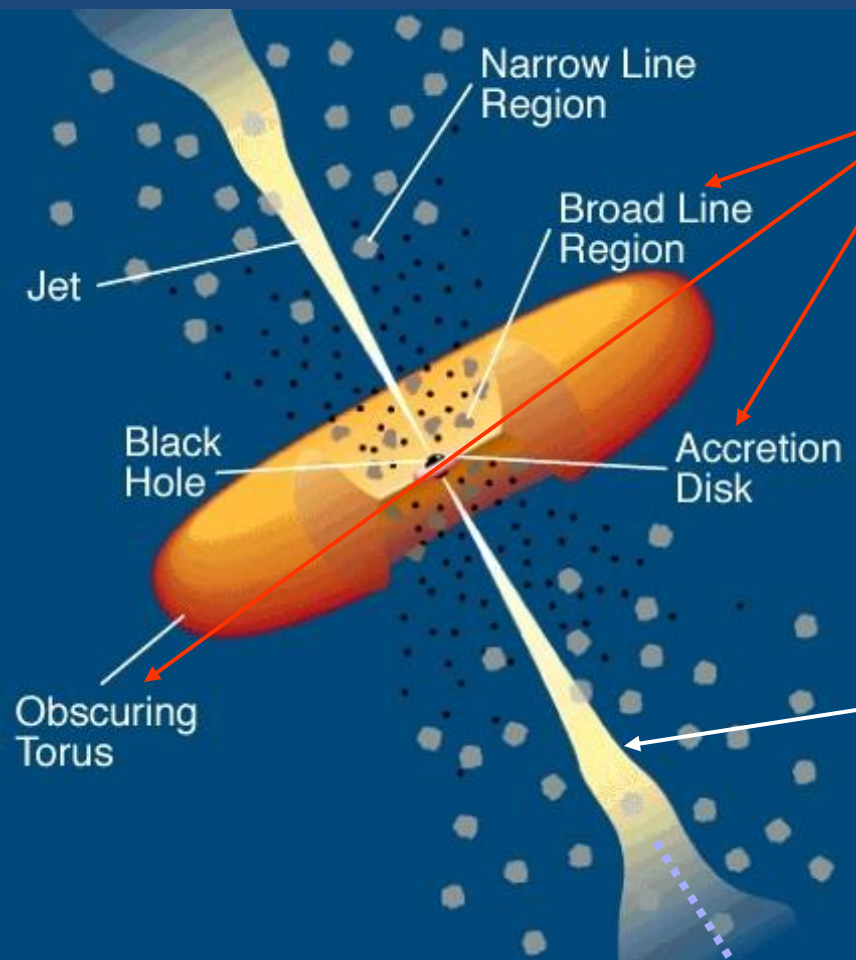


# Gamma-ray flares from 3C454 and PKS 1830 in late 2010: electron energization in the jet is not enough!

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# FSRQ model



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

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

produce

**External Compton (EC)**

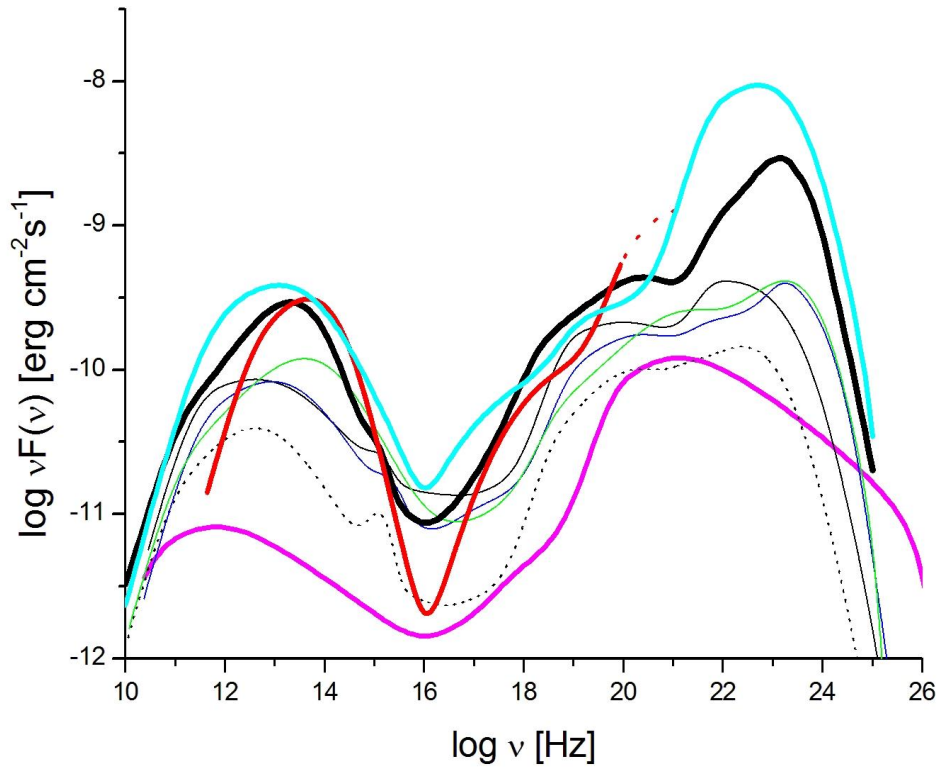
**Jet:** blob moving with Lorentz factor  $\Gamma$ ,  
beamed, non thermal radiation

