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 $\rho = 1$).

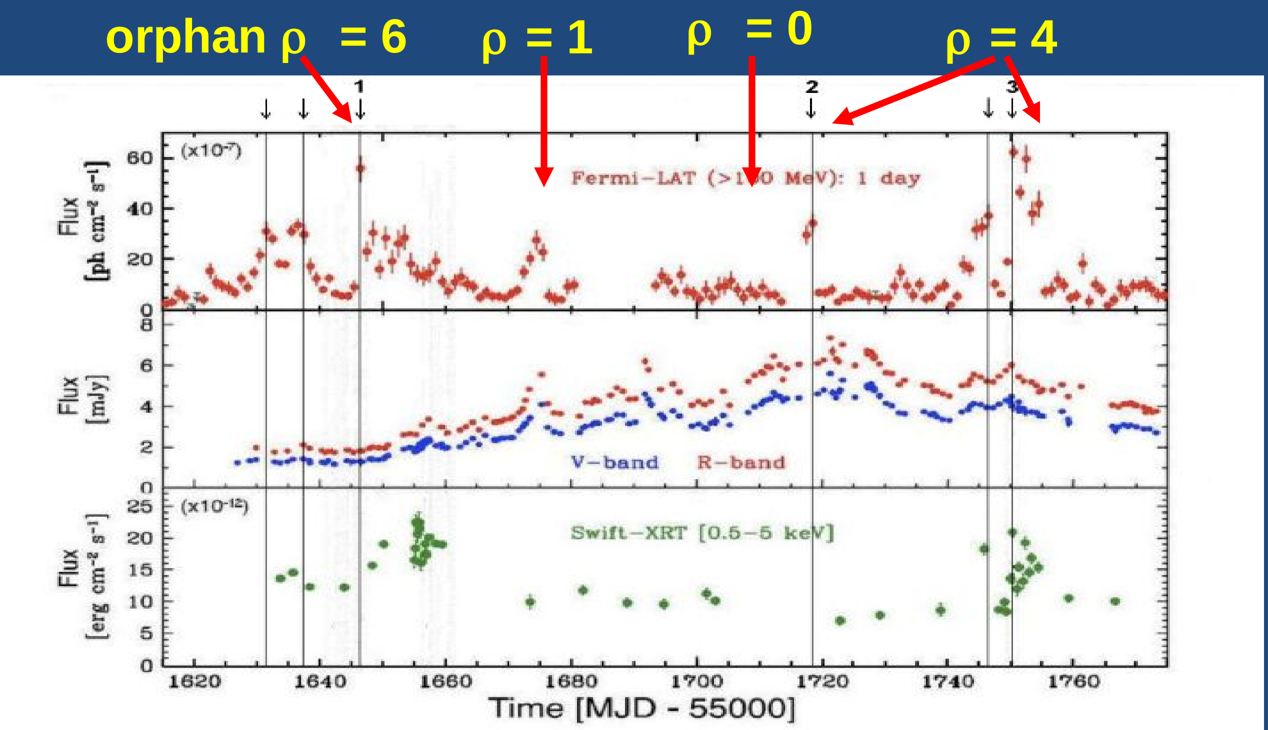
Moreover, in these events the correlation between γ-ray and optical bands is often absent,

The Compton dominance attains values 100 or more,

γ-flux shows doubling time of few minutes!

high energy spectrum can be unusually hard.

V.Vittorini, M. Tavani, A. Cavaliere
on behalf of the AGILE AGN WG

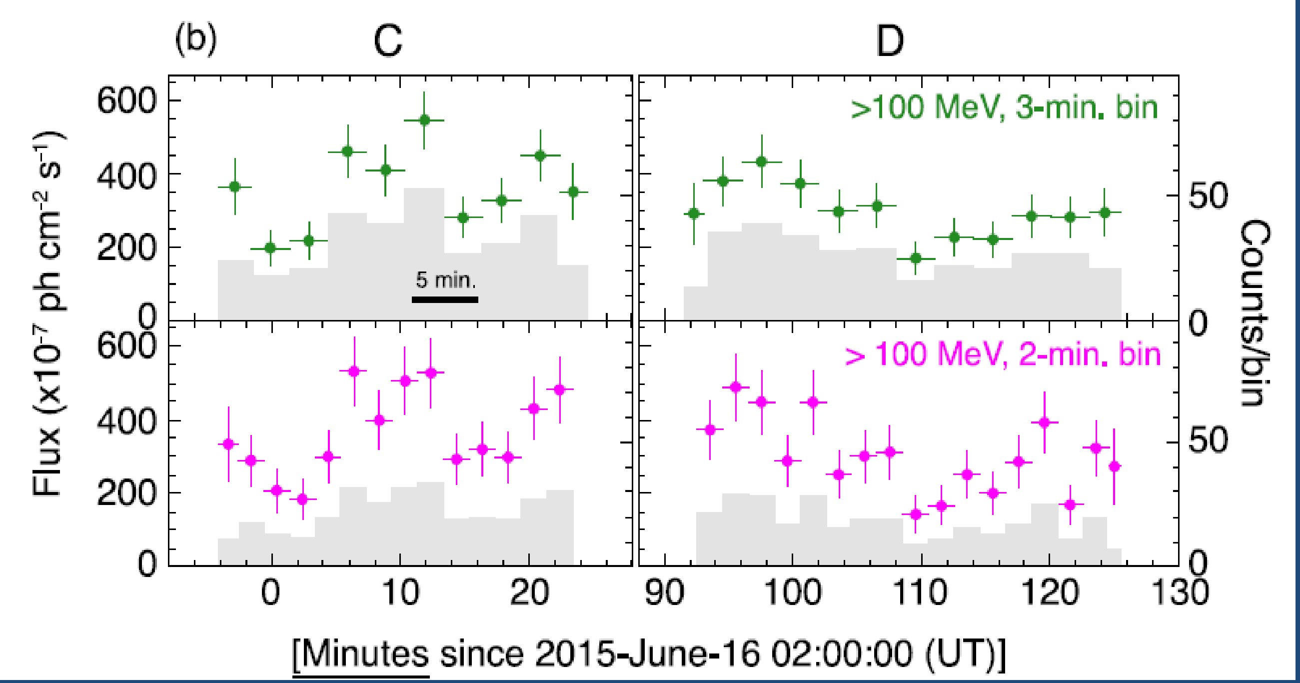


3C 279 shows in detail different kinds of correlation opt - γ.

