Mirror Effects in Flat Spectrum Radio Quasars

Some remarkable events in:
3C 454.3, 3C 279, PKS 1830-211
and PKS 1510

show ratios between optical and γ-rays variation factors

$\rho = A_{\gamma} / A_{opt} > 2$ **or more, that is, Compton dominance varies.**

Standard EC predicts $\rho = 1$

Moreover, in these events the correlation between γ-ray and optical bands is often Complex or absent,

γ-flux shows doubling time of few hours or less,

high energy spectrum can be unusually hard.

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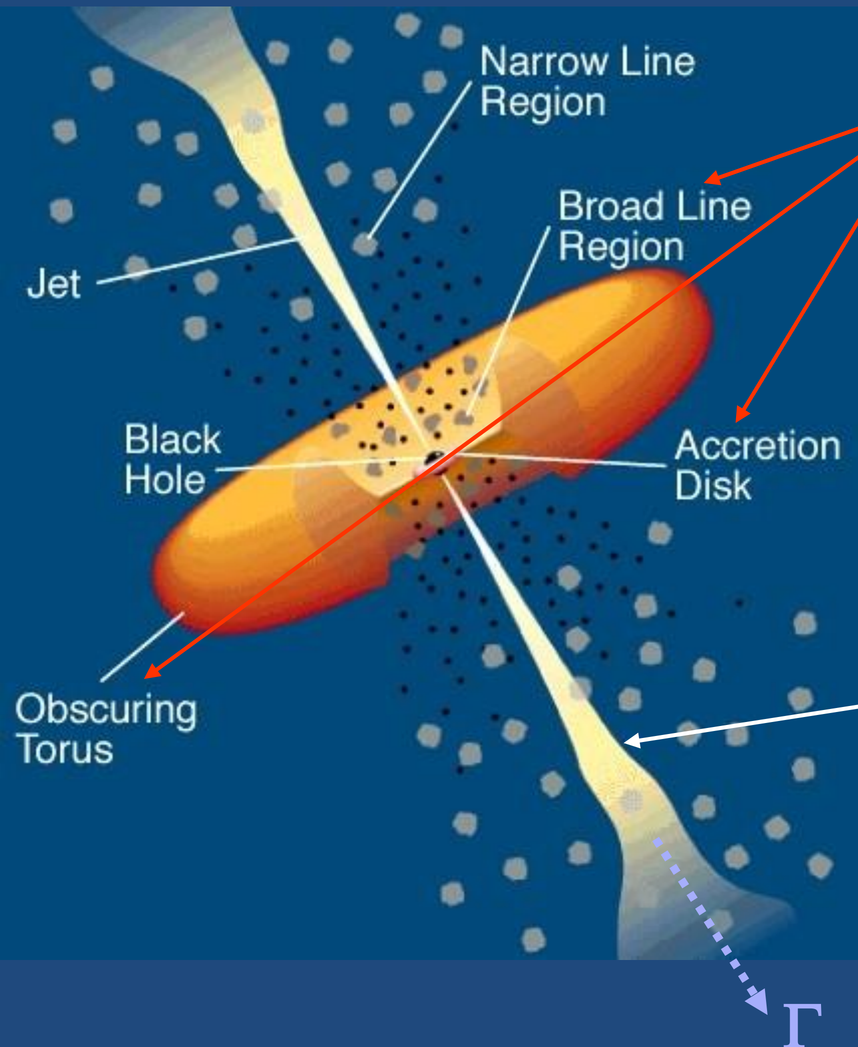
on behalf of the AGILE AGN WG

FSRQ standard model



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

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

produce → **External Compton (EC)**

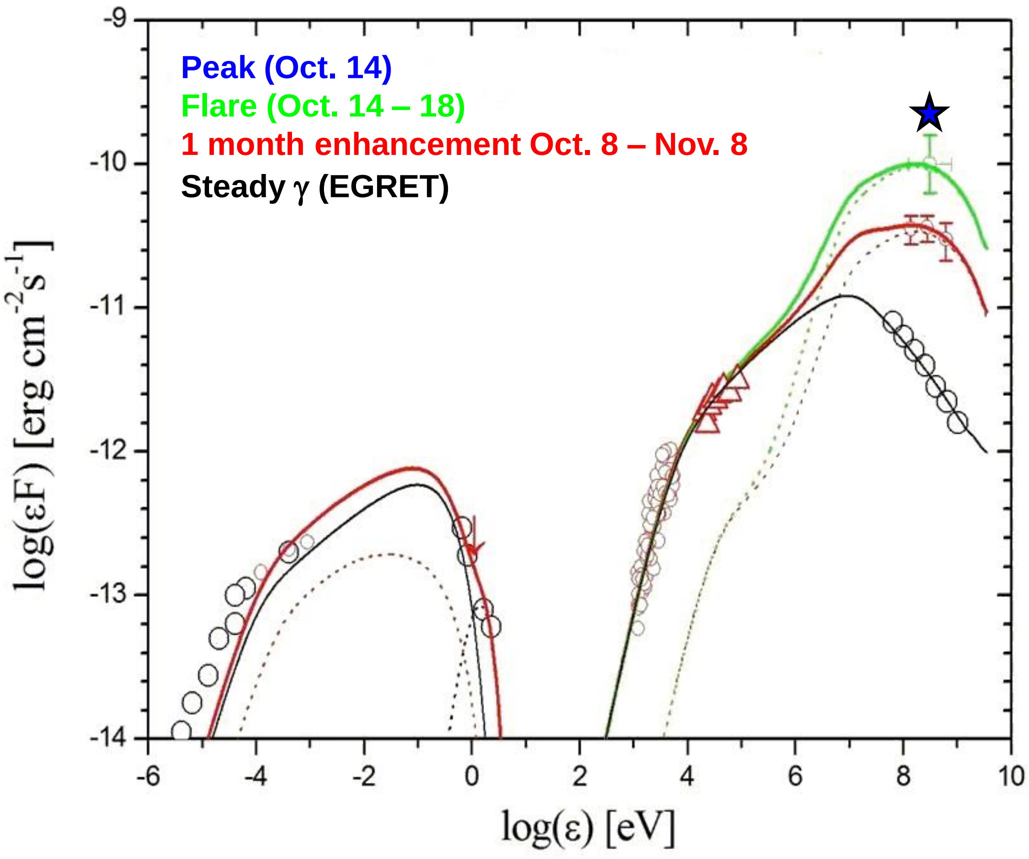
Jet: blob moving with Lorentz factor Γ,
beamed, non thermal radiation

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

produce

Synchrotron + Inverse Compton (SSC)

PKS 1830: an extreme instance



Orphan gamma-flare during a montly activity (A_γ=3): Optical and X-ray remain at hystorical steady levels.

