F-GAMMA program

high-cadence, multi-wavelength radio monitoring as a probe of the physical conditions and variability processes in AGN jets

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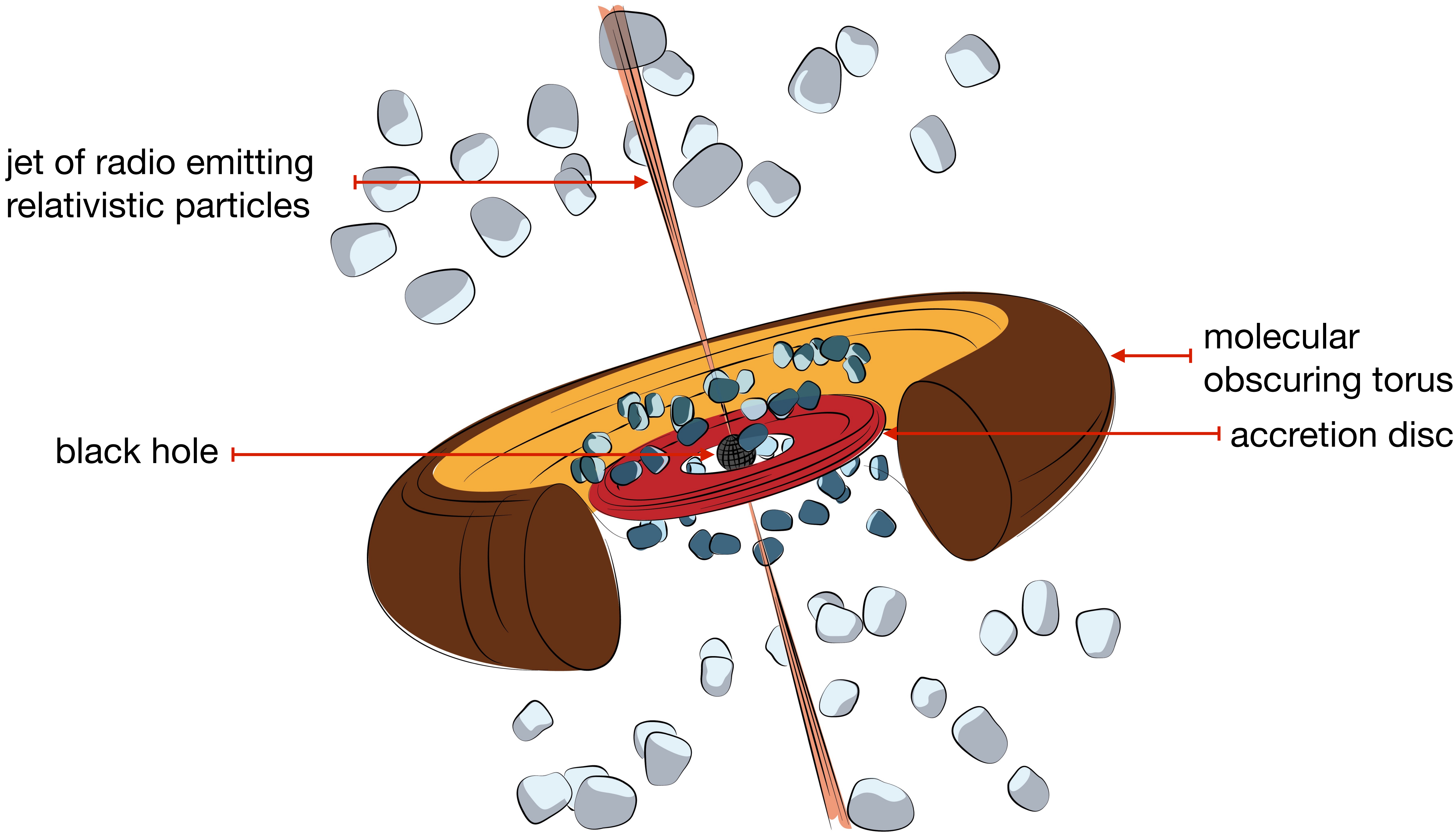


credit: S. Kiehlmann

"blazars":

- jet aligned to the line of sight (≤ 20–30º):
- relativistic flow & :

$$\Gamma = \frac{1}{\sqrt{1-\beta^2}}, \beta = \frac{u}{c}$$

$$\delta = \frac{1}{\Gamma(1-\beta cos\theta)}$$

- boosted emission:

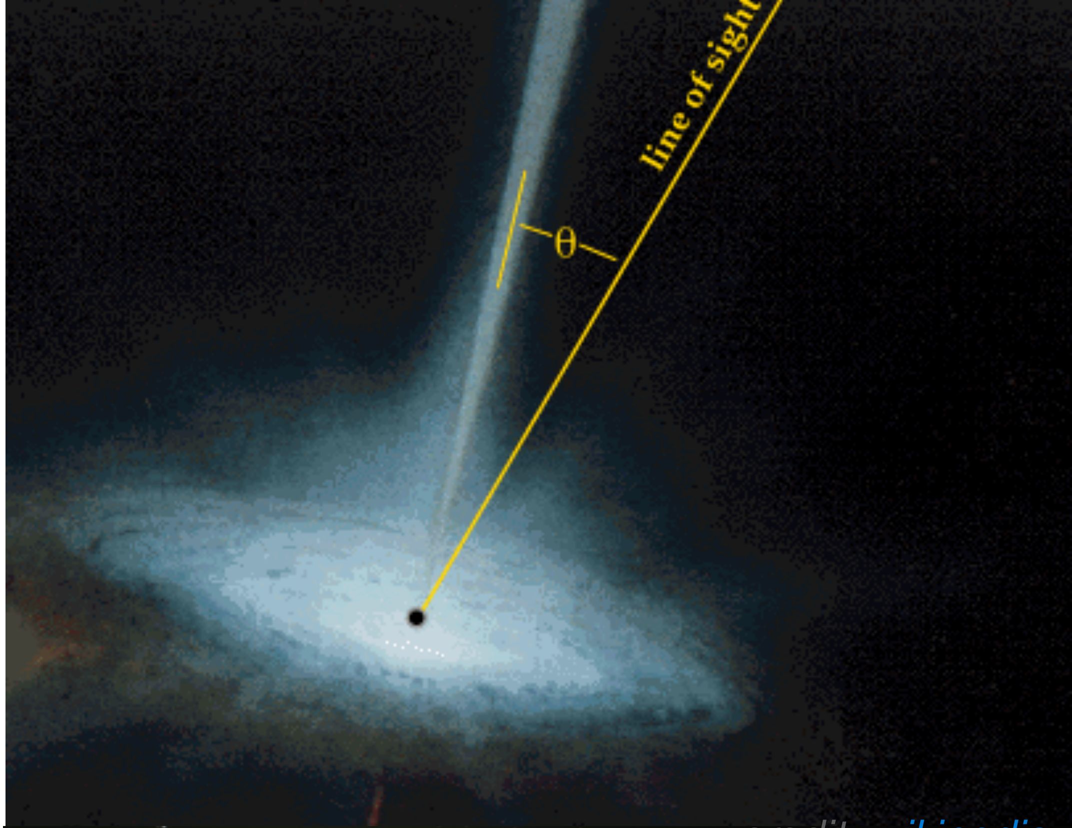
$$L_{\rm app} = L_{\rm e} \times \delta^b$$

- superluminal apparent speeds:

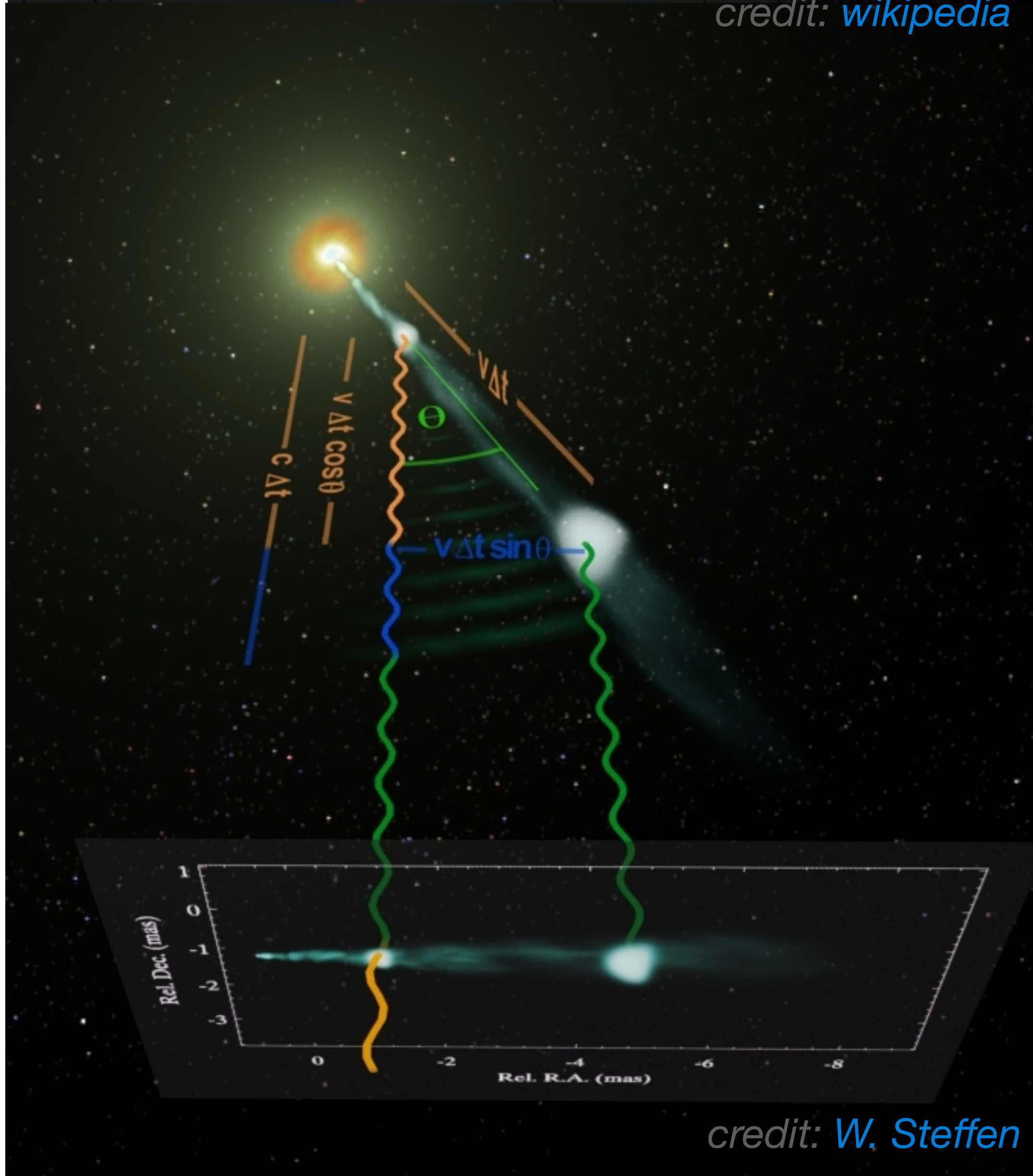
$$\beta_{\rm app} = \frac{\beta sin\theta}{1-\beta cos\theta}$$

- compressed timescales:

$$dt_{\rm obs} = dt_{\rm rest} \times \delta^{-1}$$



credit: *wikipedia*



credit: *W. Steffen*

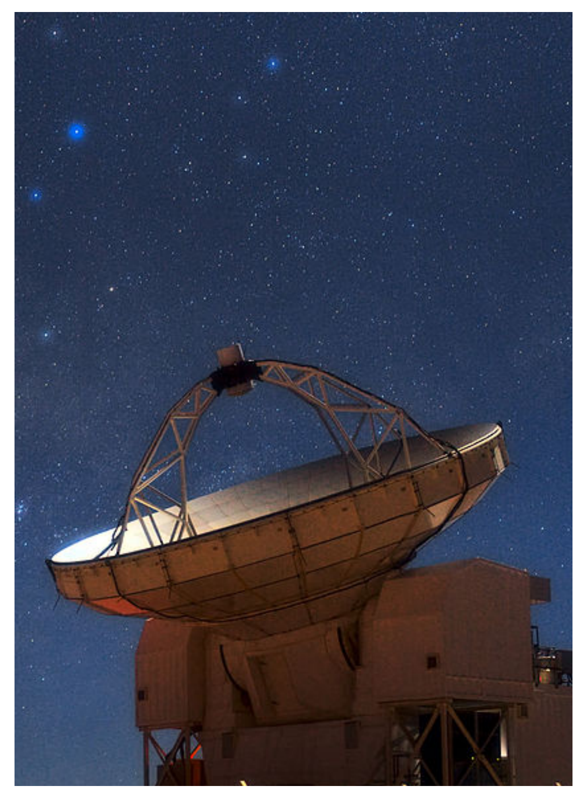
the F-GAMMA program (Jan 2007 — Jan 2015):

- key science project of the VLBI group at MPIfR
- understand the broad-band variability
- localise the gamma-ray emission site
- estimate the properties of the emitting elements

Fuhrmann et al. 2016A&A...596A..45F
Angelakis et al. 2010, astro-ph.CO/1006.5610


100m Effelsberg (MPIfR)


30m Pico Veleta (IRAM)


12m APEX (MPIfR)


Fermi-GST (NASA)

the F-GAMMA program (Jan 2007 — Jan 2015):

- almost 90 mostly *Fermi* sources
- 2.64 - 142, 345 GHz at 12 frequency steps
- mean cadence 1.3 months
- **LP** at 2.64, 4.85, 8.35, 10.45 and 14.6 GHz
- **CP** at 2.64, 4.85, 8.35, 10.45, 14.6, 23.05 GHz