The correlation is often absent.

Compton dominance rises to values > 100 in few hours.

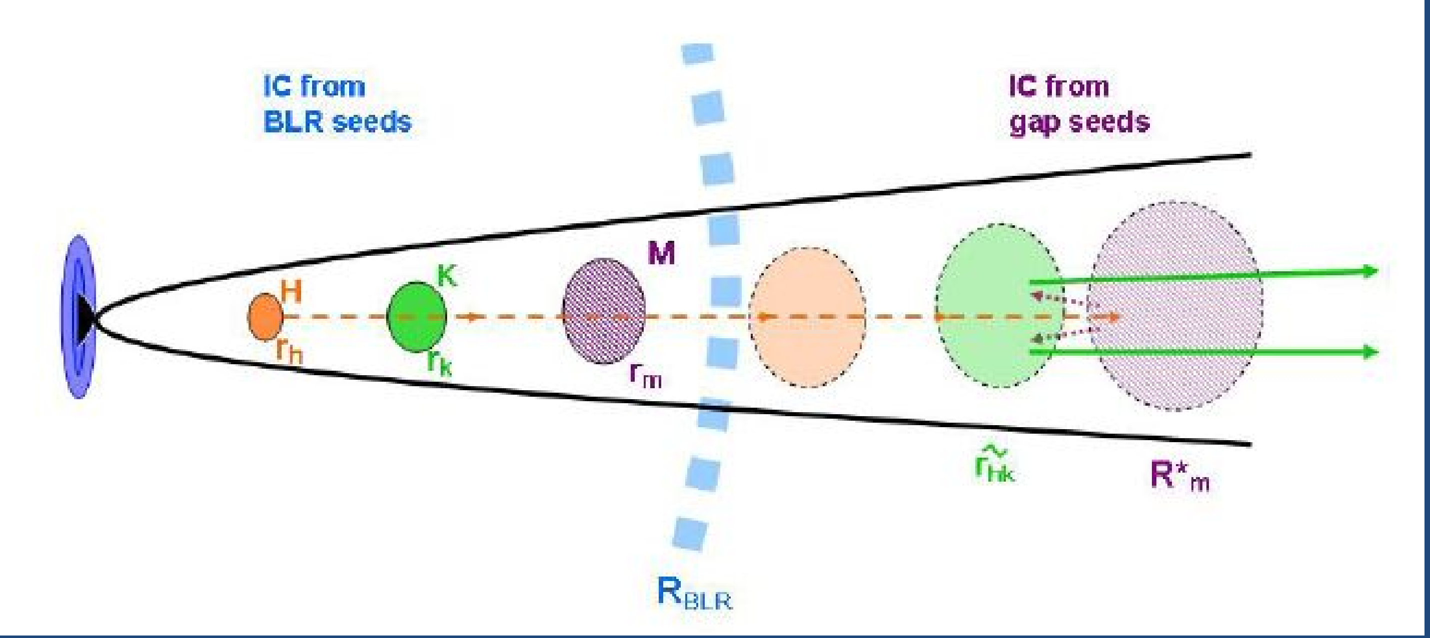
(Data: Hayashida et al. 2015)



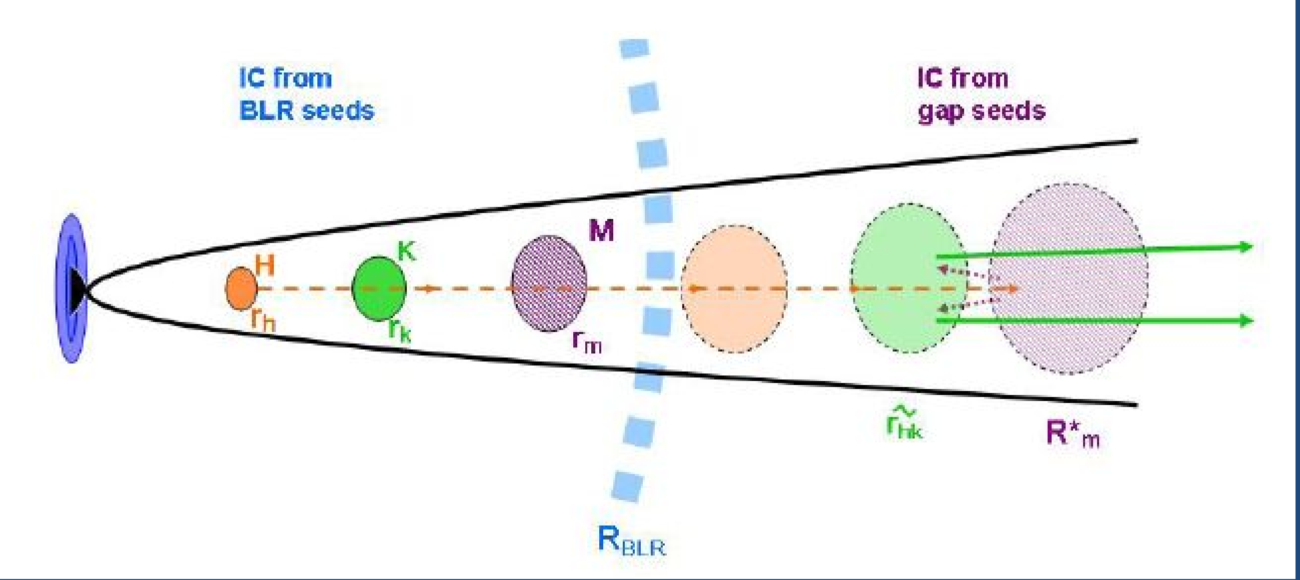
Here the Compton dominance rises in few **minutes**!

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

(Data: Ackermann et al. 2016)



Mirroring between the leading plasmoid and the following others provide local variations in the external seed photons seen by an incoming blob.



Photons emitted within the BLR are reflected far at

$R^*_m \sim 2 r_m \Gamma_m^2$

and re-enter when the incoming blob is close to the reflection point, in a small gap **$d_g \sim R_{BLR} (2\Gamma_r)^{-2}$**

Here reconnection events are favoured.

