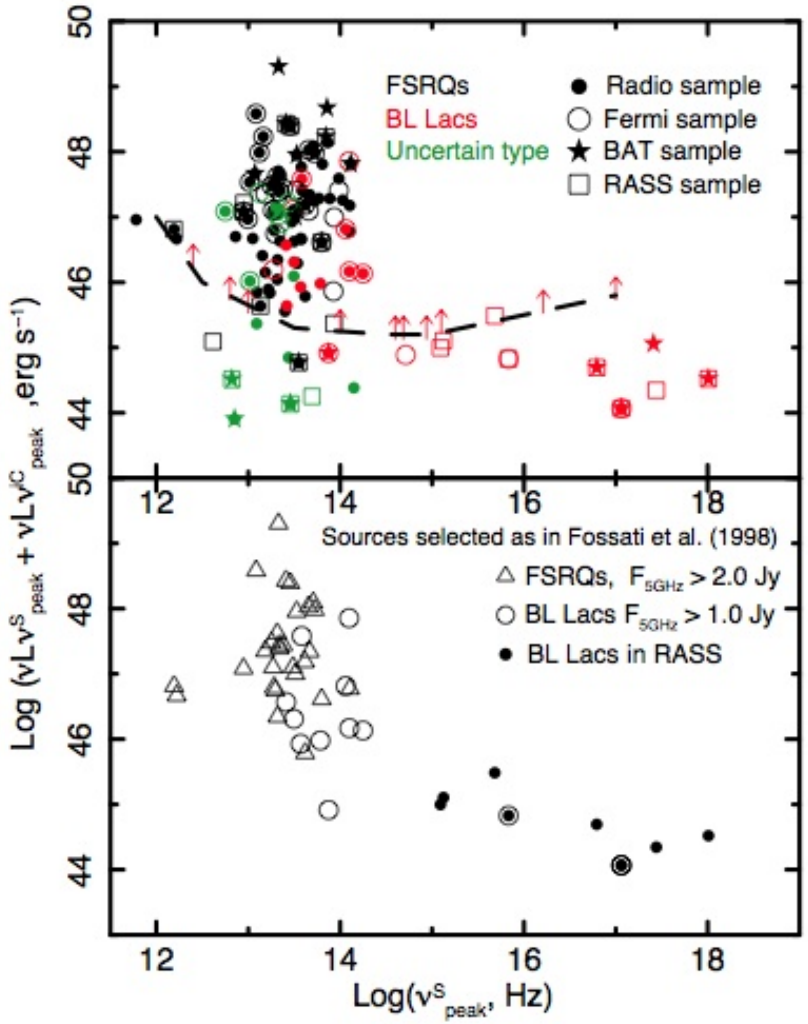
P. Giommi[2,3], G. Polenta[2,23], A. Lähteenmäki[1,19], D. J. Thompson[5], M. Capalbi[2], S. Cutini[2], D. Gasparrini[2], J. González-Nuevo[42], J. León-Tavares[1], M. López-Caniego[32], M. N. Mazziotta[33], C. Monte[14,33], M. Perri[2], S. Rainò[14,33], G. Tosti[35,15], A. Tramacere[28], F. Verrecchia[2],

A&A accepted,
arXiv:1108.1114





Planck Early Results



- Simple SSC models cannot explain the SED of many blazars

- No obvious correlation of the type predicted by the blazar-sequence was found.

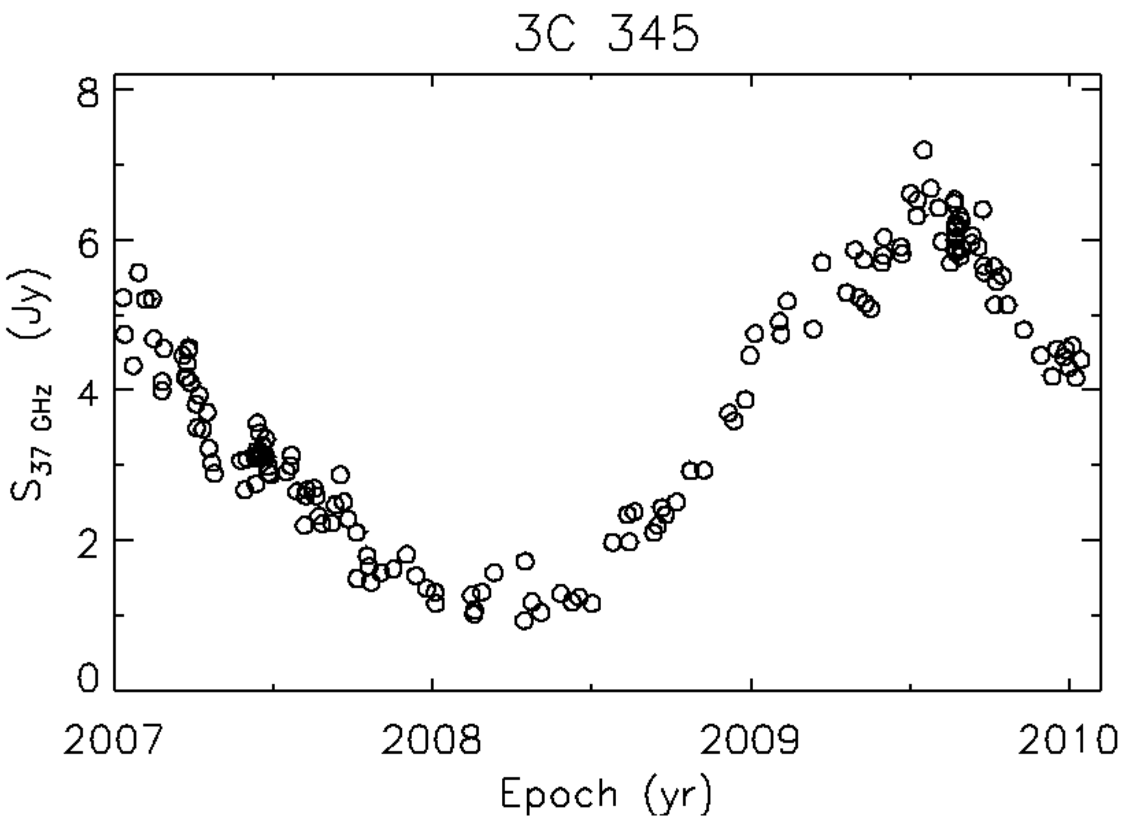
Giommi et al. 2011, A&A, arXiv:1108.1114

mm and γ-ray connection

- From the Metsahovi QSO monitoring program, we select the 45 best sampled light curves.

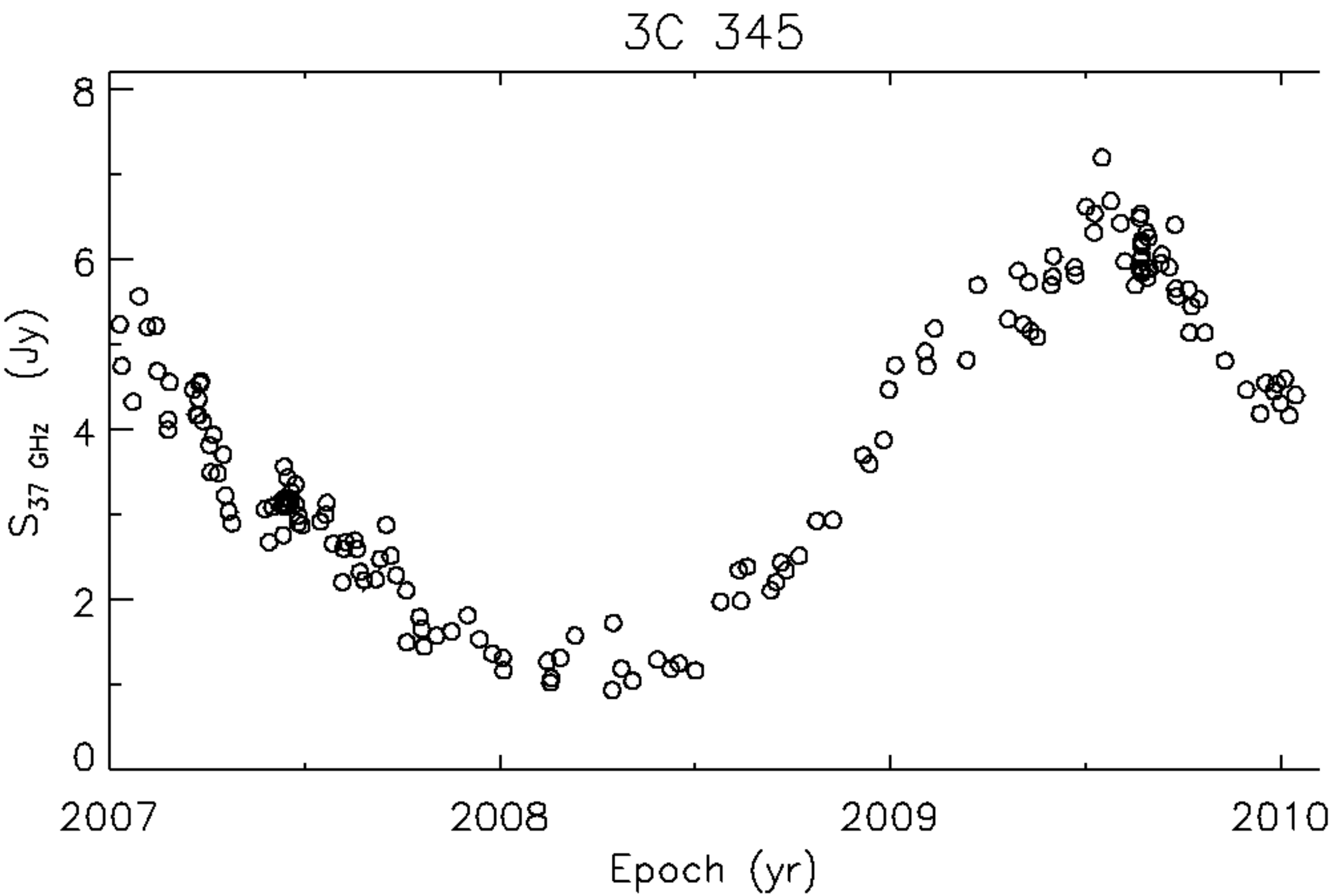
- We decompose the 37 GHz Metsahovi light curves into individual exponential flares as in Valtaoja et al. (1999)

