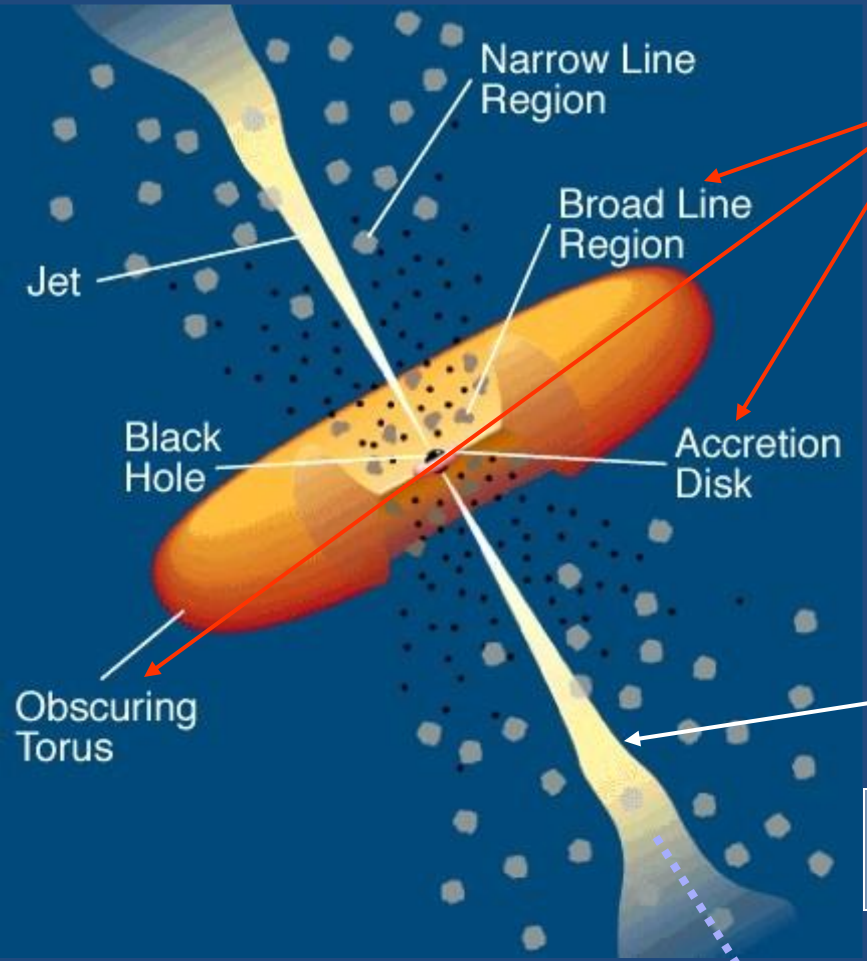
Gamma-ray flares from 3C454 and PKS 1830 in late 2010: electron energization in the jet is not enough!

V.Vittorini, S. Vercellone, M. Tavani, A. Cavaliere et al. on behalf of the AGILE AGN WG

Name	Affiliation
A. Bulgarelli	INAF-IASF Bologna
A.W. Chen	INAF-IASF Milano
I. Donnarumma	INAF-IASF Roma
P. Giommi	ASDC Roma
A. Giuliani	INAF-IASFMilano
F. Longo	INFN Trieste
C. Pittori	ASDC Roma
L. Pacciani	INAF-IASF Roma
G. Pucella	ENEA Roma
E. Striani	INAF-IASF Roma
S. Vercellone	INAF-IASF Palermo
V. Vittorini	INAF-IASF Roma & Univ. Tor Vergata

FSRQ model



Γ

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

External photons $N_{\mathbf{ext}}$ and jet electrons $n_{\mathbf{e}}(\gamma)$

produce

External Compton (EC)

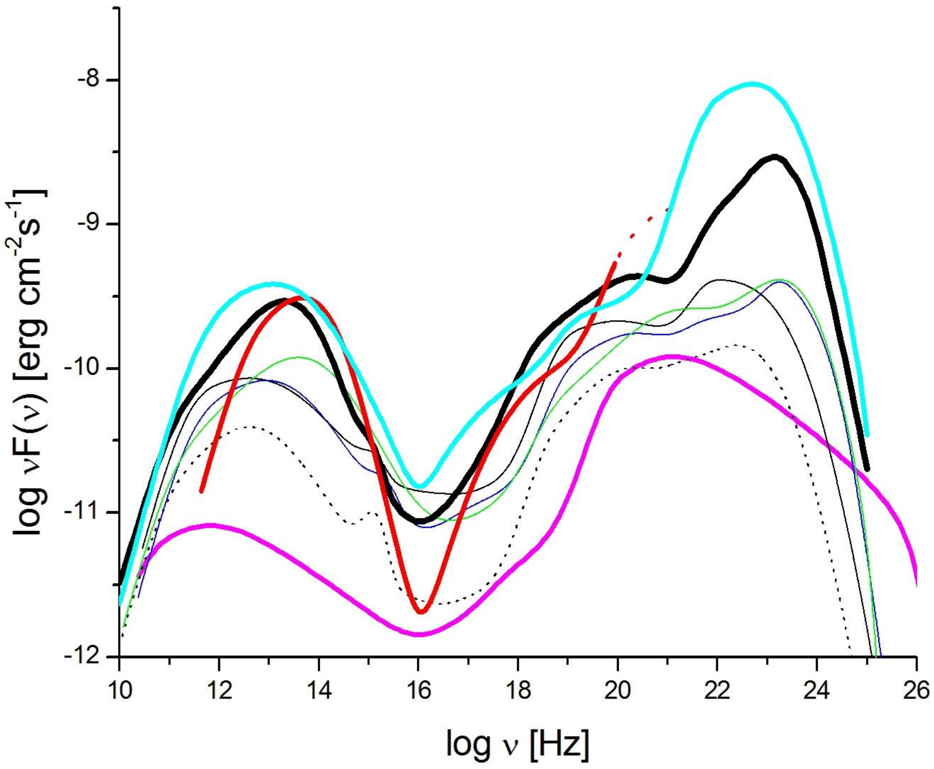
Jet: blob moving with Lorentz factor Γ,
beamed, non thermal radiation

