From *EGRET* to *Fermi*:
mm-radio data and the origin of gamma-ray emission

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EGRET:

What determines the gamma-ray brightness?

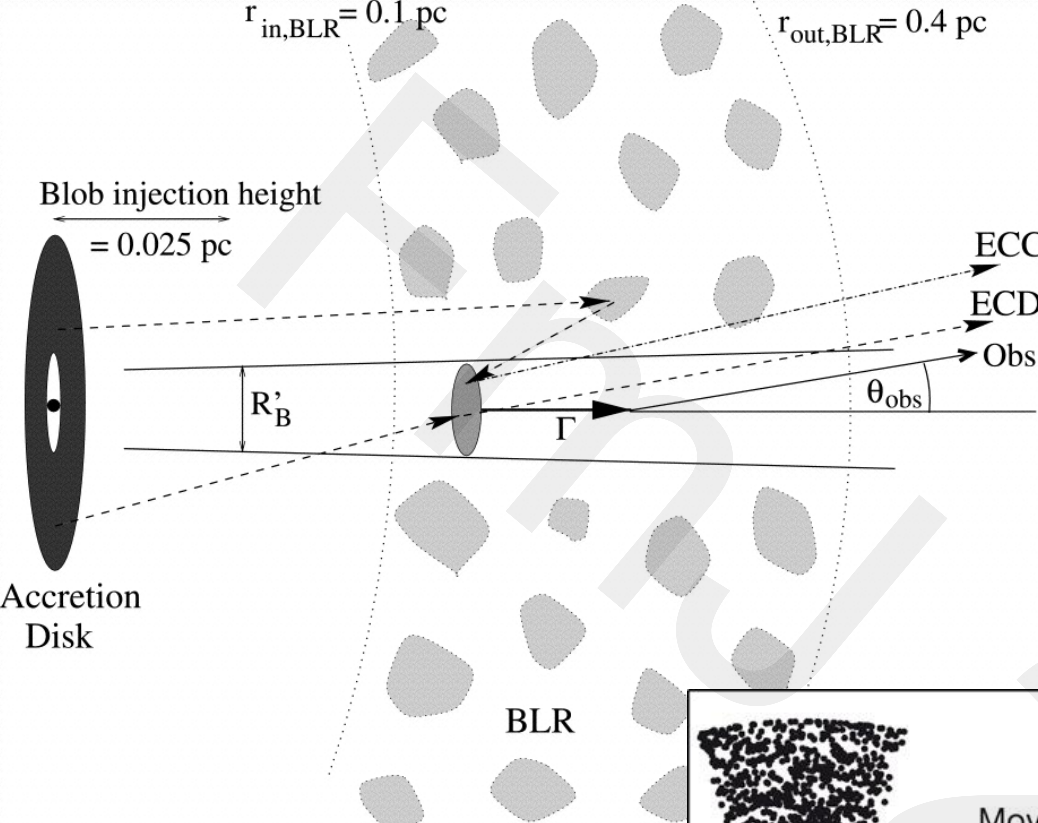
- must have relativistic jets (i.e., radio bright)

What mechanisms are responsible?

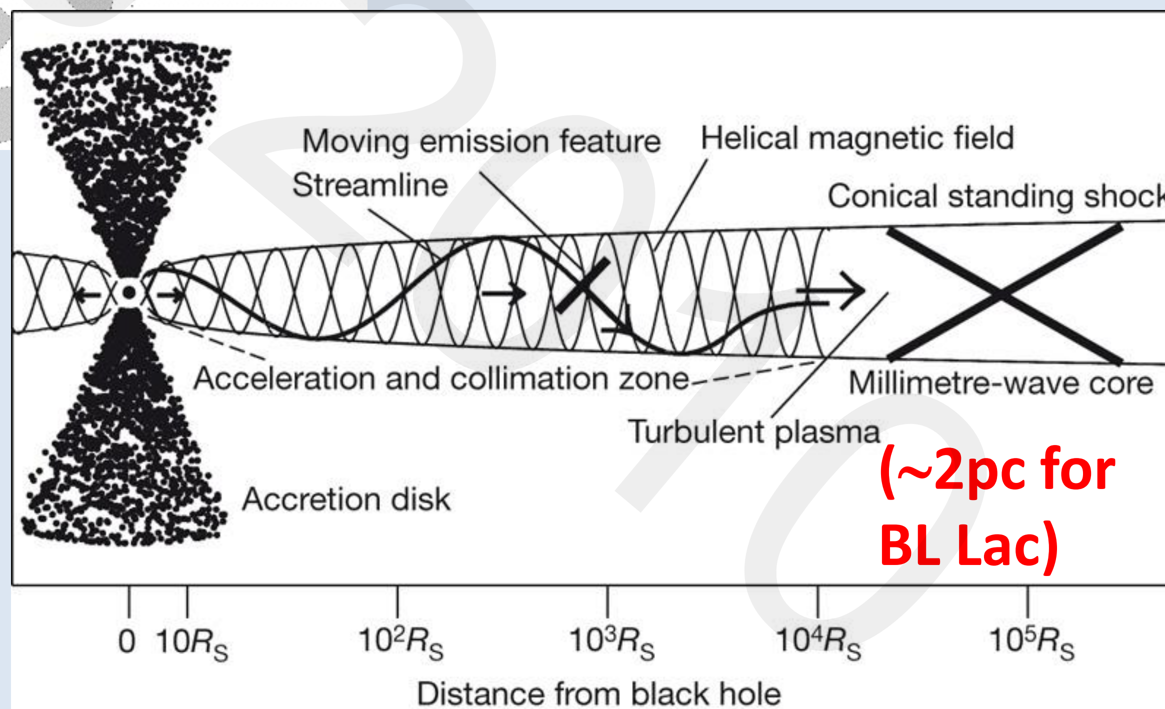
- inverse Compton $\Rightarrow$ relativistic electrons + seed photons

Where in the source do gamma-rays originate?

- close to the BH/accretion disk (plenty of photons – but electrons?)
- downstream from the radio core (plenty of electrons – but photons?)