- Each of the individual outburst corresponds to the ejection of a new component into the jet (Savolainen et al. 2002).



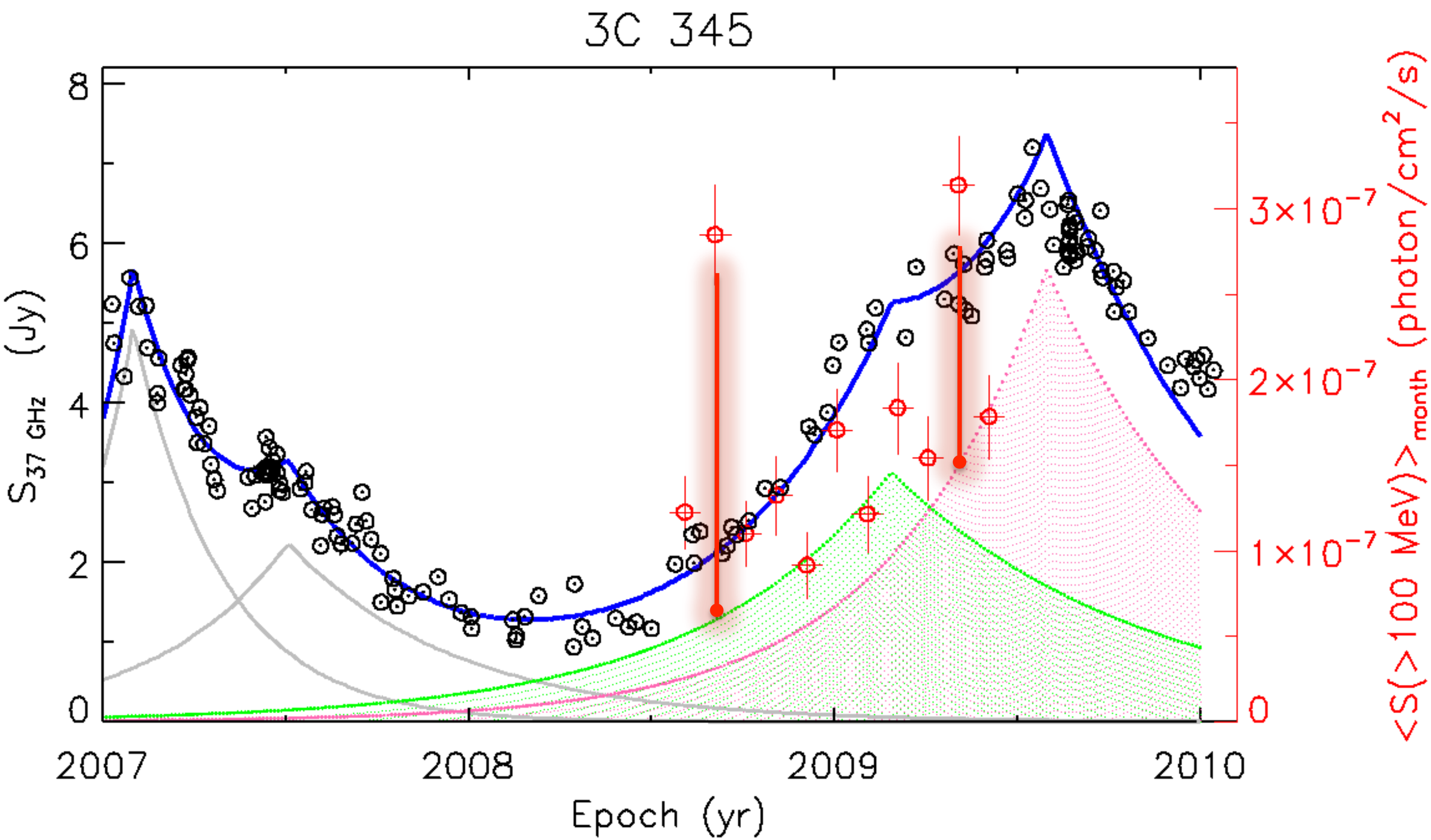
León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

mm and γ-ray flares



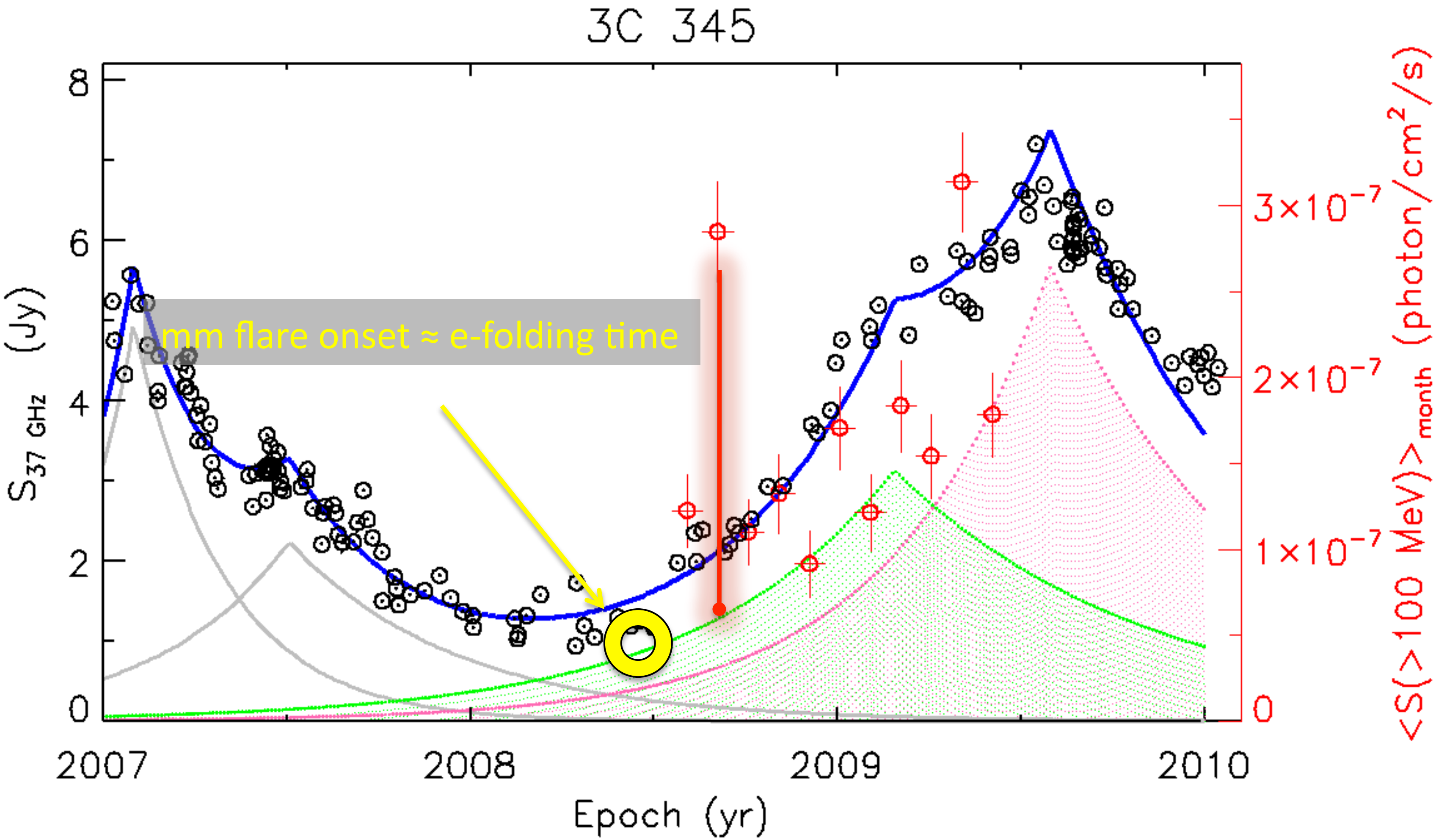
León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