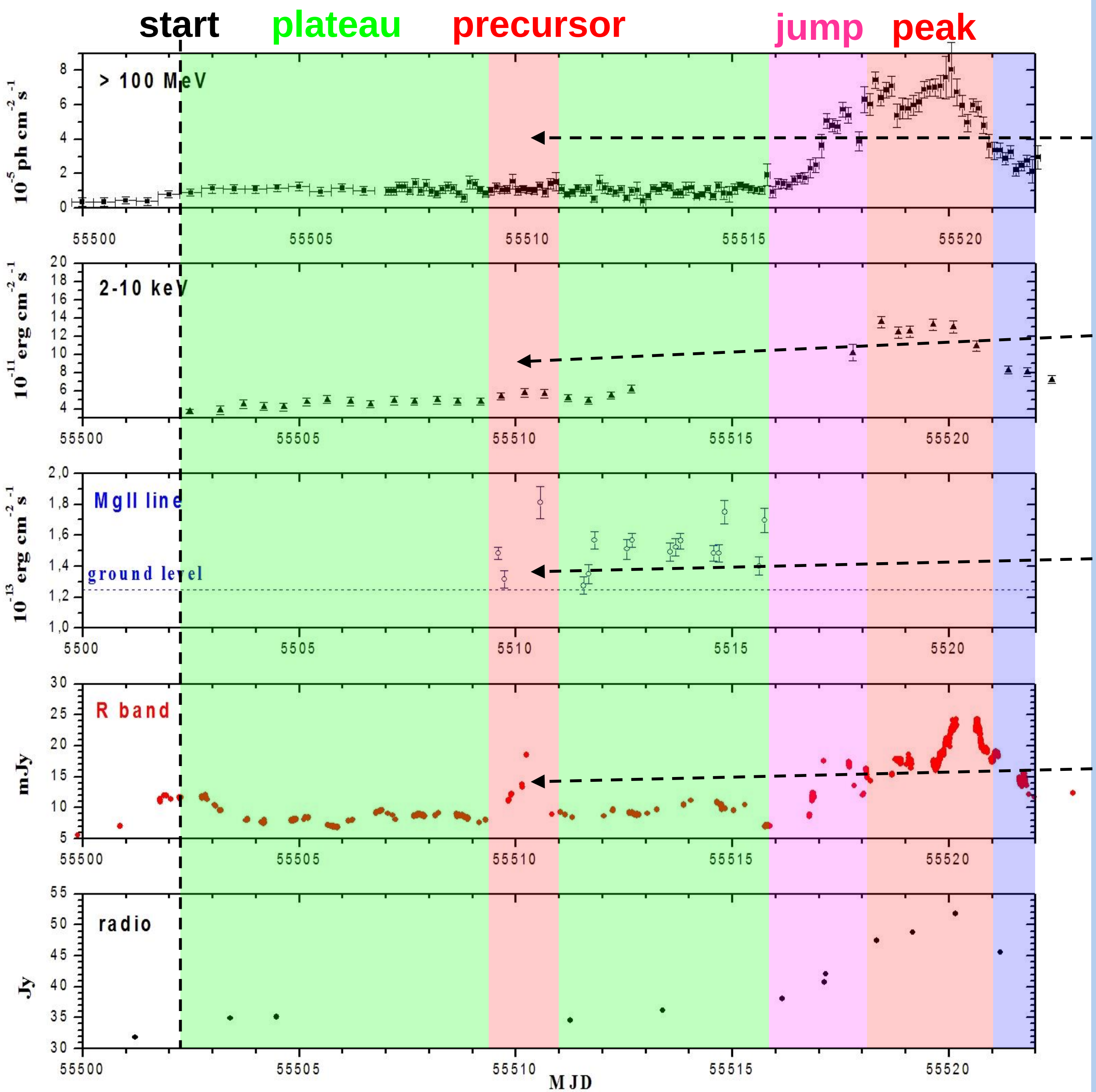
A second component of shocked particles (red dotted lines) can account for this **monthly enhancement** in gamma-rays with little or no contributions in optical and X-rays.

But the fast orphan flare (**A_γ = 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)



No gamma-ray counterpart:
$\rho = 0$ at the precursor,
whereas at the start $\rho = 1$

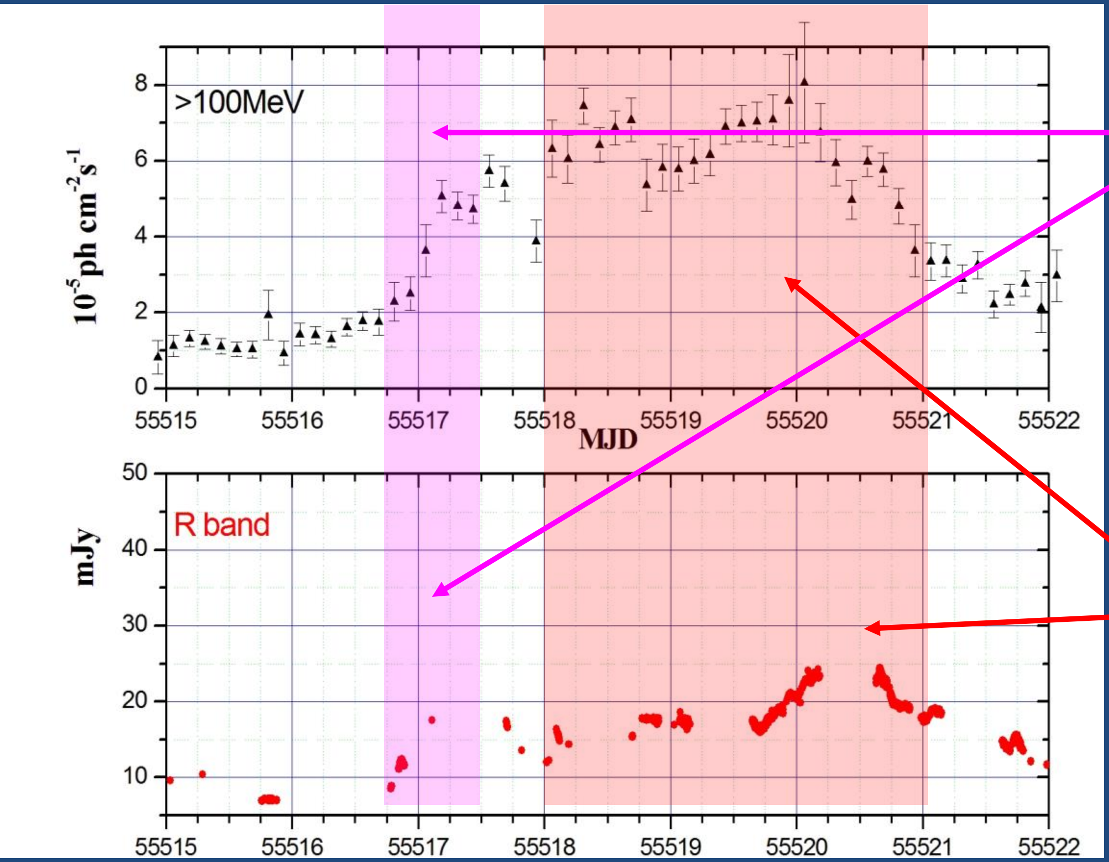
Faint soft X-ray counterpart
(SC plays a secondary role!)