Fuhrmann et al. 2016A&A...596A..45F
Angelakis et al. 2010, astro-ph.CO/1006.5610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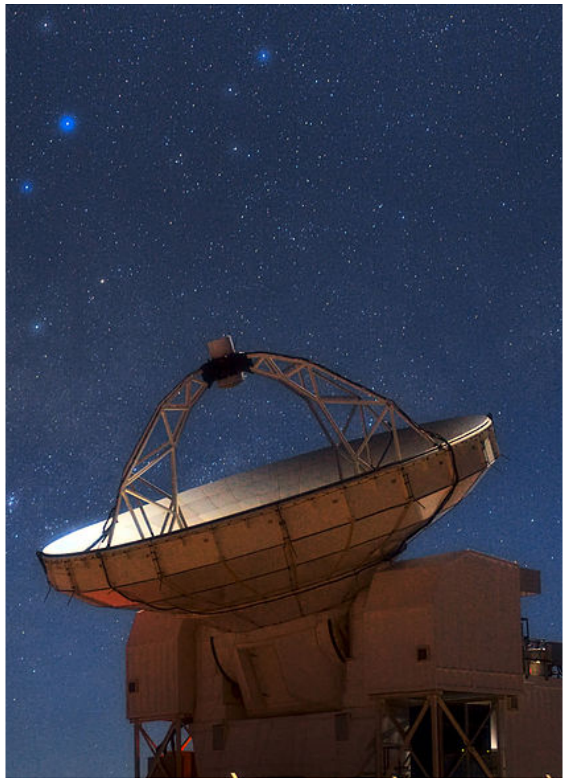
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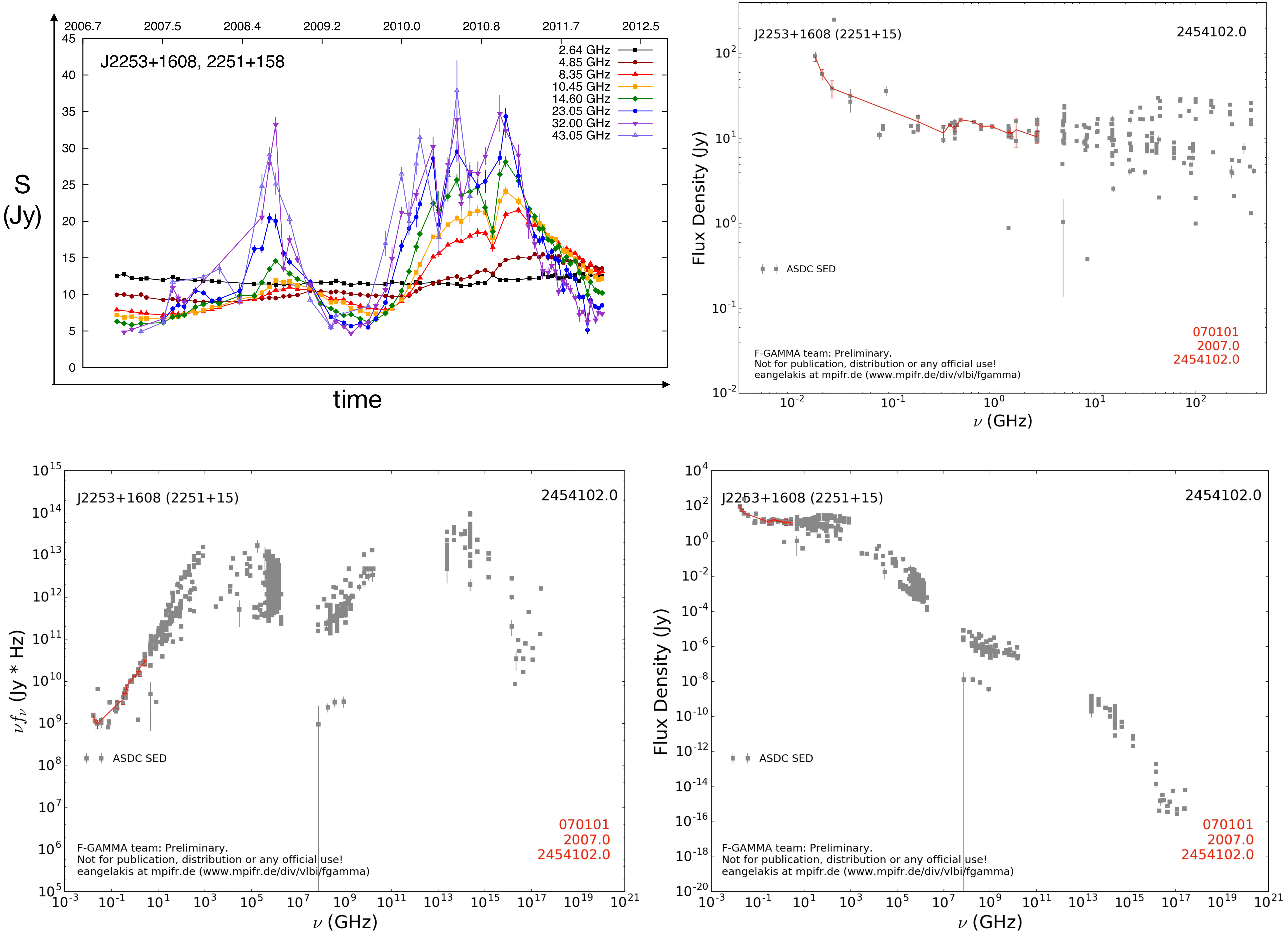
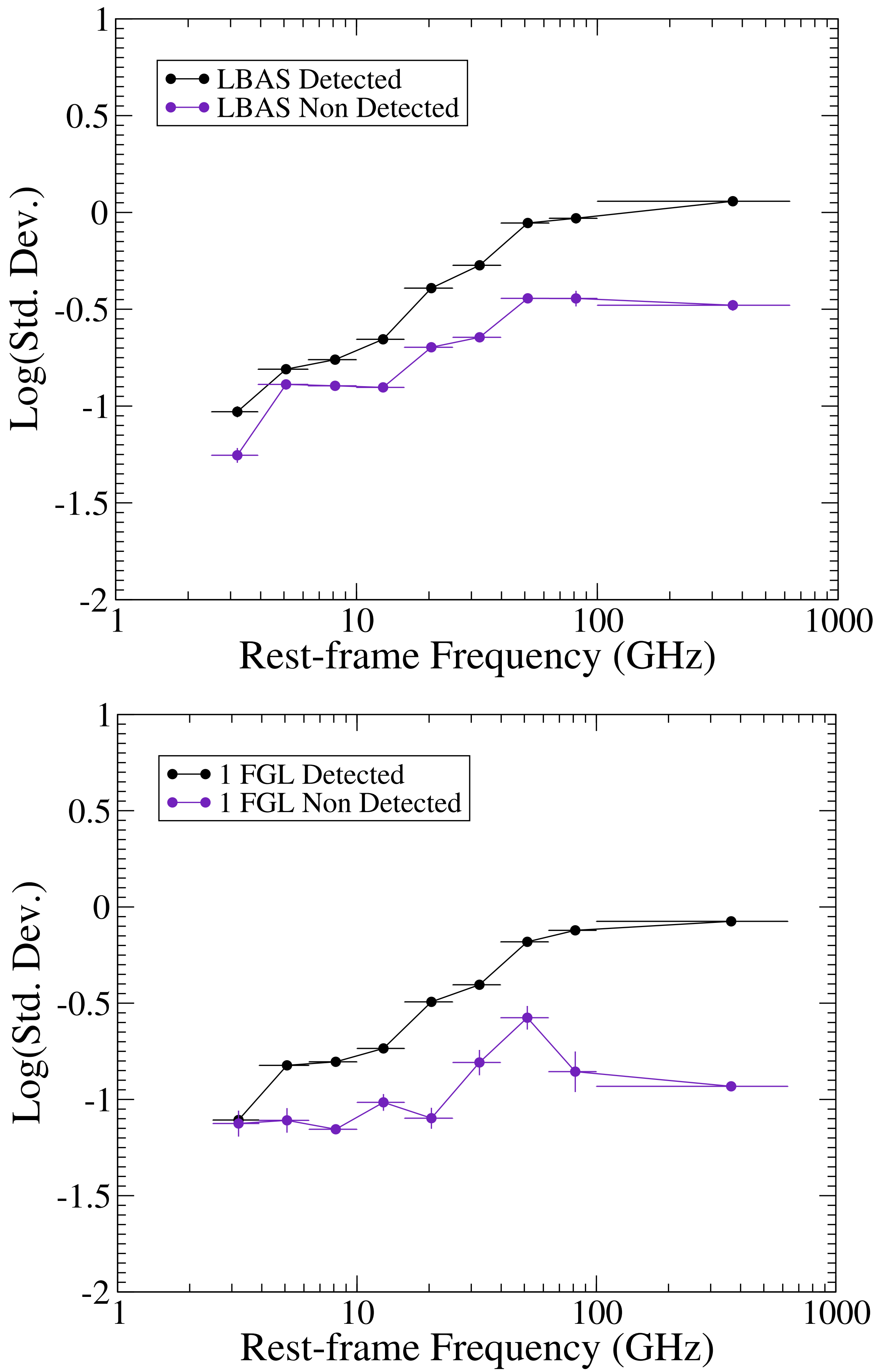
Fermi-GST (NASA)


J2253+1608, 2251+158
2.64 GHz
4.85 GHz
8.35 GHz
10.45 GHz
14.60 GHz
23.05 GHz
32.00 GHz
43.05 GHz
2006.7
2007.5
2008.4
2009.2
2010.0
2010.8
2011.7
2012.5
S (Jy)
time
J2253+1608 (2251+15)
2454102.0
ASDC SED
F-GAMMA team: Preliminary.
Not for publication, distribution or any official use!
eangelakis at mpifr.de (www.mpifr.de/div/vlbi/fgamma)
070101
2007.0
2454102.0
Flux Density (Jy)
ν (GHz)
νf_ν (Jy * Hz)

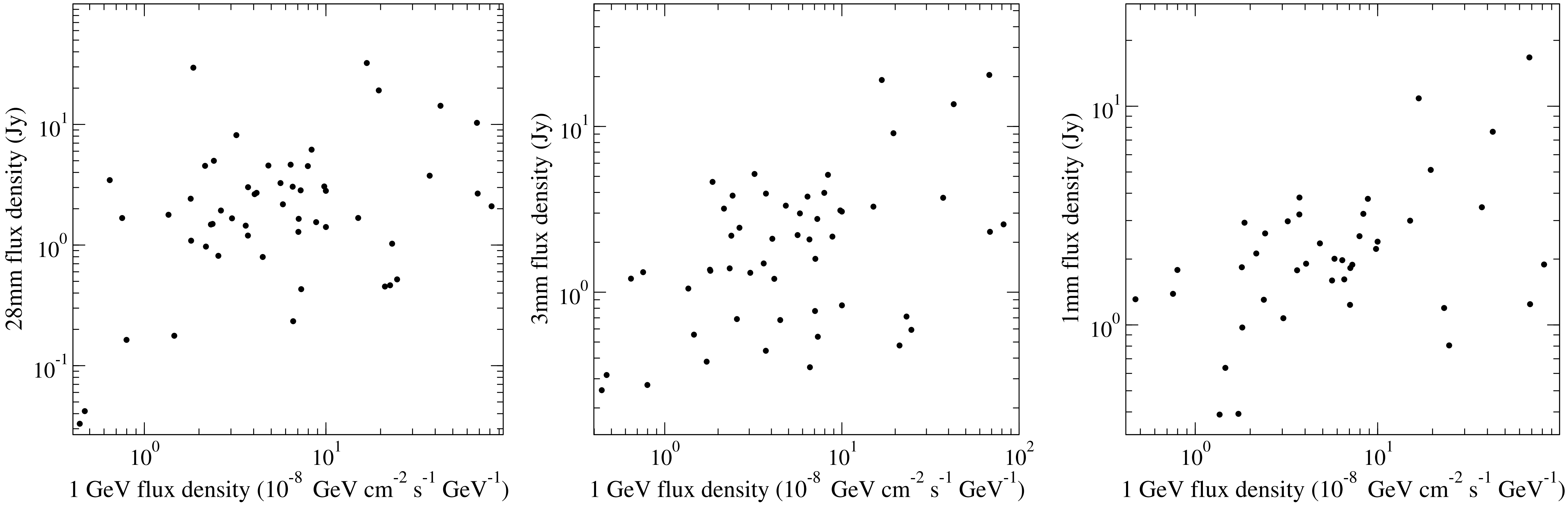
radio - γ-ray activity

Radio variability amplitude and *Fermi* detectability:

- γ-ray detected sources display larger variability amplitudes
  - more than a factor of 3 at the highest frequencies
- clear increase in the separation towards higher frequencies



Fuhrmann et al. 2016A&A...596A..45F



Correlation of concurrent broadband radio and γ-ray flux density measurements

Correlation significance

- account for artificial flux-flux correlations caused by
  - limited luminosity and redshift dynamic range (common distance effect)
  - flux limited sample (Malmquist bias)
- above 43 GHz better than 2σ
- at 86 and 146 better than 3σ
- at low frequencies lower than 2σ

Fuhrmann et al. 2016A&A…596A..45F
Pavlidou et al. 2012ApJ...751..149P

γ-ray emission site

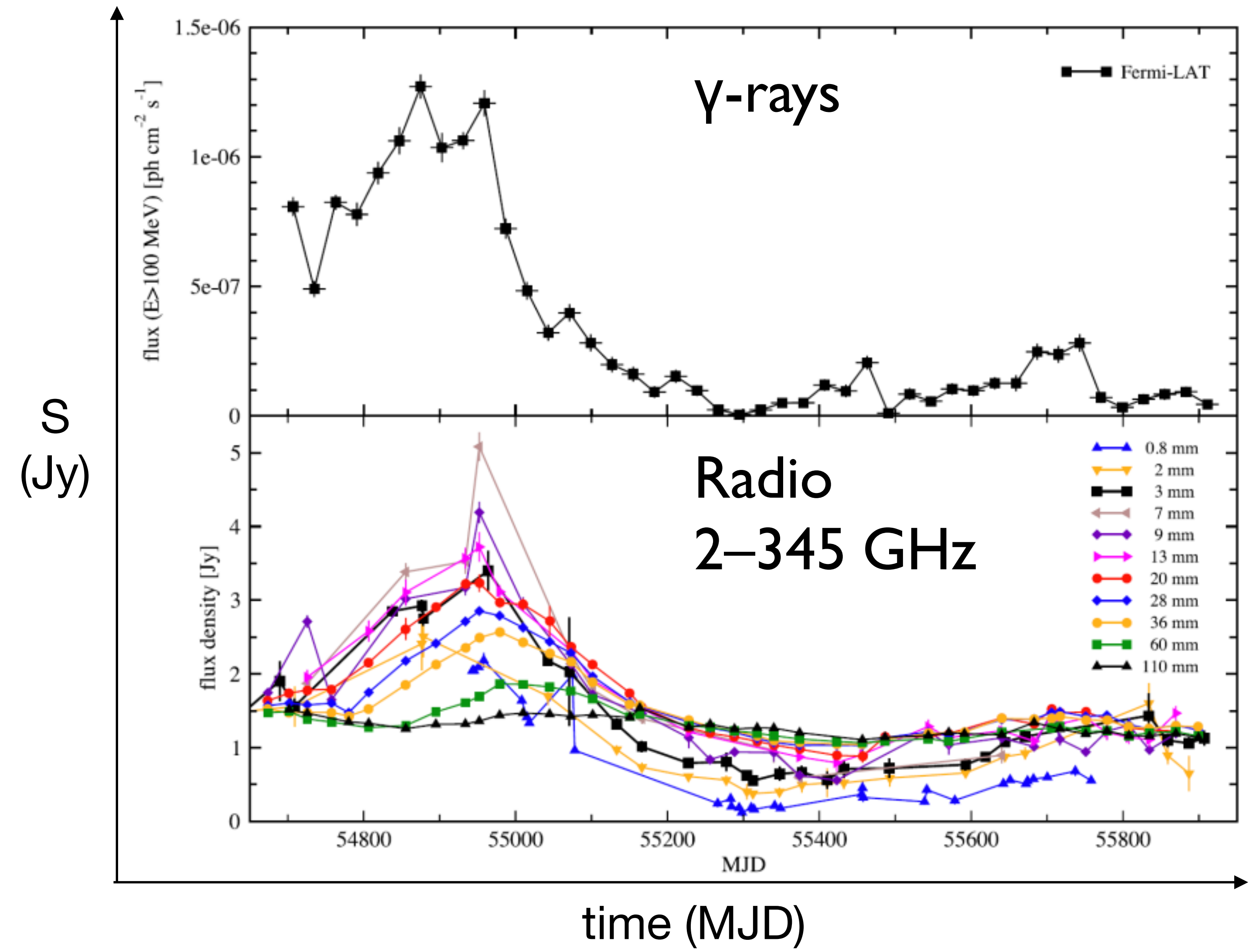
PKS 1502+106

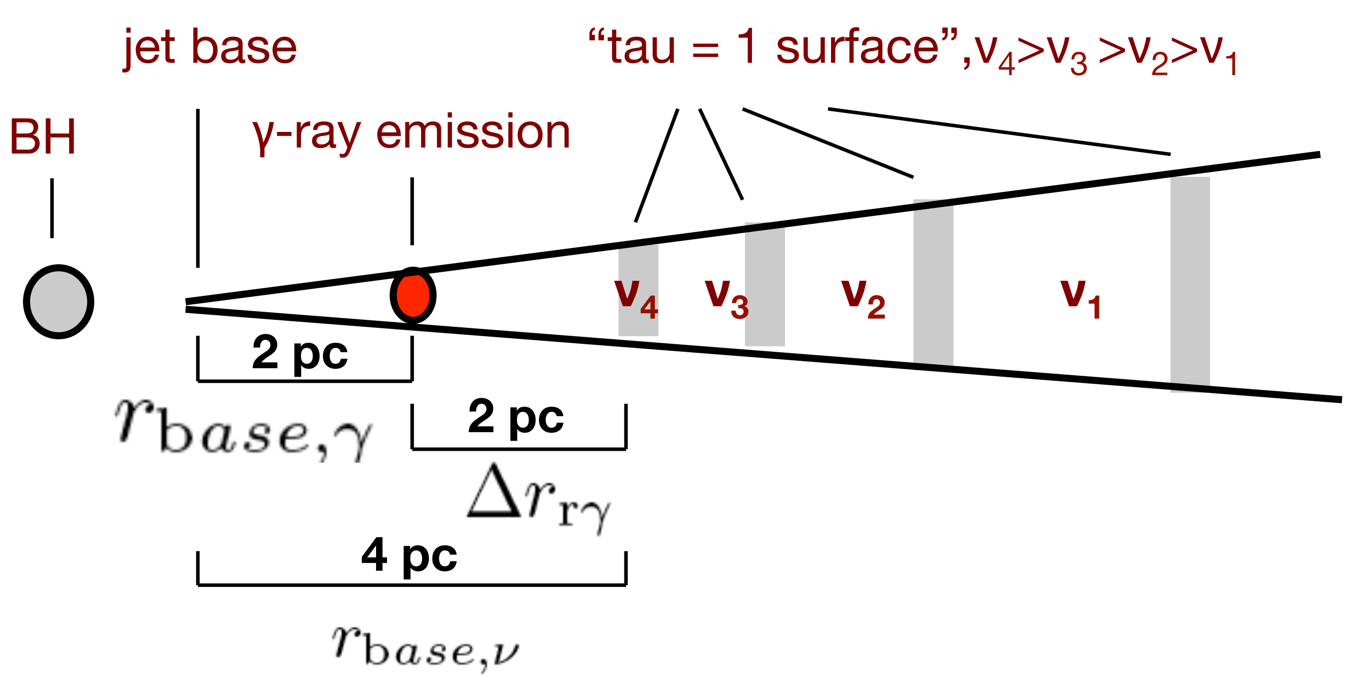
Delay origin: opacity of the synchrotron self-absorbed jet

