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

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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

(~2pc for BL Lac)
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
Highly polarized quasars are strongest gamma-ray emitters.

Strongest gamma-rays during rising or peaking mm-flares ⇒ from shocks.

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

**EGRET:** Valtaoja and Teräsranta 1995, 1996 (EGRET Phase 1 all-sky survey, Metsähovi radio sample)
AO 0235+164 at 37 GHz

Flux [Jy]

Modelled peaks

EGRET detection

Flux [Jy]
- 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 ⇒ SHOCKS
- 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).

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

THE DISTANCE OF THE MOST RECENT SHOCK FROM THE RADIO CORE DETERMINES THE STRENGTH OF THE GAMMA-RAY EMISSION IN 3C 279
Fermi: first eleven months (Abdo et al. 2010)

vs.

Metsähovi 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)

Doppler boosting factor vs. synchrotron peak frequency

Legend:
- Fnondet
- Fdet BLO
- Fdet HPQ
- Fdet GAL
- Fdet LPQ
- Fdet QSO

\[ D_{\text{var}} \]
\[ \log (\nu_{\text{peak}}) \]
GAMMA-RAY STRENGTH/DETECTION vs. $\Gamma$, $\theta$?

GREEN = HPQ
PINK = LPQ
BLUE = QSO
BLACK = BLO
RED = QSO

FILLED = DETECTED
OPEN = NONDETECTED
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

pointings from monthly averaged light curves

- All quasars: $\rho = 0.435$, $P_{null} = 2.98 \times 10^{-15}$
- HPQ: $\rho = 0.508$, $P_{null} = 5.59 \times 10^{-14}$
- LPQ: $\rho = 0.471$, $P_{null} = 1.08 \times 10^{-03}$

$I_{\text{photons/cm}^2/s} = \langle S_{100 \text{MeV}} \rangle_{\text{month}}$

$\langle S_{37\text{GHz}} \rangle_{\text{month}}$ (Jy)
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, $\Gamma$, $\theta$, $\nu_{\text{peak}}$ 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)