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

produce

Synchrotron + Inverse Compton (SSC)

3C 454 over the last 10 years

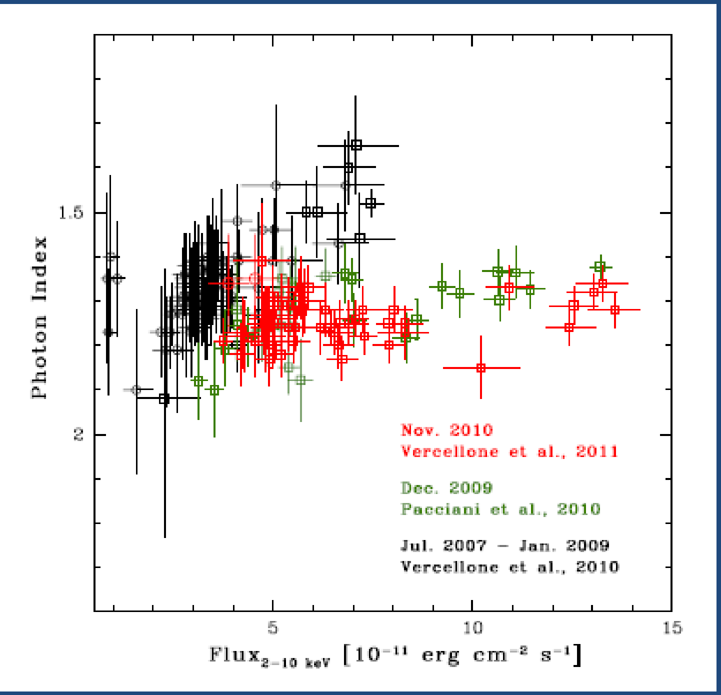


AGILE AGN WG

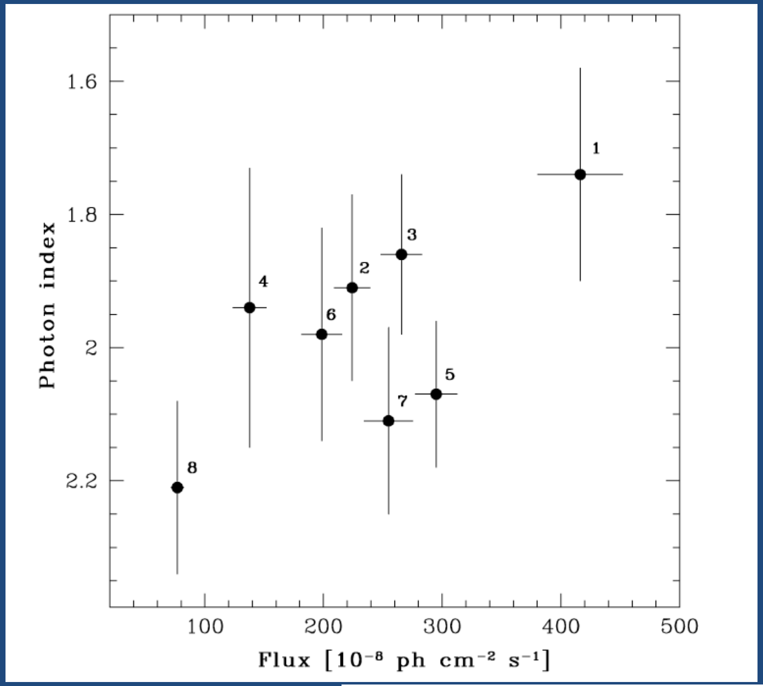
Slopes in X-ray roughly const. compared to other bands!

Long-term X-ray and γ-ray spectra of 3C 454 show only moderate harder-when-brighter trends.