Relative timing of flares (DCCF)

Knot kinematics (mm-VLBI)

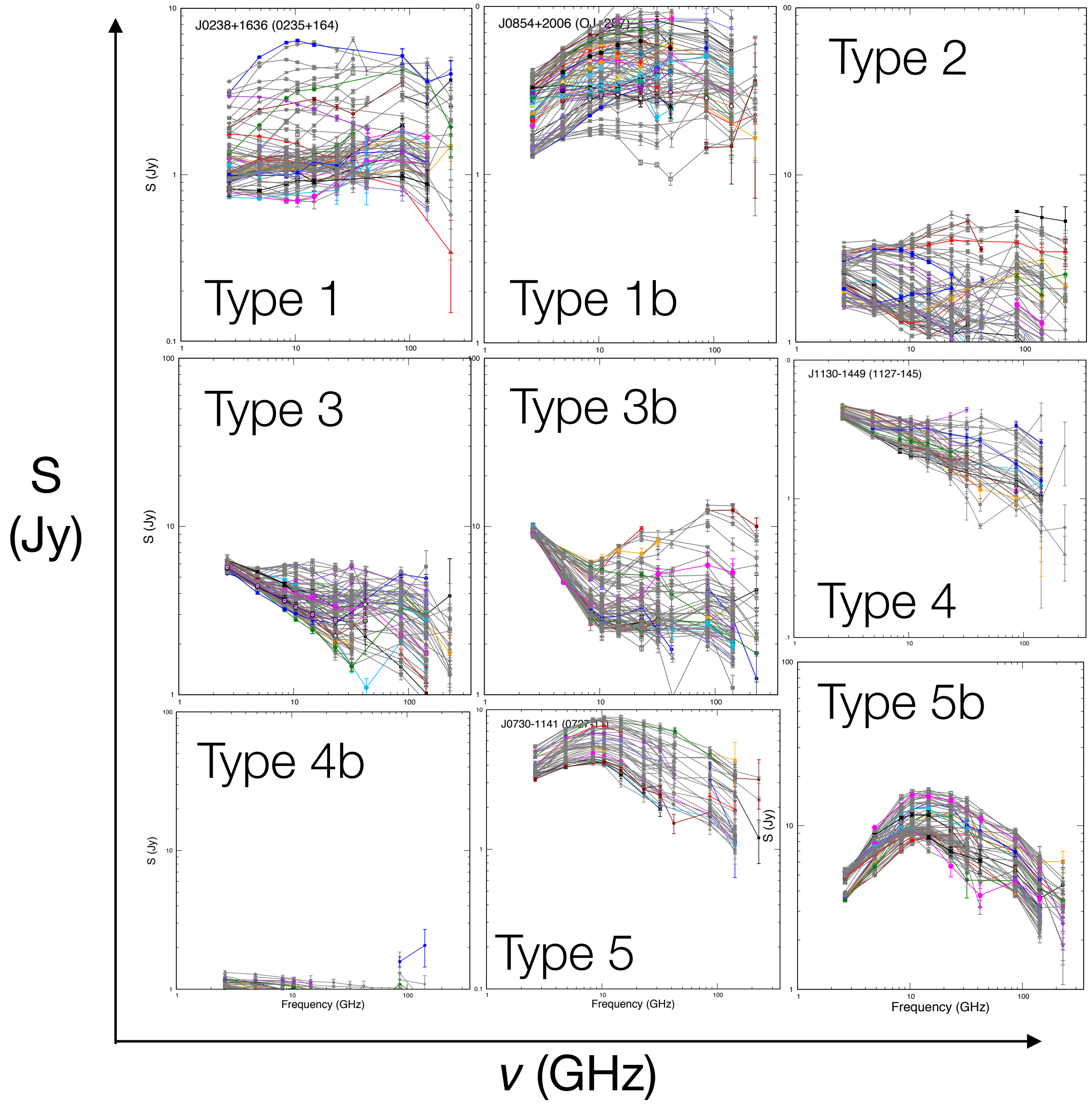
- precise core-shifts
- γ-ray emission site





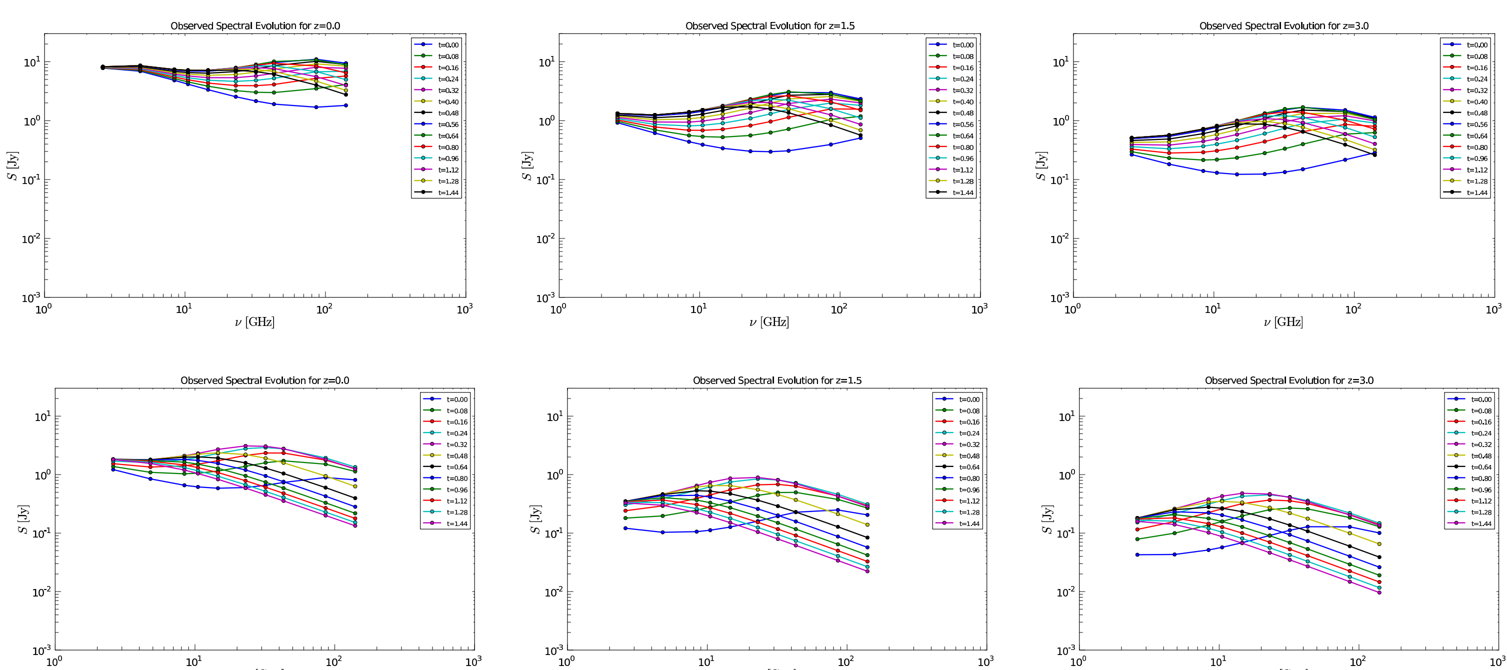
Karamanavis et al 2016 A&A 590, 48
Fuhrmann et al 2014 MNRAS 441, 1899

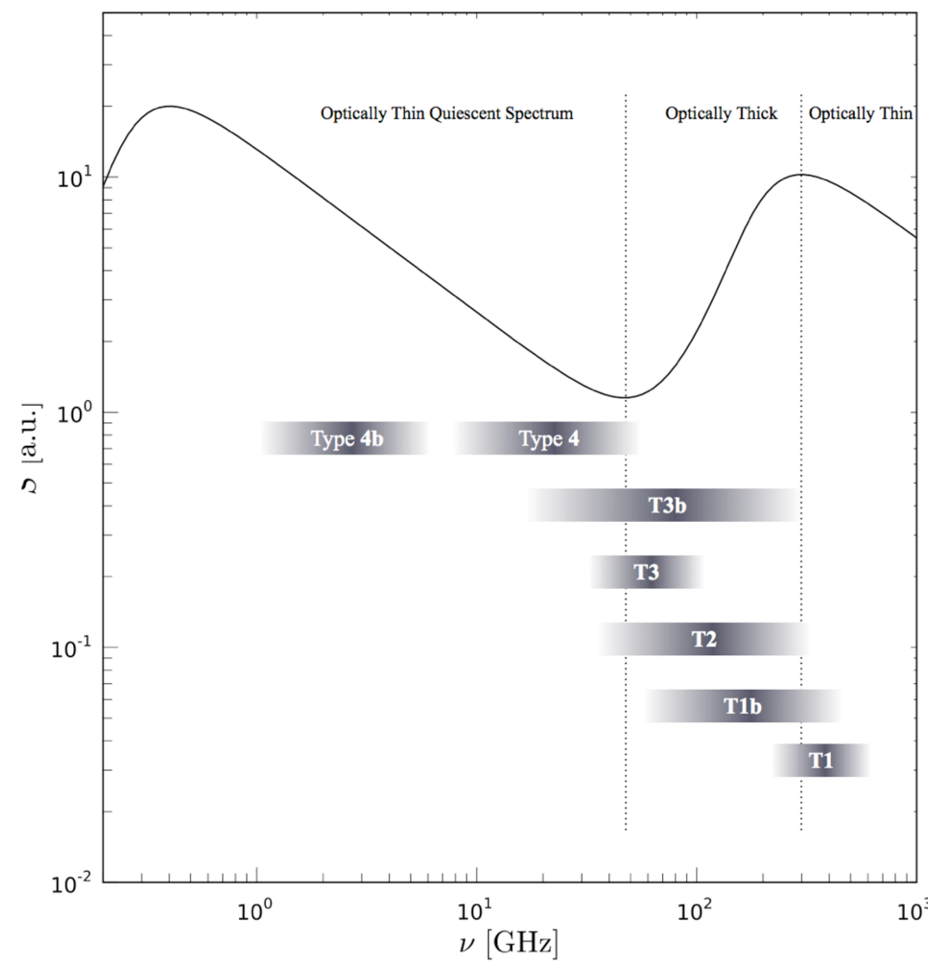
unification scheme of broad-band spectral variability



SED variability patterns can be reproduced by the combination of:

- a power-law quiescent spectrum with S ~ ν^{α} attributed to the optically thin emission of a large scale jet
- a convex synchrotron self-absorbed spectrum caused by recent outbursting superimposed on the quiescent part.