mm and γ-ray flares



León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

mm and γ-ray flares



León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

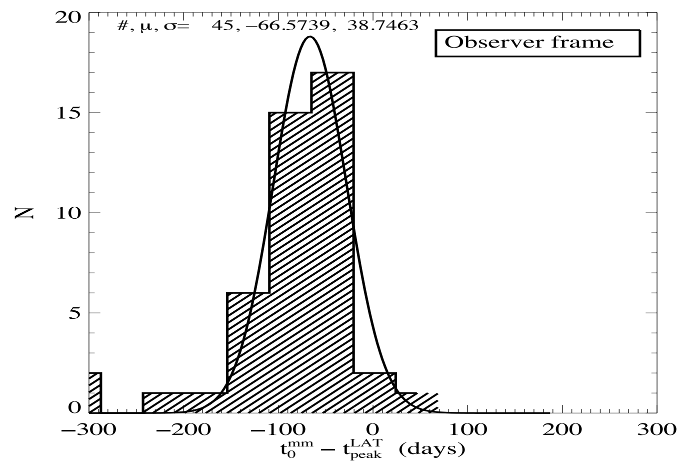
mm-γ-rays delay

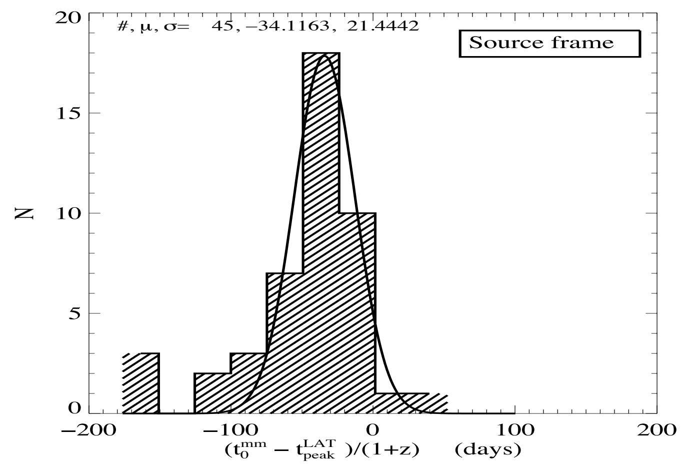
✪ The average delay from a mm-flare onset (Smax/e) to the peak of the most intense γ-rays is,

$t_0^{mm} - t_{peak}^{LAT}$ **~ -70 days**

in the source frame,

$t_0^{mm} - t_{peak}^{LAT}$ ~ -30 days





León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

The location of the γ-rays zone

We convert the observed delay into linear distances by

$$\Delta r = \frac{\beta_{app} c (t_0^{mm} - t_{peak}^{LAT})}{sin\theta \ (1+z)}$$

$< R_\gamma > \sim$ 7 pc

Well agreement with the average distance derived by Pushkarev et al. (2010)

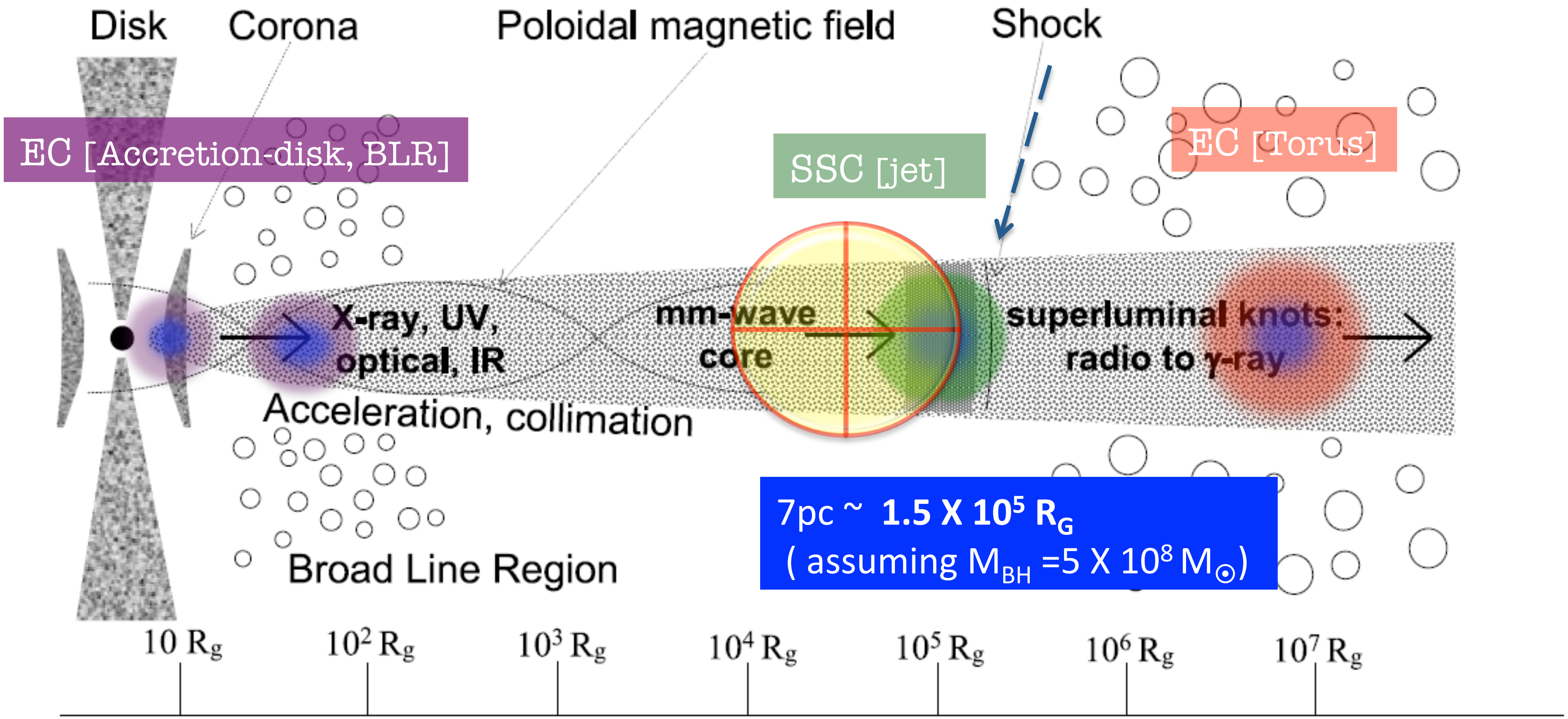
OJ 287 : R_γ > 14 pc (Agudo et al. 2010)

3C 279 : : R_γ ~ 10^5 R_G (Fermi-LAT collaboration. 2010)

source	alias	phase	t_0^{mm}-t_{peak}^{LAT} [days]	distance [pc]
0048-097		0.8	-58.90	...
0059+581		1.1	-79.32	6.44
0106+013		0.4	-63.00	8.94
0109+224	S2 0109+22	0.6	-28.54	...
0133+476		1.1	-62.15	8.36
0212+735		1.1	-88.33	1.44
0218+357		0.9	-74.68	...
0219+428	3C 66	0.9	-73.08	...
0235+164		0.6	-29.03	3.60
0316+413	3C 84	0.6	-37.50	0.03
0336-019	CTA 026	0.8	-55.96	10.18
0420-014		0.5	-33.08	3.22
0440-003	NRAO 190	0.3	16.36	...
0507+179		1.1	-76.11	...
0528+134		0.6	-34.29	6.45
0736+017		1.4	-104.29	10.50
0754+100		0.6	-44.45	3.54
0827+243	OJ 248	1.6	-143.26	20.05
0851+202	OJ 287	0.1	68.44	11.60
0917+449		0.5	-30.59	...
1055+018		0.7	-63.45	3.79
1156+295	4C 29.45	1.2	-81.55	28.22
1219+285	ON 231	1.5	-132.64	...
1222+216	PKS1222+21	1.2	-125.24	17.33
1226+023	3C 273	1.3	-207.59	35.13
1253-055	3C 279	0.8	-50.11	13.46