Swift/XRT



AGILE

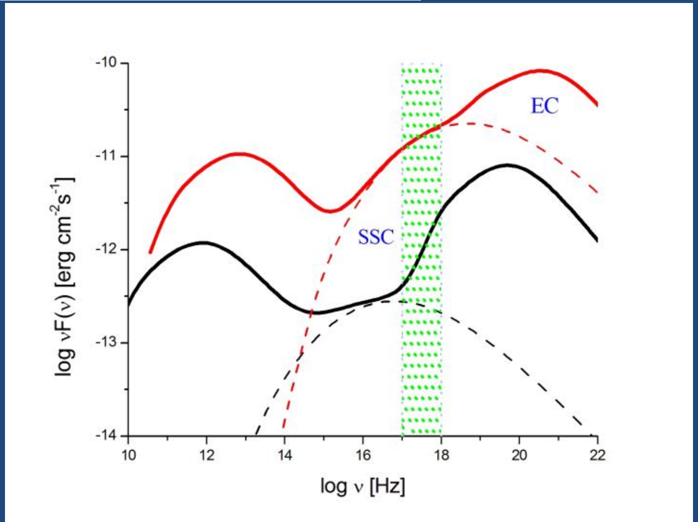


Vercellone et al. 2011

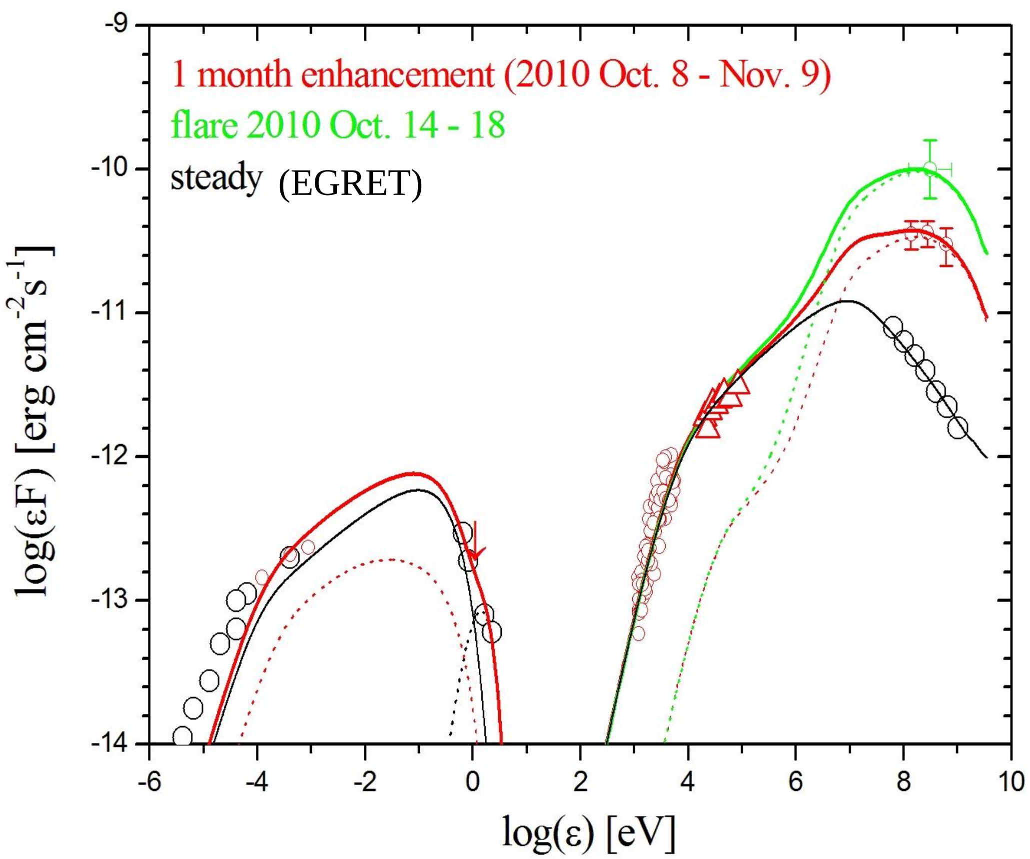
But SSC alone would cause a strong softer-when-brighter trend in the spectra!