Hartman et al. 2001



Marscher et al. 2008

CLOSE to BH/accretion disk (inside BLR):

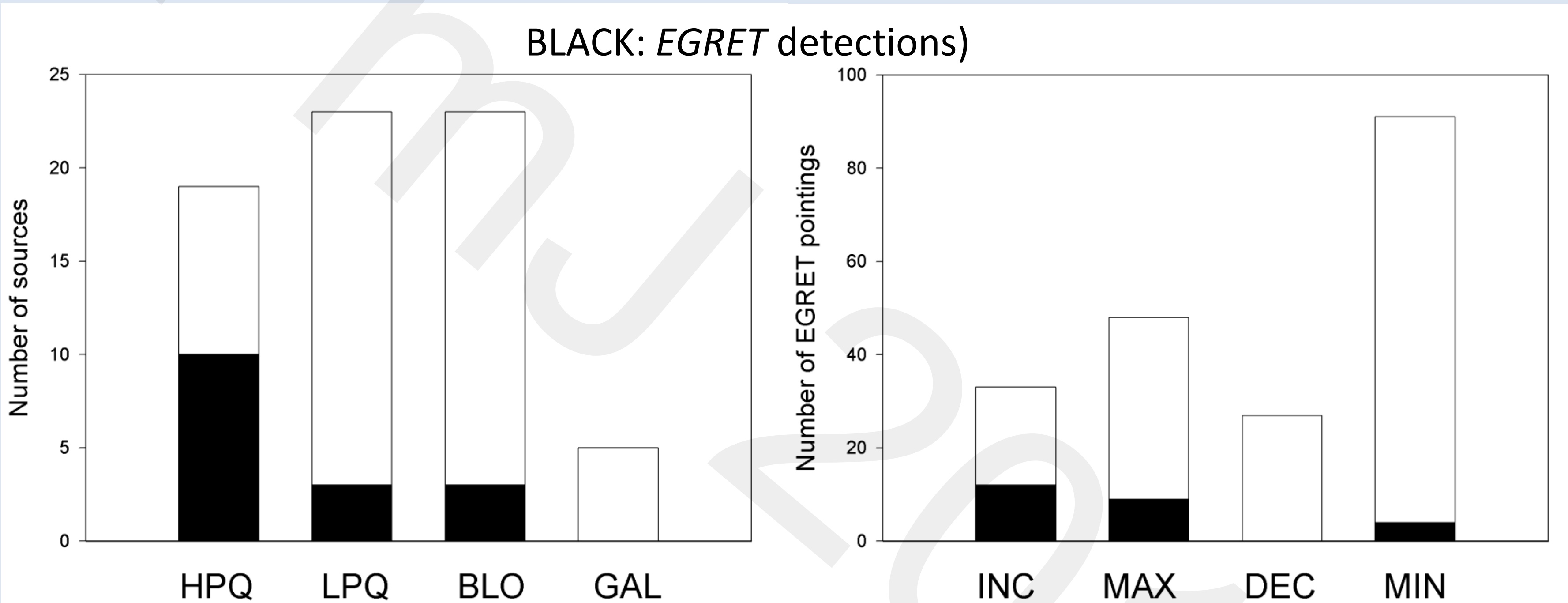
- **gamma-rays *precede* radio variations (VLBI zero epoch, beginning of a millimeter flare)**
- **little or *no correlation* with radio variations**

DISTANT, at or downstream from the radio core (outside the BLR):

- **gamma-rays *after or simultaneous* with radio variations**
- ***correlation* with radio variations**

***<u>EGRET</u>*: Valtaoja and Teräsranta 1995, 1996**

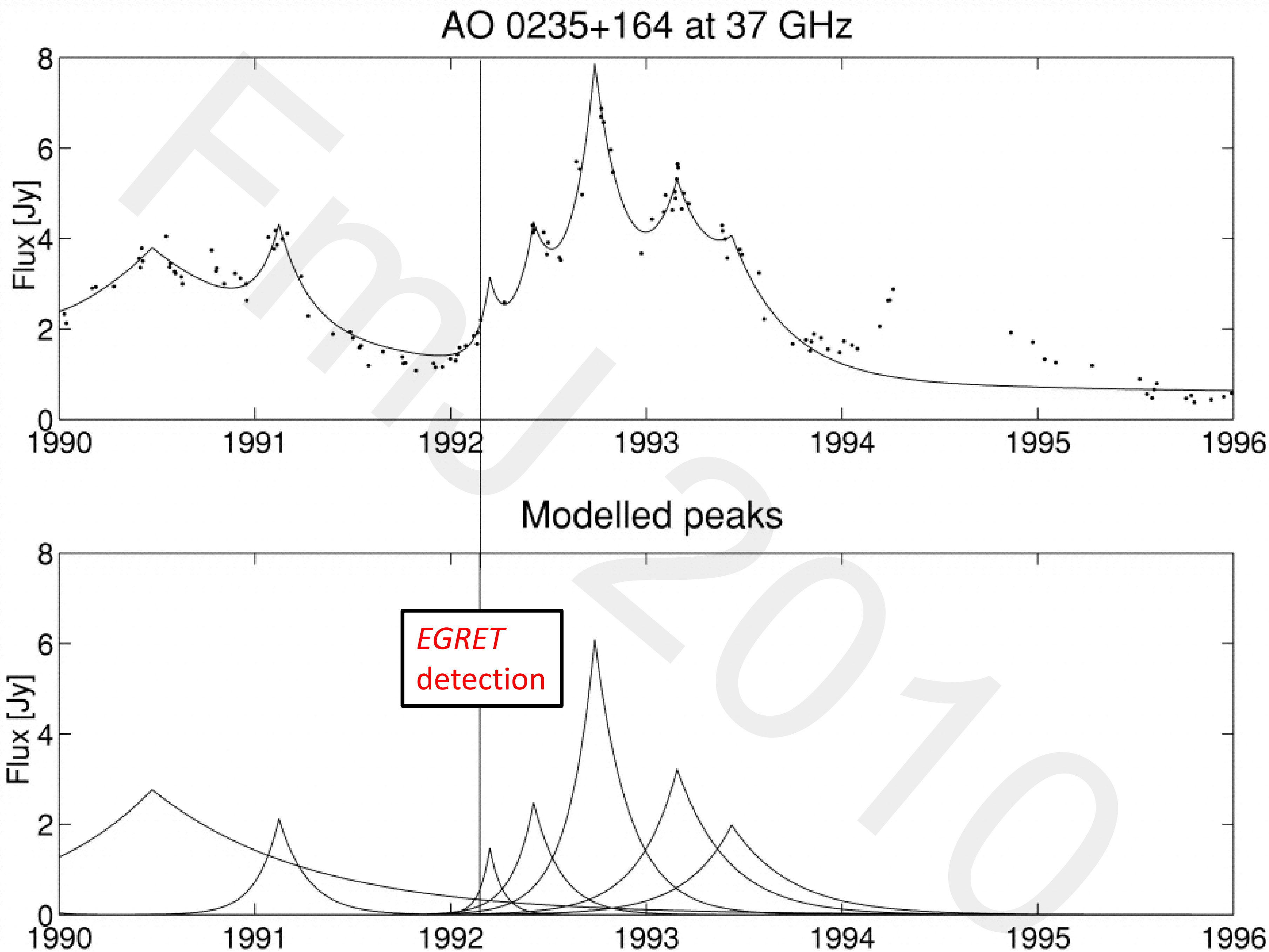
(EGRET Phase 1 all-sky survey, Metsähovi radio sample)