León-Tavares, Valtaoja, Tornikoski et al. *2011,A&A,532,146*

The γ-ray emission site



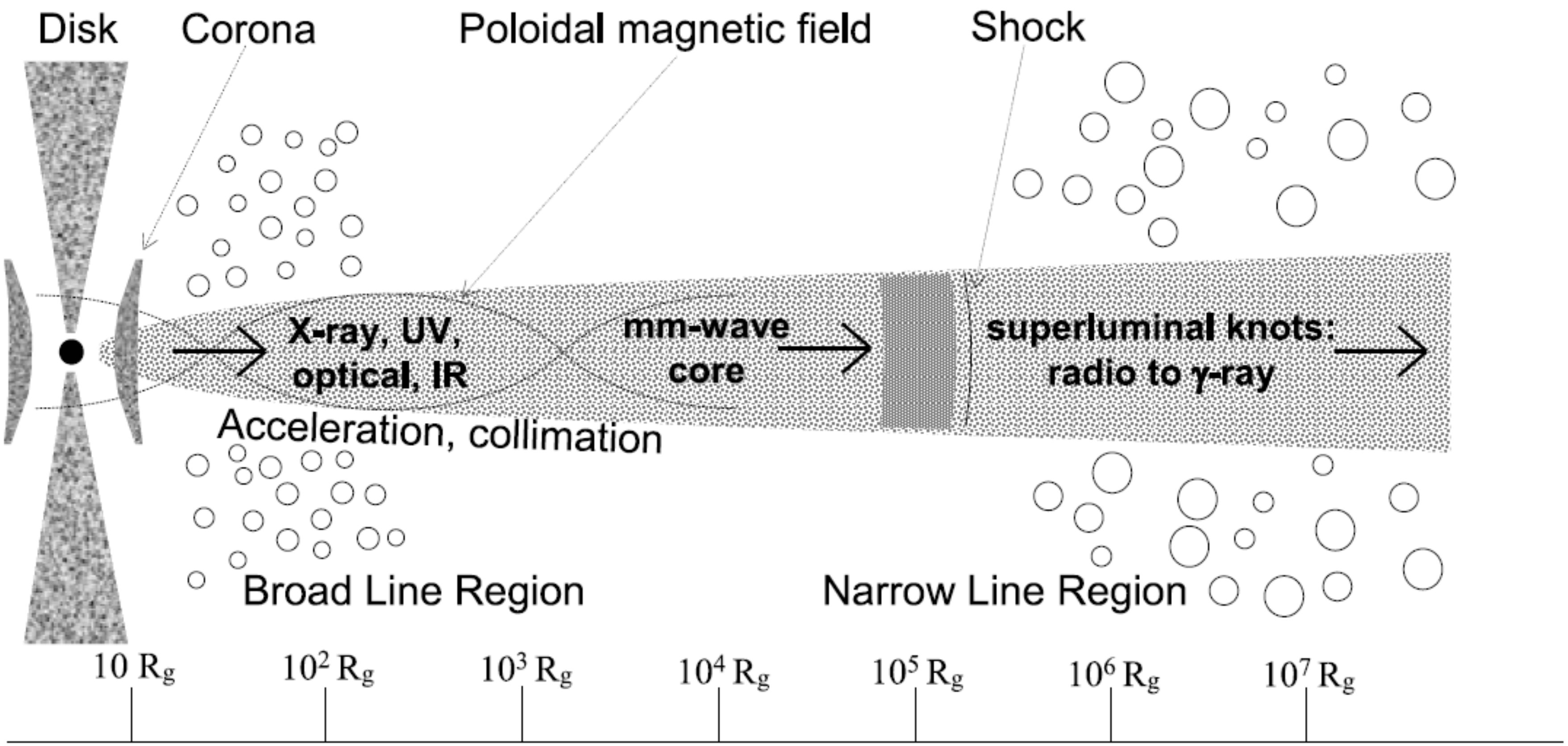
Summary I

- ✪ The strongest γ-ray flares occur after the mm flare onset and are produced at $\langle R_\gamma \rangle = 7$ pc from the radio-core

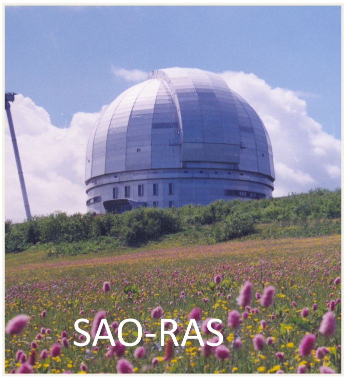
- ✪ The source of seed photons could be either the ***jet itself*** (*SSC fails to reproduce the observed γ-rays, Lindfors et al. 2006*) or the ***dusty torus*** (*few detections , Turler et al. 2006, Malmrose et al. 2011*).

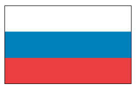
- ✪ Soft-photon field from BLR unlikely…?

is Jet Influencing BLR?



The Telescopes





3C 390.3

Optical monitoring
1992- 2007
(*Shapovalova et al. 2001;2010*)

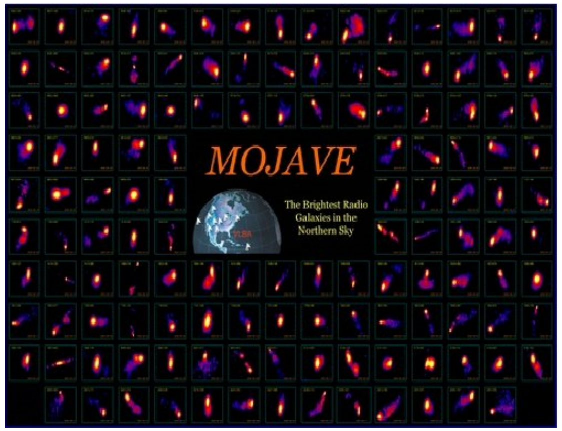
Radio monitoring
1994 – 2008

3C 120

Optical monitoring
2002 – 2008
(*Doroshenko et al. 2009*)