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

produce

**Synchrotron + Inverse Compton (SSC)**

# 3C 454 over the last 10 years

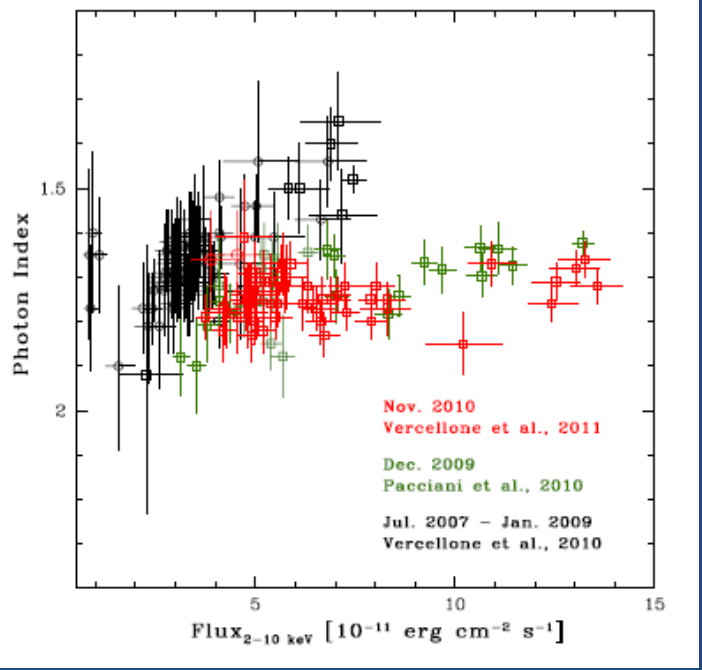


AGILE AGN WG

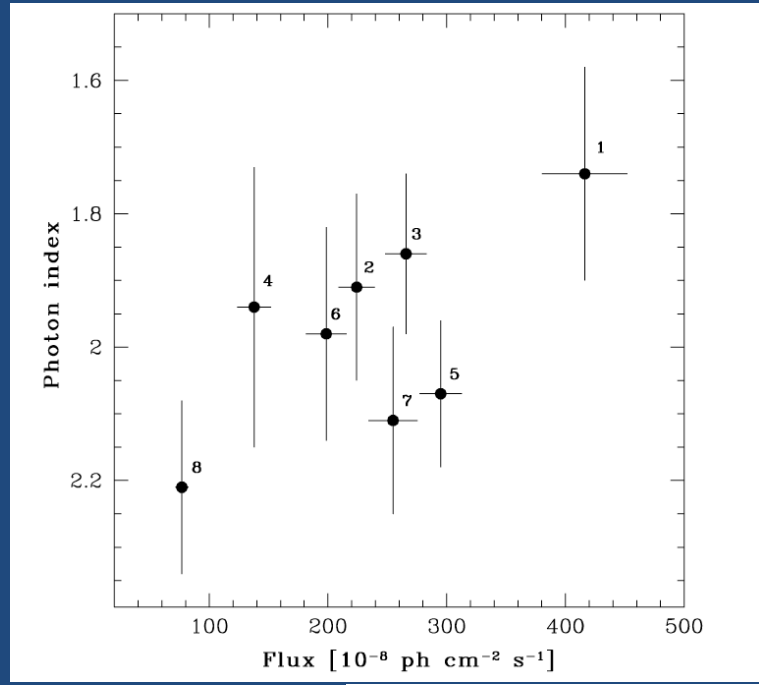
Slopes in X-ray roughly const.  
compared to other bands!

Long-term X-ray and  $\gamma$ -ray spectra of 3C 454 show only moderate **harder-when-brighter trends**.