MgII line flux variations of 30% (Leon Tavares 2013)

Strong 1 day optical flare
(energization of a new component in the inner jet)

With courtesy of E. Striani and J. Leon Tavares

3C 454 November 2010

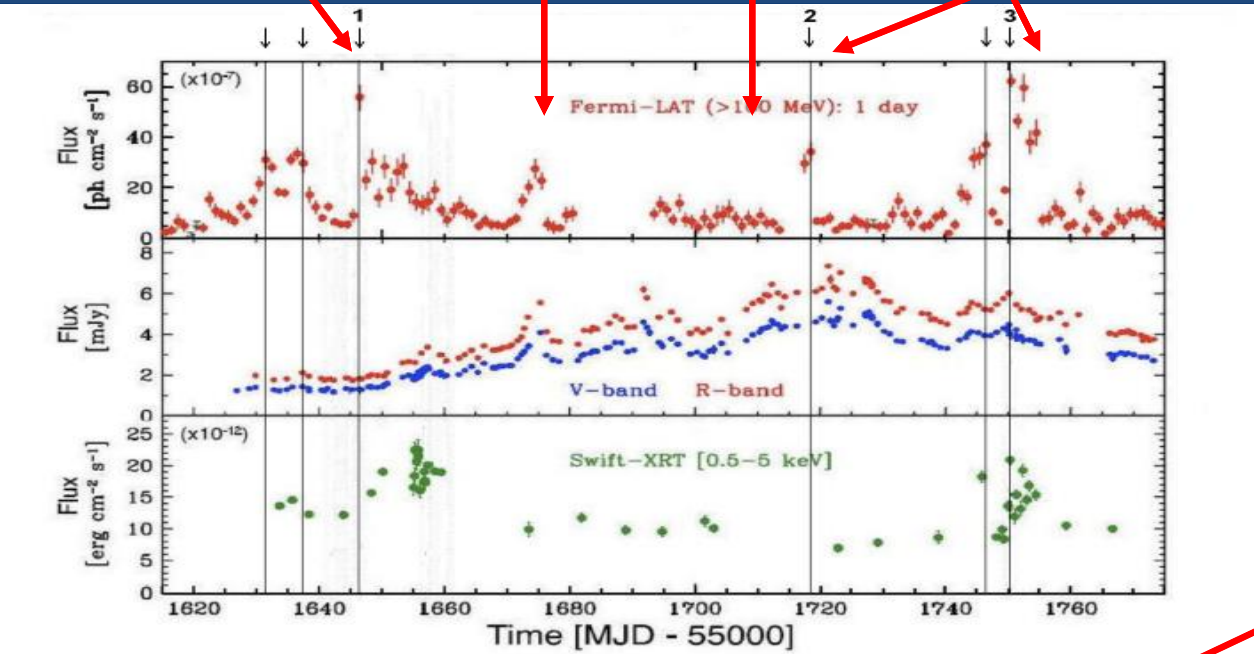


Around MJD 55517 the γ ray flux jumps by A_γ = 4 - 5 While the optical flux rises by A_{opt} = 2 only, with $\rho>2$!