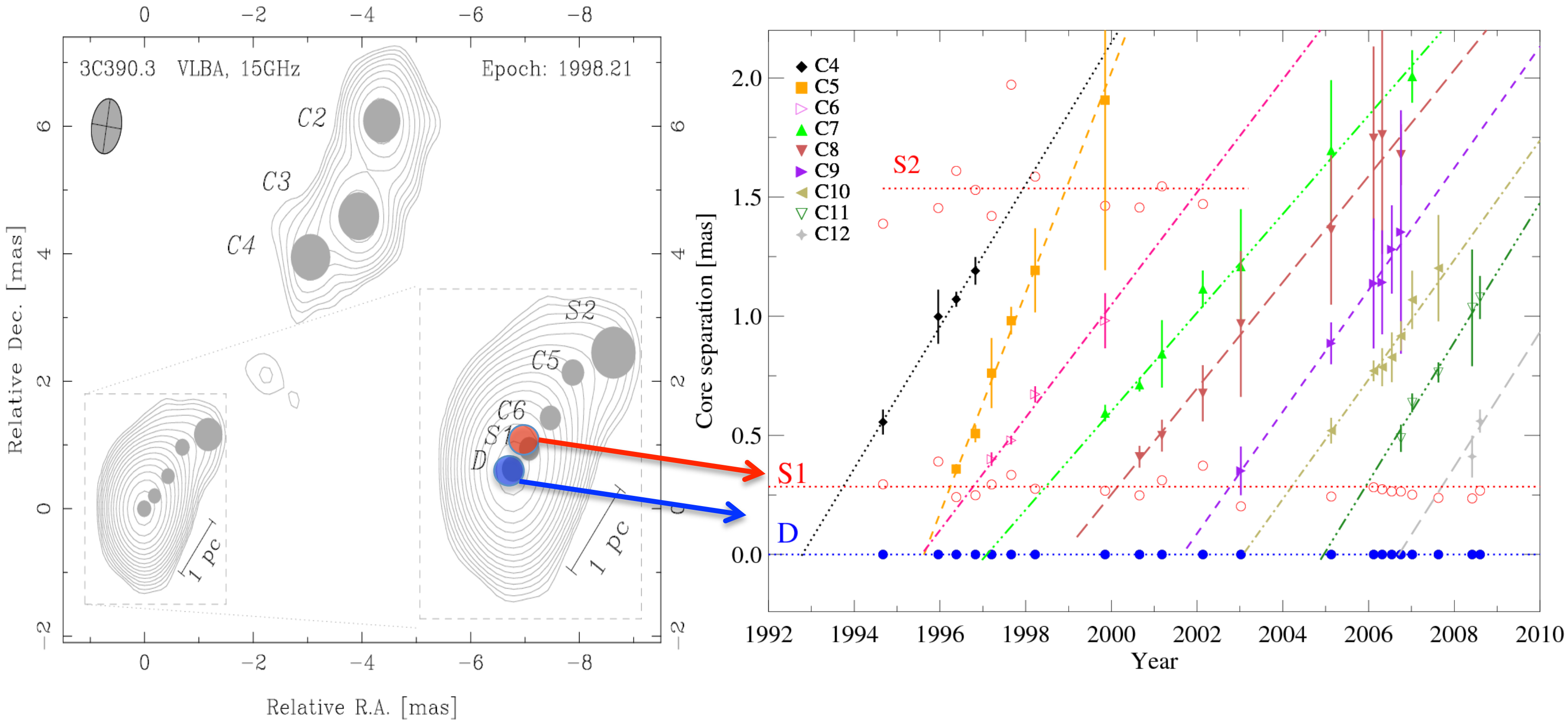
Radio monitoring
2001 – 2008

Very Long Baseline Array
11 ± 1 telescopes



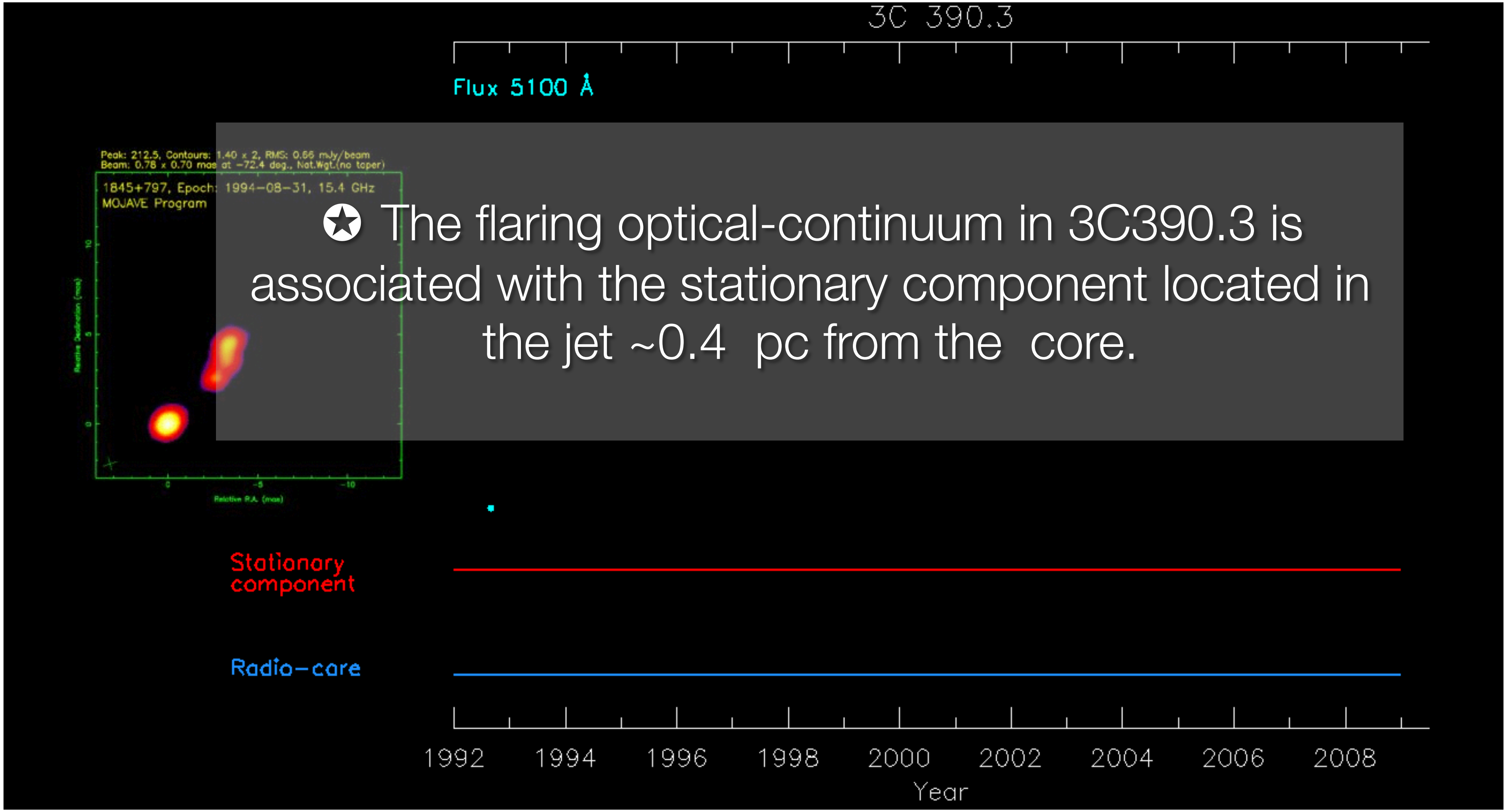
The case of 3C 390.3 (FR II)

Linear fits to component separations yield epochs of ejection from the core **D** and passages through the stationary region **S1**



Arshakian, León-Tavares, Lobanov et al. 2010, MNRAS, 401,1231

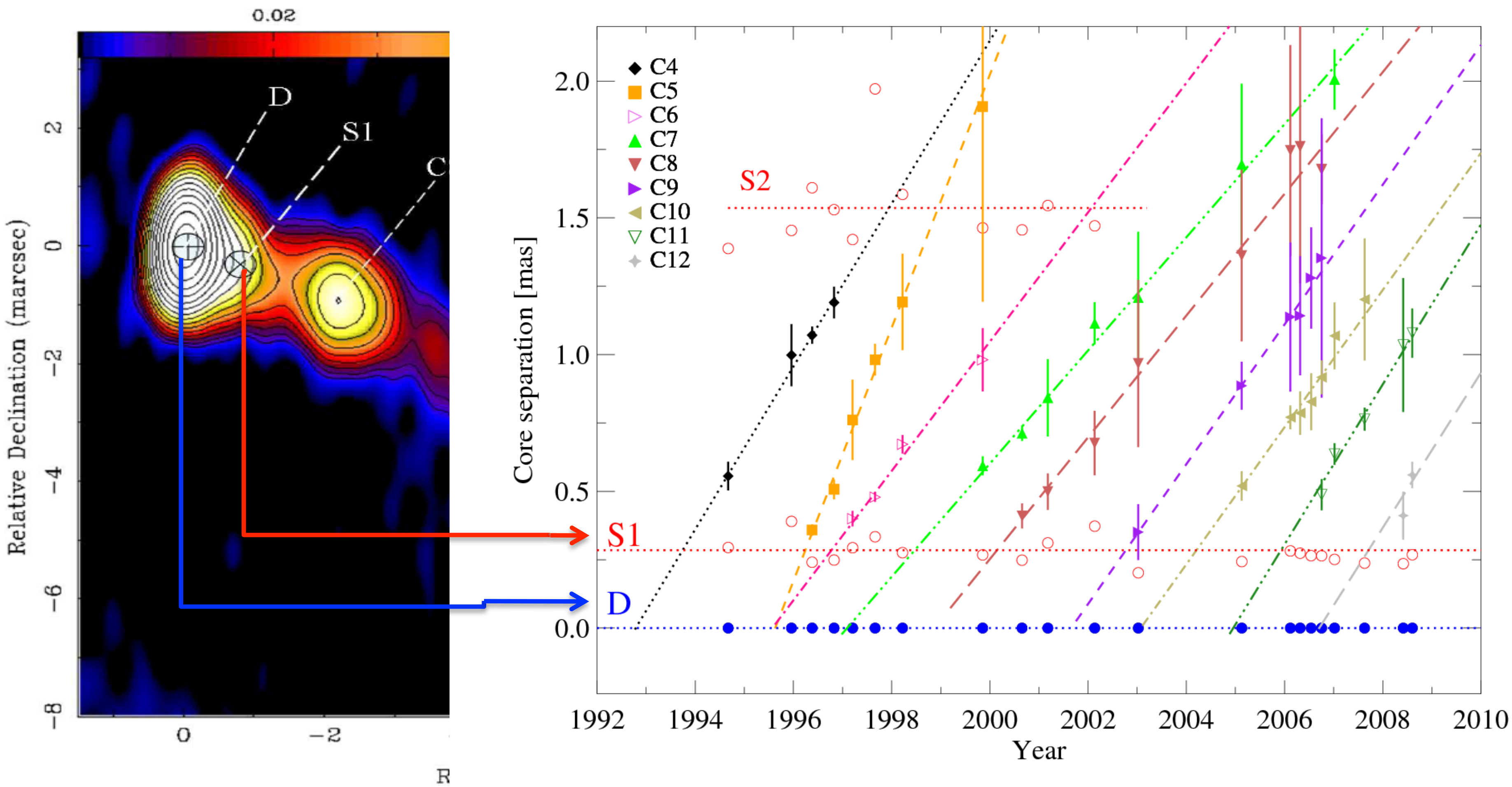
Is Jet Influencing BLR?