Swift/XRT



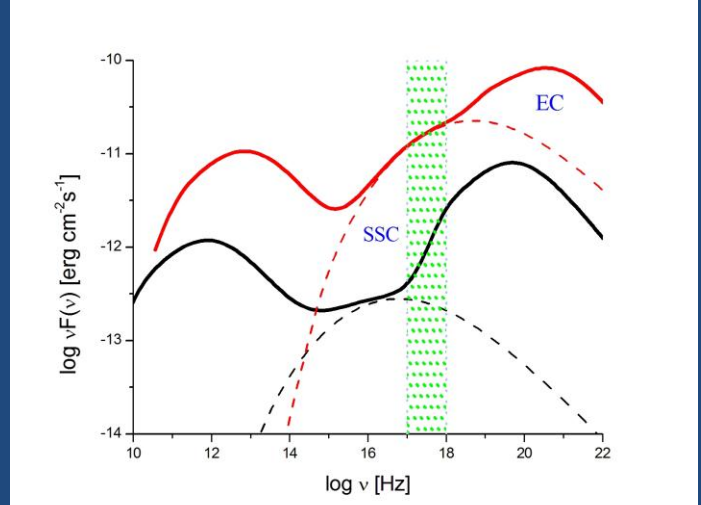
AGILE



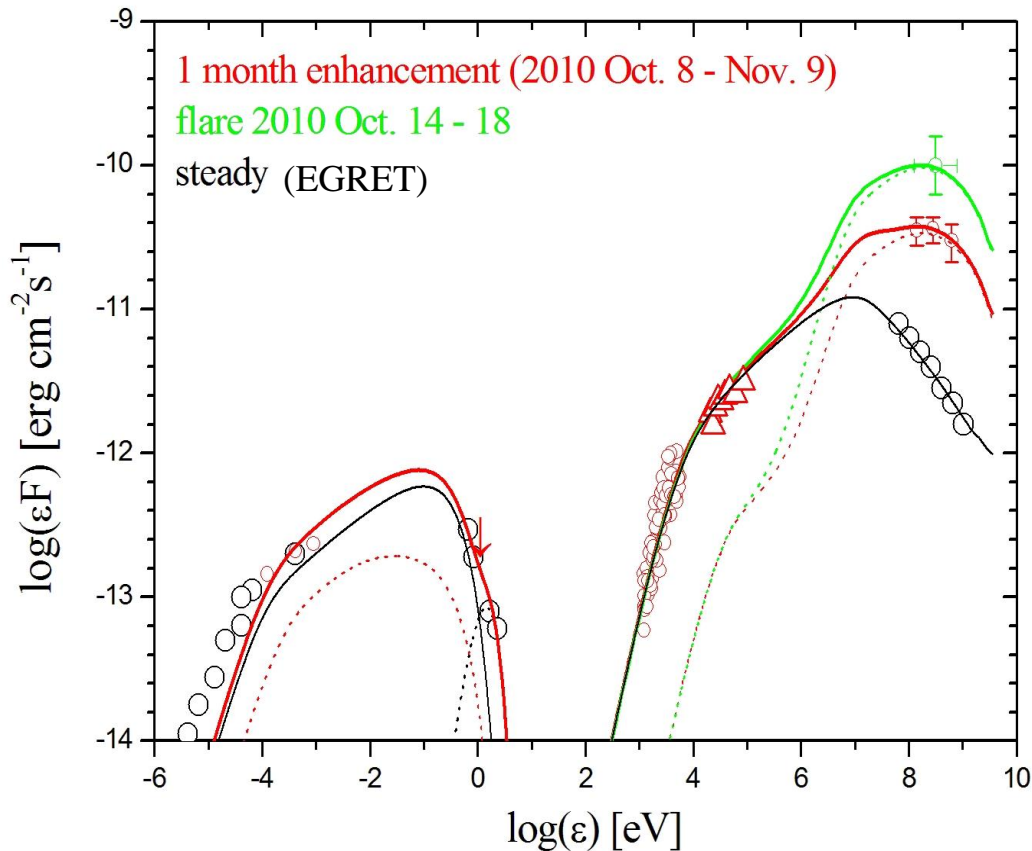
Vercellone et al. 2011

But SSC alone would cause a **strong softer-when-brighter trend in the spectra!**

This constraint the particle energy  $\gamma < 700$   
 Moreover, X-ray and gamma-ray spectra are dominated by EC radiation



## PKS 1830: an extreme instance



Orphan gamma-ray  
 monthly activity:  
 Optical and X-ray  
 remain at historical  
 steady levels.

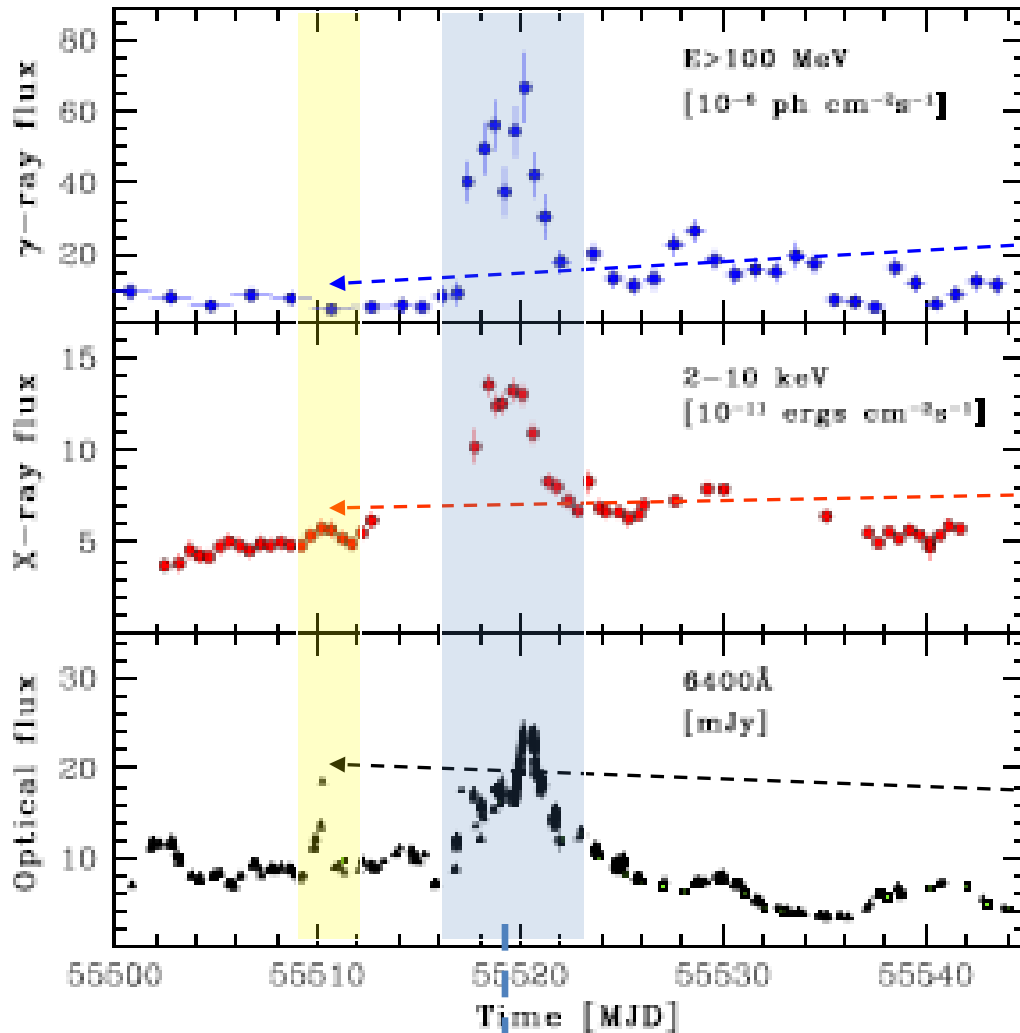
A second component of  
 shocked particles  
 (red dotted lines) can account  
 for the **monthly enhancement**  
 in gamma-rays with little  
 or no contributions in optical  
 and X-rays.