($\Gamma_r \sim \Gamma_h / 2\Gamma_m$ is the relative boost beetwen blobs and mirror)

In the blob-frame the seed photon density due to the BLR is

$U'_{BLR} \sim 7\ 10^{-3}\ L_{D,46}\ \Gamma_k^2$ erg cm^{-3}

and the synchrotron energy density is

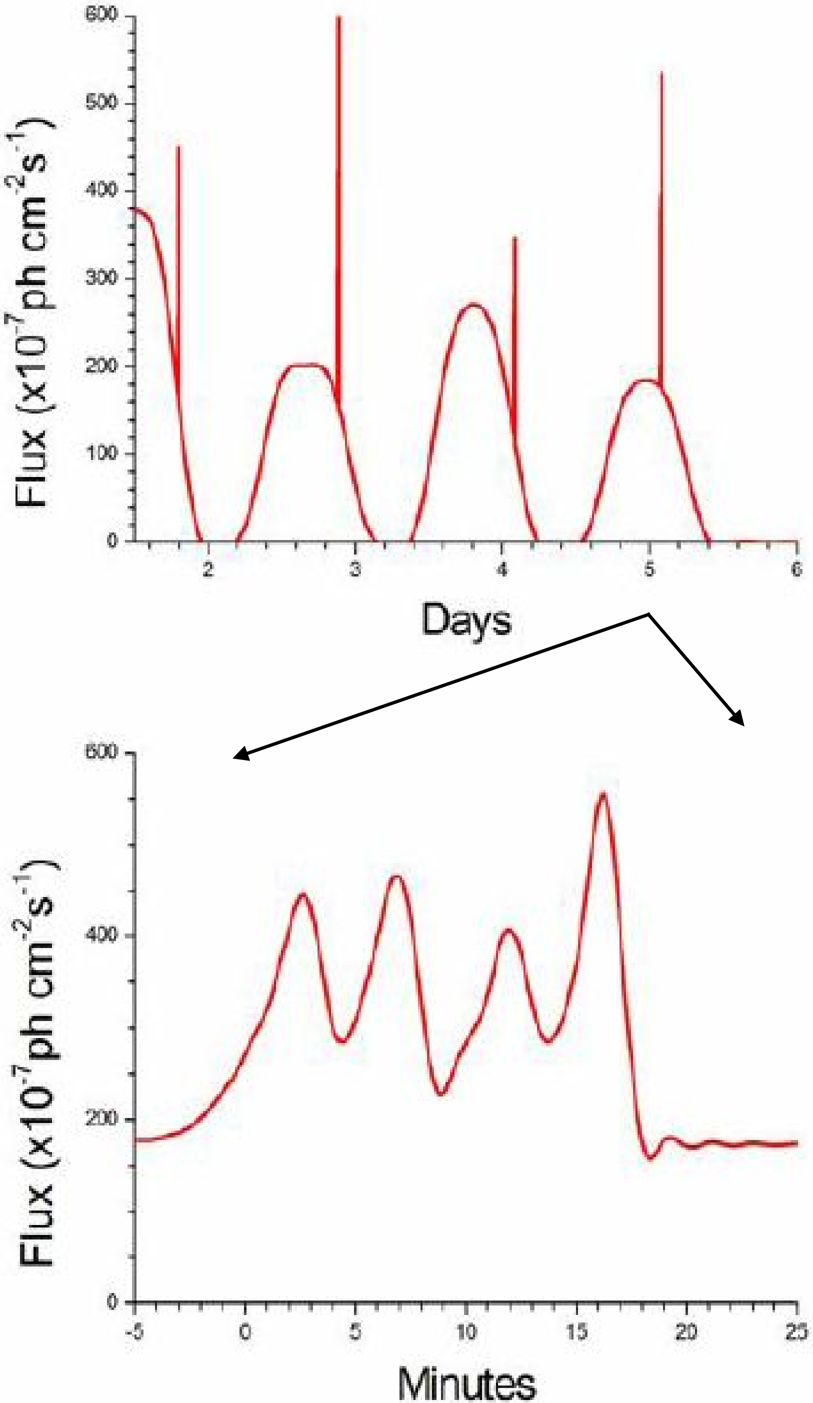
$U'_{syn} = B^2 / 8\pi \sim 4\ 10^{-2}$ erg cm^{-3}

In the gap the mirrored seed density attains

$U'_m \sim 2\ 10^{-1}\ f_{-1}\ L'_{syn,43}\ l_{m,16}^{-2}\ \Gamma_r^4$

and we can observe γ - flares rising to Compton dominance **~ 100** with rise-time **$R_{BLR} / 8c\Gamma_k^2\Gamma_r^2$** of minutes.

Here **$\Gamma_r = 5$** is the relative boost-factor between blobs and mirror, and **f = 0.1** the mirror reflectivity.



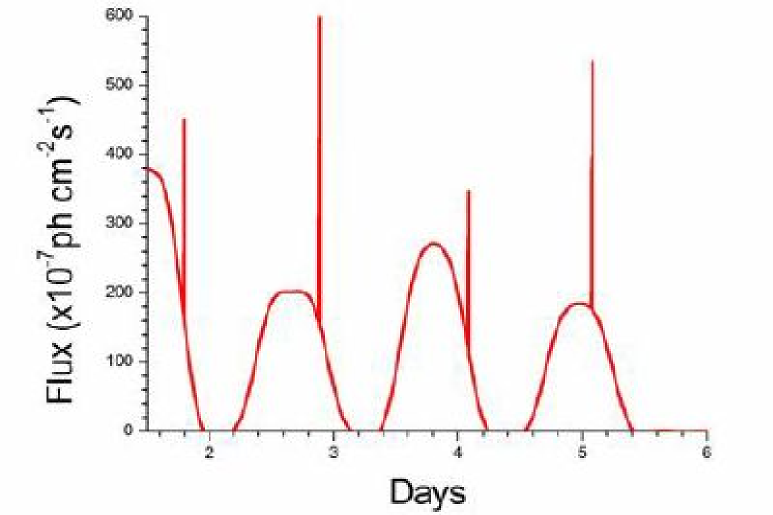
We observe strong mirror IC emission in γ rays up to **10^{49} erg / s** and Compton dominance **$U'_m / U'_B \sim 10^2$**

attained with rise time **$(1+z)\Gamma_m^2 R_{BLR} / (4c\Gamma^4) \sim$ minutes!** when **$\Gamma \sim 20$ and $\Gamma_m \sim 2$** hold