✪ The flaring optical-continuum in 3C390.3 is associated with the stationary component located in the jet ~0.4 pc from the core.

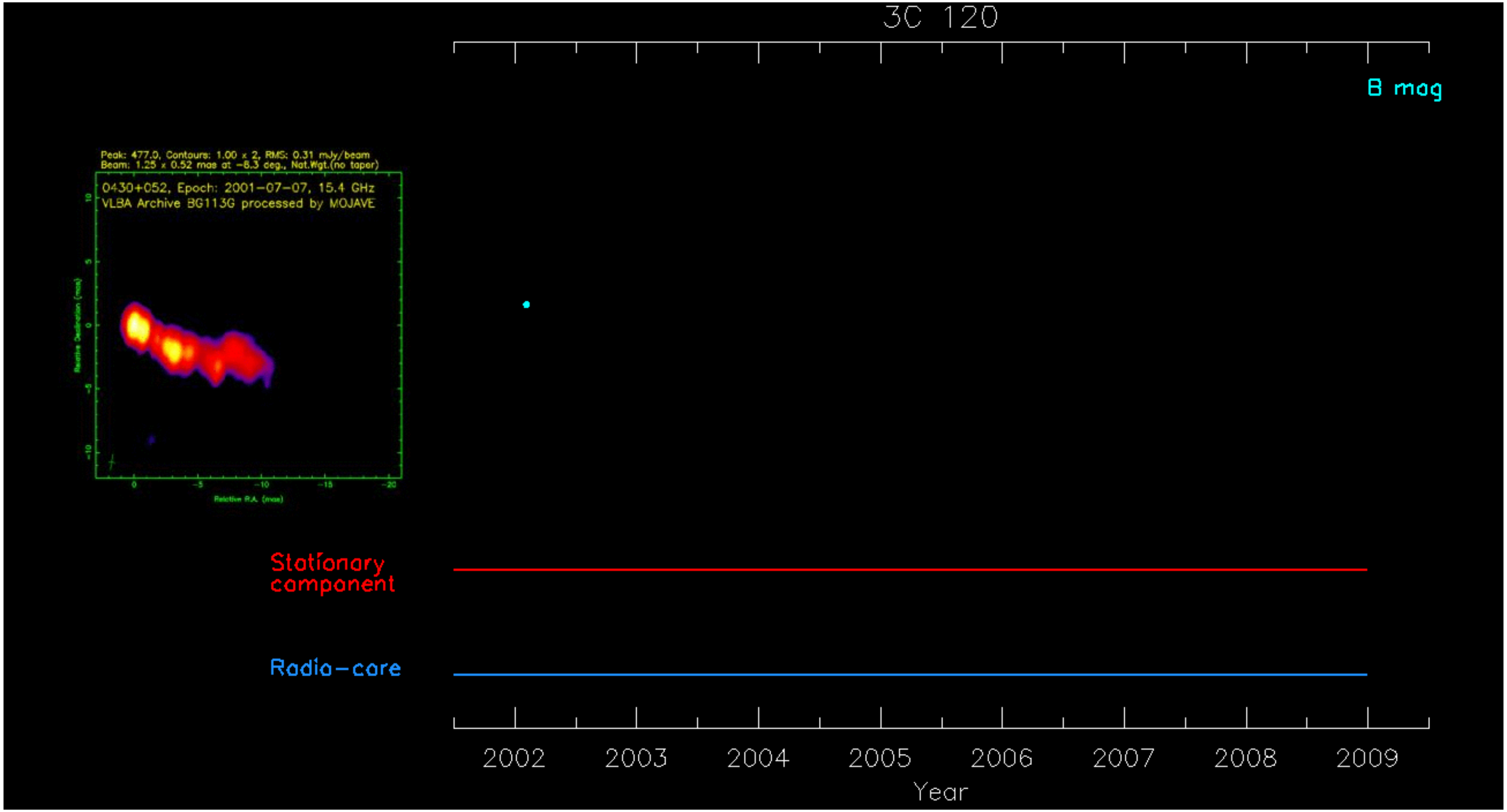
Arshakian, León-Tavares, Lobanov et al. 2010, MNRAS, 401,1231

The case of 3C 120 (FR I)



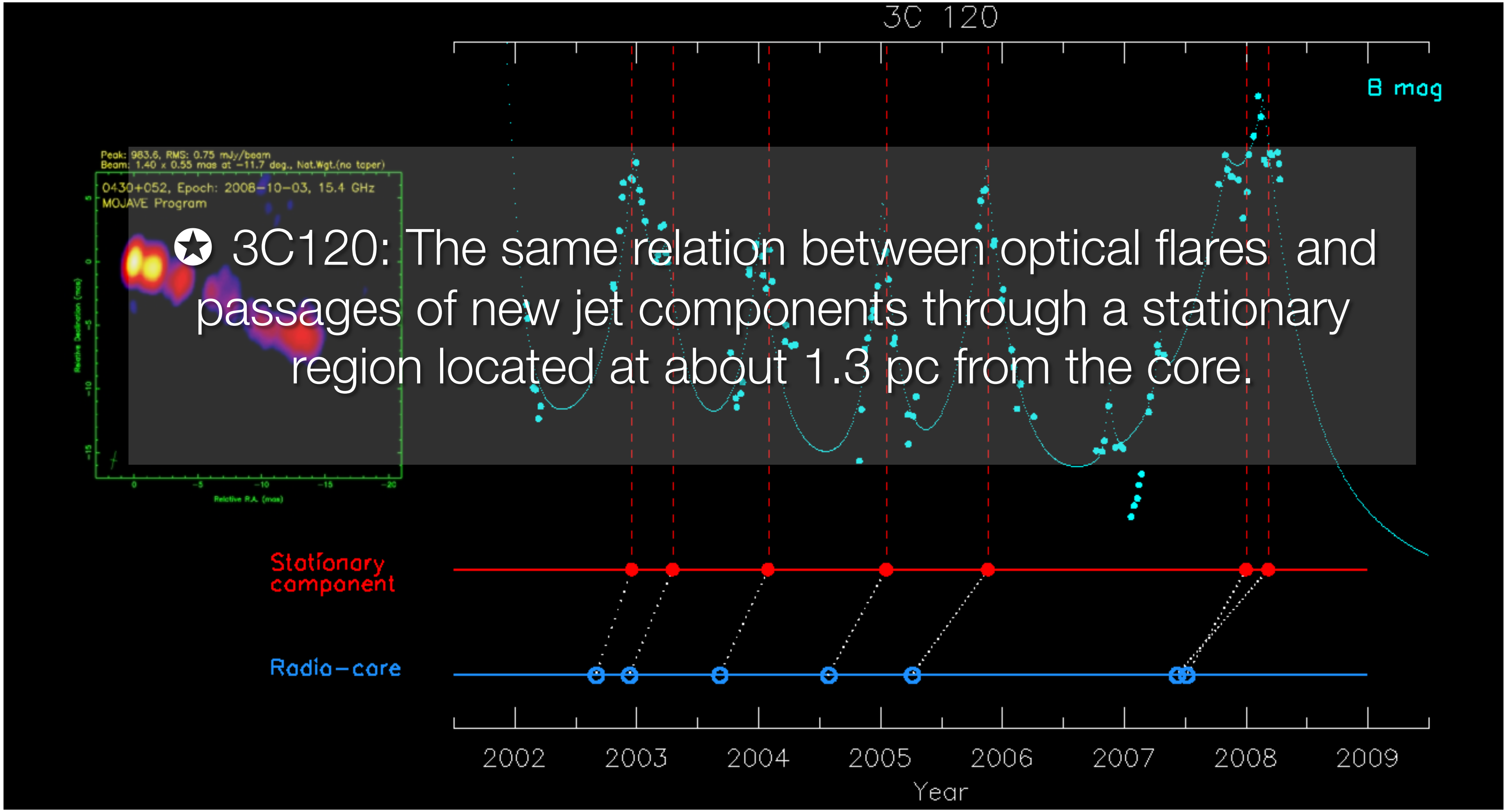
León-Tavares, Lobanov, Chavushyan et al. *2010,ApJ,715,355*

Is Jet Influencing BLR?