This constraint the particle energy $\gamma < 700$

Moreover, X-ray and gamma-ray spectra are dominated by EC radiation



PKS 1830: an extreme instance



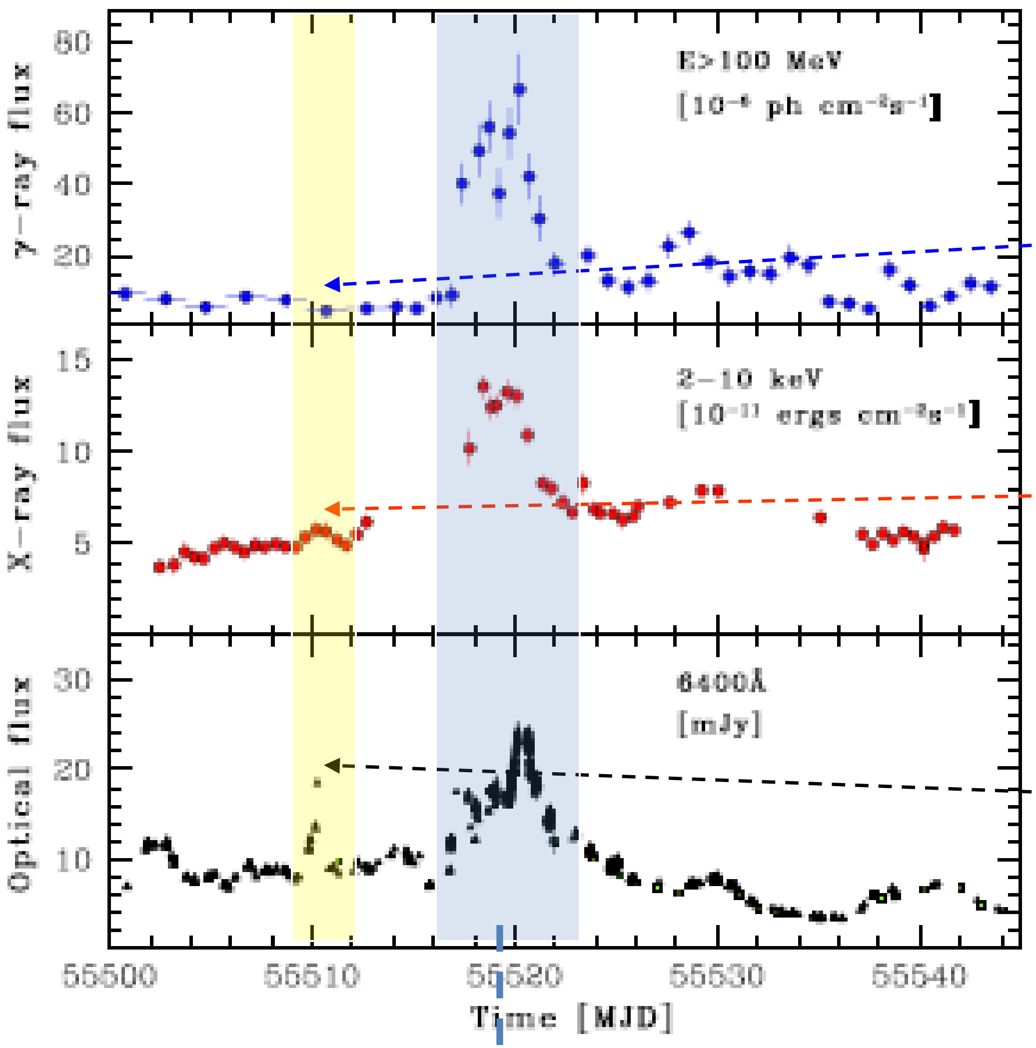
Orphan gamma-ray montly activity: Optical and X-ray remain at hystorical steady levels.