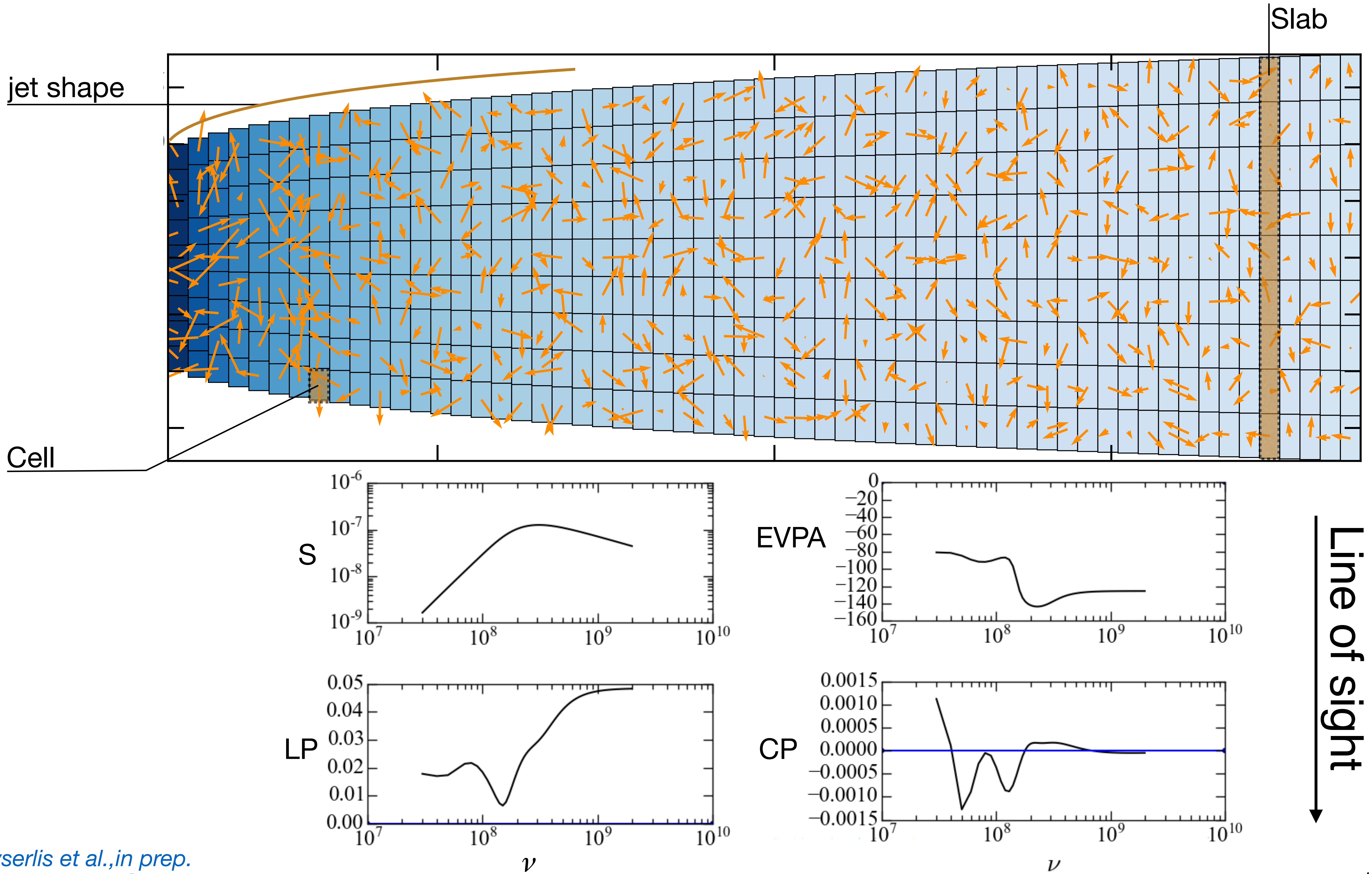


Angelakis et al. 2012, arXiv:1205.1961
Angelakis et al. in preparation

linear and circular polarization variability modeling

Constraining the jet physical conditions

by modeling the linear and circular polarization variability



Myserlis et al.,in prep.
Myserlis et al., Galaxies, vol. 4, issue 4, p. 58

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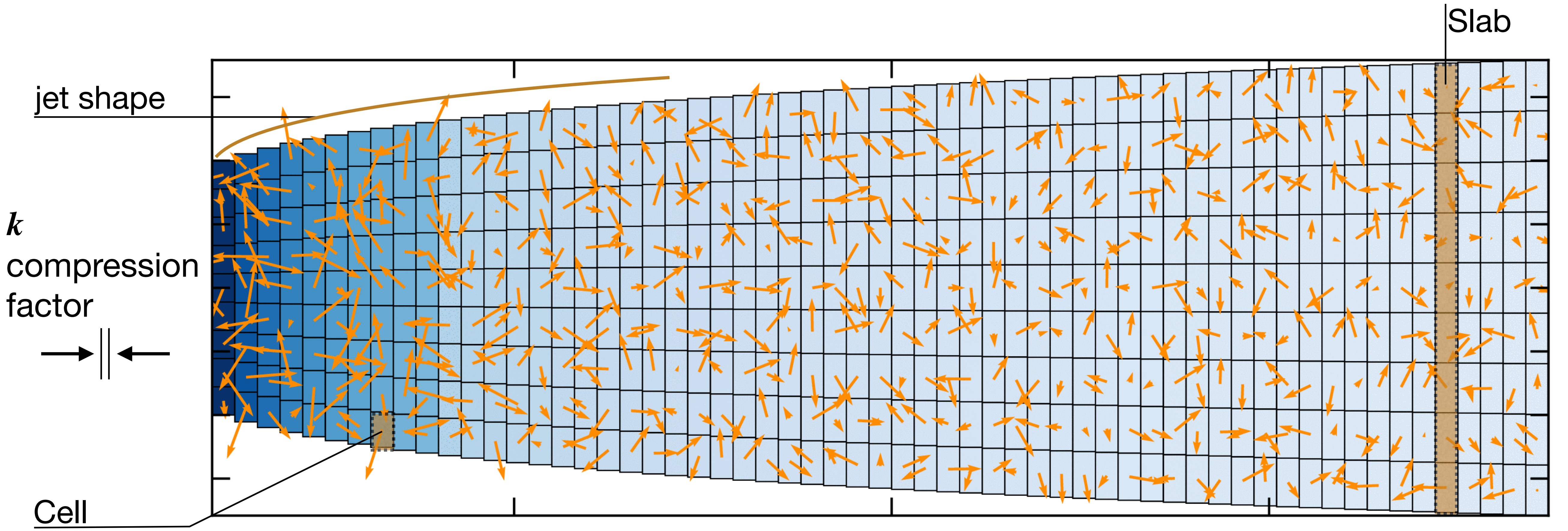


Density

$$n_0' = n_0 k^{-\frac{s+3}{6}}$$

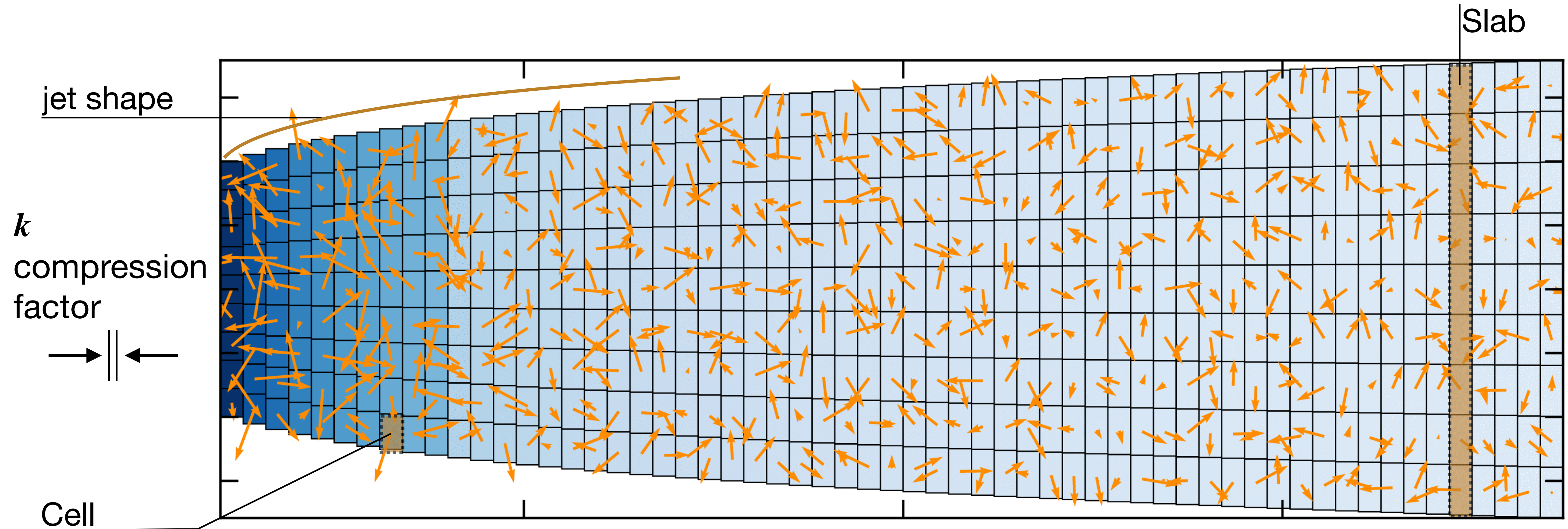
Lower energy cutoff

$$E_{\rm min}' = E_{\rm min} k^{-\frac{1}{3}}$$

B-field strength

$$B' \sim kB$$

Constraining the jet physical conditions
by modeling the linear and circular polarization variability



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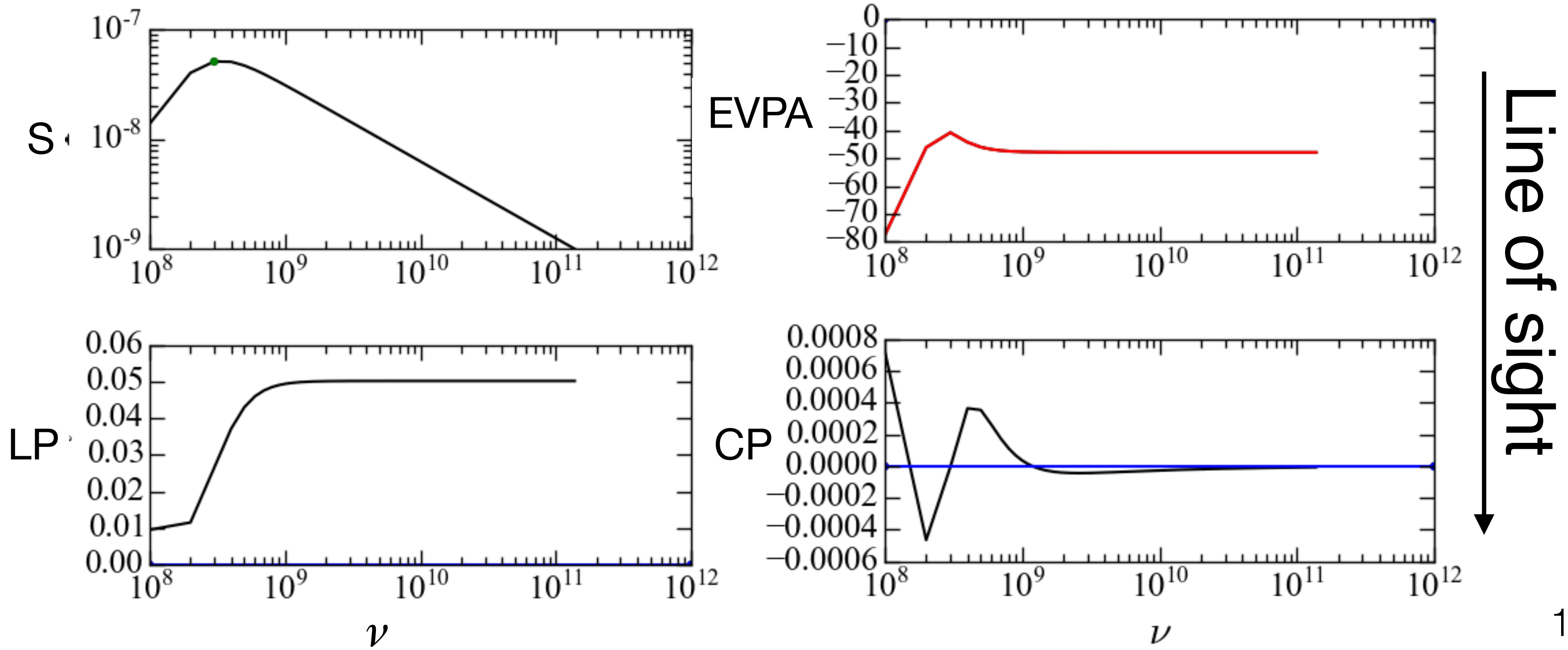

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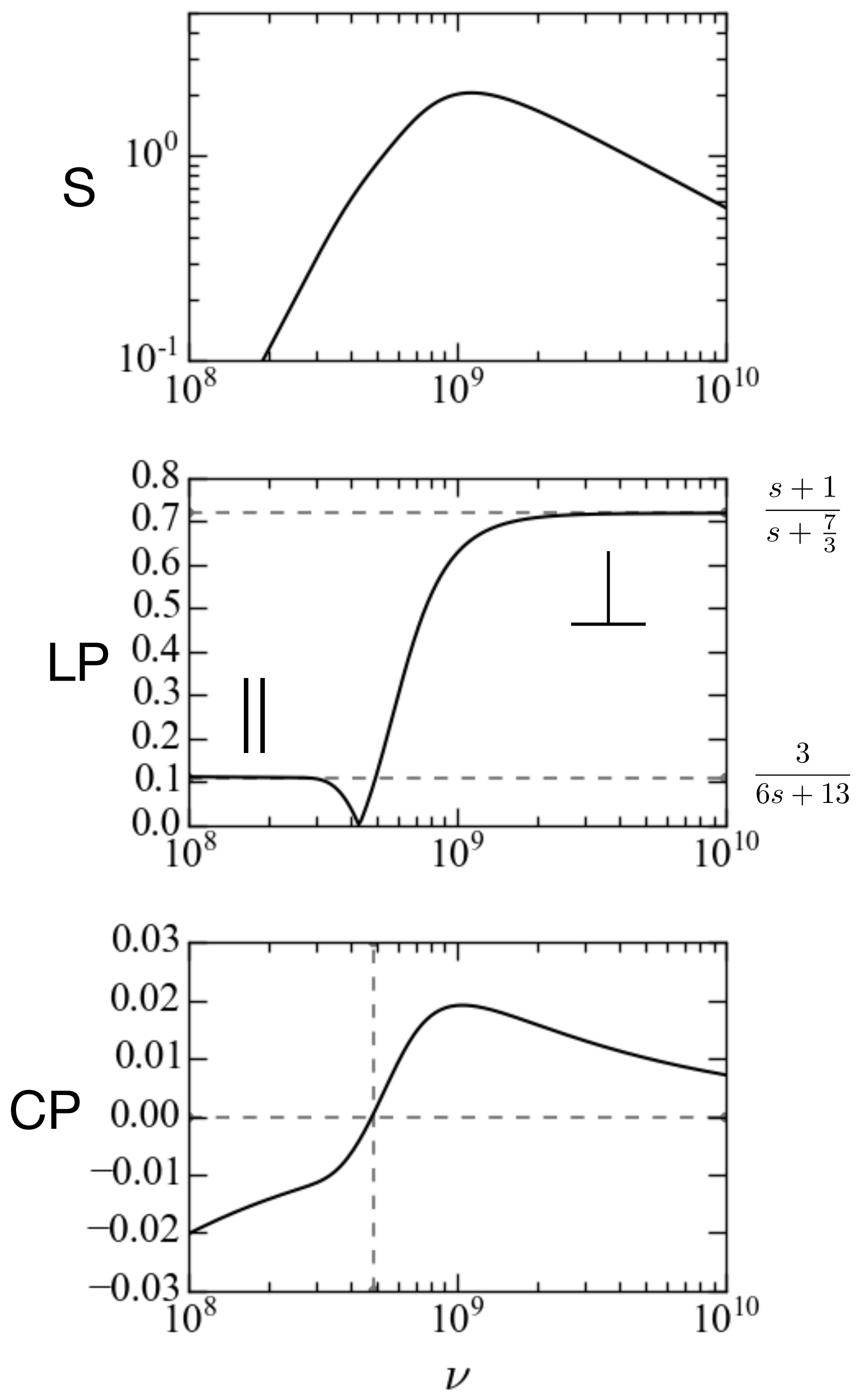
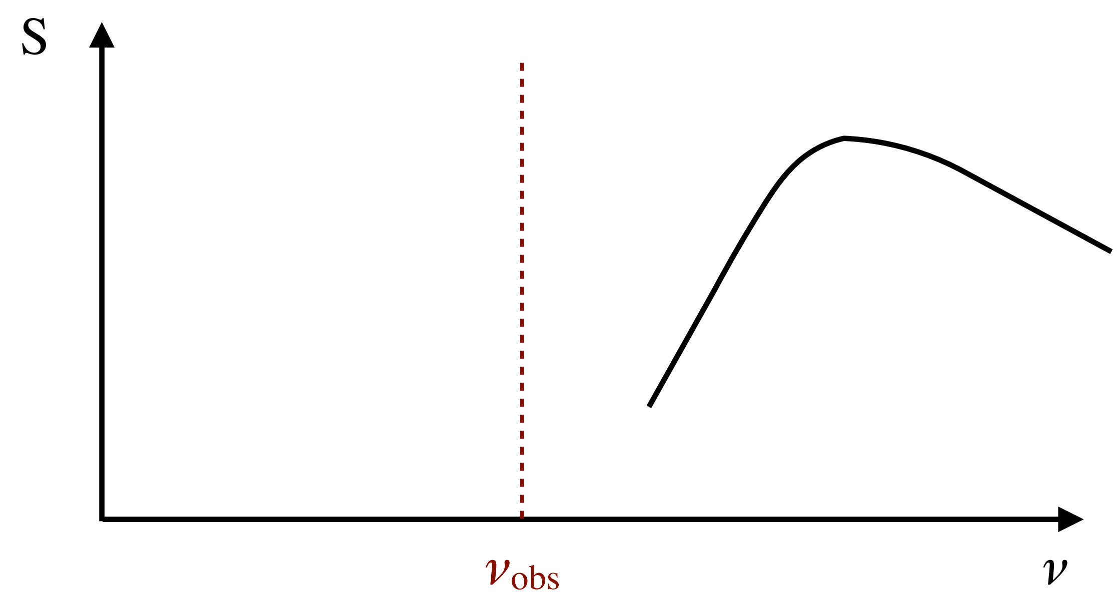
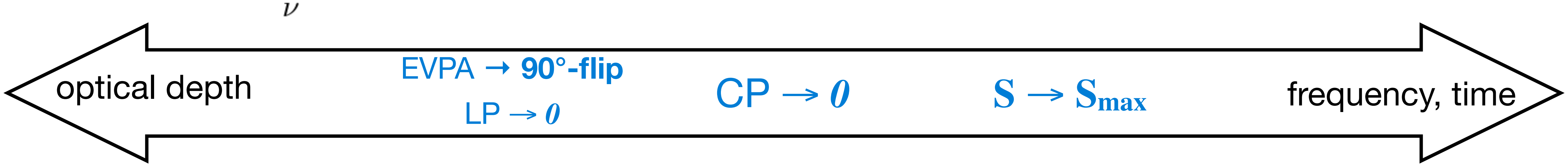
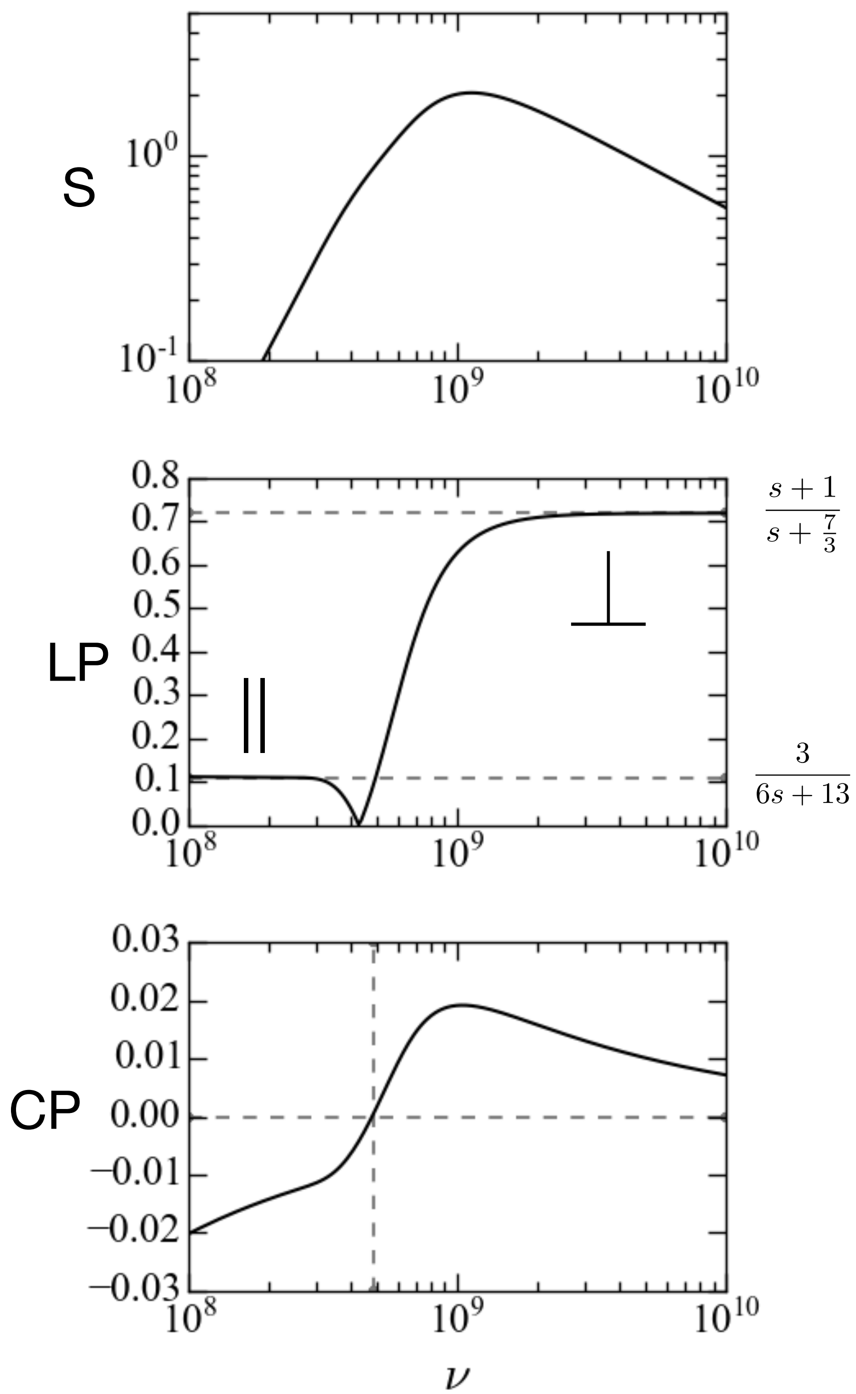