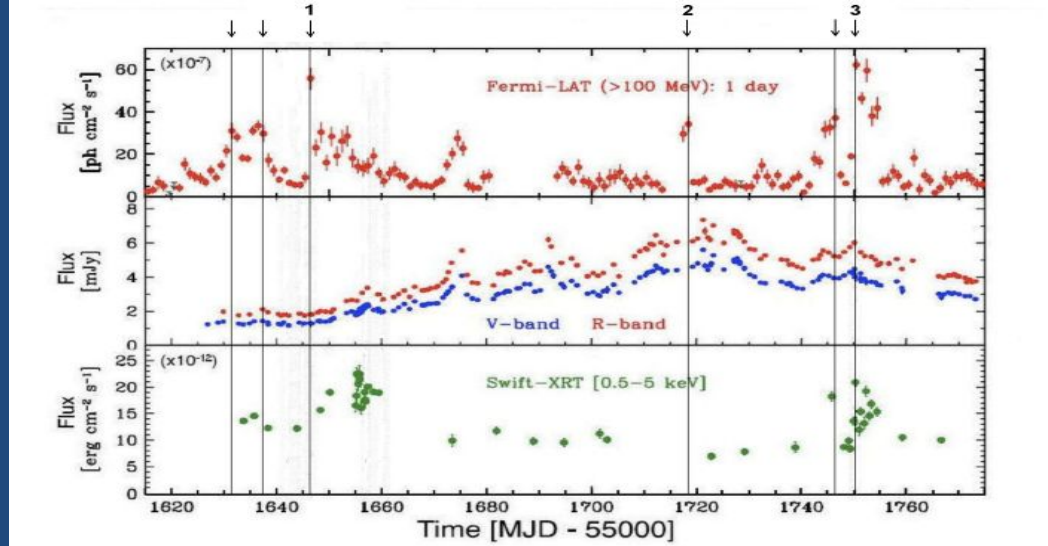
These γ-spikes appear delayed by **$R_m^* / 2c\Gamma^2 \sim$ half day** to respect the optical emitted within the BLR

Moreover, the absorption by pair production **$\sigma_T U_m d_g / 3\varepsilon \sim 0.3$** is low being the absorption path **$d_g \sim 3\ 10^{15}$ cm** small.

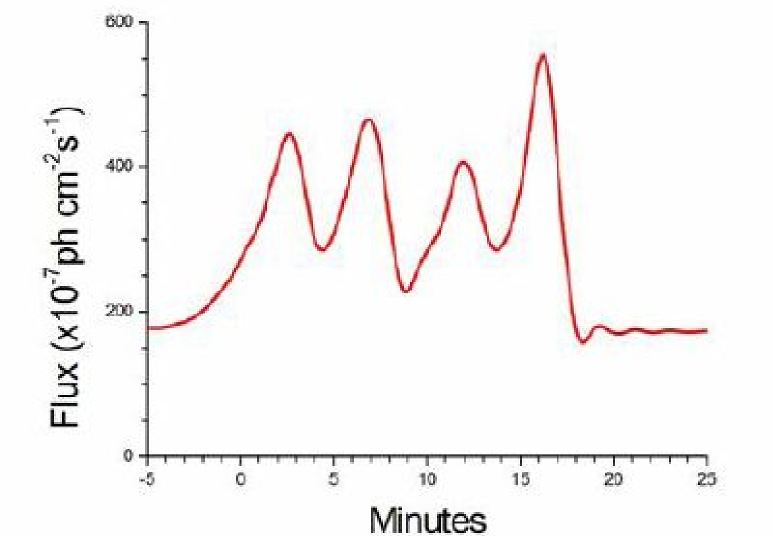
(Vittorini, Tavani & Cavaliere submitted to ApJL)



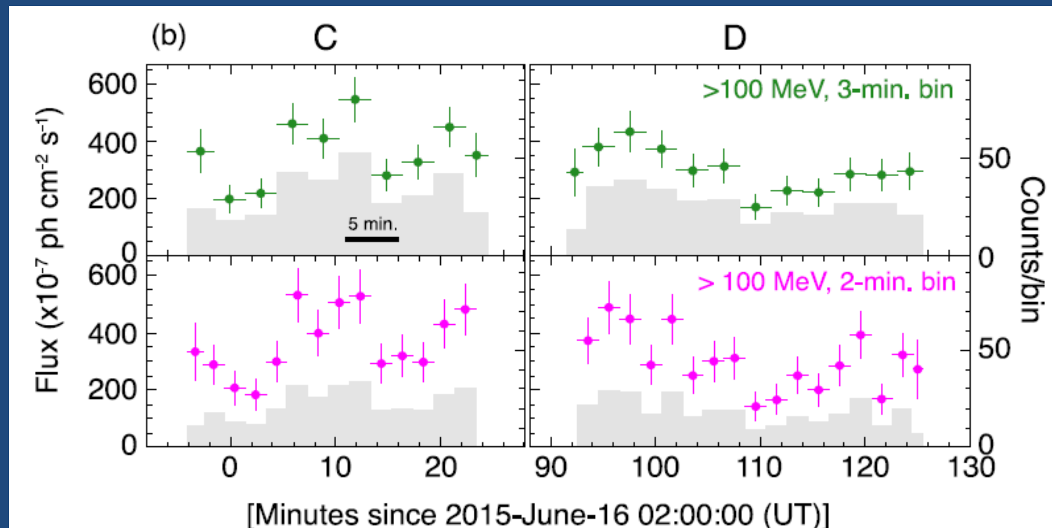
Flux (x10^{-7}ph cm^{-2}s^{-1})
Days



Fermi-LAT (>100 MeV): 1 day
V-band R-band
Swift-XRT [0.5-5 keV]
Time [MJD - 55000]