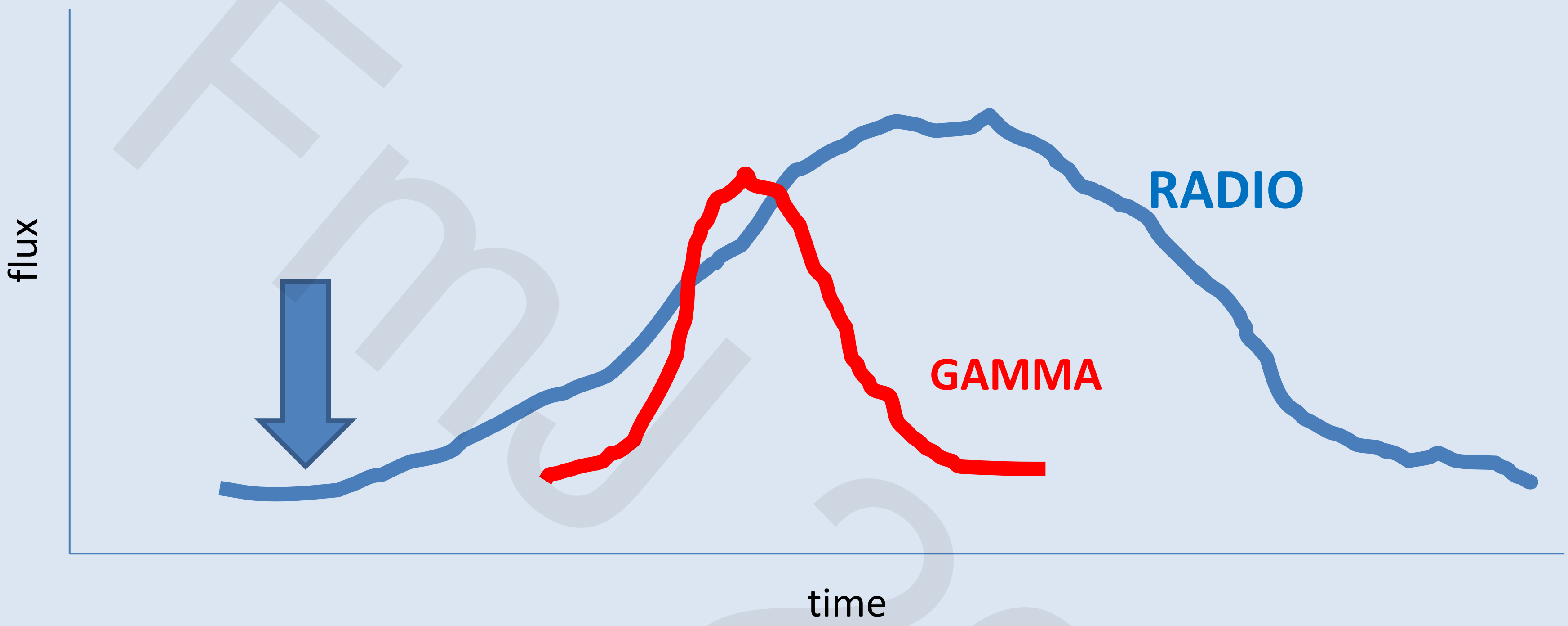
HIGHLY POLARIZED QUASARS ARE STRONGEST GAMMA-RAY EMITTERS

STRONGEST GAMMA-RAYS DURING RISING OR PEAKING MM-FLARES
⇒ <u>FROM SHOCKS</u>

The *only* unbiased statistic you could do with *EGRET*!)



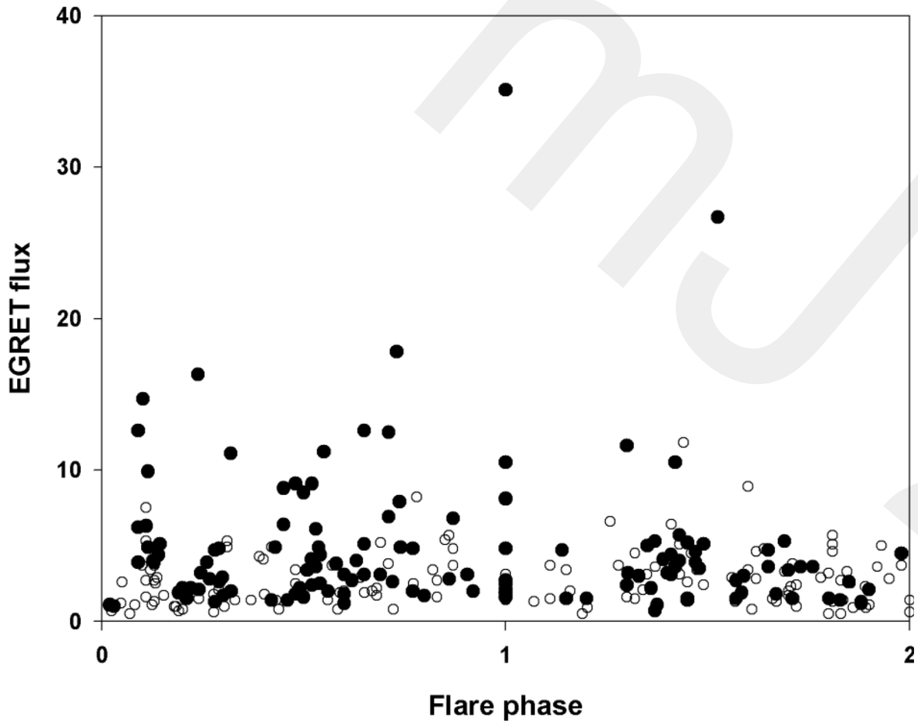
AO 0235+164 at 37 GHz
Flux [Jy]
Modelled peaks
EGRET detection
0
2
4
6
8
1990
1991
1992
1993
1994
1995
1996

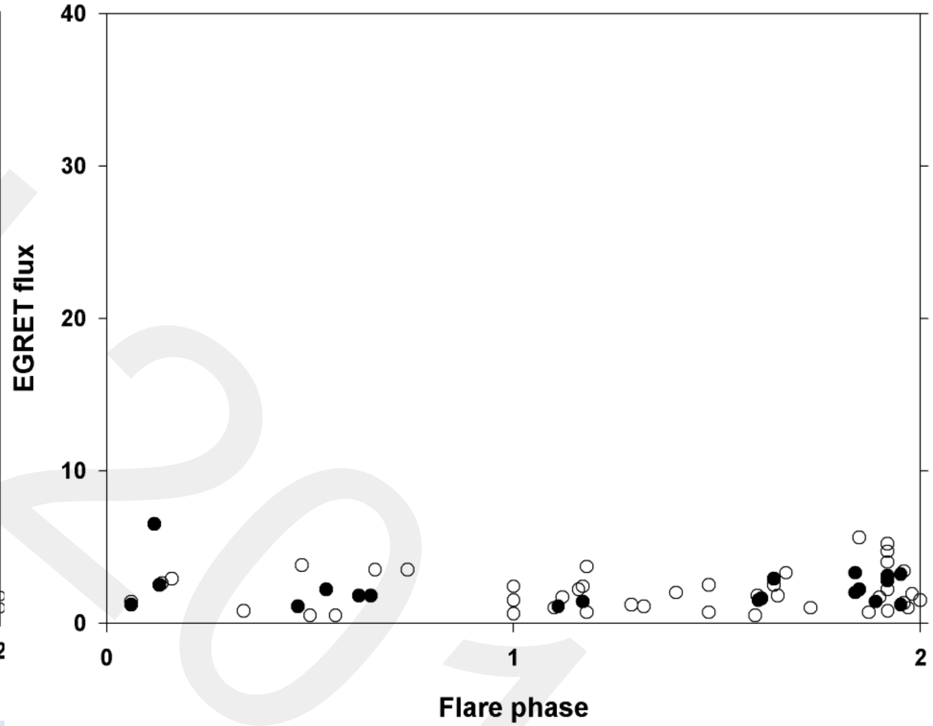


- **gamma does NOT precede radio variations (as any correlation analysis would tell you)**