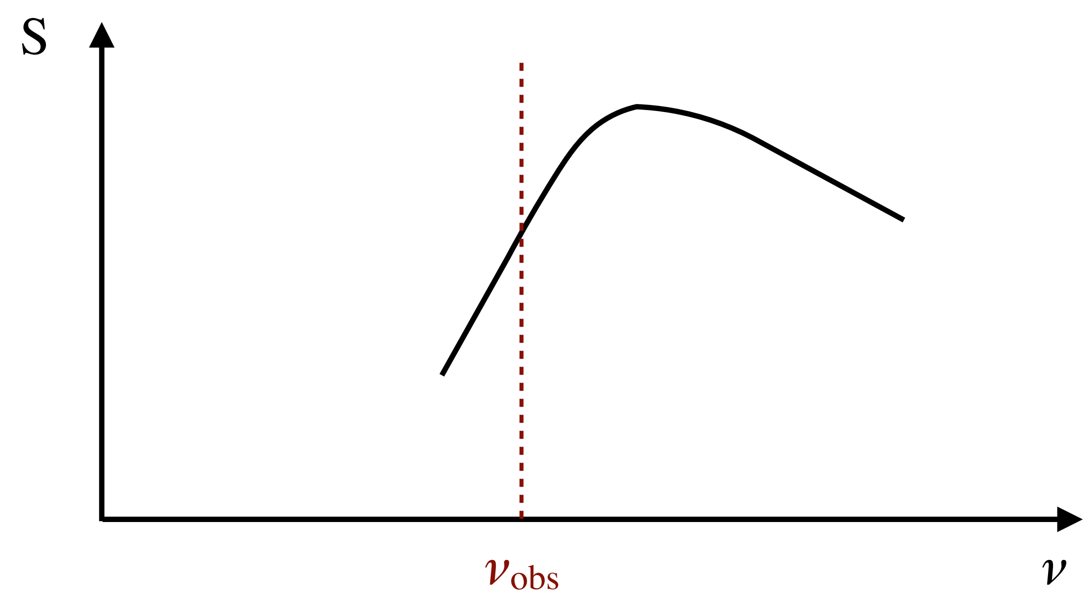




Constraining the jet physical conditions

by modeling the linear and circular polarization variability





optical depth

EVPA → **90°-flip**

LP → *0*

CP → *0*

S → S_{max}

frequency, time

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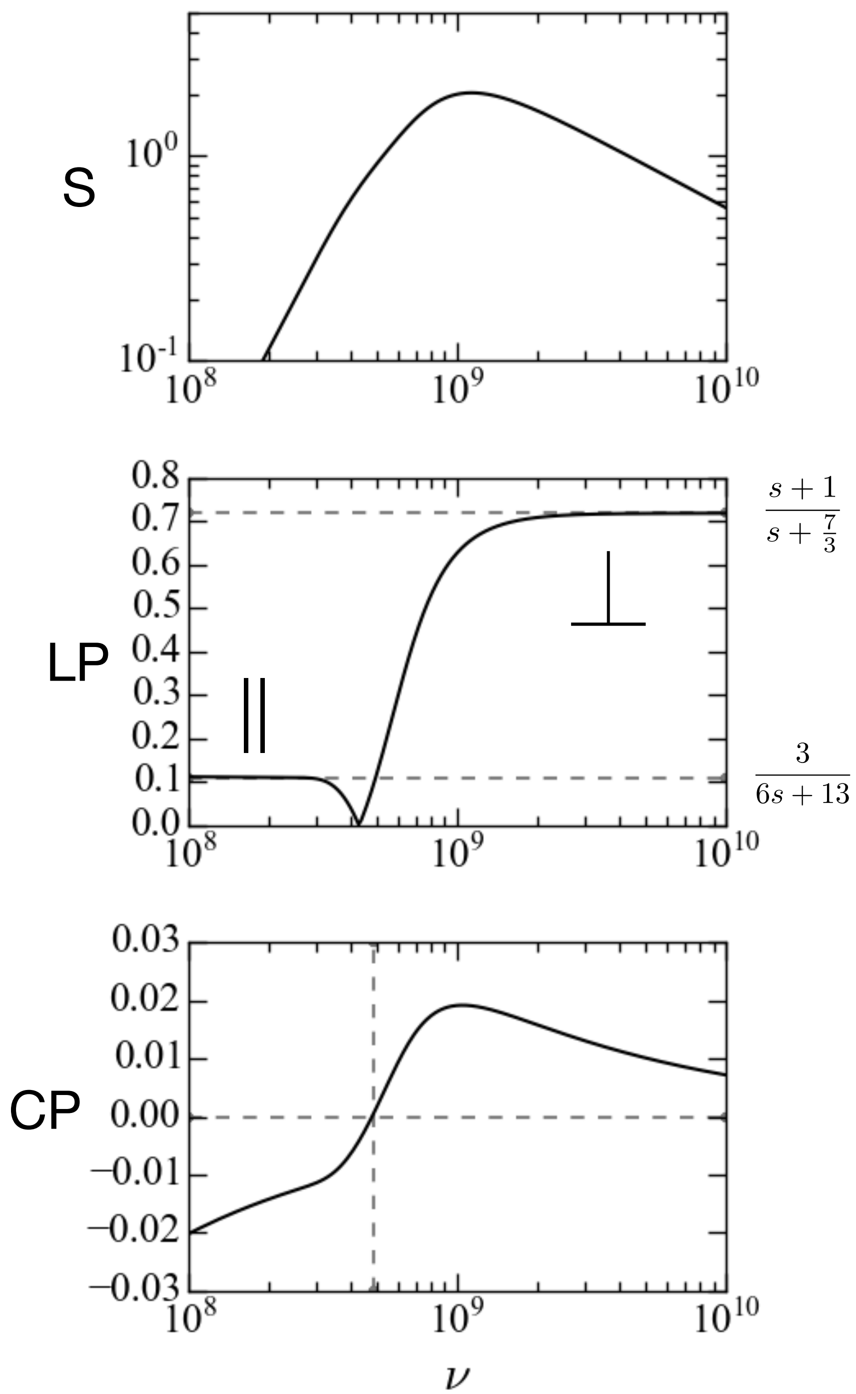

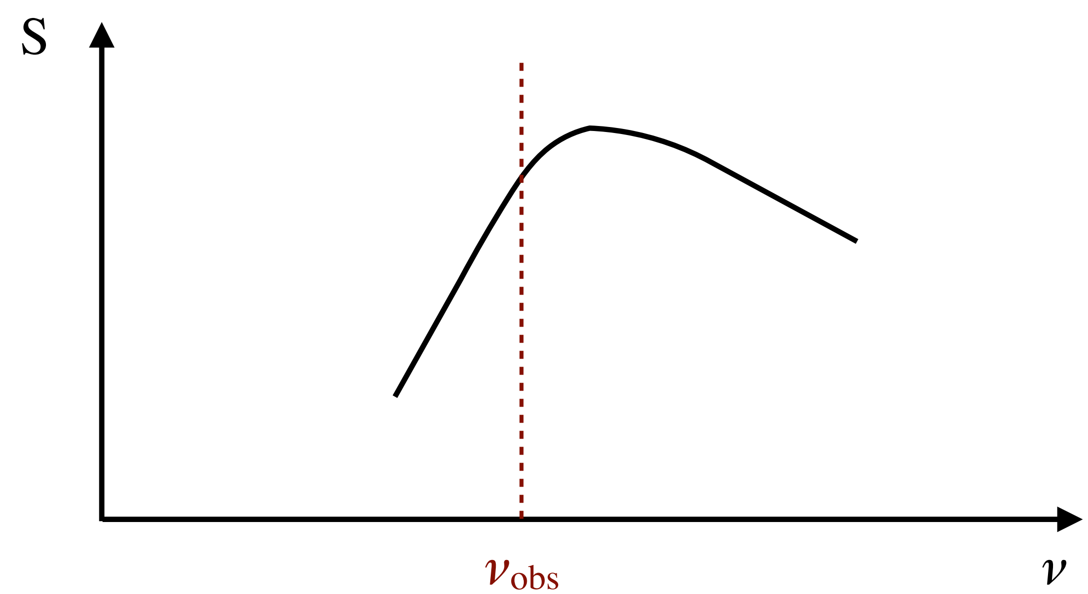

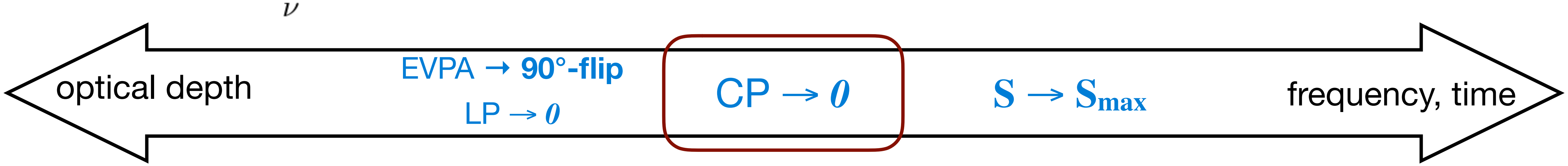

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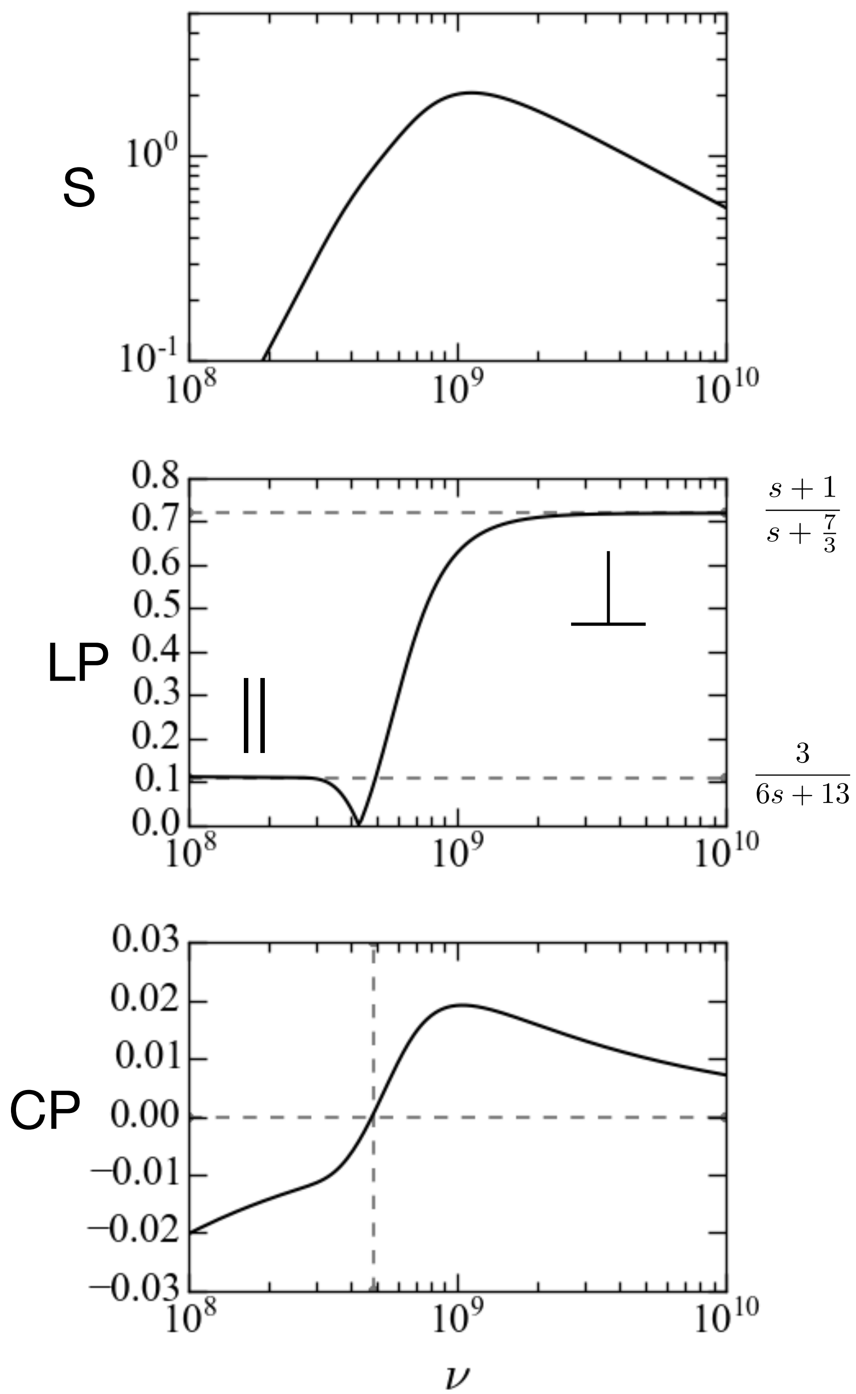