γ ray flux doubles in 6 hours whereas optical flux doubles in 10 hours

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

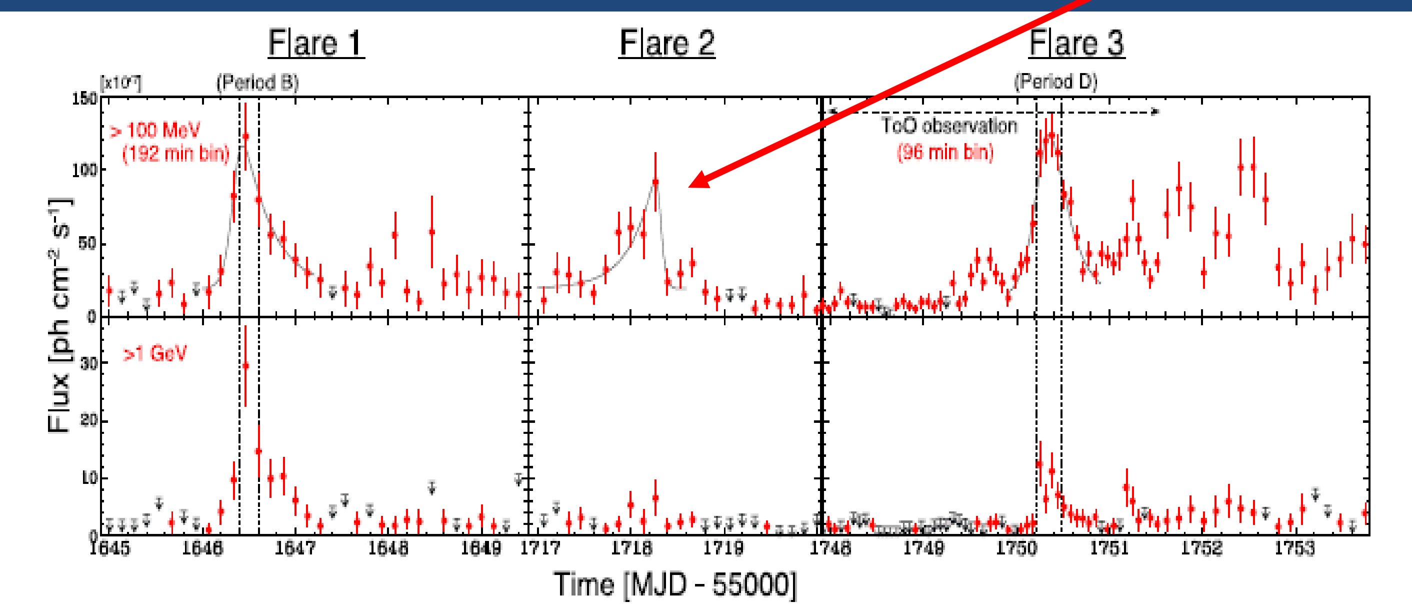
orphan ρ=6 ρ = 1 ρ= 0 ρ = 4



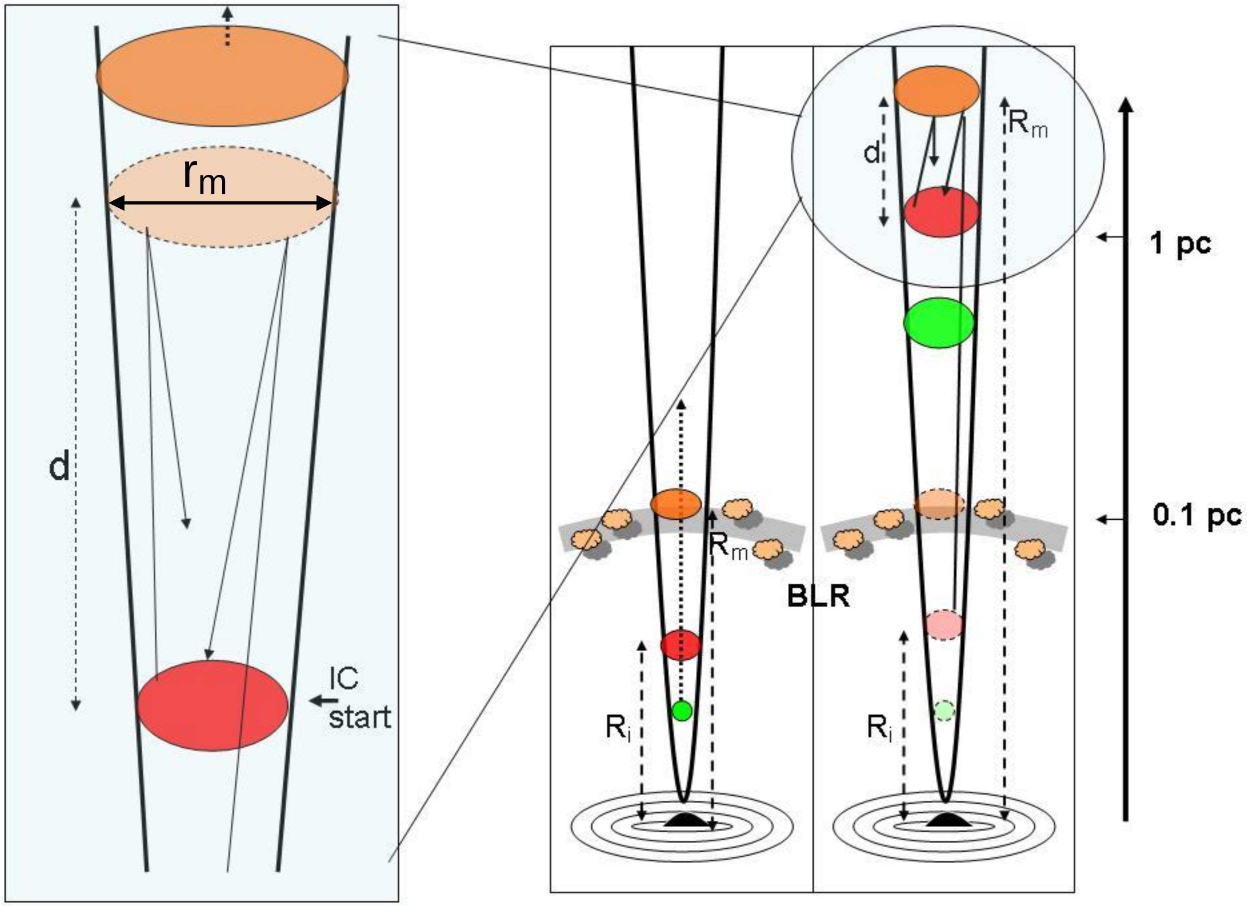
3C 279 shows in detail different kinds of correlation opt - γ.

The correlation is often absent.

Moreover, the decay of Flare 2 is very abrupt.



To account for these complex behaviours, some variations are required in the external photon field seen by the moving blob!