León-Tavares, Lobanov, Chavushyan et al. *2010,ApJ,715,355*

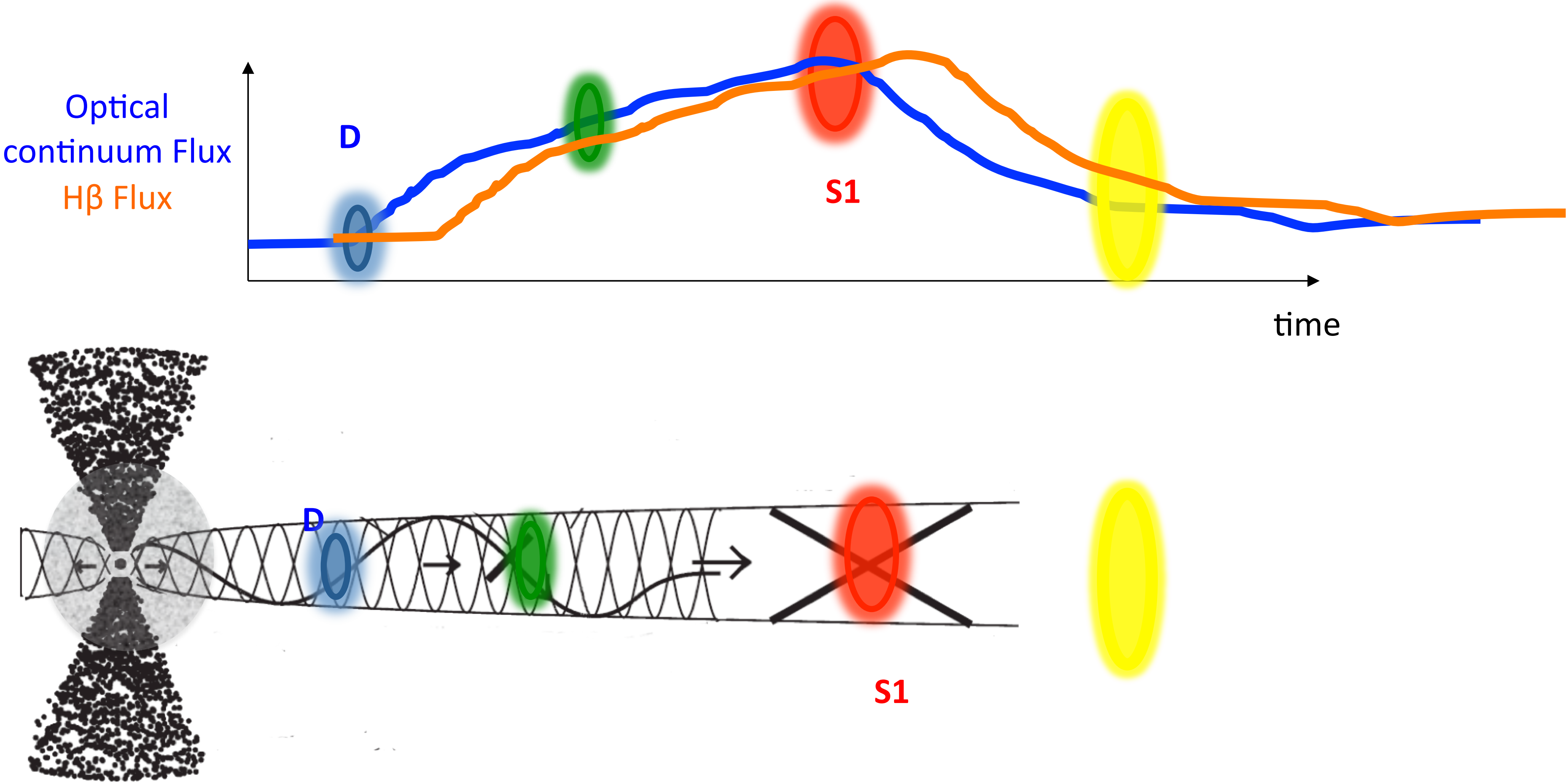
Is Jet Influencing BLR?

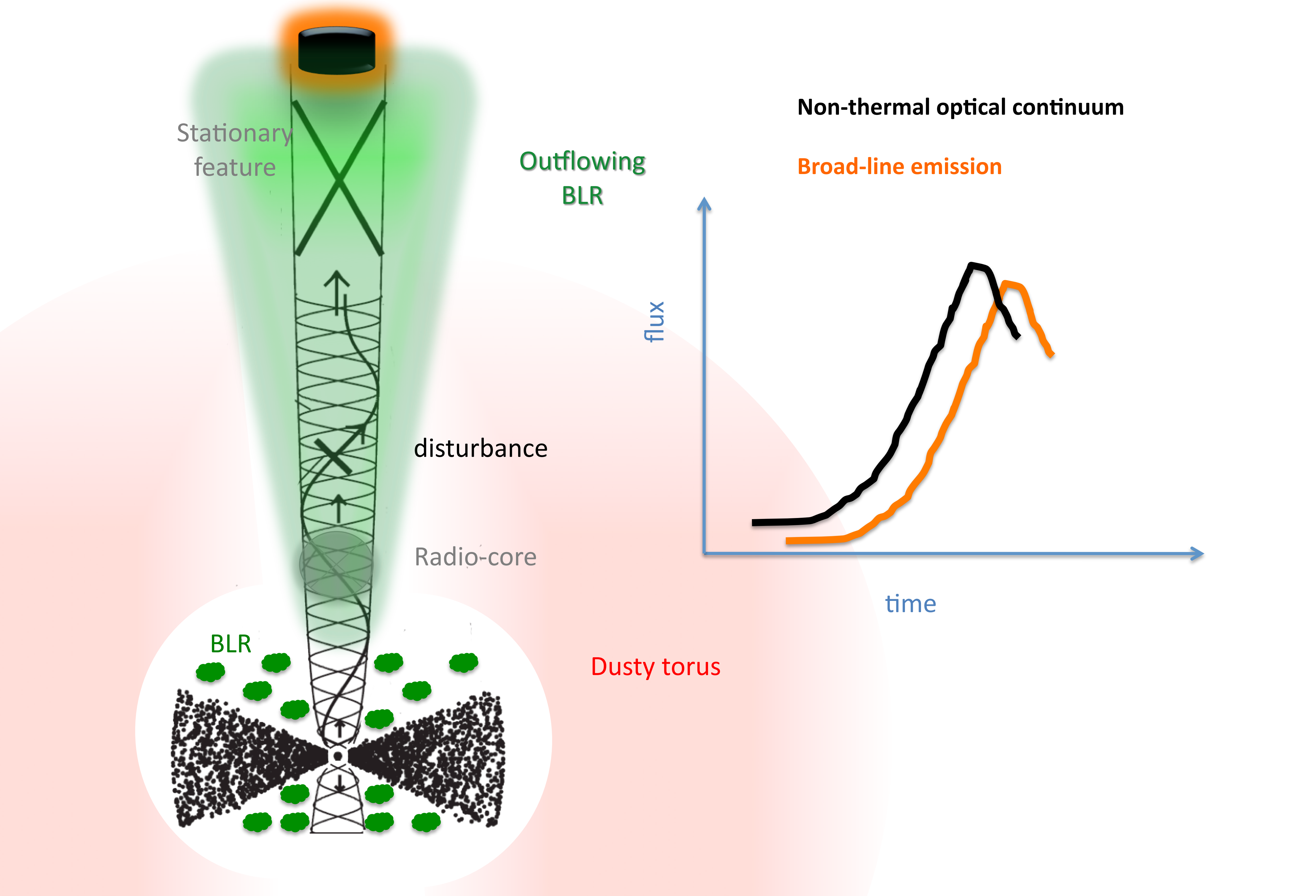


✪ 3C120: The same relation between optical flares and passages of new jet components through a stationary region located at about 1.3 pc from the core.

León-Tavares, Lobanov, Chavushyan et al. ***2010,ApJ,715,355***

The source of variable optical-continuum




Stationary
feature
Outflowing
BLR
Non-thermal optical continuum
Broad-line emission
flux
disturbance
Radio-core
time
BLR
Dusty torus

is Jet Influencing BLR?