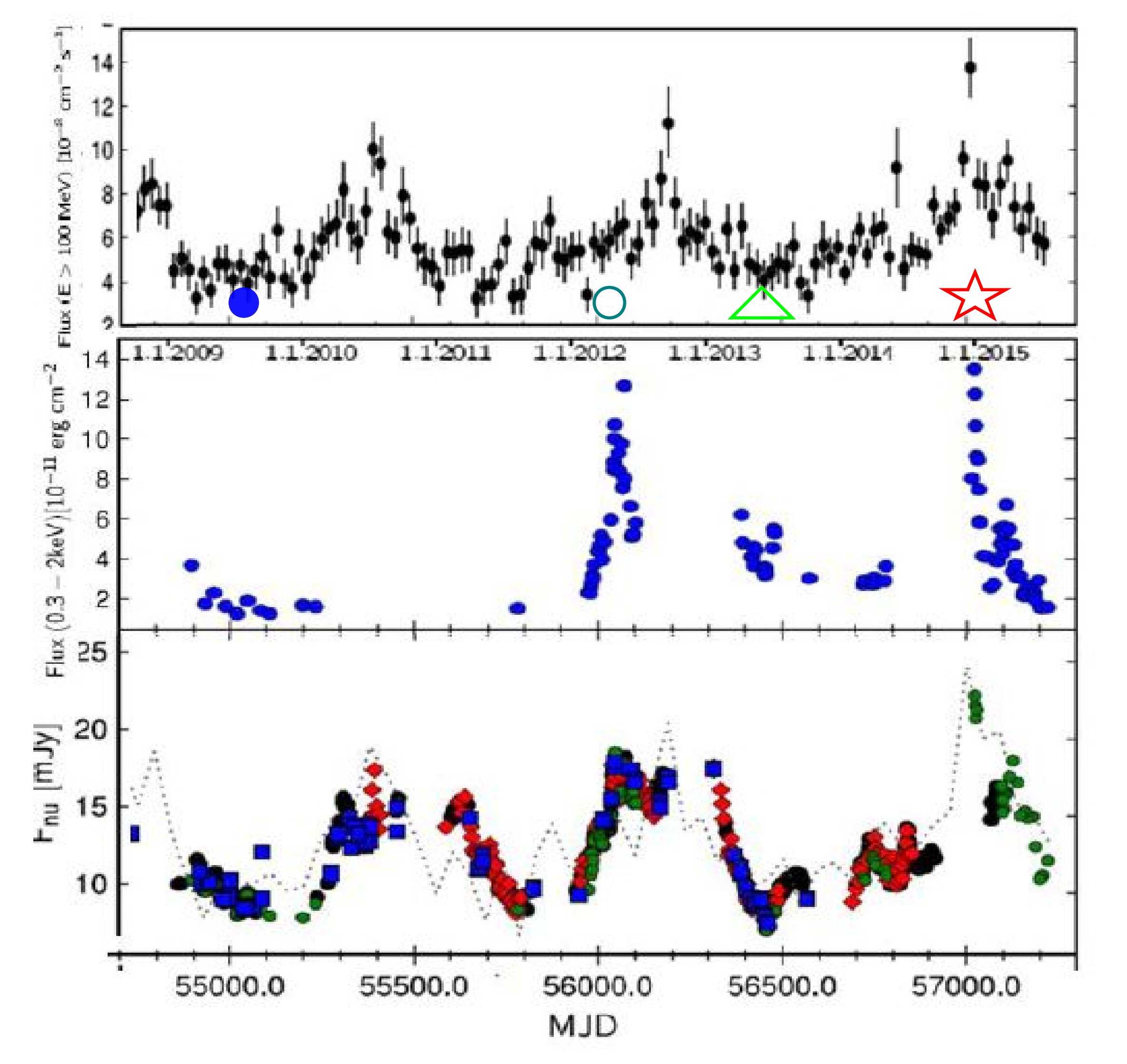


Flux (x10^{-7}ph cm^{-2}s^{-1})
Minutes

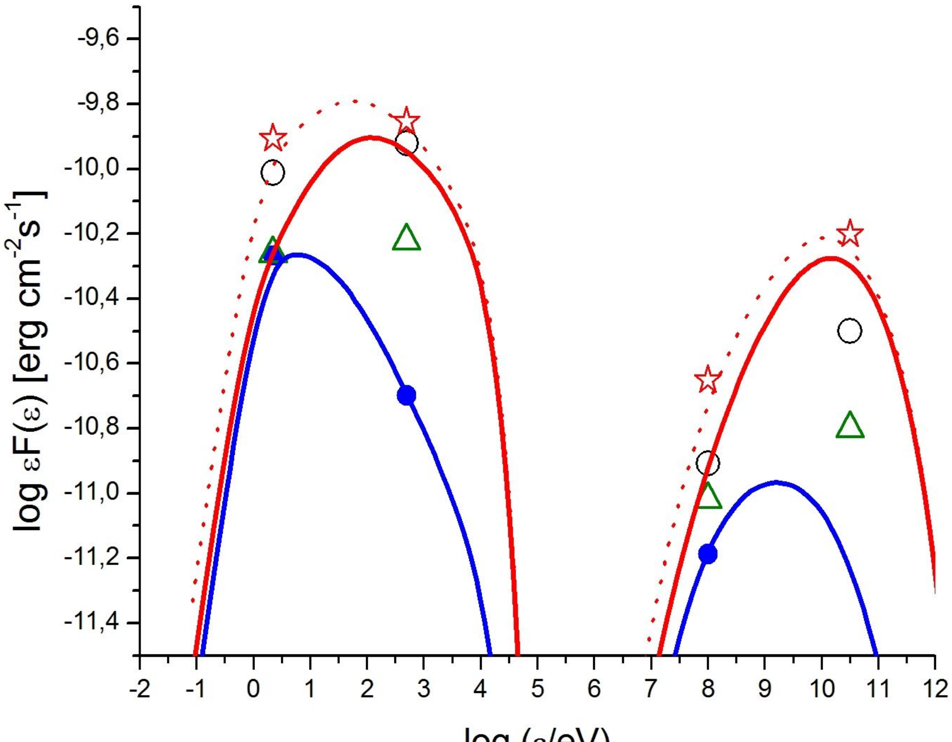


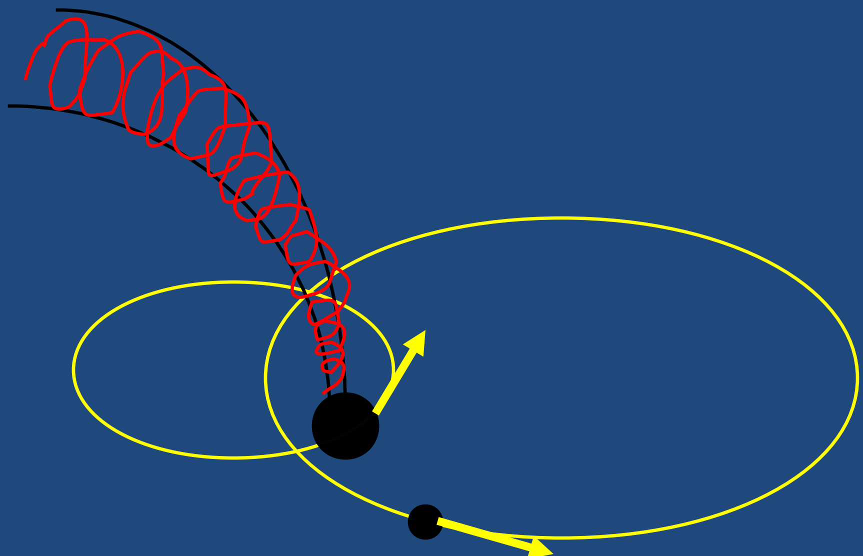
(b)
C
D
>100 MeV, 3-min. bin
> 100 MeV, 2-min. bin
5 min.
Flux (x10^{-7} ph cm^{-2} s^{-1})
Counts/bin
[Minutes since 2015-June-16 02:00:00 (UT)]

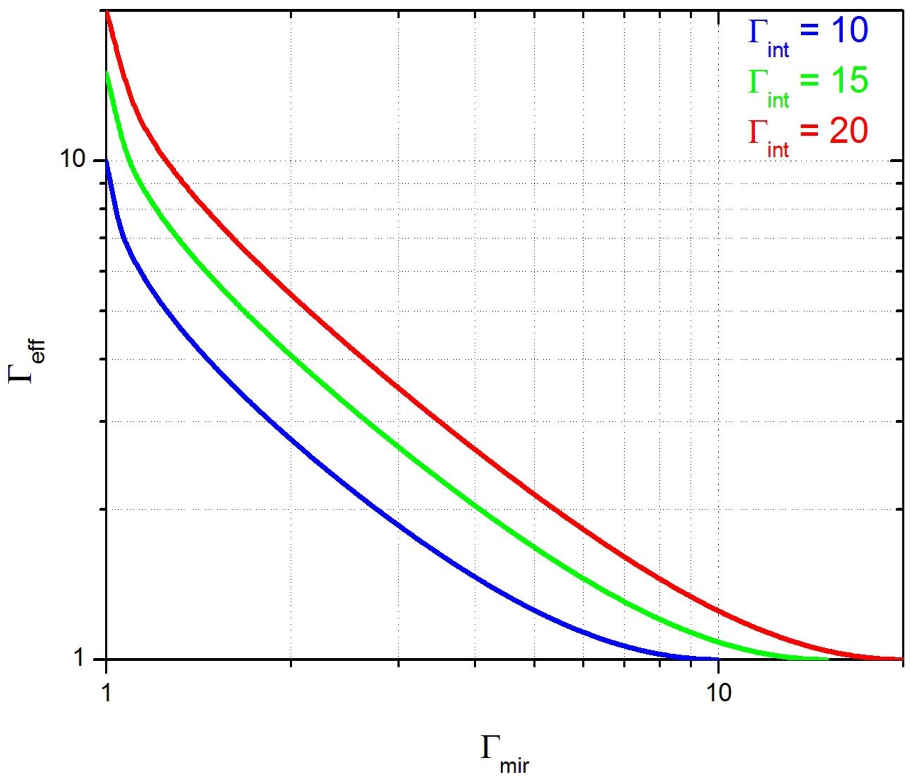
PG 1553



Flux (E > 100 MeV) [10⁻⁸ cm⁻² s⁻¹]
14
12
10
8
6
4
2
1.1.2009
1.1.2010
1.1.2011
1.1.2012
1.1.2013
1.1.2014
1.1.2015
Flux (0.3 – 2keV) [10⁻¹¹ erg cm⁻²
14
12
10
8
6
4
2
F_nu [mJy]
25
20
15
10
55000.0
55500.0
56000.0
56500.0
57000.0
MJD


log εF(ε) [erg cm-2s-1]
-9,6
-9,8
-10,0
-10,2
-10,4
-10,6
-10,8
-11,0
-11,2
-11,4
-2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
log (ε/eV)

