Inverse-Compton “mirror-flash” emissions in $\gamma$-rays?

the two remarkable cases of 3C 454.3 and PKS 1830-211 on late 2010

These challenging events show ratios between optical and $\gamma$-rays variation factors

$$\rho = \frac{A_\gamma}{A_{\text{opt}}} > 2$$ or more, that is, Compton dominance varies

Standard EC predicts $\rho = 1$

Moreover $\gamma$-flux shows doubling time of few hours in these events.

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FSRQ standard model

Jet: blob moving with Lorentz factor $\Gamma$, beamed, non thermal radiation

External: galaxy frame $(z)$, radiation connected with accretion

External photons $N_{\text{ext}}$ and jet electrons $n_e(\gamma)$ produce

External Compton (EC)

Jet: blob moving with Lorentz factor $\Gamma$, beamed, non thermal radiation

Electron distribution $n_e(\gamma)$ and magnetic field $B$ produce

Synchrotron + Inverse Compton (SSC)
PKS 1830: an extreme instance

Orphan gamma-flare during a monthly activity ($A\gamma=3$):
Optical and X-ray remain at historical steady levels.

A second component of shocked particles (red dotted lines) can account for this monthly enhancement in gamma-rays with little or no contributions in optical and X-rays.

But the fast orphan flare ($A\gamma = 5$ on 6 hours) around Oct. 14 would require some variation in the external field of seed photons!

Ciprini et al. 2010; Donnarumma et al. 2011
The November 2010 super flare of 3C 454 (Vercellone et al. 2011)

- Strong 1 day optical flare (energization of a new component in the inner jet)
- Faint soft X-ray counterpart (SC plays a secondary role!)
- No gamma-ray counterpart: $\rho = 0$, whereas at the start and during the plateau $\rho = 1$
- MgII line flux variations of 30% (Leon Tavares 2013)

With courtesy of E. Striani and J. Leon Tavares
Around MJD 55517 the $\gamma$ ray flux jumps by $\Lambda_\gamma = 4 - 5$
While the optical flux rises by $A_{\text{opt}} = 2$ only, with $\rho > 2$!

$\gamma$ ray flux doubles in 6 hours whereas optical flux doubles in 10 hours

Later on, variation factors appear to be comparable with $\rho = 1$

To account for this complex correlation, some variations are required in the external photon field seen by the moving blob!
Four models for EC from clouds

1a: EC from the whole BLR that reprocess the disk radiation

1b: EC from a single cloud reprocessing the disk radiation

2a: a single cloud mirrors the approaching blob within the BLR

2b: same as 2a, but beyond the BLR
What happens when a scattering system crosses the jet trajectory at $R < R_{BLR}$? (case 1b)

In standard EC from BLR, clouds cover $a = 10\%$ at distance $R_{BLR} = 5 \times 10^{17}$ cm, and reprocess $f = 20\%$ of the disk luminosity $L_D$. The energy density of photons seen by a plasmoid moving with bulk Lorentz factor $\Gamma$ is

$$U_{BLR} \approx a f \frac{L_D \Gamma^2}{4\pi c R_{BLR}^2}$$

When the plasmoid approaches at distance $b \ll R_{BLR}$, a scattering system of size $r$, a gain can be obtained with

$$U'_{loc} = g U'_{BLR}$$

on time-scale

$$\Gamma^{-2} \left( r + r_{blob} \right) / c$$

$U'_{\text{MIR}} = f L'_{\text{syn}} \Gamma^4 / (cd^2) = U'_{\text{BLR}} (L_s/L_D) (R_{\text{BLR}}/\Gamma d)^2$

But causality constrained $d < R_m / (4 \Gamma^2)$, then $U'_M > U'_{\text{BLR}}$ results for a crossing time

$\Delta t_{\text{obs}} = (d+r)/(c\Gamma^2)$

Is the observed duration

$t_{\text{del}} = d/(c\Gamma^2) = \text{half hour}$

Blob impact delay

Adequate $\gamma$ amplification

Rise-time of few hours

Shock delay of half hour

$\gamma$-ray emitted at pc scale

Optical precursor with 30% line enhancement

...And beyond the BLR? (case 2b)

This idea explains the SED during the entire period of activity, by a plasmoid train:

Plasmoids are continuously ejected emitting the plateau and the opt. precursor within the BLR.

When the edge of the train attains the mirror located at distance $R_m = \text{few pc}$, strong mirror-EC is produced causing the jump in $\gamma$ rays with $\rho > 2$!

The peak in $\gamma$ rays is emitted when the dominant plasmoid (responsible of the opt. precursor) attains the mirror. The lag between the opt. precursor and the related peak is $\Gamma^{-2}R_m / c = 7 \text{ days}$ with $\Gamma = 10$.
Data concerning PKS 1830 and 3C 454 suggest:

**Ejection of several plasmoids** seem unavoidable in order to account for the complex **optical vs. γ-ray** correlations and for the **2-week plateau**.

**Standard EC models are challenged!**

In fact, **variations in the external photon field seen by the blob** are required to understand the **strong variations observed in Compton dominance** with **very fast γ-ray variations** (100% in few hours).

**Mirroring of the blob photons by scattering material beyond the BLR** ensures **fast optical events within the BLR and fast γ-ray emission at pc-scales** correlated with **lag of weeks**.

Moreover, **enhancements in the line-emission** are predicted.
The knot K10 emerges from the core $T=160$ days after the flare (Jorstad et al. 2012).

With a jet opening angle $1.6^\circ$ K10 traveled $R_c=16$ pc before being resolved.

For $\Gamma = 10$ and $\theta = \Gamma^{-1}$ the predicted lag is

$T=(1-\beta \cos \theta) \frac{R_c}{c}$

$T=\Gamma^{-2} \frac{R_c}{c} = 0.5$ years