But the **fast orphan** flare  
 around Oct. 16 requires  
 some variation in the  
 external field of seed photons !

Donnarumma et al. 2011

# The super flare of 3C 454 in November 2010

Vercellone et al. 2011



**No gamma-ray counterpart**

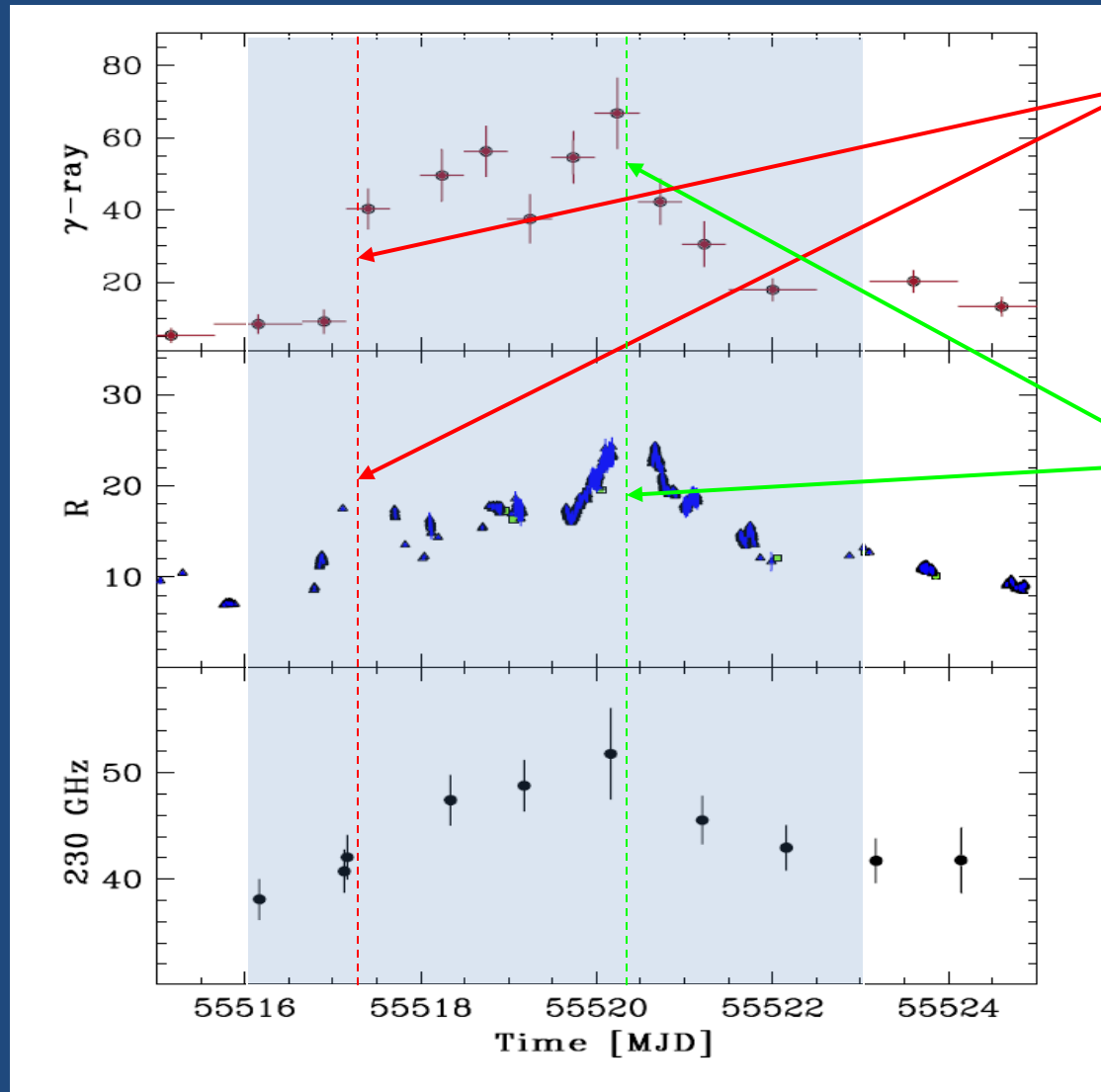
**Faint soft X-ray counterpart**

(SC plays a secondary role!)

**Strong 1 day optical flare  
2010 Nov. 10**

(energization of a new  
component in the inner jet)

# 3C 454 last flare



Around MJD=55517 (2010 Nov. 17)  
 the gamma ray flux jumps by a  
 factor 4 while the optical flux  
 rises by a factor 2 only!