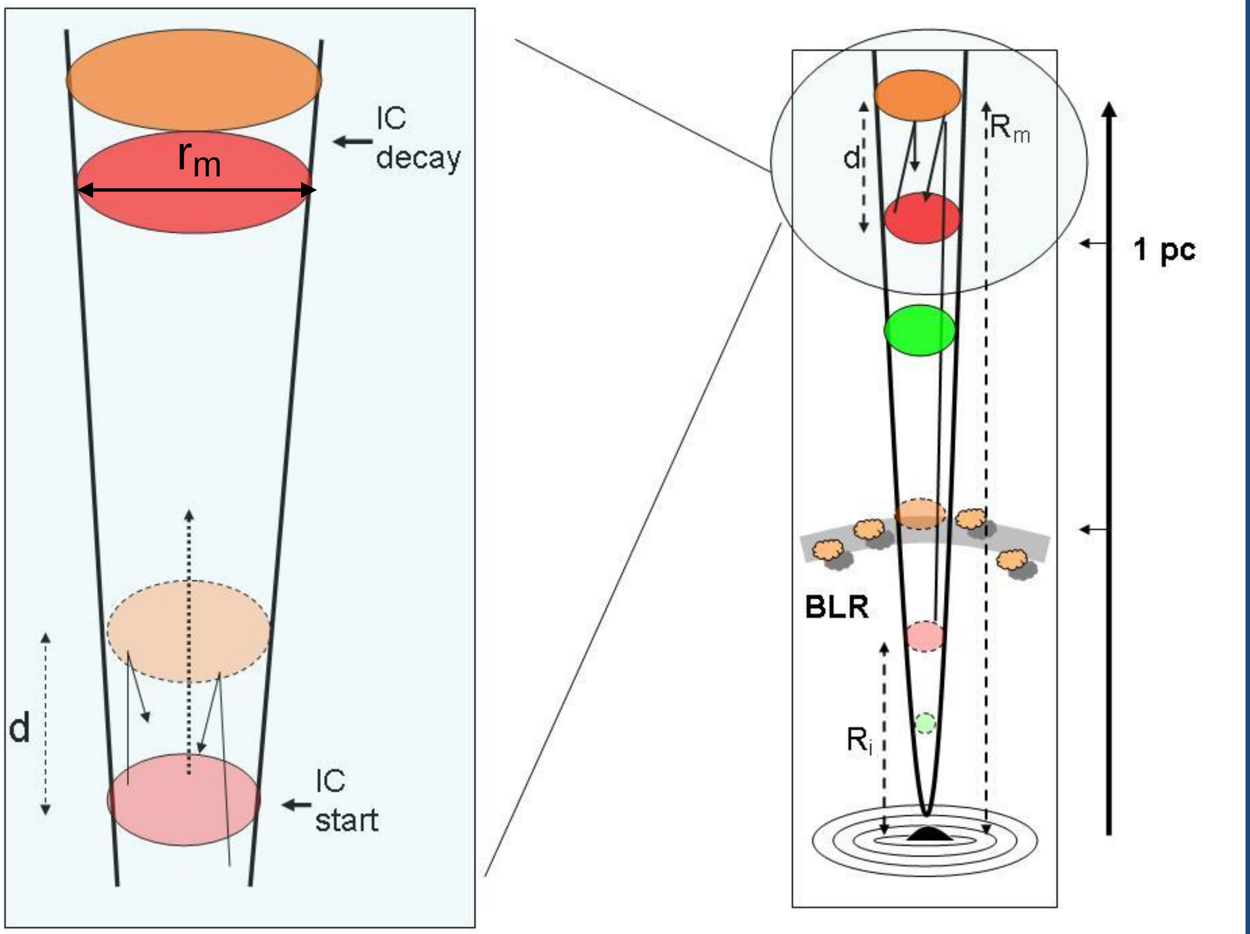
Mirroring between the leading plasmoid and the following others is a viable model to provide local variations in the external seed photons seen by a blob.

Photons emitted at R_i are reflected by the mirror at the larger distance R_m and re-enter the emitter when the latter approaches the mirror at distance $d = R_m (2\Gamma_e)^{-2}$.

EC starts with seed photon density $U'_m = \frac{f\, L'_s \Gamma_e^4\, r_m^2}{\pi\, c\, R_m^2\, d^2} > U'_{BLR}$

and rises with timescale $\frac{d}{c\, \Gamma_e^2}$ half day

Here $\Gamma_e = 5$ is the relative boost-factor between mirror and emitter, and $f = 0.1$ the mirror reflectivity.



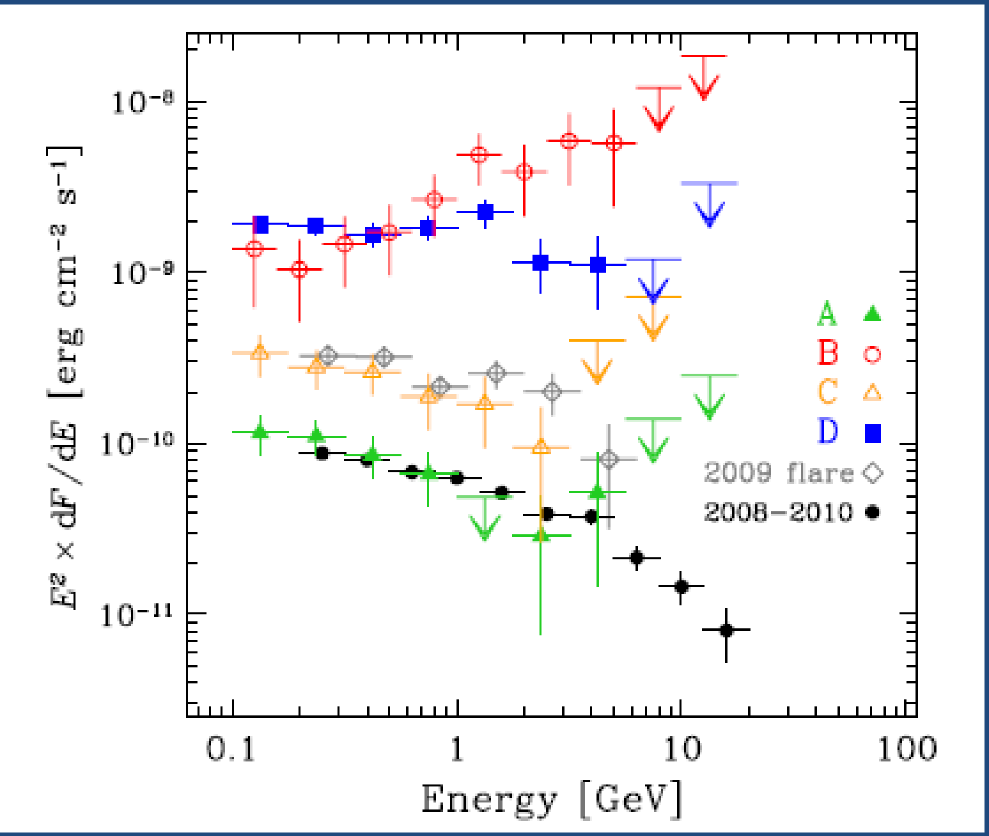
EC decays when **d → r_m** by de-boosting of the local photon field when the emitting blob pass the mirror and moves away.