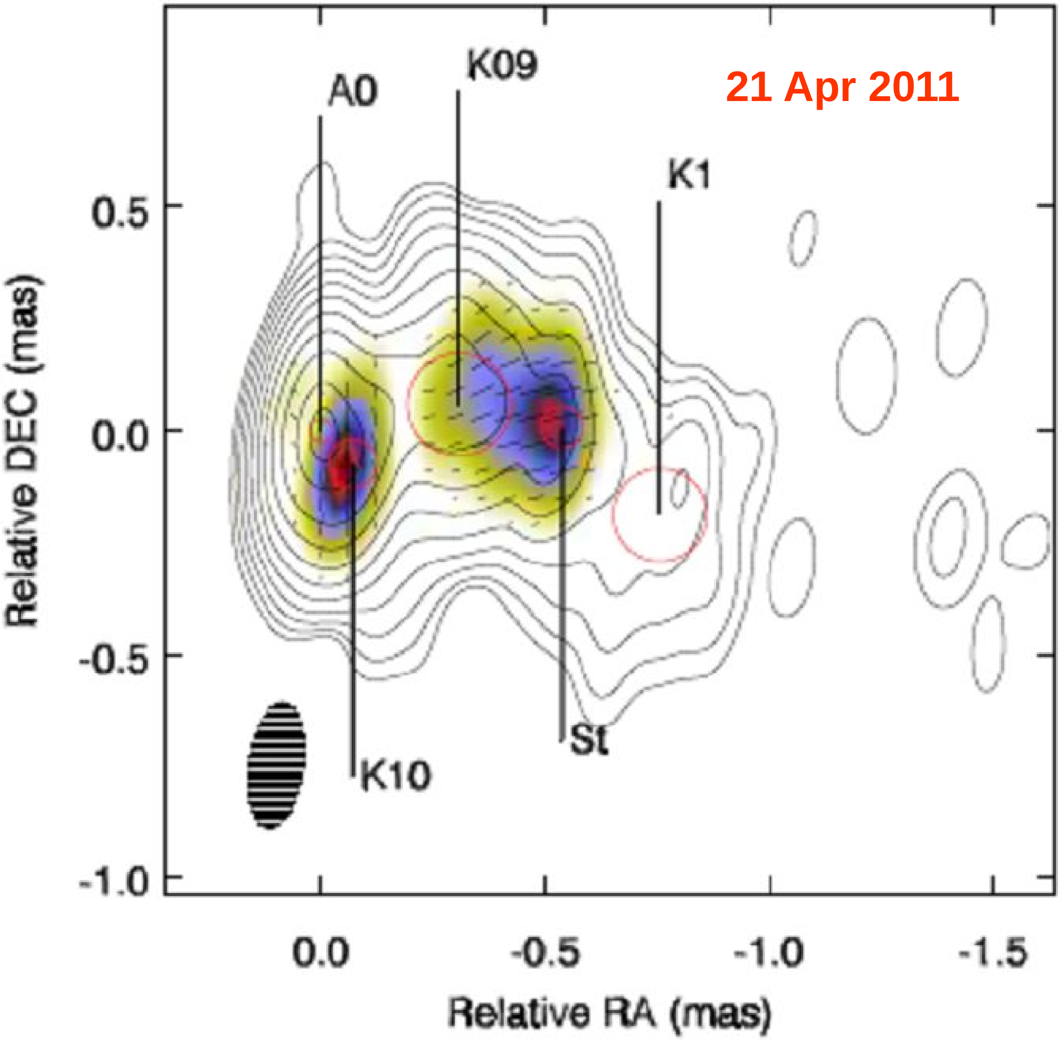




Here we plot the relative boost factor

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

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



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

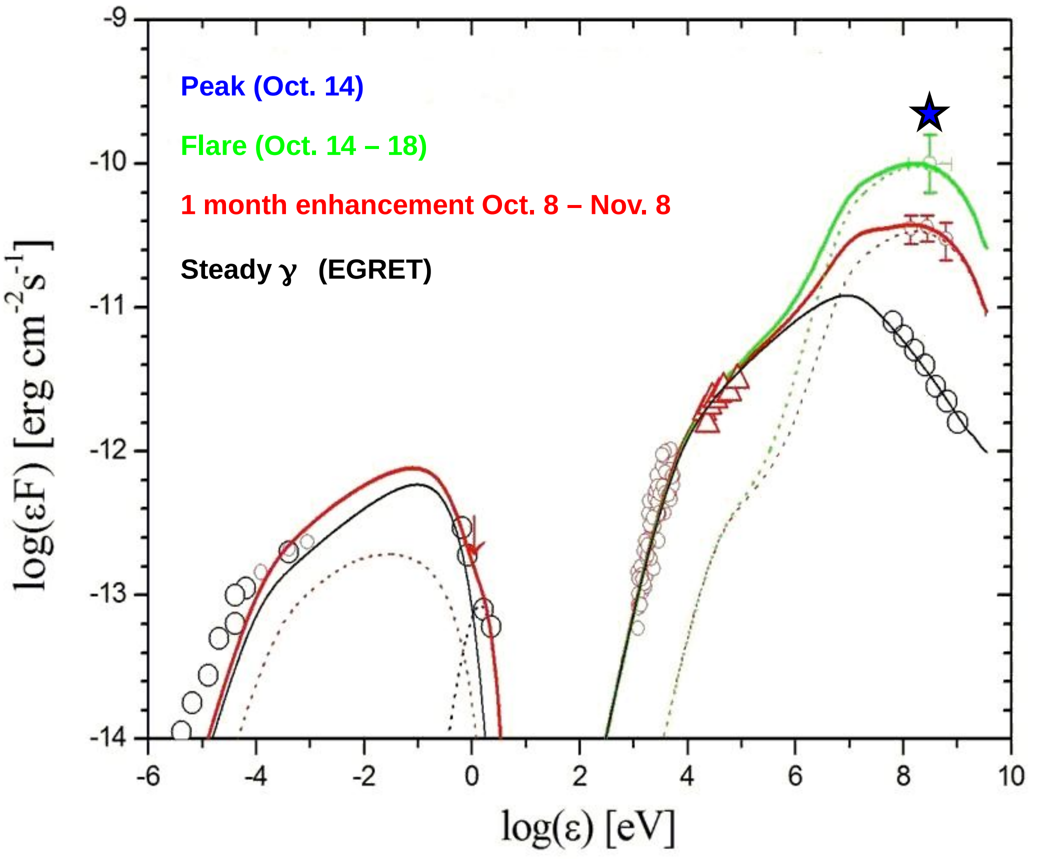
With a jet opening angle 1.6° K10 traveled **R_c=16** pc before being resolved.

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

PKS 1830: an extreme instance



Ciprini et al. 2010; Donnarumma et al. 2011

Orphan gamma-flare during a montly activity

(A_γ=3):
Optical and X-ray remain at hystorical steady levels.