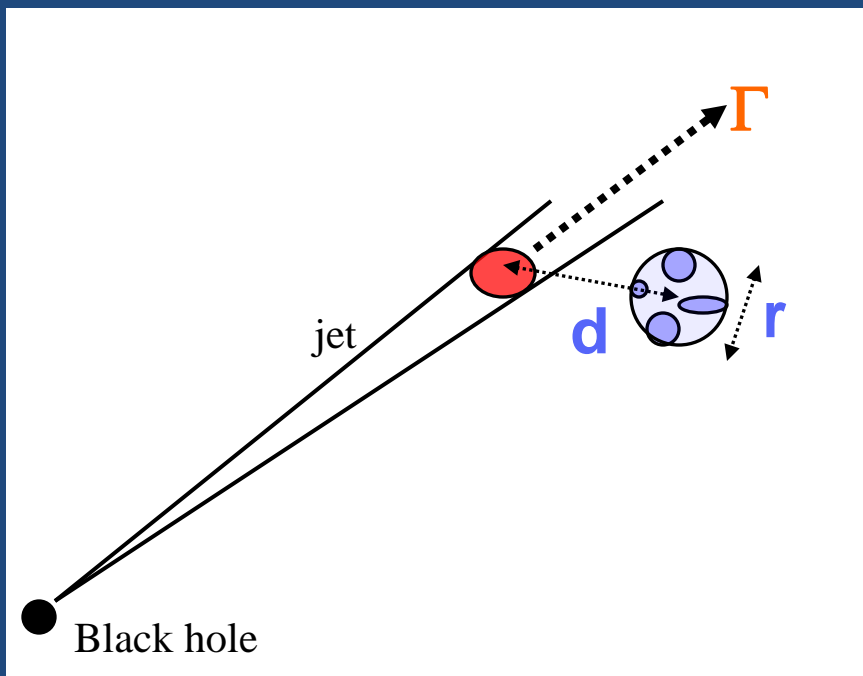
Later on, variation factors  
 appear to be comparable

To account for this complex  
 correlation, some variation  
 is required in the external  
 photon field seen by the jet!

e.g., a local enhancement of the external photon field seen by the blob is possible when the blob approaches a system of clouds in the broad line region

In standard EC from BLR clouds cover  $a=10\%$  at distance  $R_{\text{BLR}}=10^{18}\text{cm}$ , and reflect the disk luminosity  $L_{\text{D}}$ . The energy density of photons seen by a far blob moving with bulk Lorentz factor  $\Gamma$  is

$$U'_{\text{BLR}} \sim \frac{17}{12} \frac{aL_{\text{D}}\Gamma^2}{4\pi R_{\text{BLR}}^2 c}$$



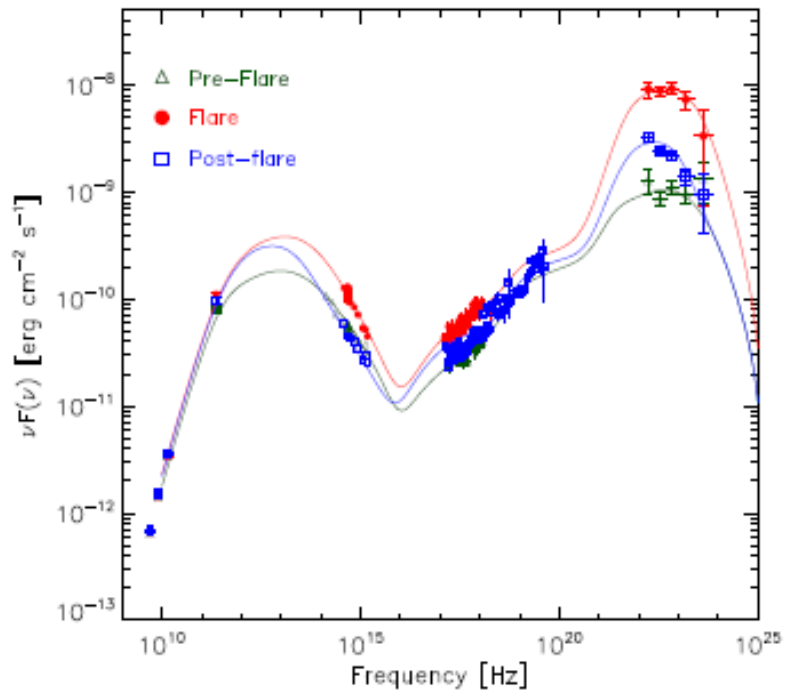
If the blob approaches at distance  $d \ll R_{\text{BLR}}$  a system of size  $r$ , a gain  $g = a^{-1}(r/d)^2 < 10$  can be obtained, with time-scale  $\Gamma^{-1} r/c$  and

$$U'_{\text{EXT}} = U'_{\text{BLR}} (1+g)$$



# 3C 454 in Nov. 2010

Vercellone  
et al. 2011



This idea explains the SED during the entire period of activity, by **two** electron populations in the jet

Parameter	Pre-flare	Flare	
SEDs model parameters			
$\alpha_l$	2.35	2.35	
$\alpha_h$	4.2	4.8	
$\gamma_{\min}$	50	80	
$\gamma_b$	650	700	
$K$	300	700	$\text{cm}^{-3}$
$R_{\text{jet}}$	7.0	3.6	$10^{18} \text{ cm}$
$B$	0.65	1.1	G
$\delta$	34.5	34.5	
$L_d$	2	2	$10^{48} \text{ erg s}^{-1}$
$T_d$	$10^4$	$10^4$	$^{\circ}\text{K}$
$r_d$	0.05	0.05	pc
$\theta_0$	1.15	1.15	degrees
$\Gamma$	20	20	

Data concerning PKS 1830 and 3C 454 suggest:

Optical activity may involve **limited injection/acceleration** of electrons in the jet. In fact,  $\gamma_b < 700$  is implied to avoid a **softer-when-brighter trend** not actually observed in the Inverse Compton component.