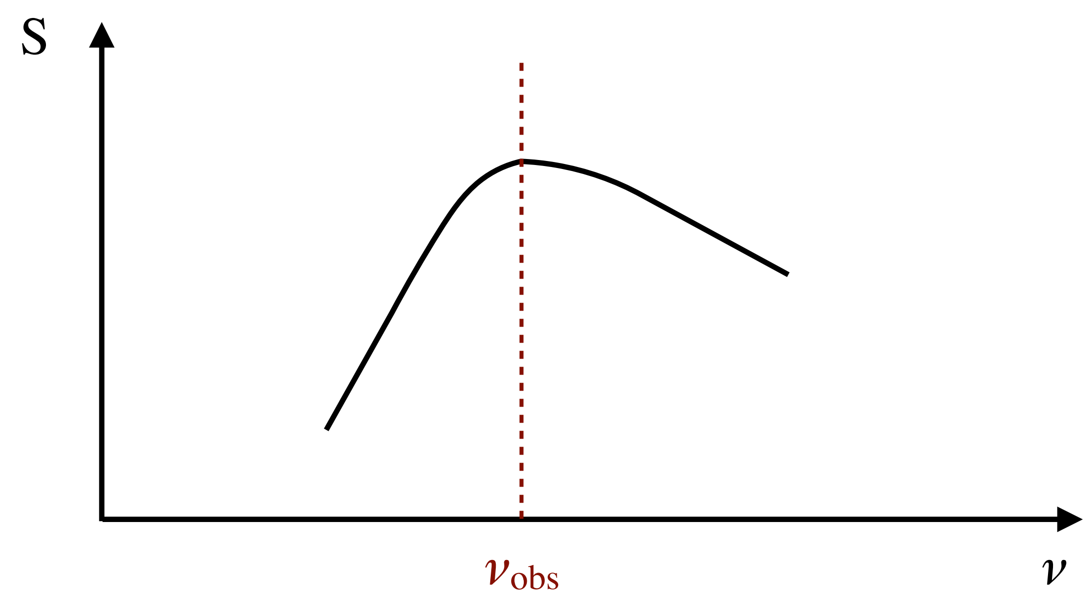

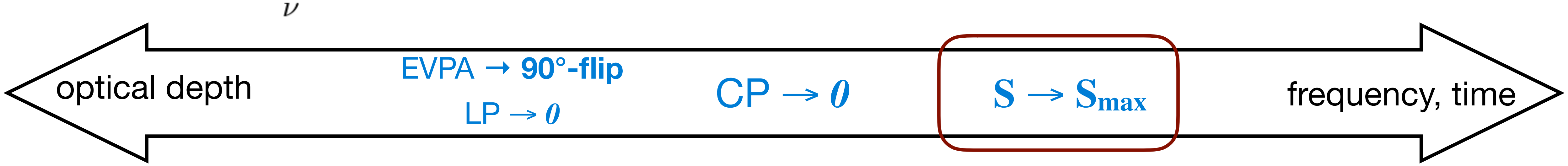

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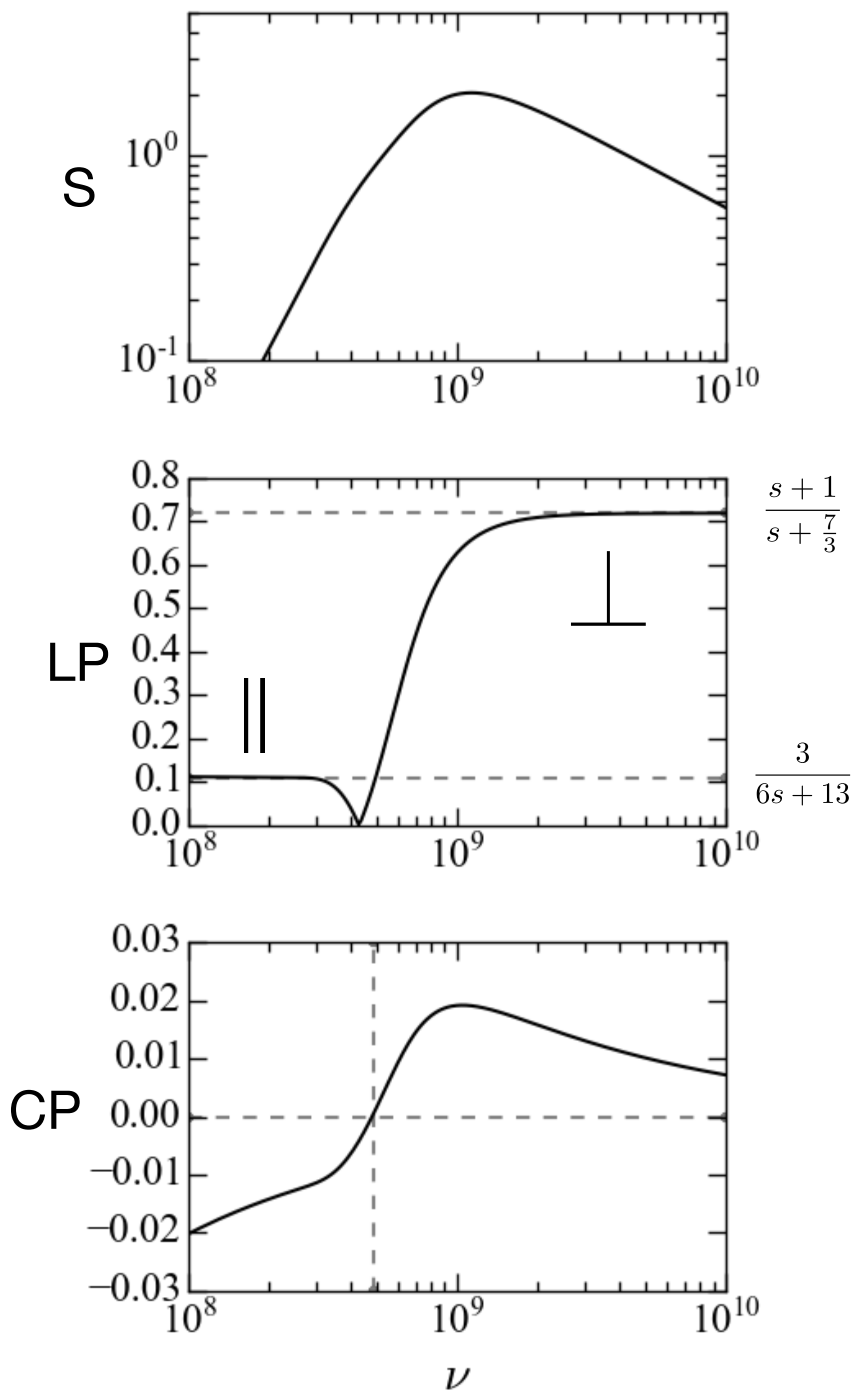
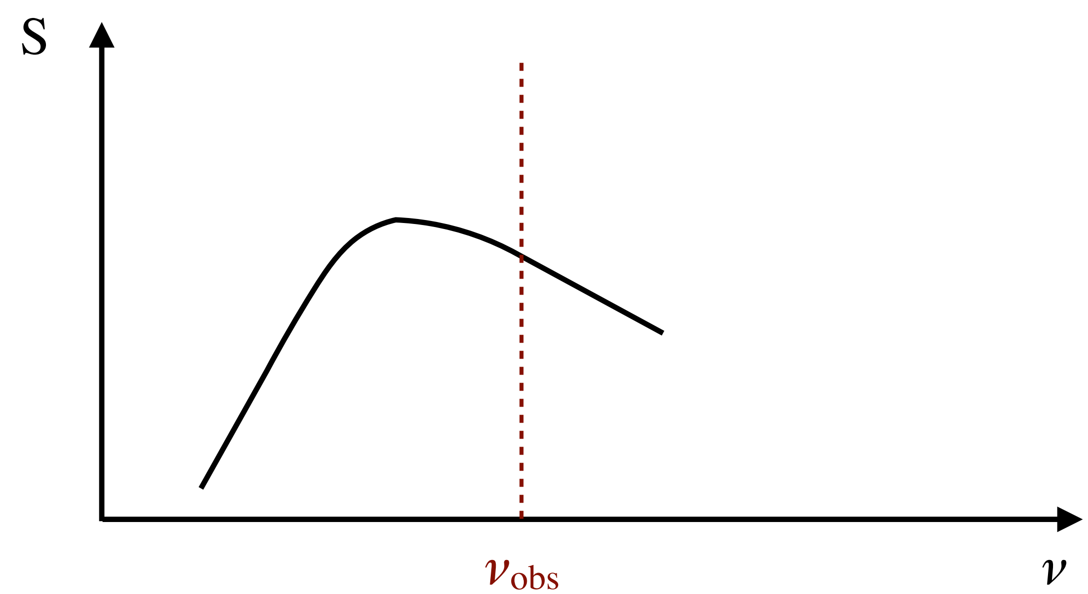
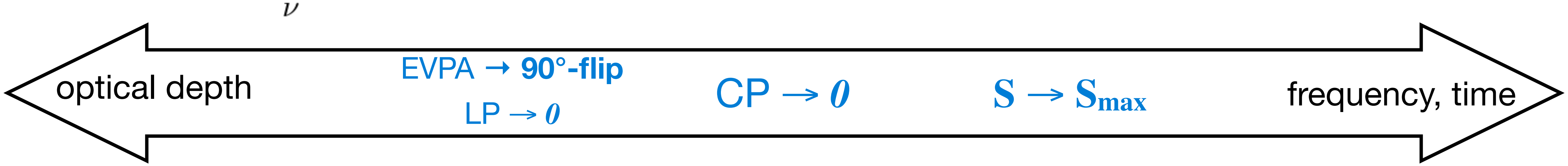
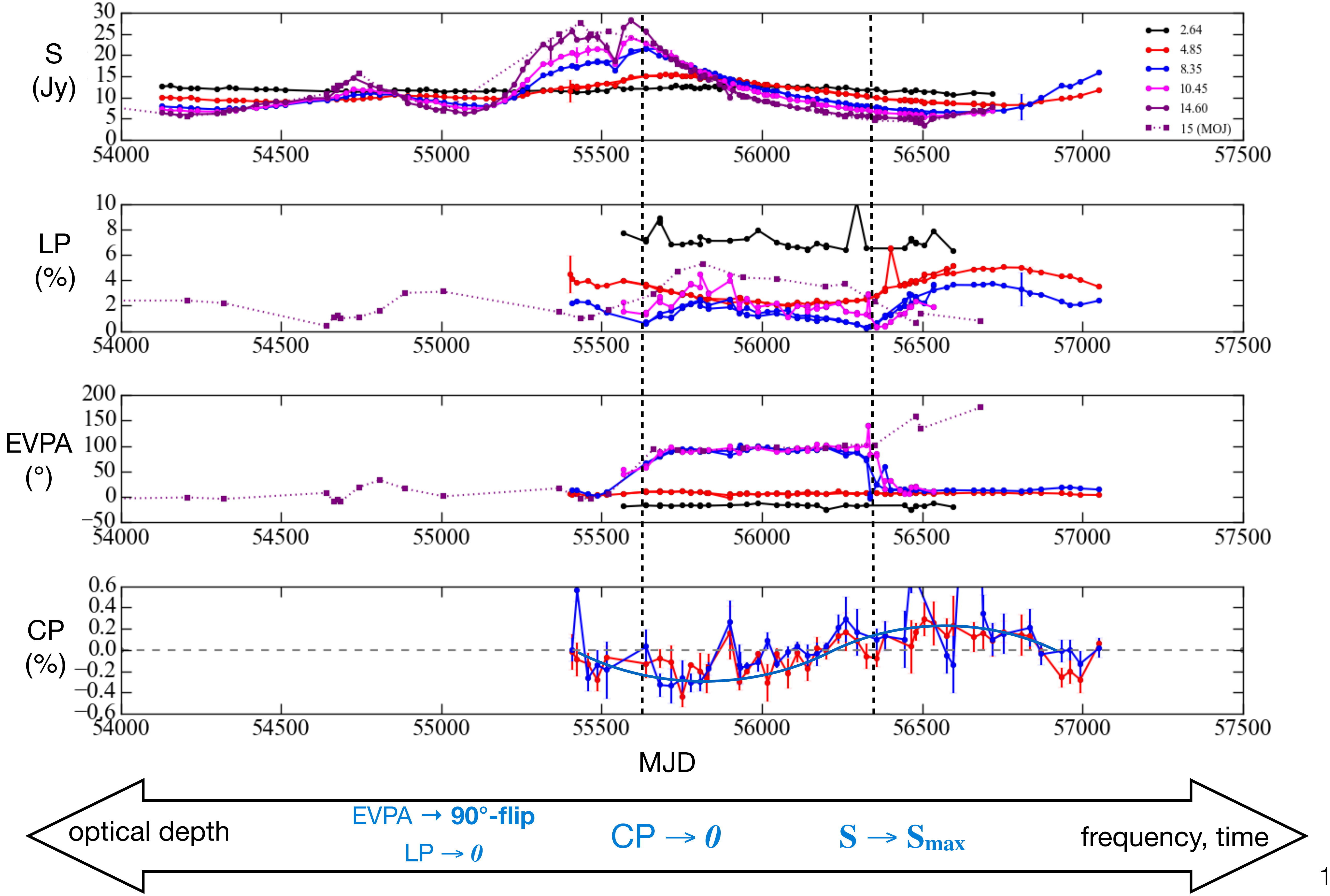