✪ The ***flaring*** component of the ***optical-continuum*** in 3C 390.3 and 3C 120 is associated with the stationary region located ***in the jet***.

✪ Since the strength of Hβ and continuum emission is correlated in 3C 390.3 and 3C 120 then a significant amount of ***broad-line emission*** is ***driven*** by continuum radiation from the ***jet***.

✪ Thus, BLR is complex and NOT completely virialized.

Arshakian, León-Tavares, Lobanov et al. 2010, MNRAS, 401,1231
León-Tavares, Lobanov, Chavushyan et al. *2010,ApJ,715,355*

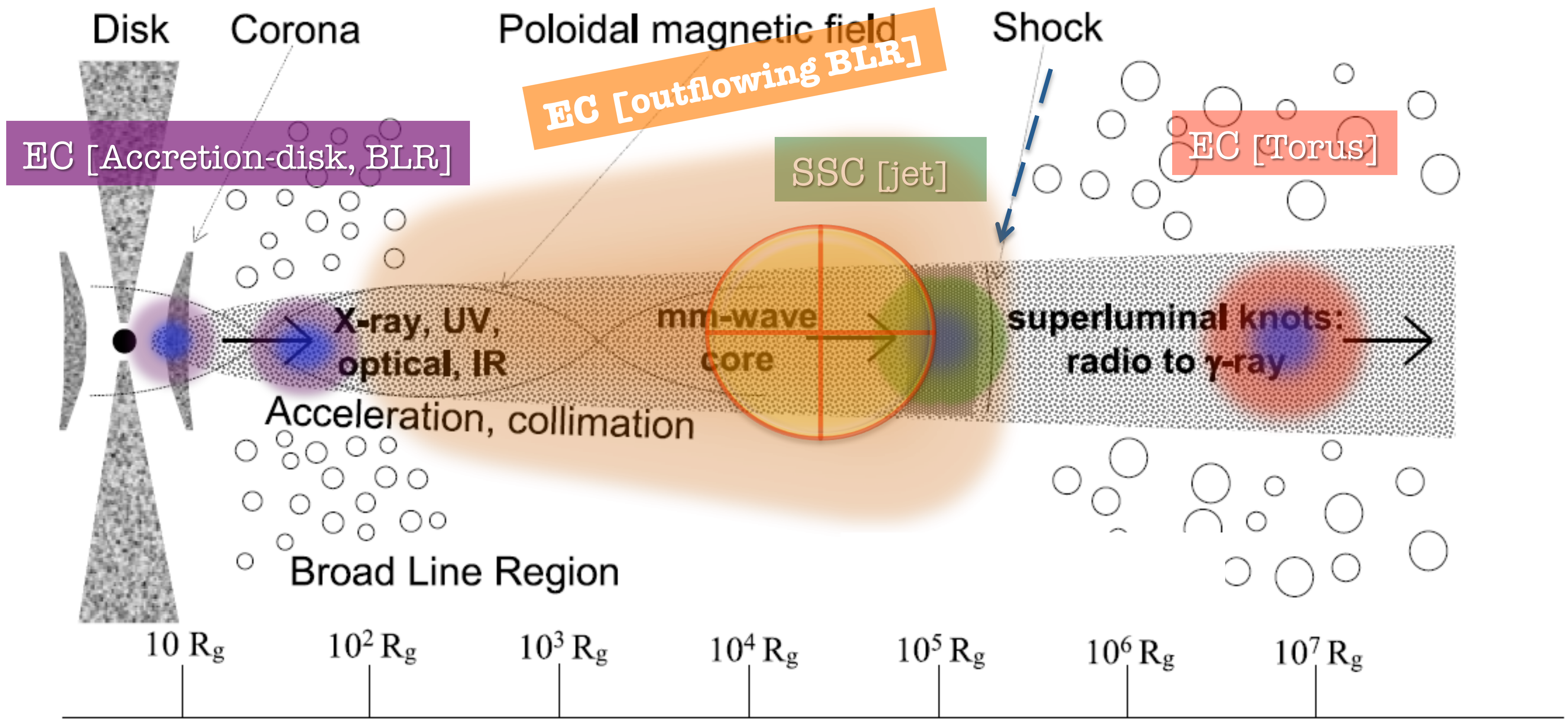
Implications of an outflowing BLR

✪ **AGN models**: BLR is complex and may have other components (e.g inflows, outlfows).

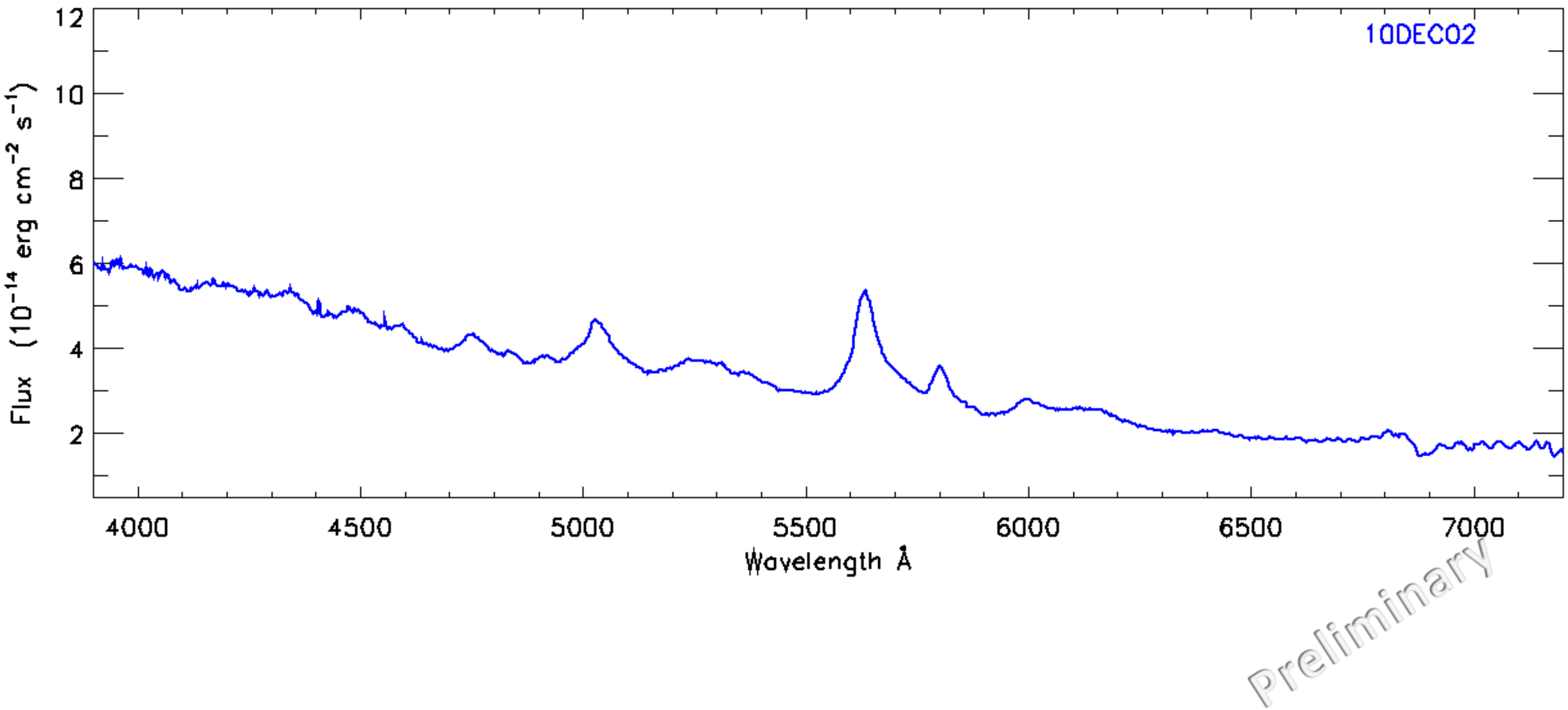
✪ **BH mass**: estimates using reverberation mapping relations (assume BLR is virialized) .

✪ **γ-rays**: Outflowing BLR may serve as a source of seed photons for inverse Compton scattering?
 (Leon-Tavares et al. 2011, A&A, 532, 146)

The γ-ray emission site



Work in progress: Spectroscopic monitoring



Monitoring a sample of bright gamma-ray blazars with prominent broad-line emission

Summary II

- ✪ The strongest γ-ray flares occur after the mm flare onset and are produced at <R_γ> = 7 pc from the radio-core
- ✪ The source of seed photons could be either the *jet itself* , *dusty torus* or....
- ✪ An outflowing BLR might be an alternative source of BLR seed photons to produce γ-rays, even at distances of several parsecs from the BH.