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

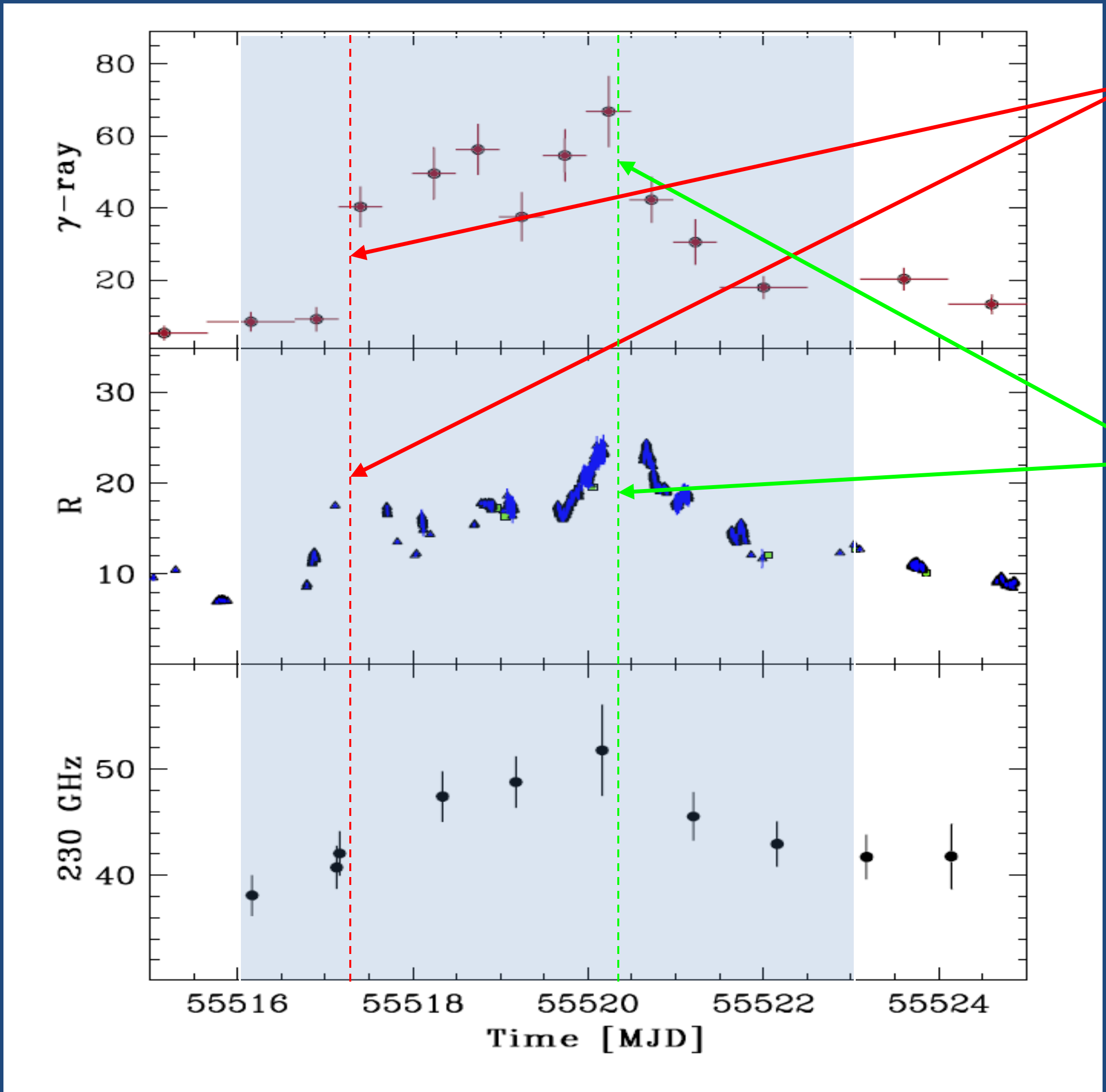
Faint soft X-ray counterpart

(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!

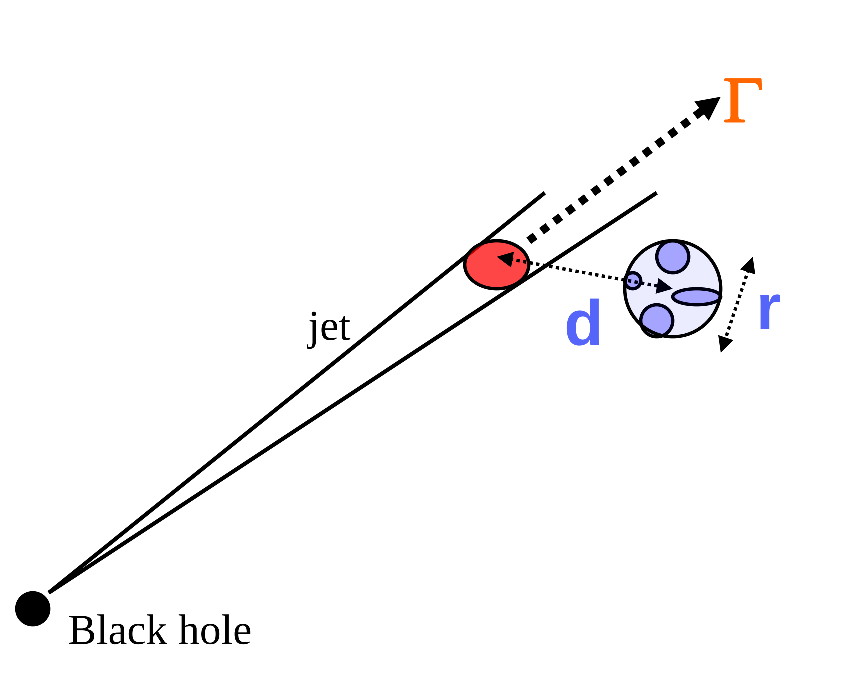
Later on, variation factors appear to be comparable

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 $R_{BLR}=10^{18}$cm, and reflect the disk luminosity L_D. The energy density of photons seen by a far blob moving with bulk Lorentz factor Γ is

$$U'_{\mathrm{BLR}} \sim \frac{17}{12} \frac{a L_{\mathrm{D}} \Gamma^2}{4\pi R^2_{\mathrm{BLR}} c}$$

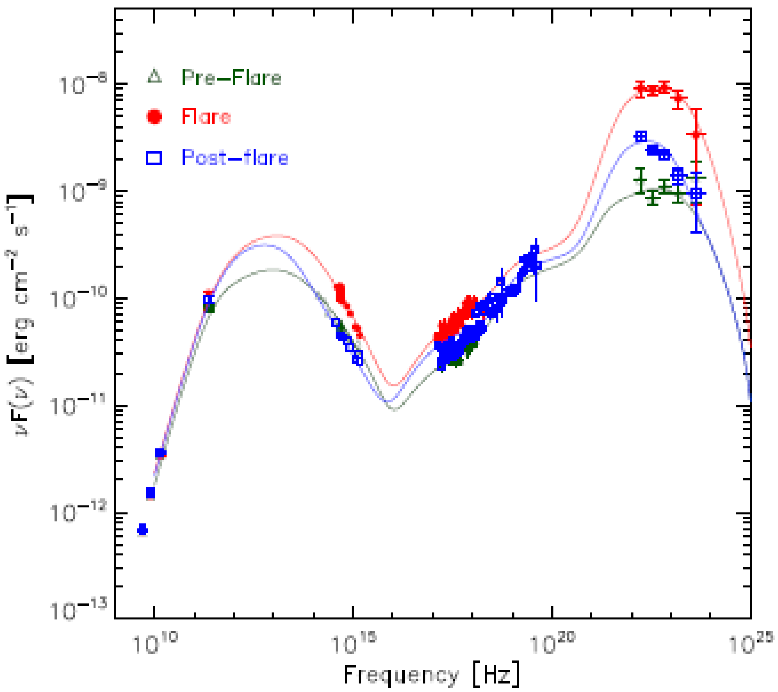


If the blob aproaches at distance **$d \ll R_{BLR}$** a system of size **r,** a gain **$g=a^{-1}(r/d)^2$** < 10 can be obtained, with time-scale **Γ^{-1} r/c** and

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

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	
α_l	2.35	2.35	
α_h	4.2	4.8	
γ_{min}	50	80	
γ_b	650	700	
K	300	700	cm^{-3}
R_{blob}	7.0	3.6	10^{16} cm
B	0.65	1.1	G
δ	34.5	34.5	
L_d	2	2	10^{46} erg s^{-1}
T_d	10^4	10^4	$^\circ K$
r_d	0.05	0.05	pc
Θ_0	1.15	1.15	degrees
Γ	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.