- **radio precedes gamma (radio flux starts to rise / a new shock is ejected from the VLBI core BEFORE the gamma flare)**

EGRET: Lähteenmäki and Valtaoja 2003
(all *EGRET* data, Metsähovi sample)

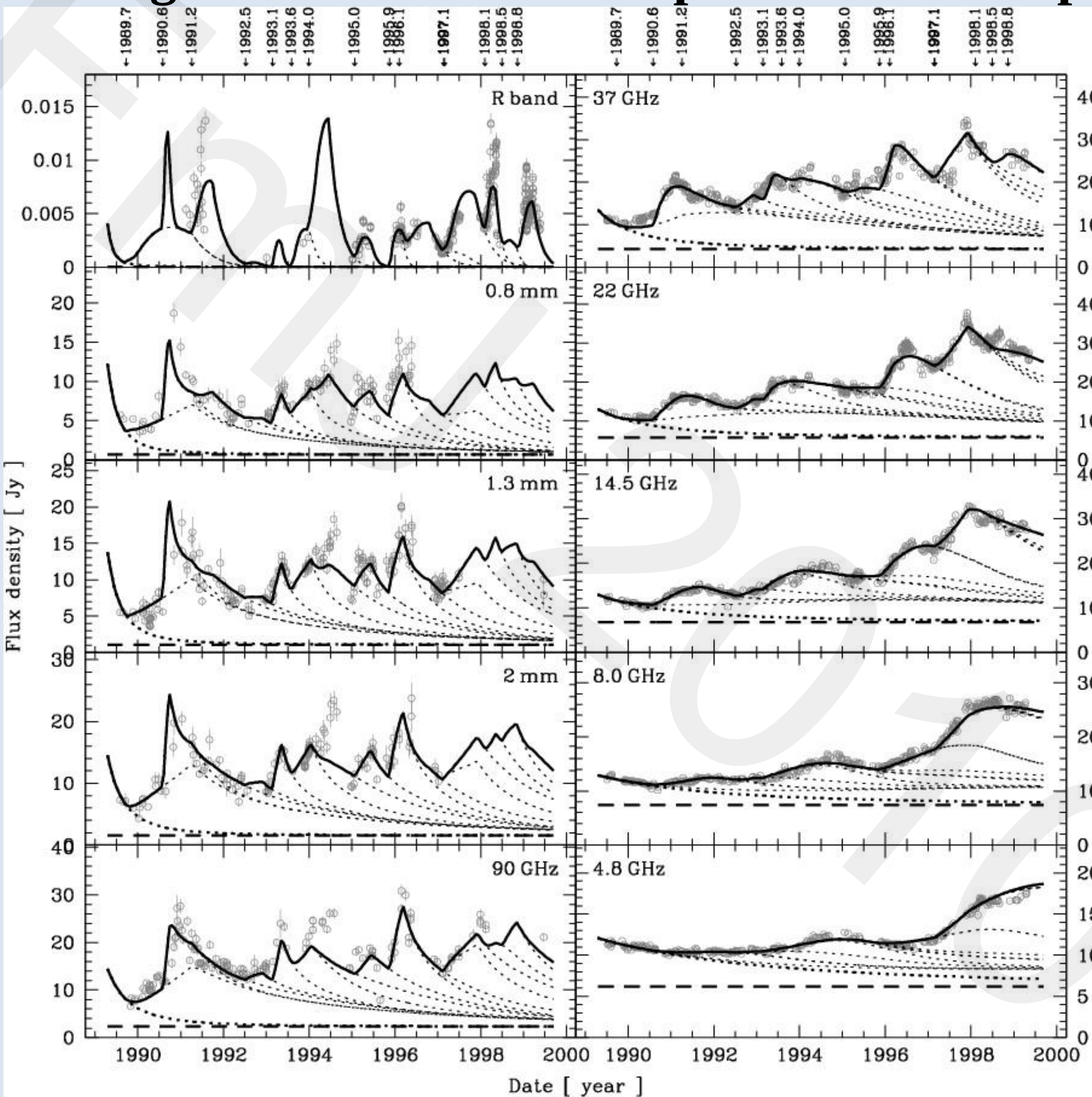




- STRONGEST GAMMA-RAY EMISSION DURING FLARE RISE/PEAK ⇒ <u>SHOCKS</u>
- BL LACS MUCH WEAKER GAMMA-RAY EMITTERS
- STRONG/WEAK EMISSION (HPQ/BLLAC?) TWO DIFFERENT MECHANISMS?

average: gamma 2 months after the beginning of the radio flare = Jorstad et al. (VLBI) 2001

EGRET: *Lindfors et al. 2006*
(3C 279 gamma and radio-to-optical flares comparison)



EGRET: Lindfors et al. 2006
(3C 279 gamma and radio-to-optical flares comparison)

Table 1. EGRET gamma-ray observations of 3C 279 versus the time elapsed since the onset of the latest synchrotron flare. Gamma-ray state according to Hartman et al. (2001).

Epoch	Time elapsed (years)	Gamma-ray state
1996.09	0.006	very large flare
1999.07	0.195	high
1996.06	0.206	high
1991.47	0.225	high
1993.86	0.288	moderate
1997.47	0.328	moderate
1993.98	0.409	moderate
1993.00	0.490	low
1997.01	0.924	low
1994.97	0.990	low

THE DISTANCE OF THE MOST RECENT SHOCK FROM THE RADIO CORE DETERMINES THE STRENGTH OF THE GAMMA-RAY EMISSION IN 3C 279

<u>Fermi</u>: first eleven months (Abdo et al. 2010)