Then the decay can be abrupt because **U'_m** decreases by a factor **Γ_e^{-8}** with time-scale

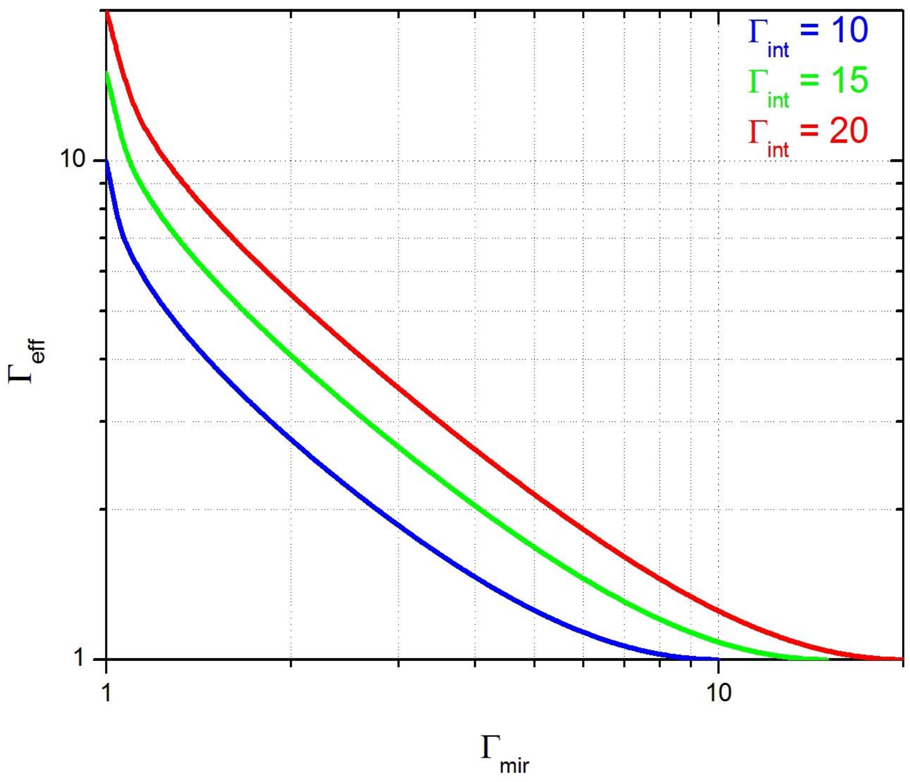
$$\frac{r_m}{c\,\Gamma_e^2}$$ few hours

But if radiation pressure or the emmitting blob itself push away the mirror, the decay is slower and IC cooling also concurs.

$$\tau_{\gamma\gamma} = U'_m\, \varepsilon'^{-1}_m\, \sigma_{\gamma\gamma}\, d \;=\; 0.1\, \frac{f_{-1}\, L'_{42}\, r^2_{m\,16}\, \Gamma^6_{e\,1}}{(R_m / pc)^4\, (\varepsilon'_m / 10eV)}$$ at 0.1 TeV



Absorption of γ-ray photons that interact with the mirror seed photons is negligible and The spectrum can be hard at 100 GeV



Here we plot the relative boost factor

$$\Gamma_e = \Gamma_m \Gamma_{int} (1 - \beta_m \beta_{int})$$

between mirror
and emitter as a function of the mirror boost Γ_m and the emitter boost Γ_{int}

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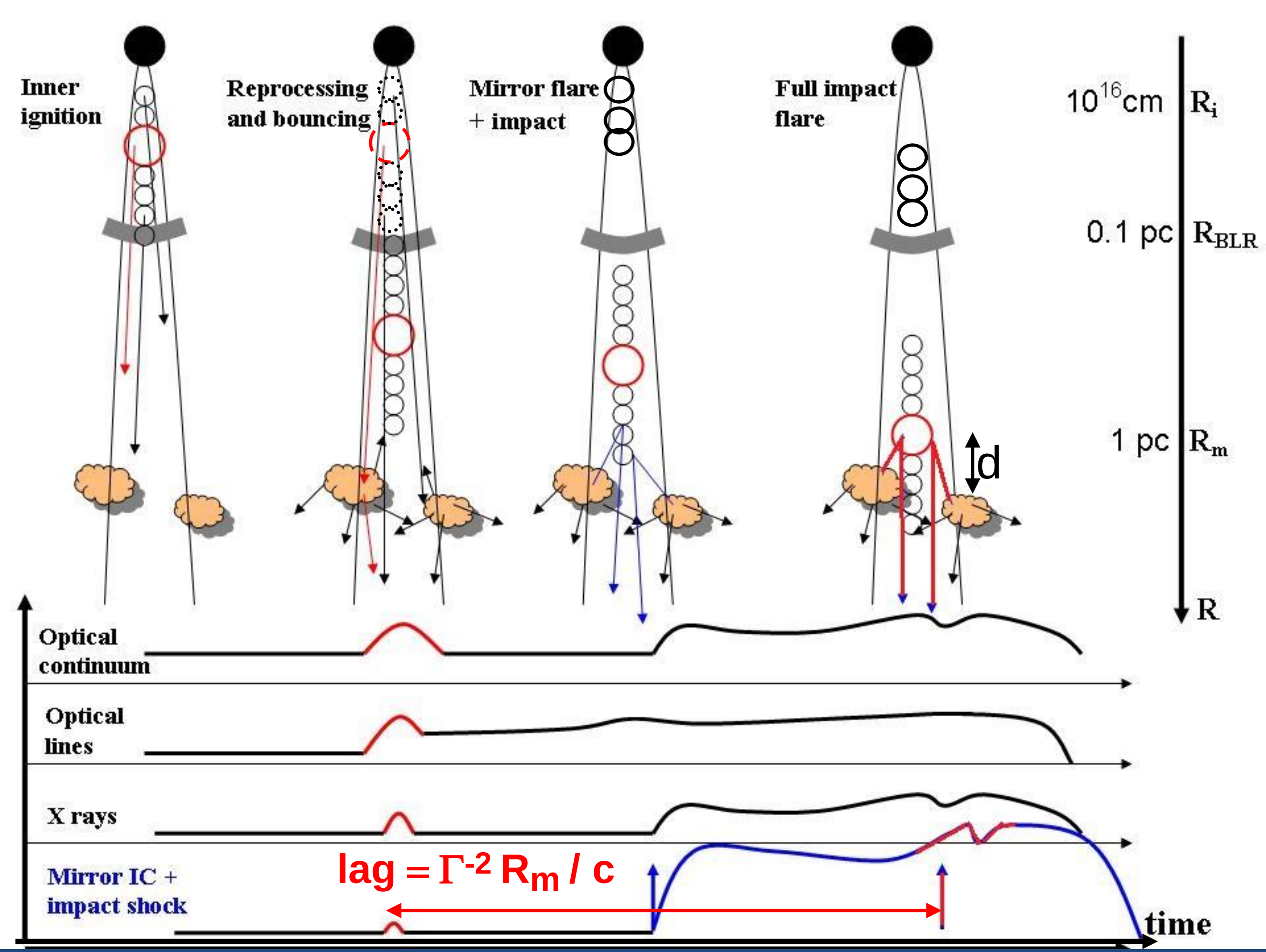
Summary

Ejection of several plasmoids seem unavoidable in order to account for the complex **optical vs. γ-ray** behaviour, a train of plasmoids can be provided by magnetical reconnection event (see Nalewaiko et al. 2015).