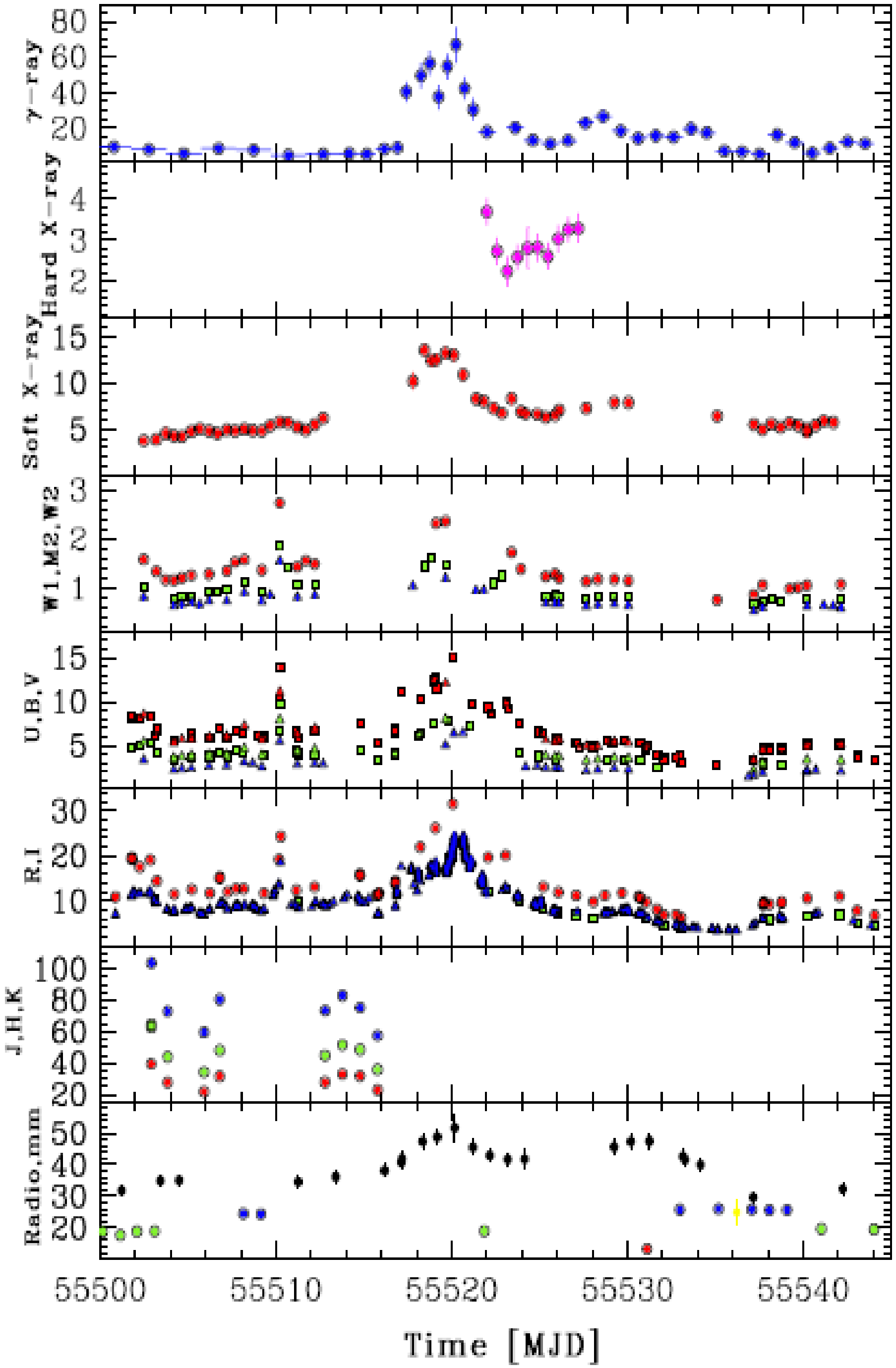
Even standard EC models are challenged!