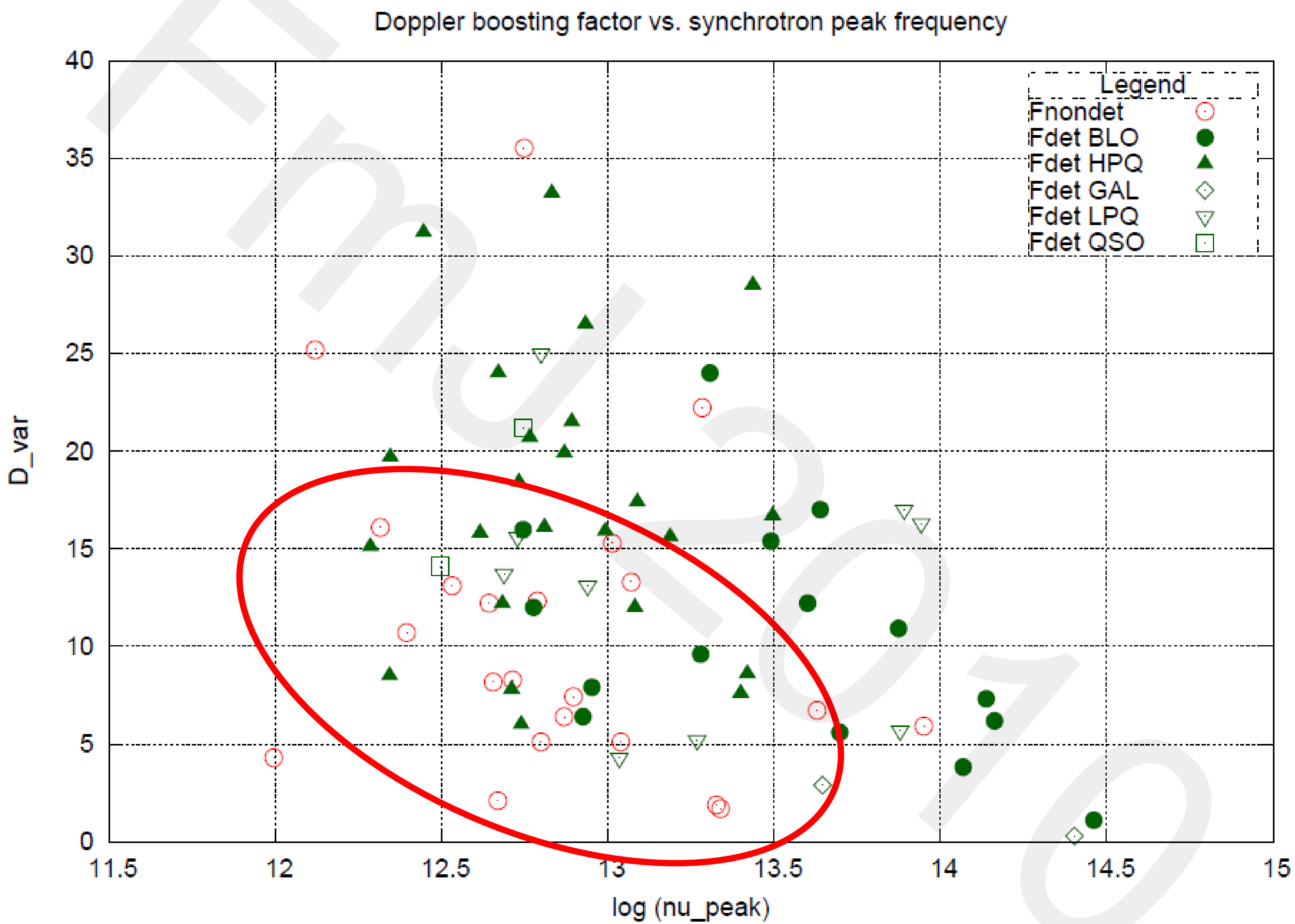
vs.

<u>Metsähovi</u> 37 GHz flux-limited complete Northern monitoring sample (+ others)

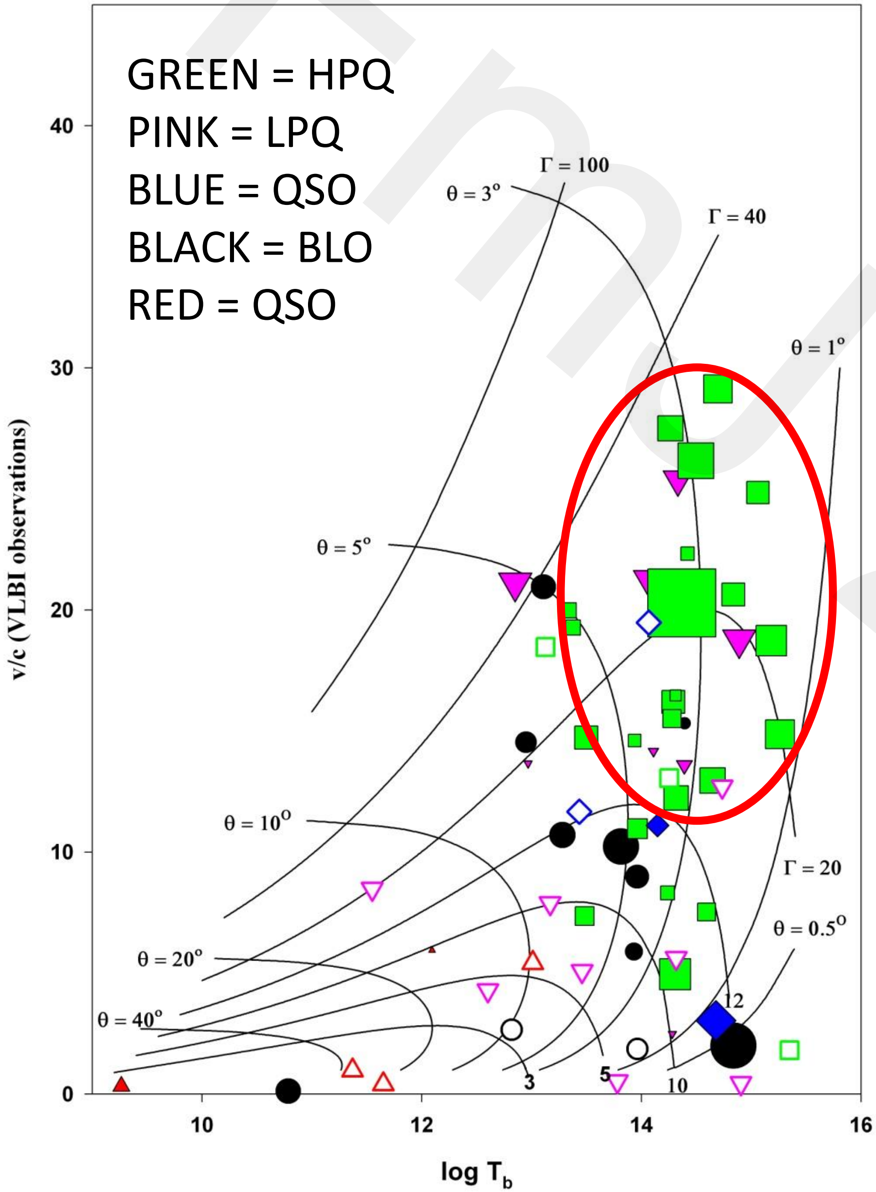
POSTERS: León-Tavares et al.
Nieppola et al.
Tornikoski et al.