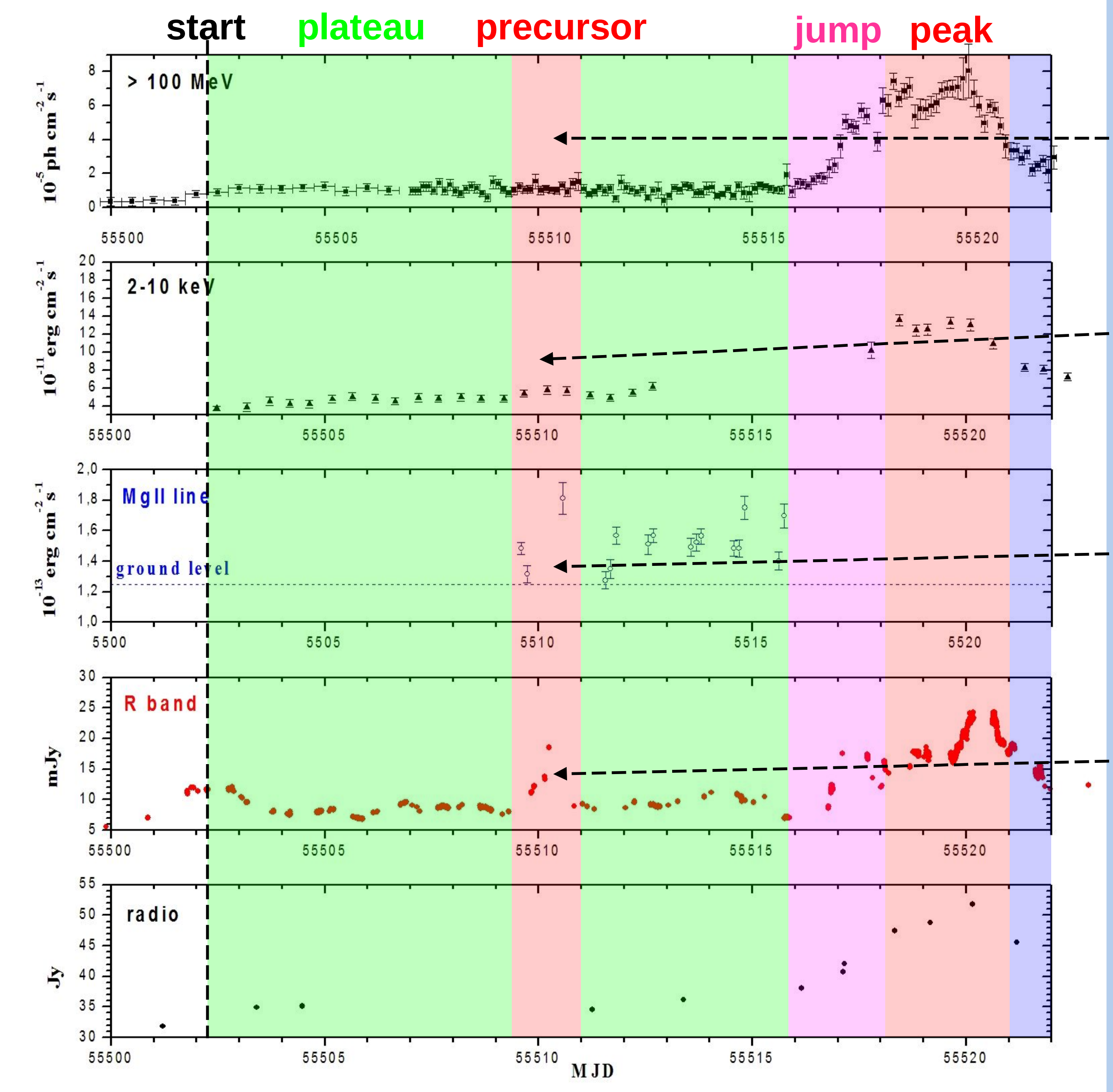
A second component of shocked particles (red dotted lines) can account for this **monthly enhancement** in gamma-rays with little or no contributions in optical and X-rays.

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 !

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 $\rho = 1$

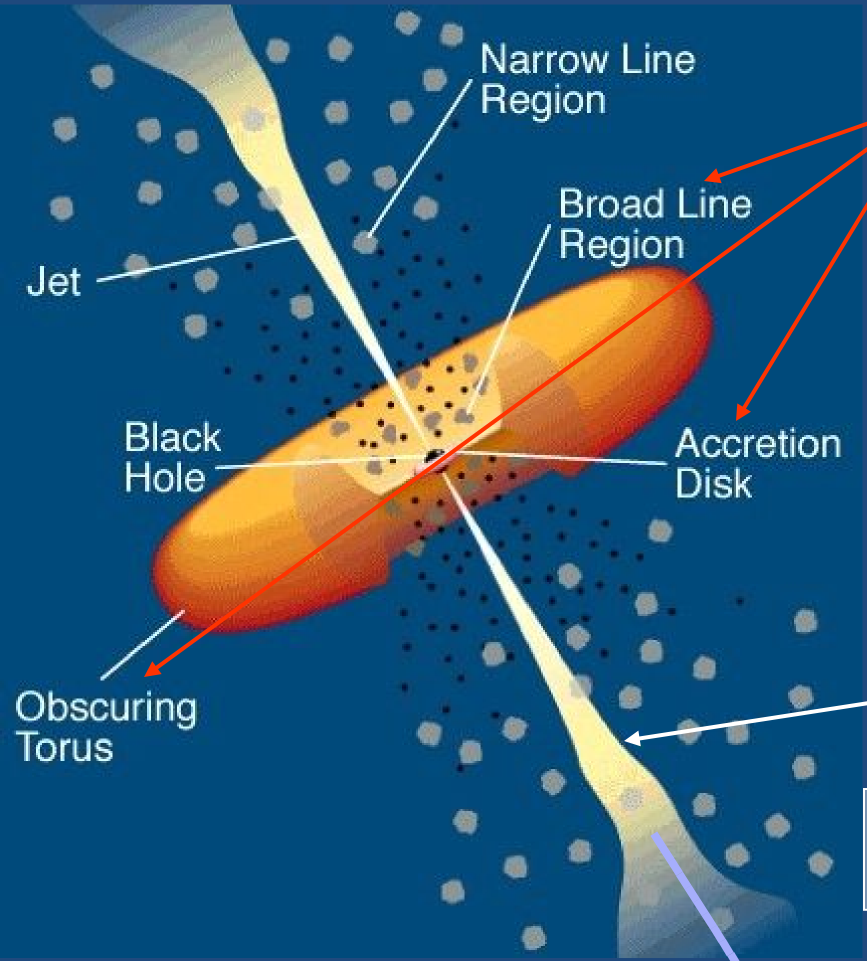
Faint soft X-ray counterpart
(SC plays a secondary role!)

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

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

Γ

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

produce

Synchrotron + Inverse Compton (SSC)