**Two populations** of electrons seem unavoidable.

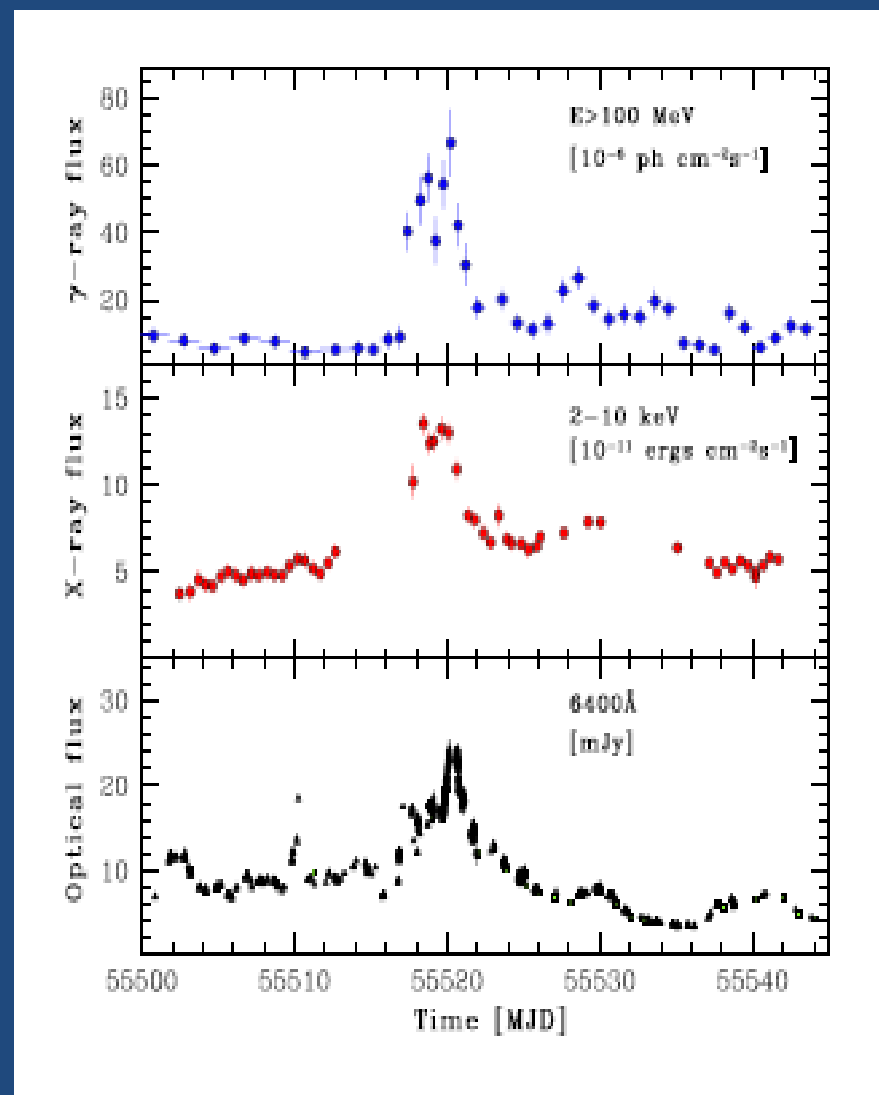
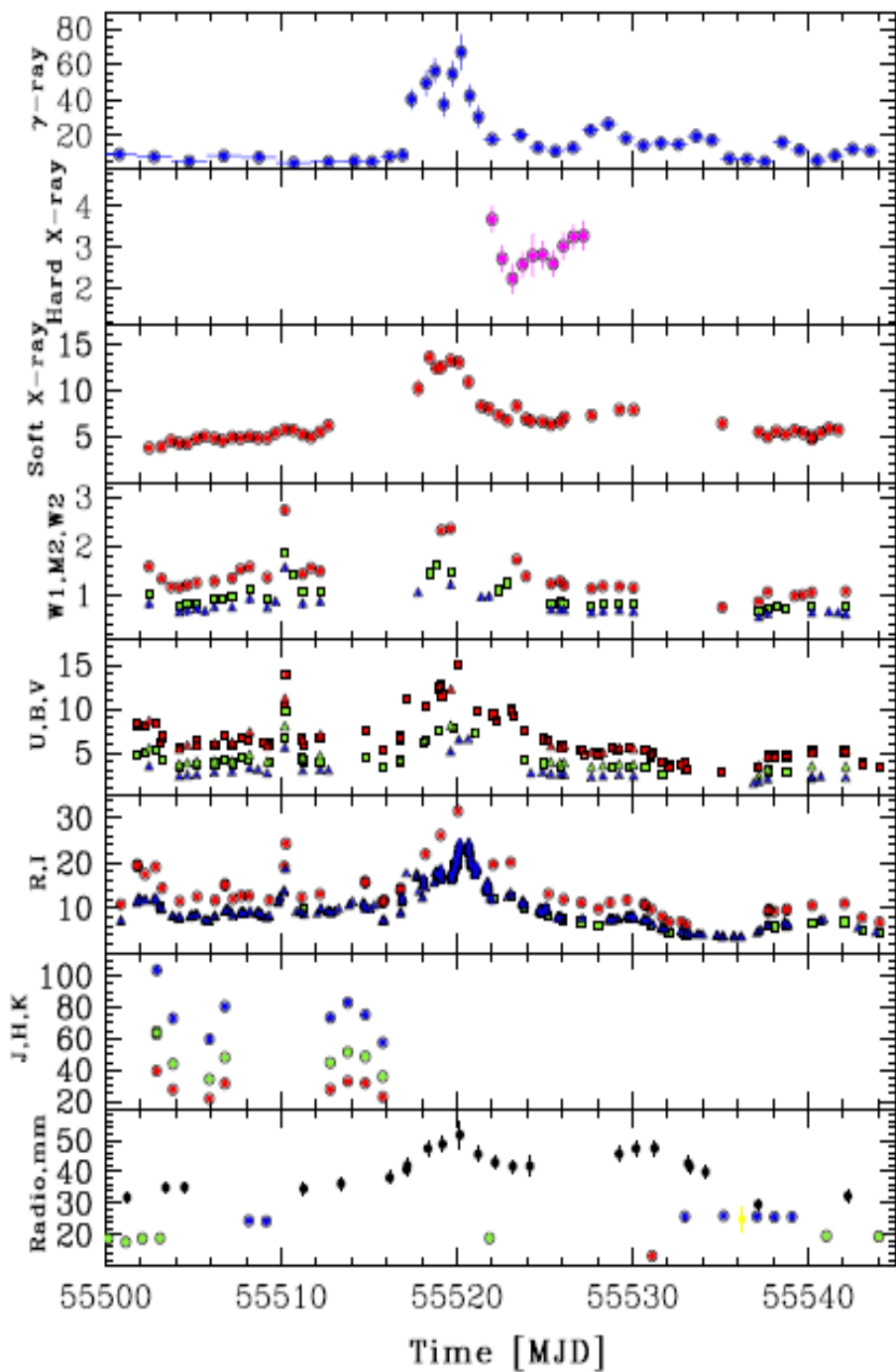
**Even standard EC models are challenged!**