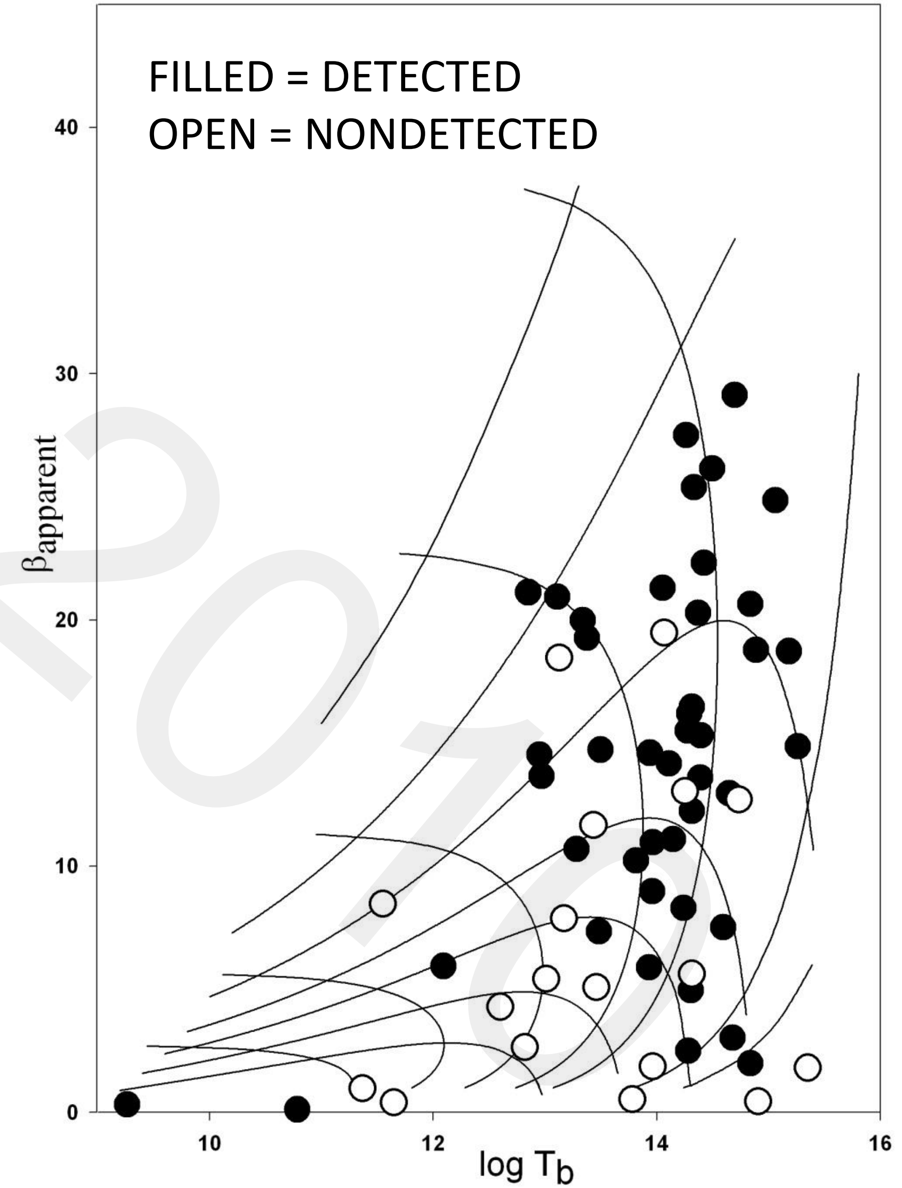
(work in progress…)

DETECTION vs. NONDETECTION? (Tornikoski poster)

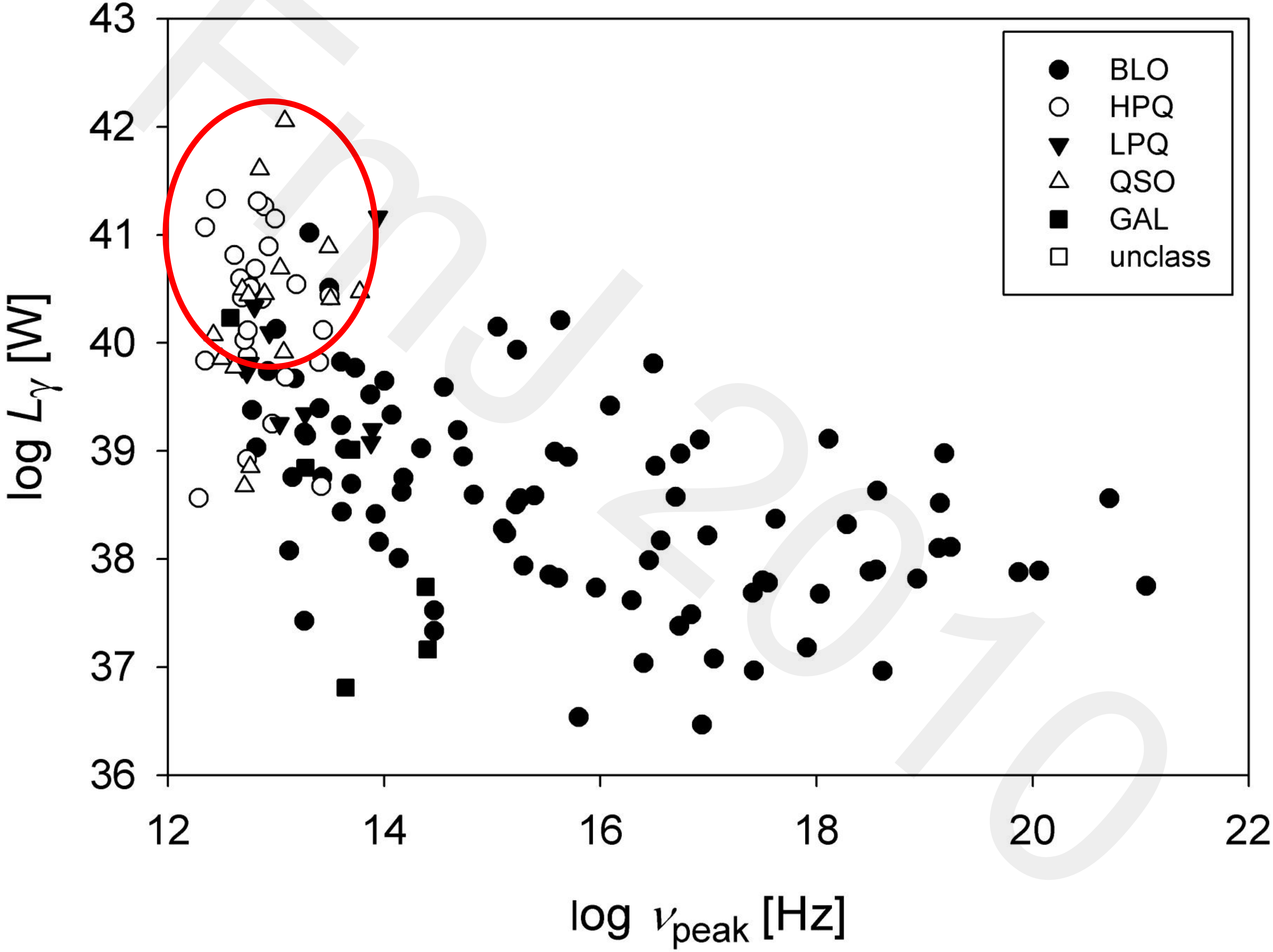


GAMMA-RAY STRENGTH/DETECTION vs. Γ, θ?