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 or leading blob in the train ensures **fast optical events within the BLR** with **fast γ-ray emission at pc-scales** correlated with **lag of weeks**, and **γ-ray orphan flares**.

Absorption by pair-production is mild and the γ-ray spectrum can be **hard at 10 GeV**.



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

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

$\Delta t_{obs} = (d+r)/(c\Gamma^2)$
Is the observed duration

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

Adequate γ amplification

Rise-time of few hours

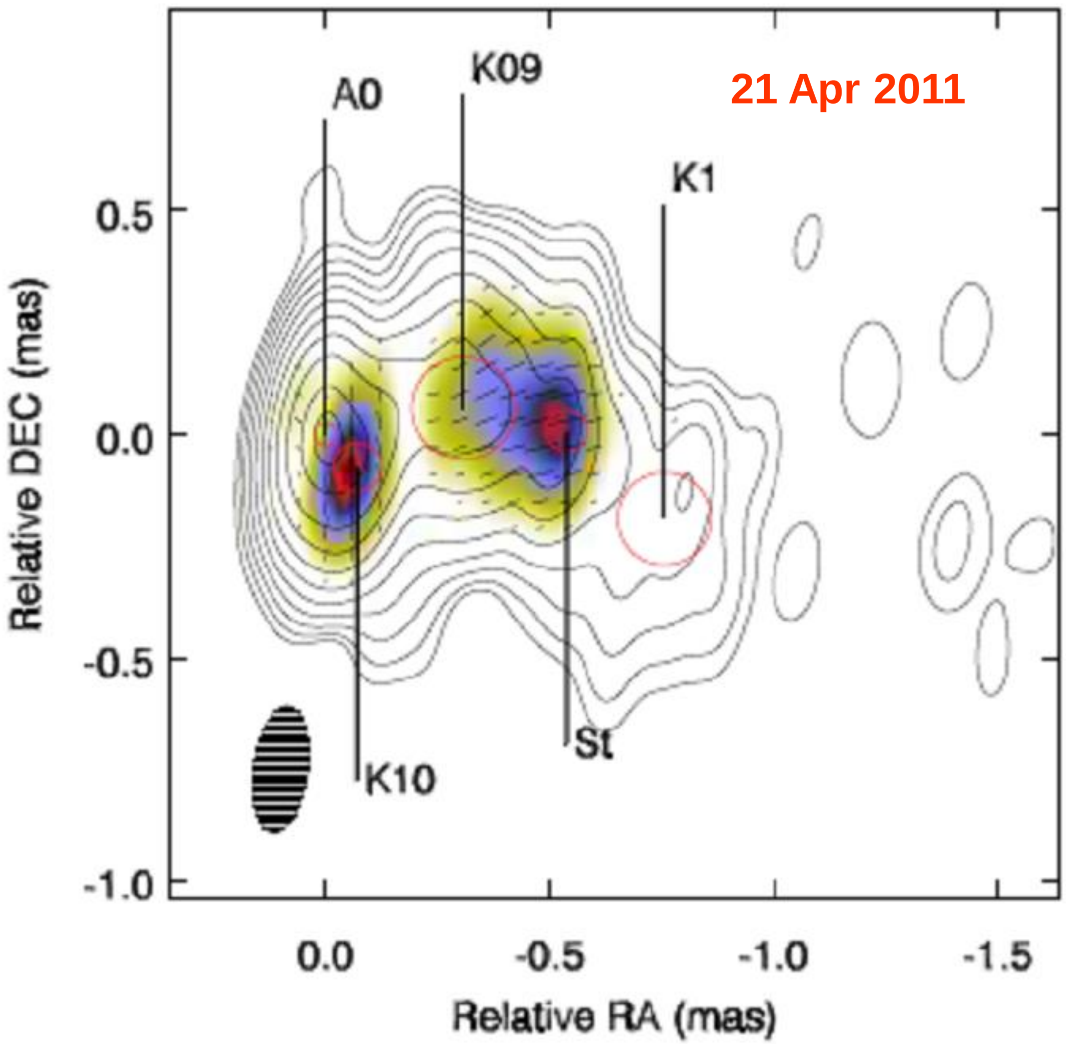
Shock delay of half hour

γ-ray emitted at pc scale

Optical precursor with 30% line enhancement

…And beyond the BLR? (case 2b)