In fact, **variations in the external photon field seen by the blob** are required to understand the observed **complex  $\gamma$ -ray vs. Opt. correlations**.

# The Crab nebula suggestion

If electrons with densities  $n_e=10^{-3} \text{ cm}^{-3}$  are accelerated around  $\gamma=10^9$  far from the BLR where magnetic field lower at  $B=1 \text{ mGauss}$  and bulk Doppler factor is  $\delta=5-10$  then synchrotron flare at  $100-200 \text{ Mev}$  obtains, with time-scale of  $1 \text{ day}$  or less.

Moreover, the IC scattering of these electrons with the radio photons in Thomson regime can produce TeV photons at distance  $>pc$  from the BH, also in close FSRQ avoiding absorption by pair production.



**Variability  
patterns when  
particles are  
energized**

## Synchrotron

$$\epsilon_s = h \frac{3.7 \times 10^6 B \gamma_b^2 \delta}{1 + z}$$

$$\epsilon_s F(\epsilon_s) \propto \delta^4 R^3 B^2 K \gamma_b^2$$

## Self-Compton

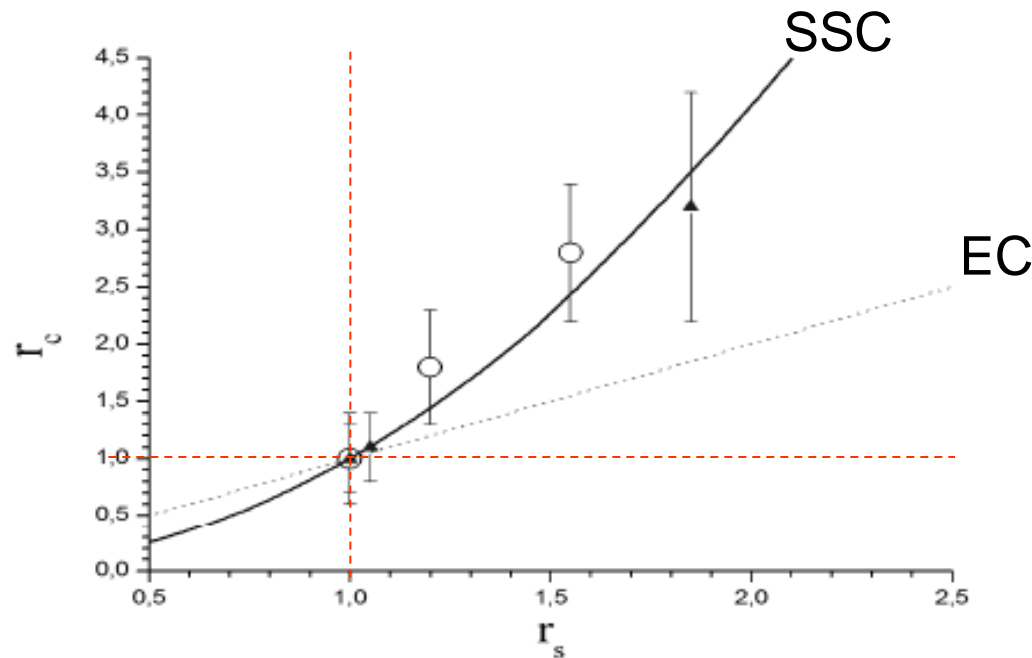
$$\epsilon_c = \frac{4\gamma_b^2 \epsilon_s}{3}$$

$$\epsilon_c F(\epsilon_c) \propto \delta^4 R^4 B^2 K^2 \gamma_b^4$$

$$r_s = \epsilon_s F(\epsilon_s; t) / \epsilon_s F(\epsilon_s; t_0)$$

$$r_c = \epsilon_c F(\epsilon_c; t + t_{\text{del}}) / \epsilon_c F(\epsilon_c; t_0 + t_{\text{del}})$$