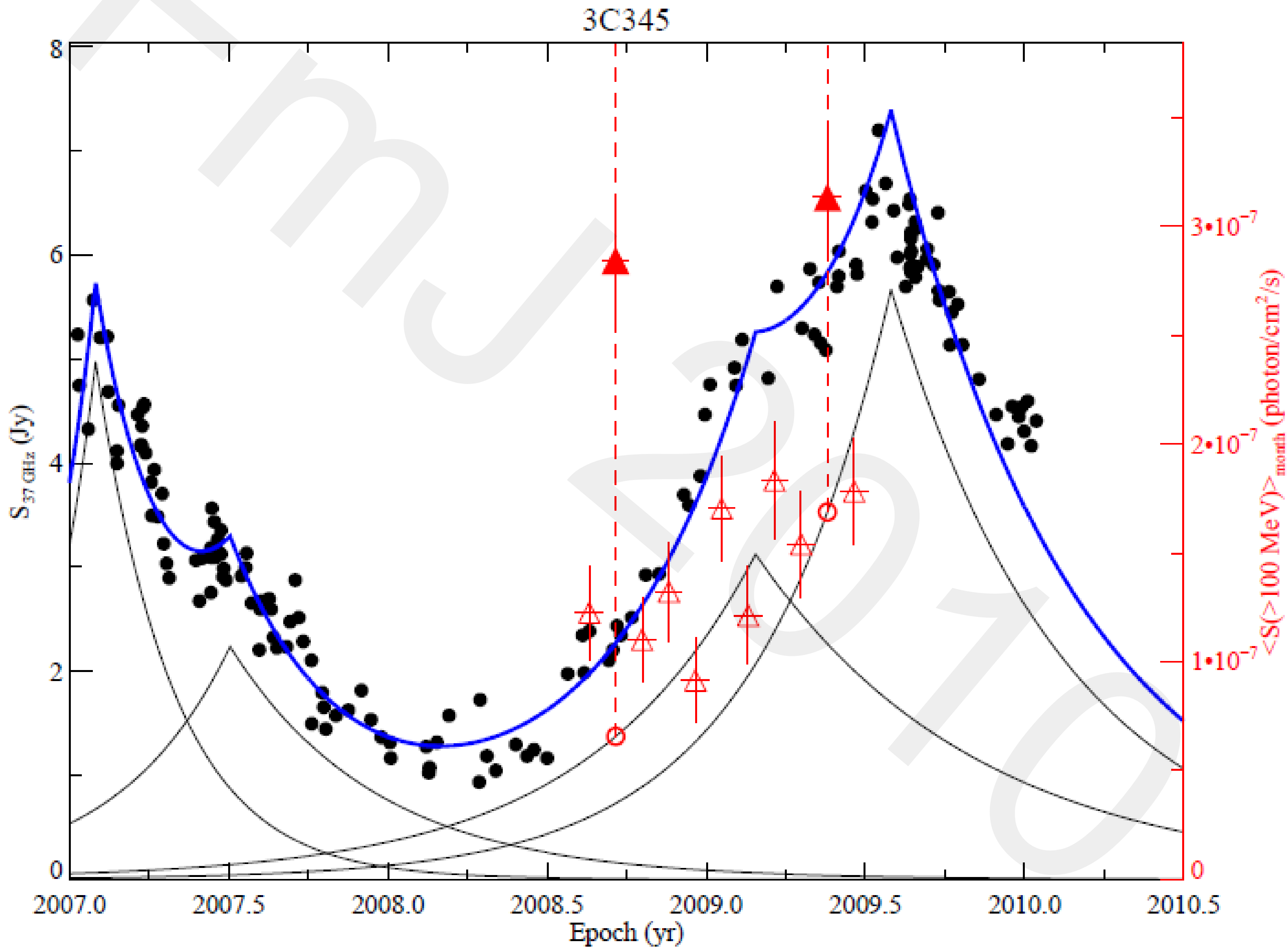




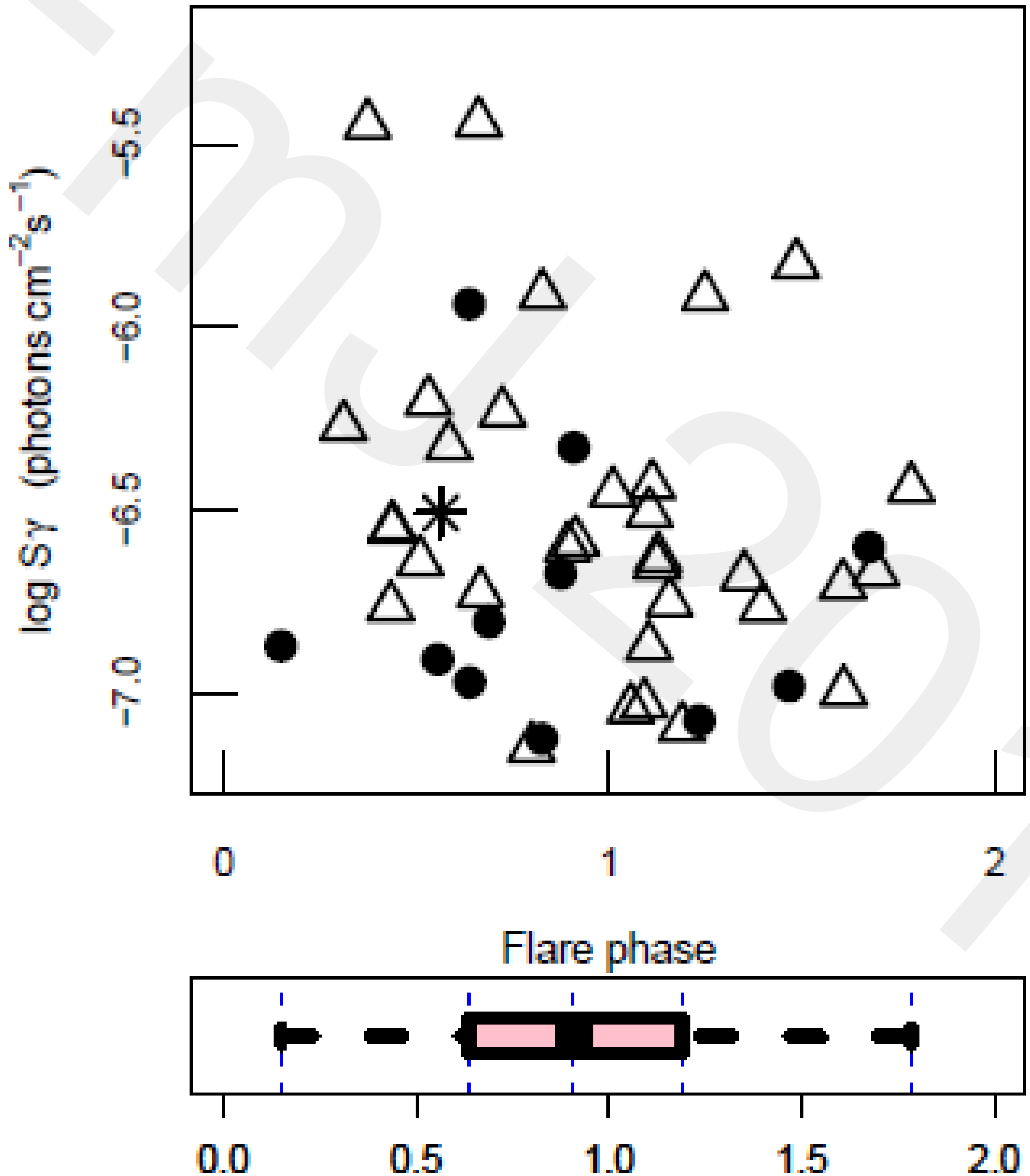
GAMMA-RAY LUMINOSITY? (Nieppola poster)