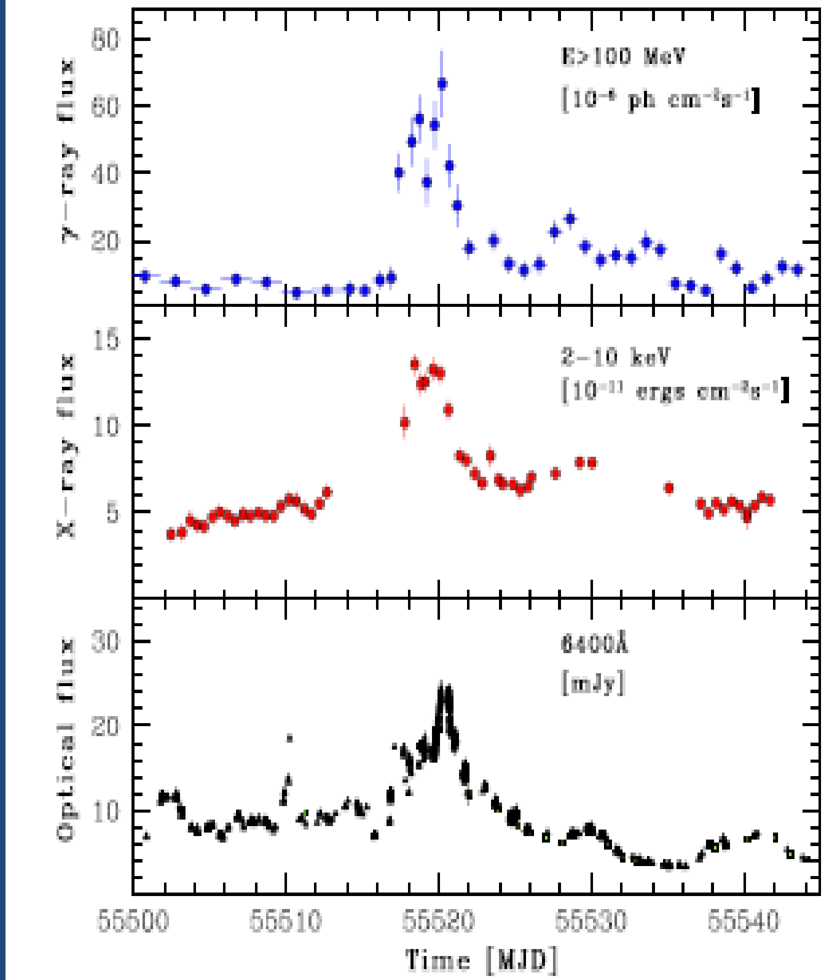
In fact, variations in the external photon field seen by the blob are required to understand the observed complex γ-ray vs. Opt. correlations.

The Crab nebula suggestion

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


γ-ray
Hard X-ray
Soft X-ray
W1,M2,W2
U,B,V
R,I
J,H,K
Radio,mm
55500
55510
55520
55530
55540
Time [MJD]


γ-ray flux
E>100 MeV
[10⁻⁶ ph cm⁻²s⁻¹]
X-ray flux
2-10 keV
[10⁻¹¹ ergs cm⁻²s⁻¹]
Optical flux
6400Å
[mJy]
55500
55510
55520
55530
55540
Time [MJD]

Variability patterns when particles are energized

Synchrotron

$$\epsilon_s = h\,\frac{3.7\times10^6 B\,\gamma_b^2\,\delta}{1+z}$$

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

Self-Compton

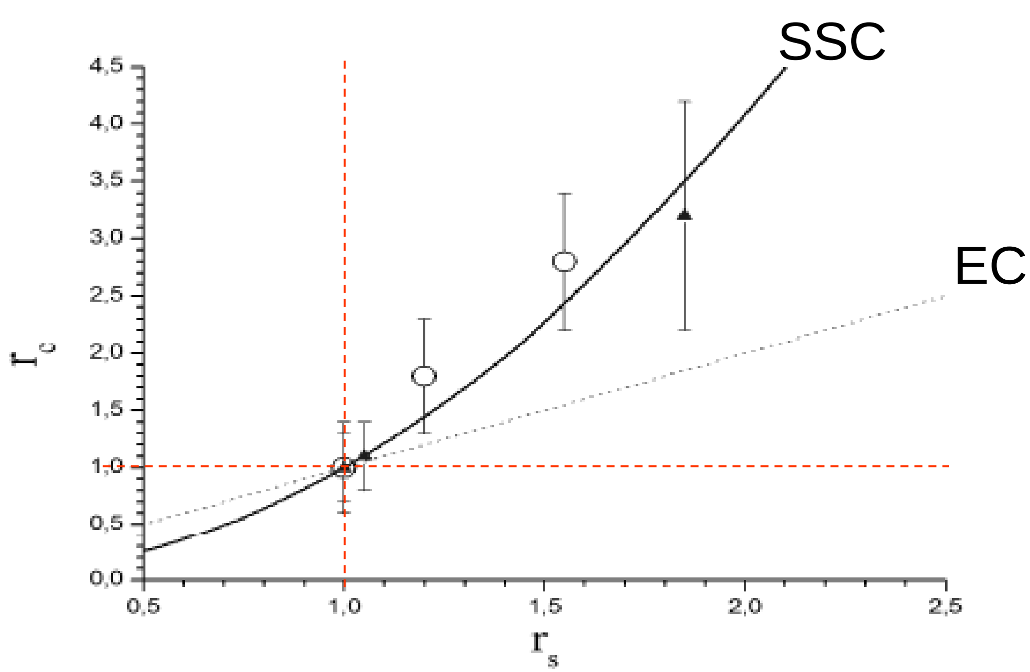
$$\epsilon_c = \frac{4\gamma_b^2\epsilon_s}{3}$$