Vittorini et al. 2014 ApJ submitted



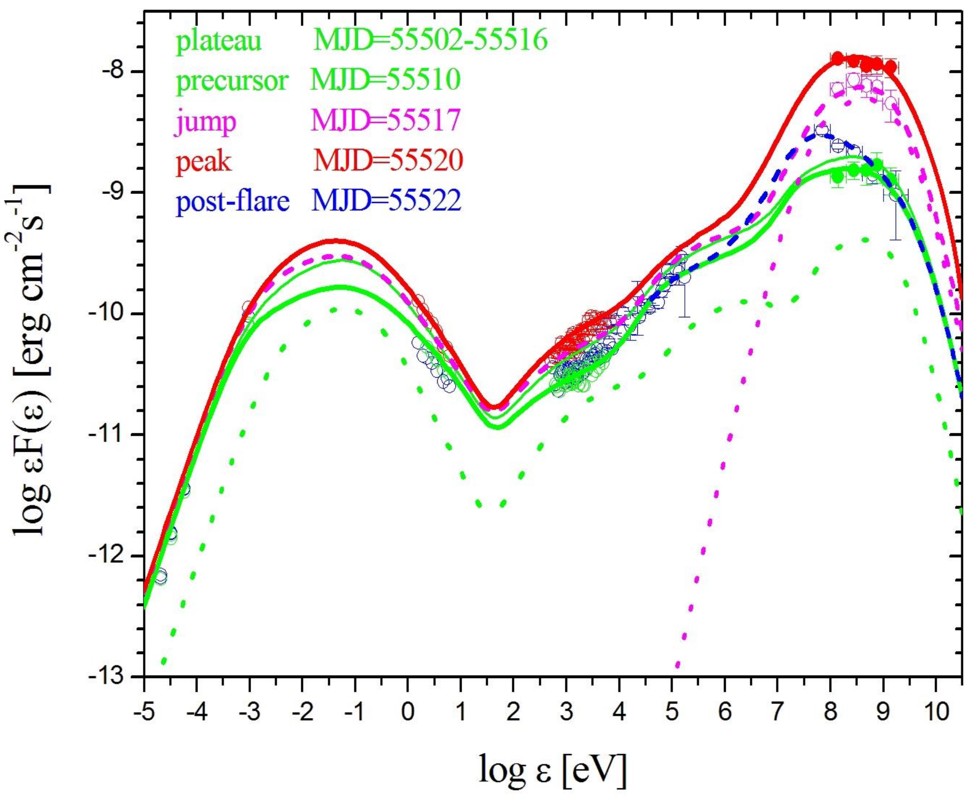
The knot K10 emerges from the core **T=160** days after the flare (Jorstad et al. 2012).

With a jet opening angle 1.6° K10 traveled **R_c=16** pc before being resolved.

For **Γ = 10** and **$\theta = \Gamma^{-1}$** the predicted lag is
$T=(1-\beta\cos\theta)\ R_c\ /\ c$
$T=\Gamma^{-2}R_c\ /\ c$ = 0.5 years

3C 454 in Nov. 2010

Vittorini et al. 2014
ApJ submitted



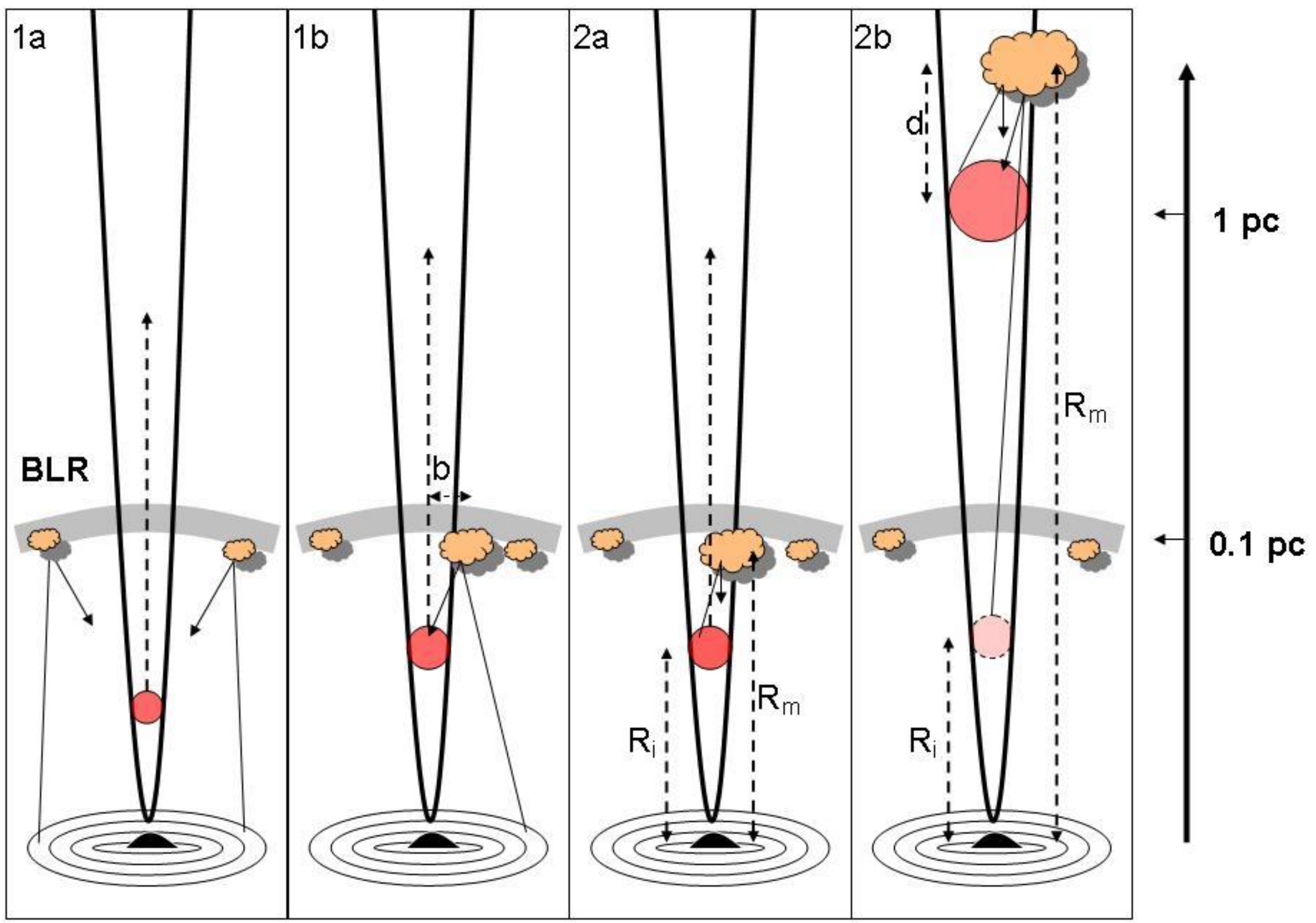
This idea explains the SED during the entire period of activity, by **a plasmoid train:**

Plasmoids are continuosly 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 = few pc**, strong mirror-EC is produced causing the **jump** in **γ rays** with **ρ > 2** !

The **peak** in **γ 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 days** with **Γ=10**

Four models for EC from mirrors



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

1b: **EC from a single mirror reprocessing the disk radiation**

2a: **a single mirror reflects the approaching blob within the BLR**

2b: **same as 2a, but beyond the BLR**

Vittorini et al. 2014 ApJ submitted