THE RADIO (SHOCK) - GAMMA CONNECTION?
(posters by León-Tavares, Nieppola, Tornikoski)

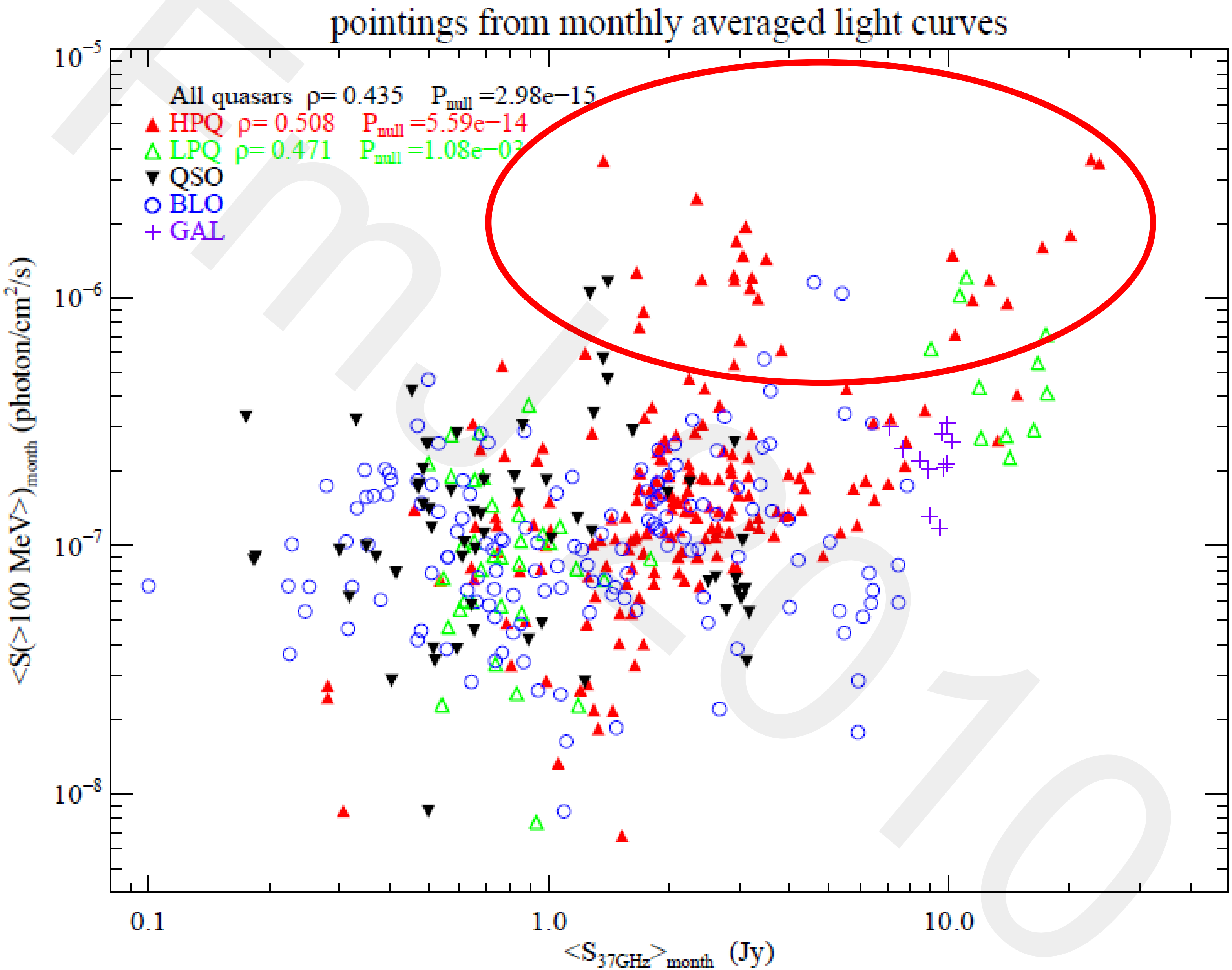


STRONGEST GAMMA-RAYS DURING RISE/PEAK OF MM-RADIO FLARE (as in Lähteenmäki & Valtaoja 2003)



TRIANGLES = QSO
DOTS = BL LAC
ASTERISK = GALAXY

QUASARS: CORRELATION FOR MONTHLY AVERAGES



CONCLUSIONS

1) At least the strongest gamma-rays come from shocks, parsecs downstream

2) Weaker gamma-rays / BL Lacs may have different emission sites / mechanisms / seed photons

3) HPQs tend to be the strongest gamma emitters, BL Lacs and ordinary quasars being weaker

4) The strength of the gamma-ray emission is a combination of (at least) source type, Γ, θ, υ_{peak} and the concurrent radio state (shocks!)

NEED: new observations–based modelling for the "distant origin" (shocks) case

”The new *Fermi* data are in accordance with our earlier conclusions from *EGRET.* Most importantly, strong gamma-ray emission does seem to occur far away from the black hole and the accretion disk, in shocks parsecs downstream from the radio core and well outside the BLR.

Modelling is required for this scenario, incorporating information on the properties of shocks, available from the radio data. Since simple SSC models usually fail to produce the observed levels of gamma-ray flux, more sophisticated models should be developed and the possibilities of external seed photon sources outside the BLR should be investigated.”

(Valtaoja, Proceedings)