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

$r_s = \varepsilon_s F(\varepsilon_s;t) \,/\, \varepsilon_s F(\varepsilon_s;t_0)$

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

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

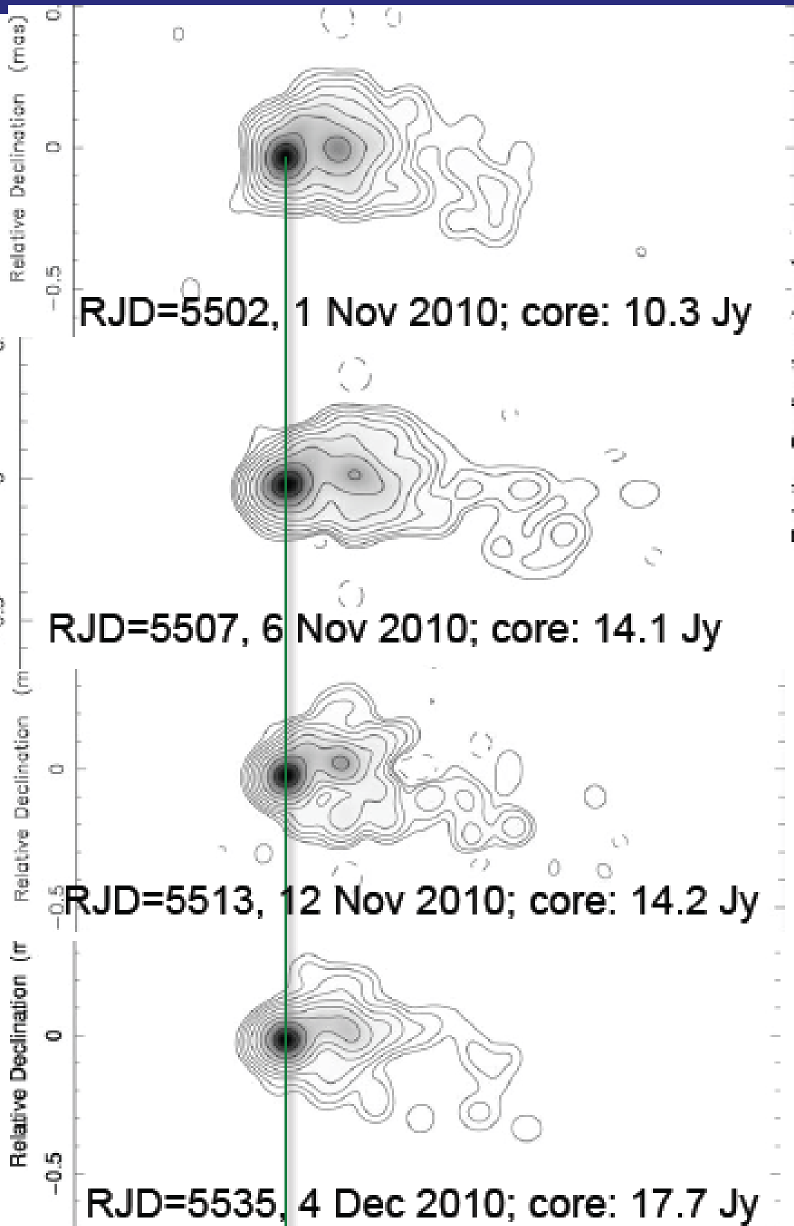


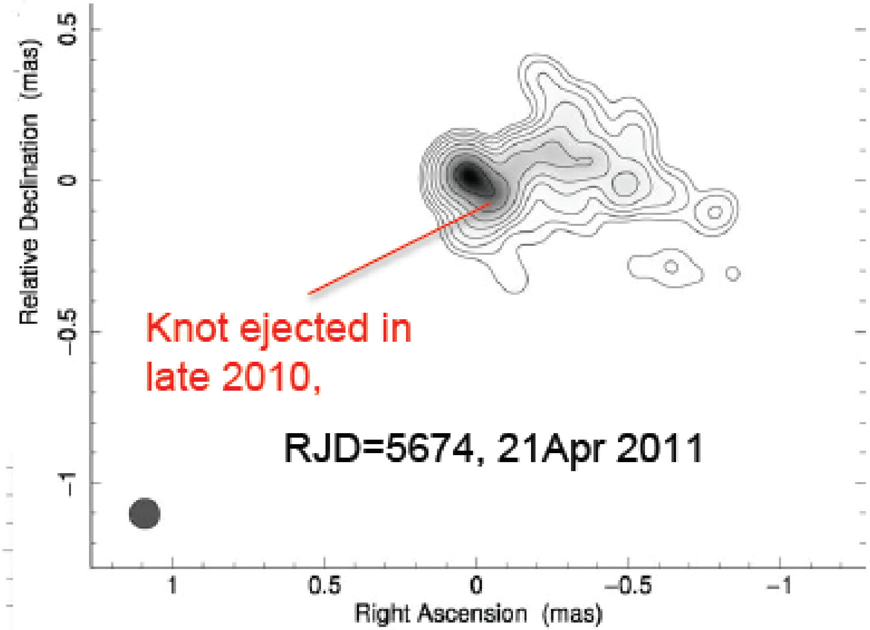
External Compton

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

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

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