$$t_{\text{del}} \simeq \frac{t_{\text{cr}}(1+z)}{\delta}$$

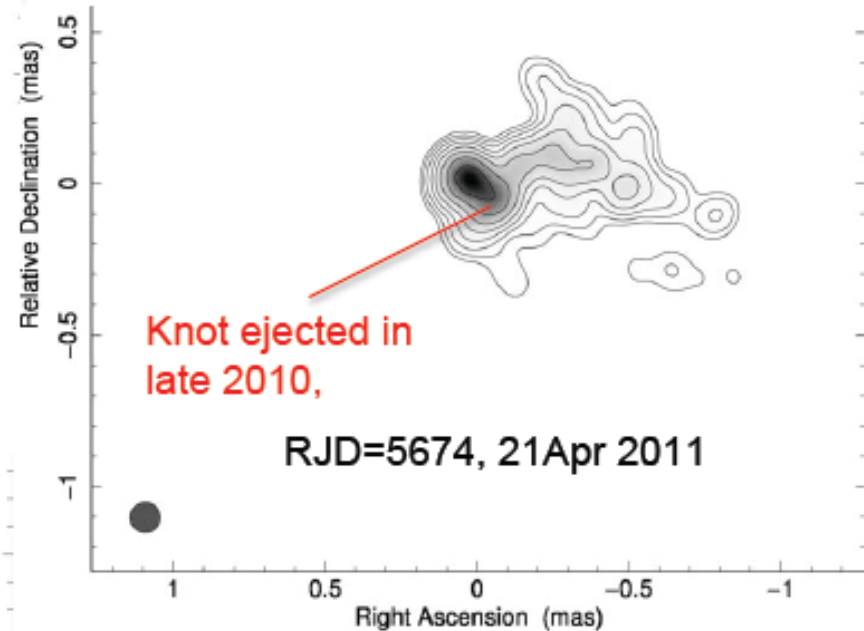
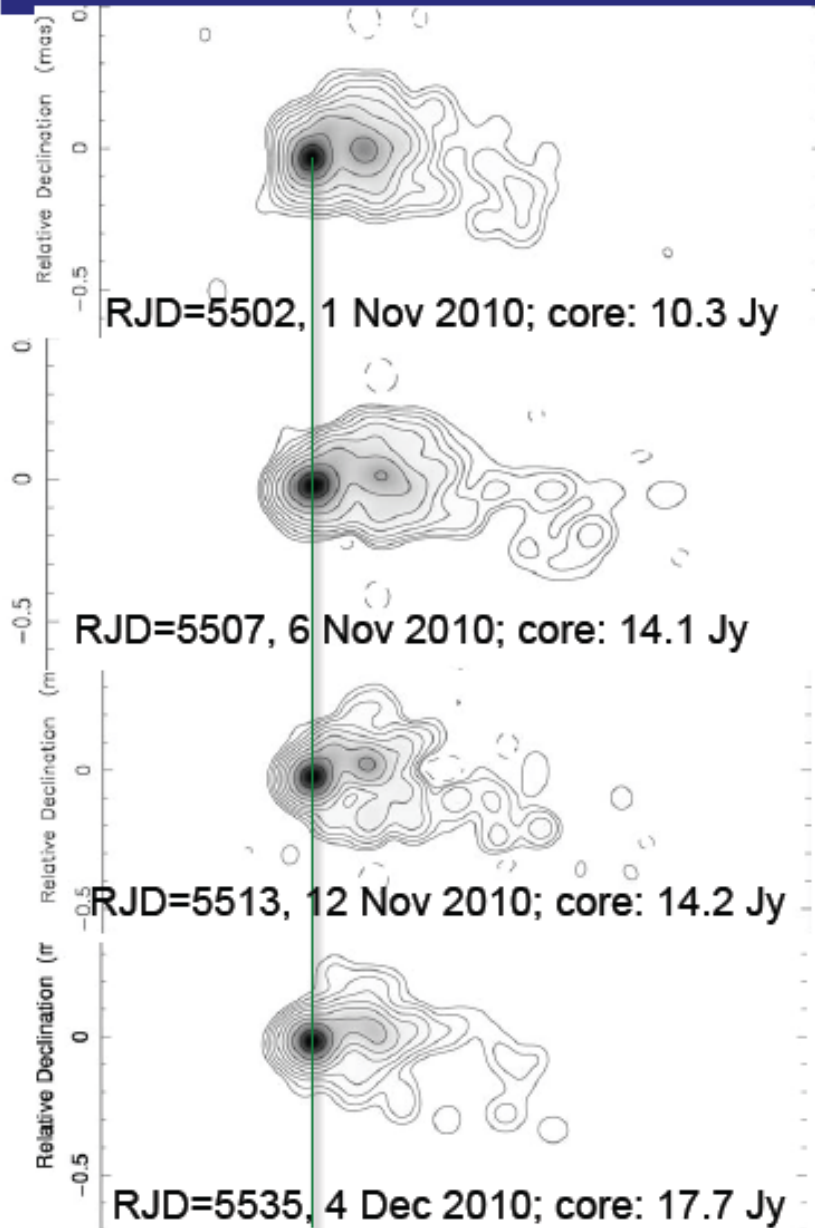


## External Compton

$$\epsilon_c = \frac{4\gamma_b^2 \epsilon'_{\text{ext}} \delta}{3(1+z)}$$

$$\epsilon_c F(\epsilon_c) \propto \delta^4 R^3 K \gamma_b^2 N'_{\text{ext}} \epsilon'_{\text{ext}}$$

# 3C 454.3: Knot from mega-outburst moving in new direction



Jorstad et al. (2010 ApJ): core has triple structure, with a flare occurring as a knot passes each feature

Marscher FERMI Symp. 2011