3C 454.3

a case study



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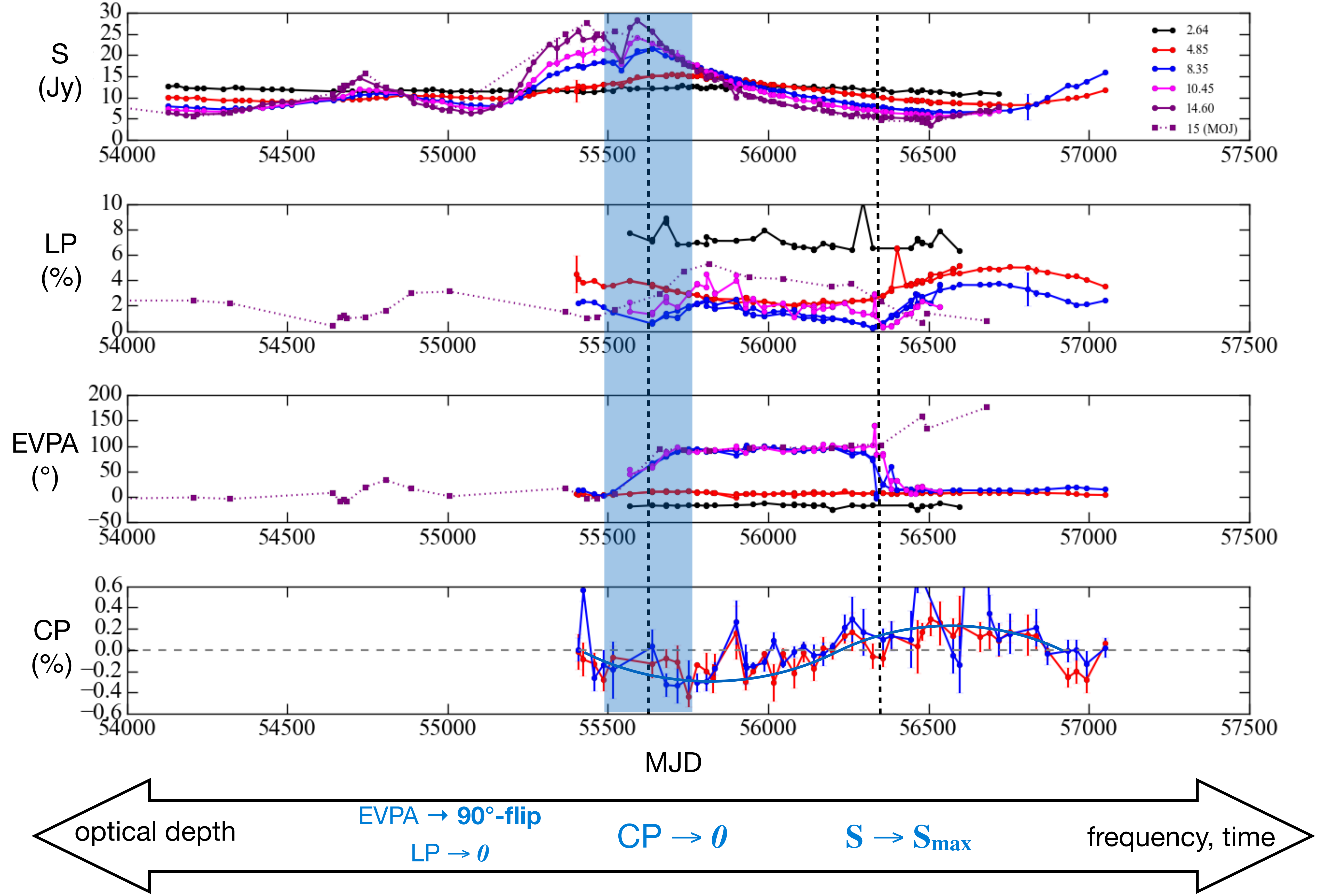


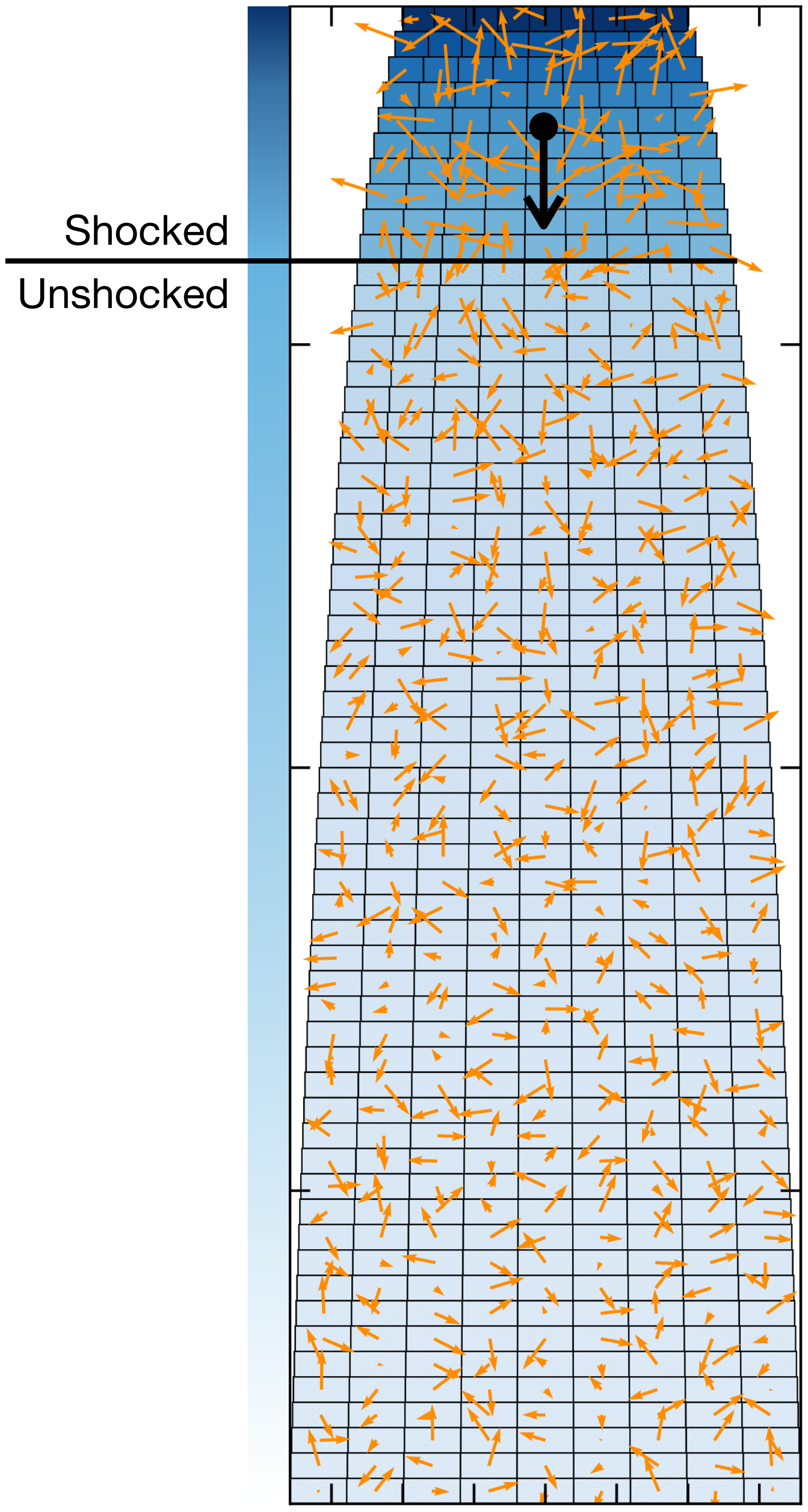
Constraining the jet physical conditions
by modeling the linear and circular polarization variability

Shocked flow parameters

- Compression factor: k = 0.8
- Doppler factor: D ~ 30, consistent with D_{var} at 37 GHz
  Hovatta et al. 2009, A&A, 494, 527

Unshocked flow parameters

- Density: $n_0 = 10^1$–10^2 cm^{-3}
- Magnetic field coherence length: 9 pc
  - equal to the cell size

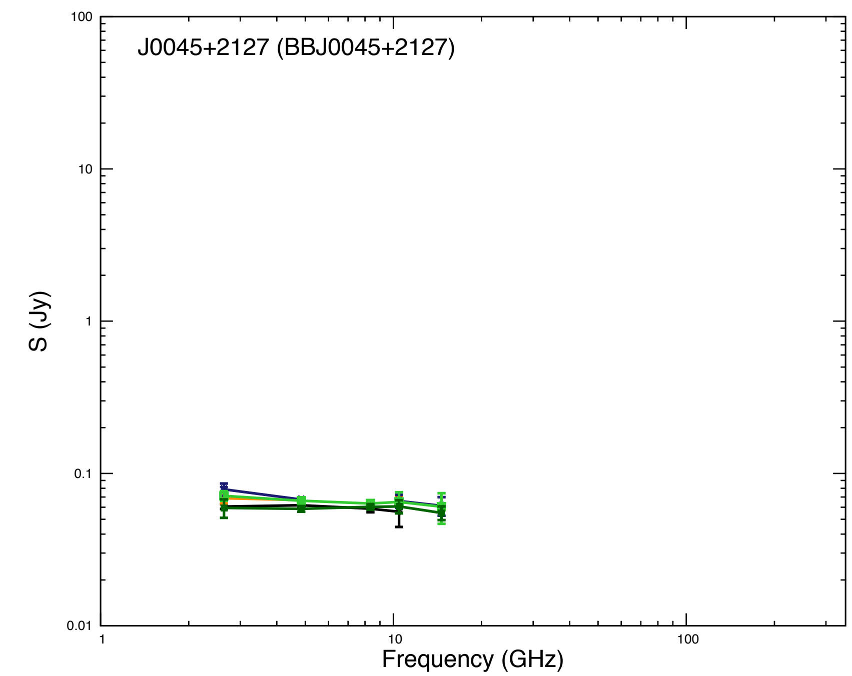


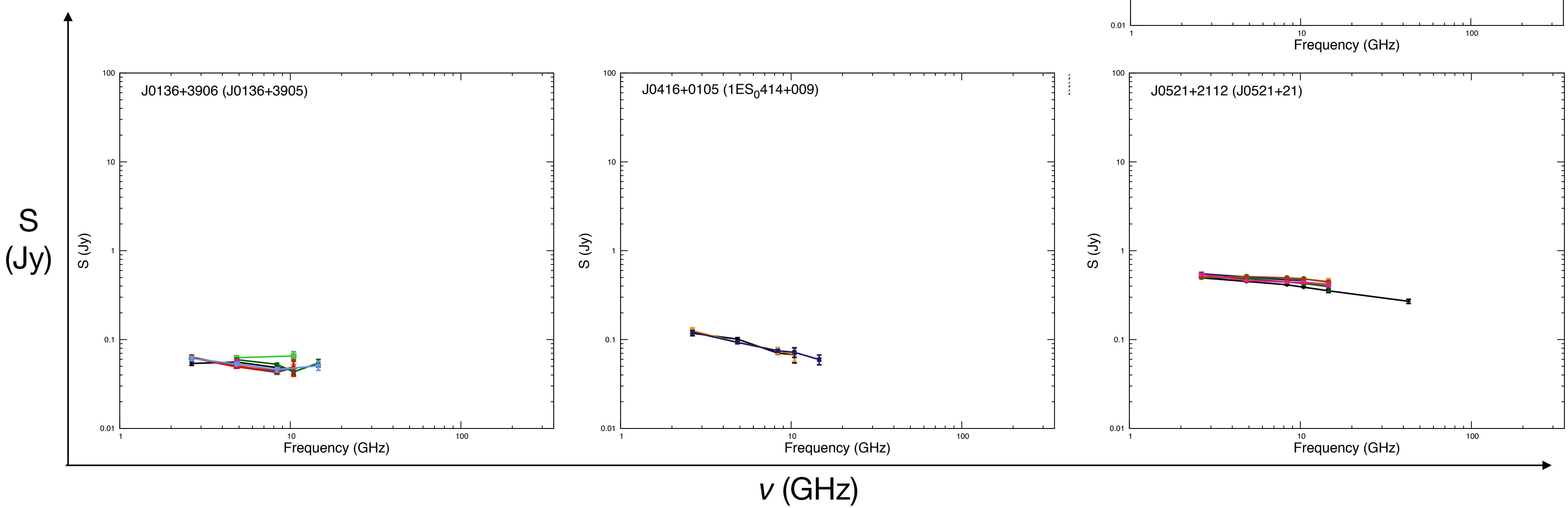
Myserlis et al.,in prep.
Myserlis et al., Galaxies, vol. 4, issue 4, p. 58

TeV sources

radio **variability**, **spectra** and **polarization** of TeV sources:

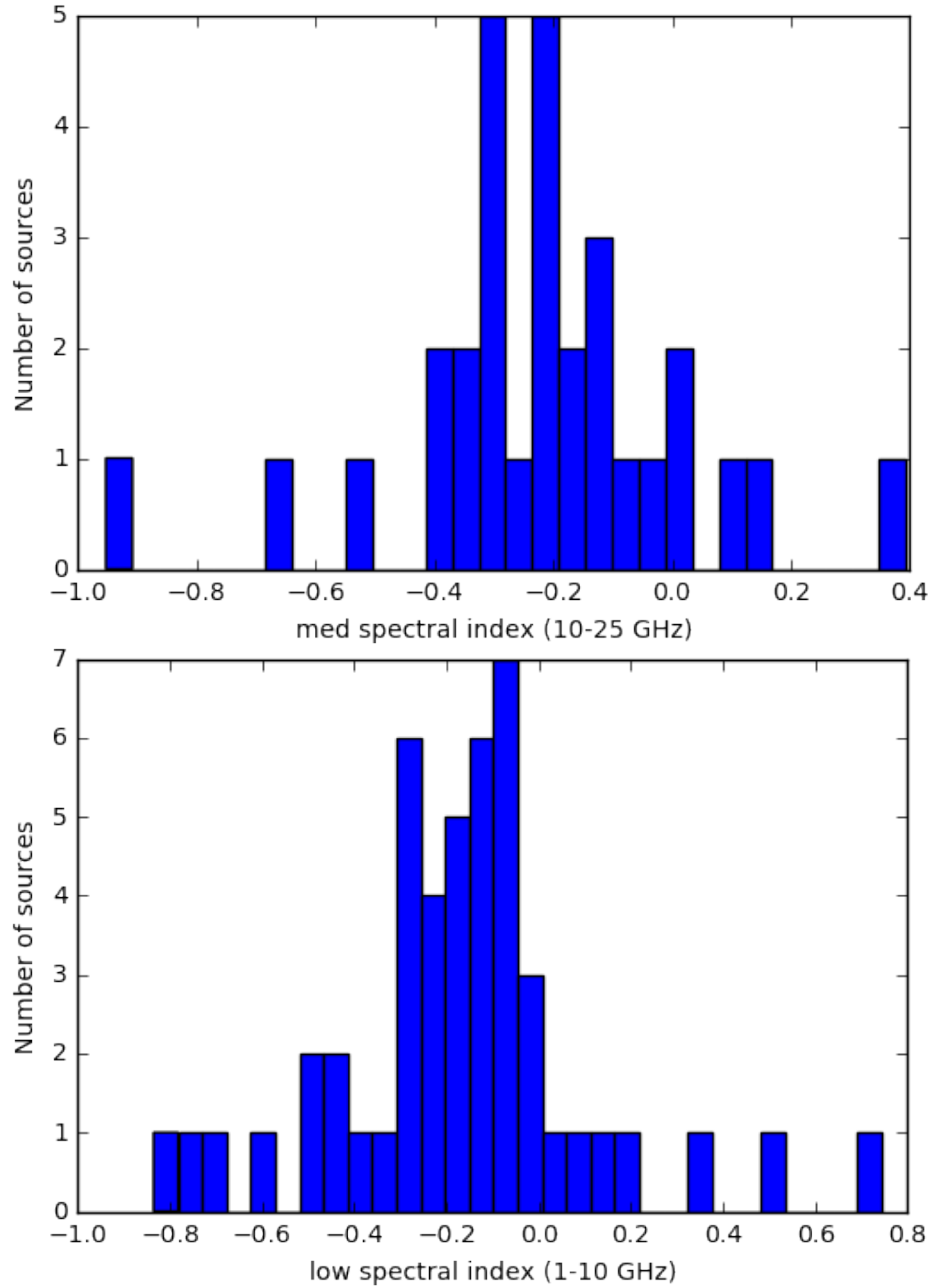
- 50 sources:
  - 5 control sources (lower fluxes in the 2FHL)
  - 2.64 — 43 GHz (April 2014 - January 2015)
- the idea:
  - study their radio spectra
  - variability must increase with energy (low-end of the γ distribution hence new particle injection would leave low energies unaffected)
  - polarization





variability, spectra and polarisation of TeV sources:

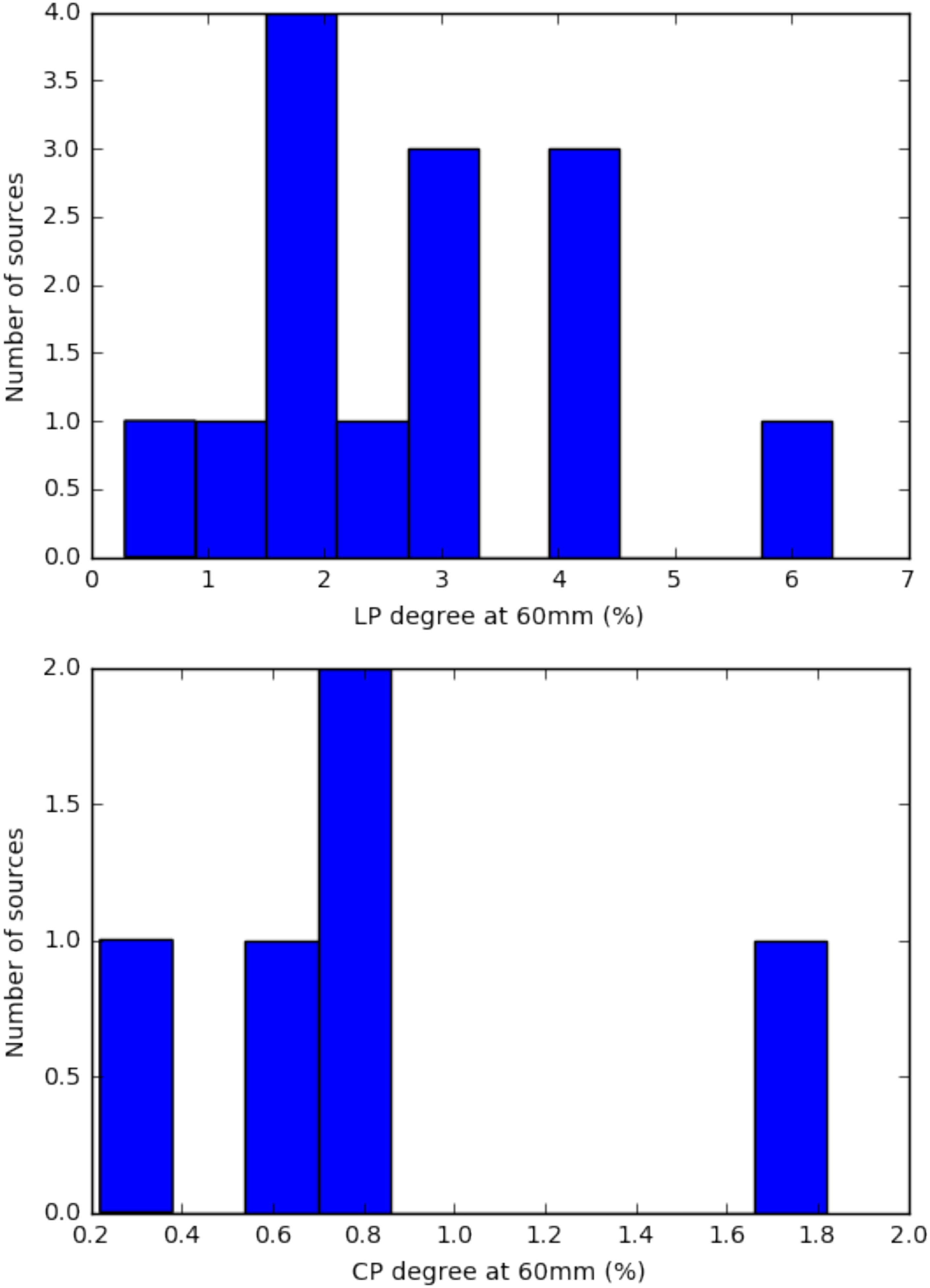
- radio spectral indices
  - mostly flat ($\alpha \sim -0.2$ with $f_\nu \sim \nu^\alpha$)



Myserlis et al.,in prep.

variability, spectra and polarization of TeV sources:

- radio polarization **linear**
  - ~3 %
- radio polarization **circular**
  - ~0.9 % at 4.9 GHz and
  - ~0.5 % at 8.4 GHz
- possible serious ***B*** filed amplification during outbursts (Sciama & Rees 1987)



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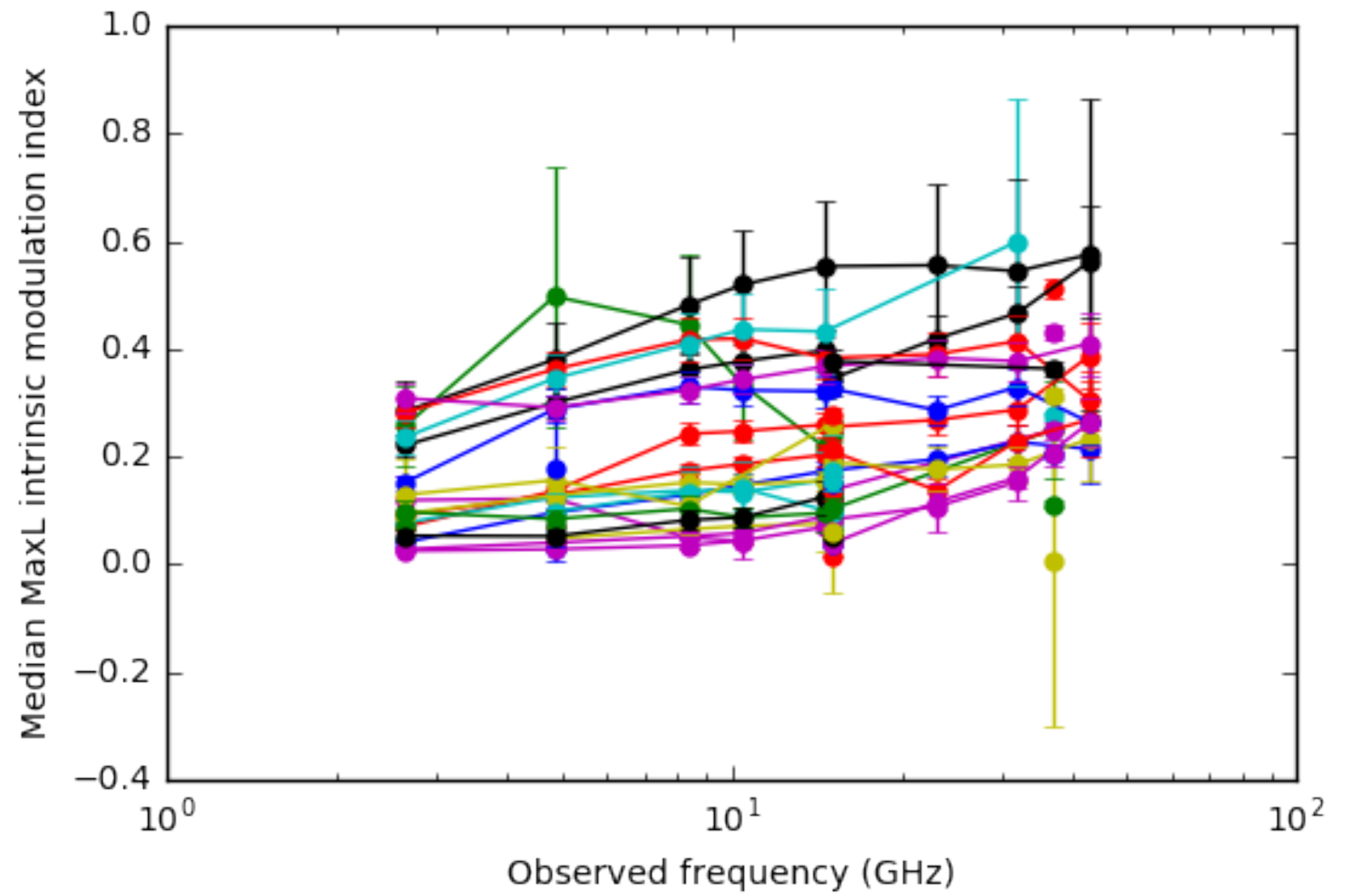

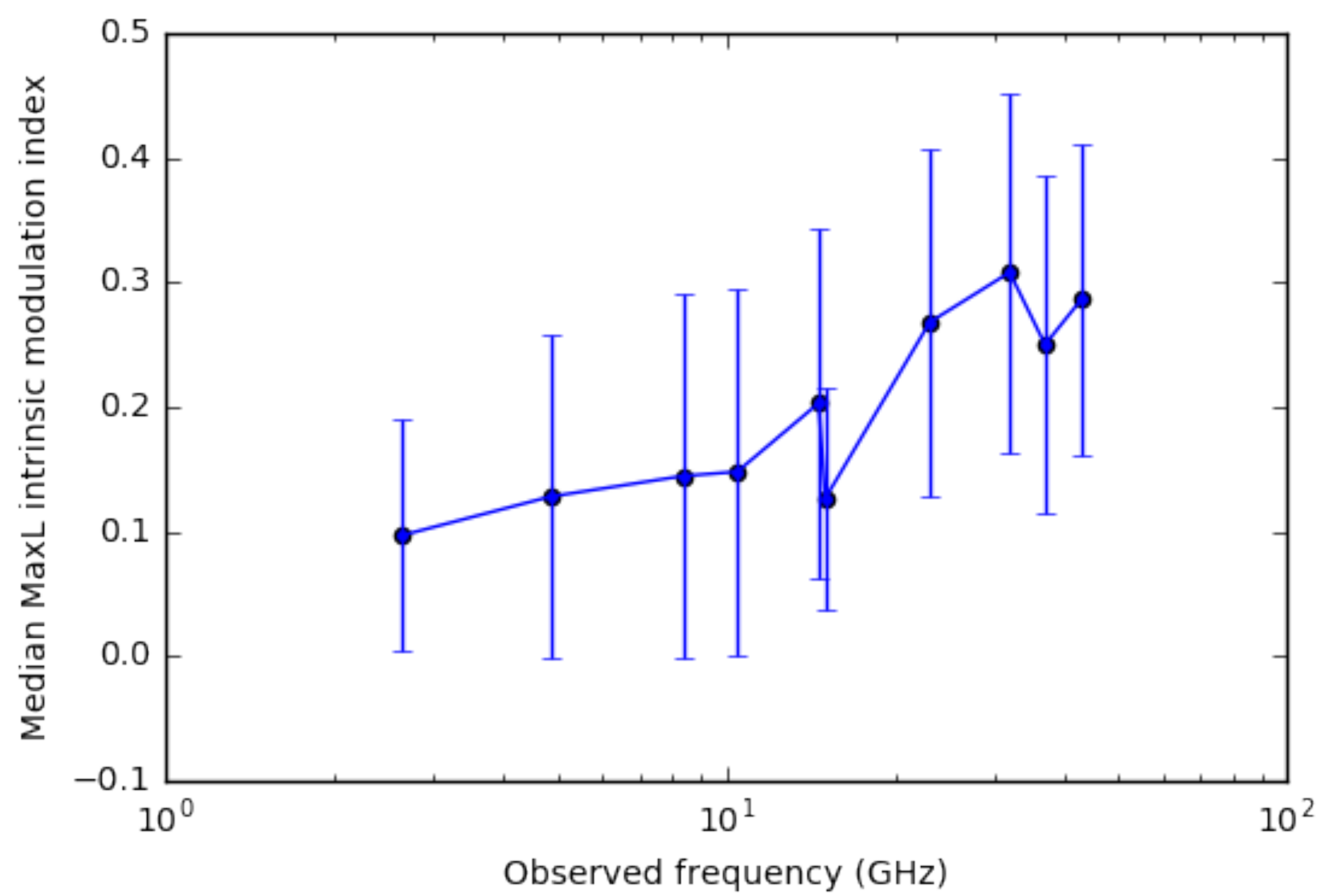

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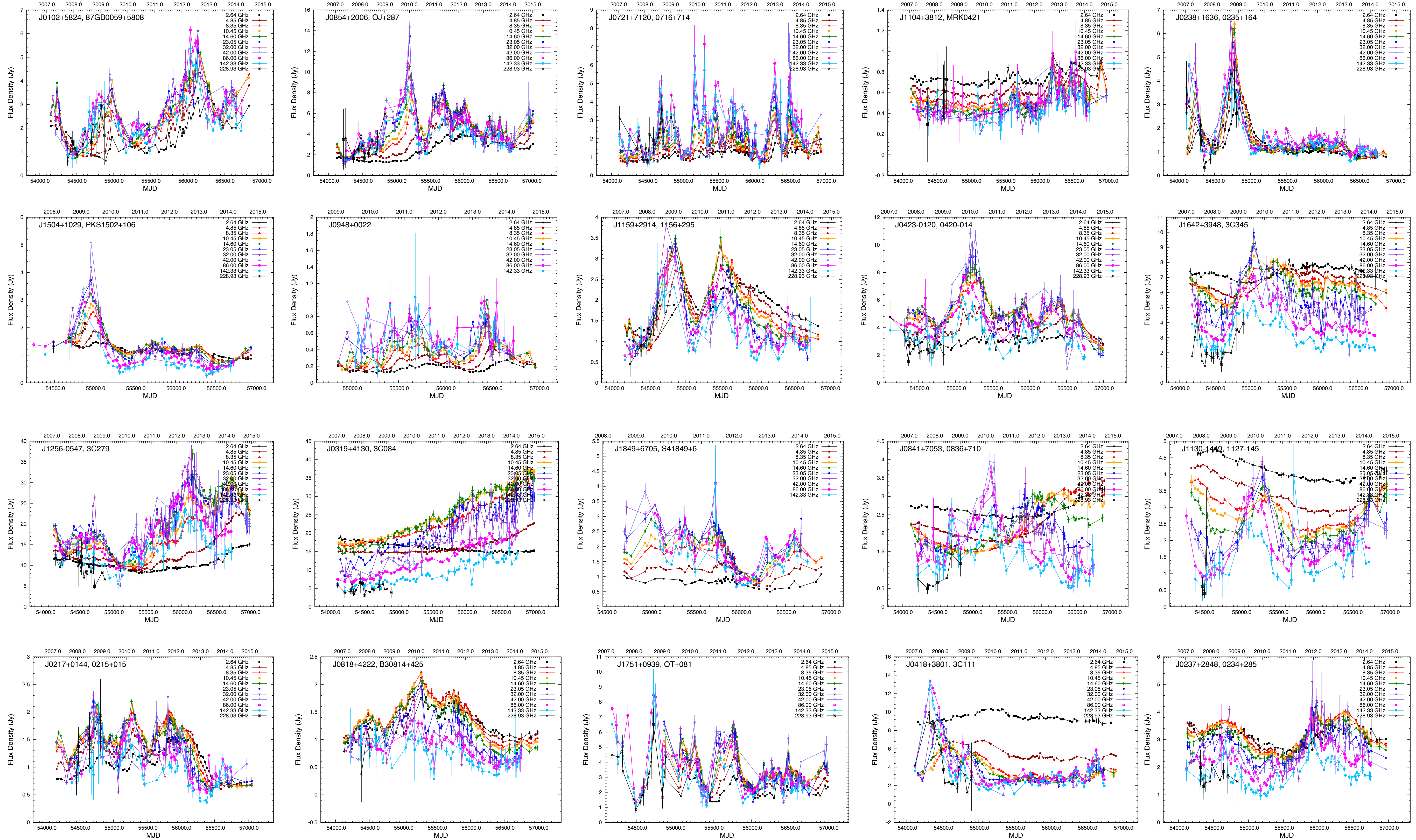

data requests eangelakis@mpifr.de

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