What causes a blazar to have optical flares without γ-ray counterparts

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Recent Results in Astrophysics
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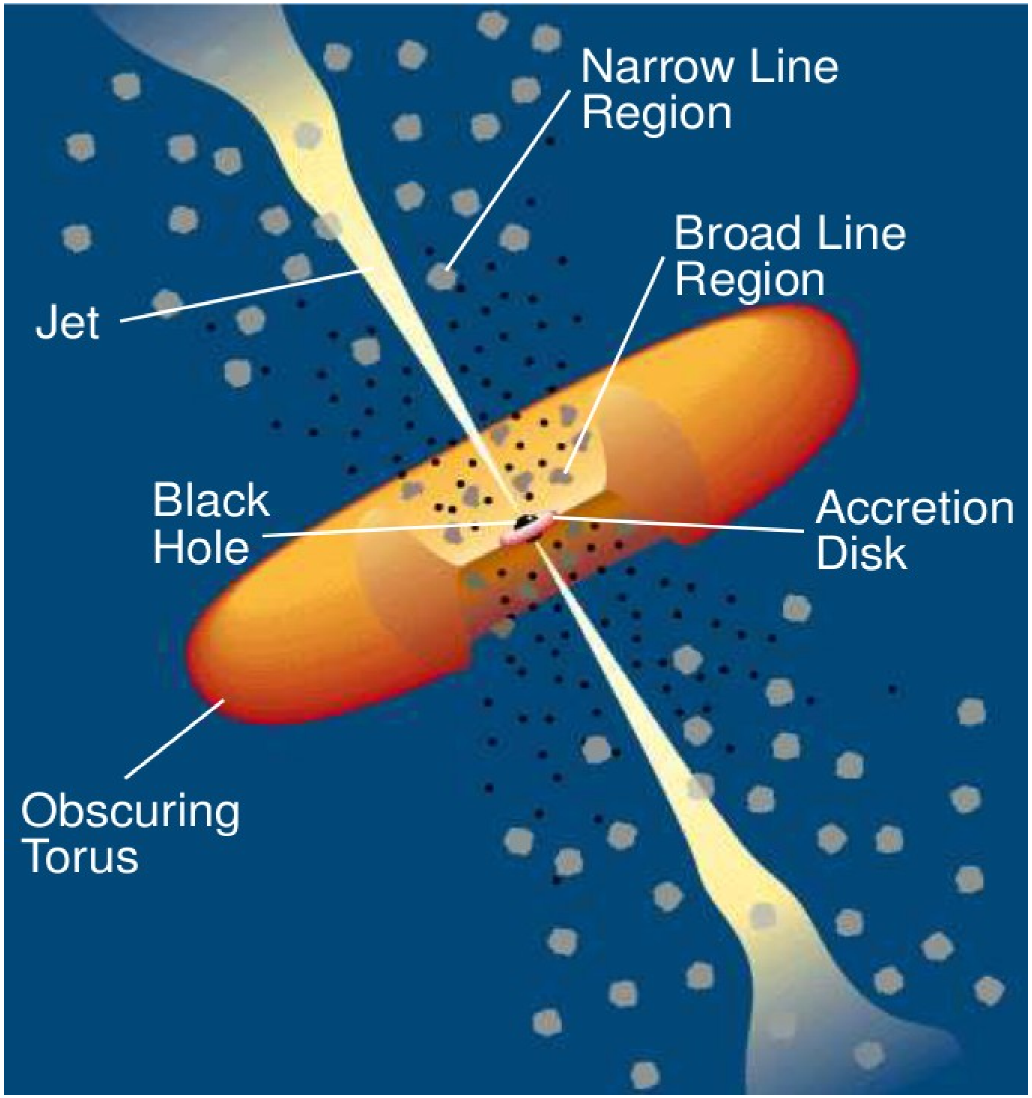
Outline

- Introduction
- Observed odd flare of PKS0208-512
- Simulation of blazar flares
- Discussion

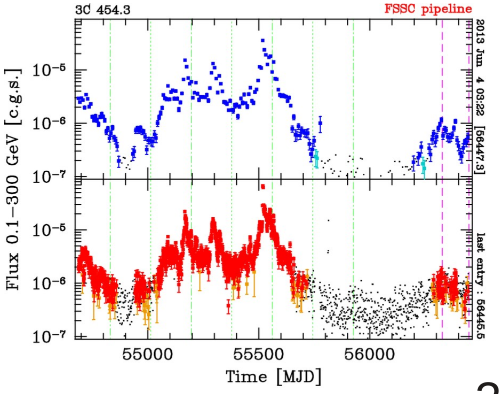
Active Galactic Nucleus (AGN)



Blazars: Along the Jet

Jet moving relativistically

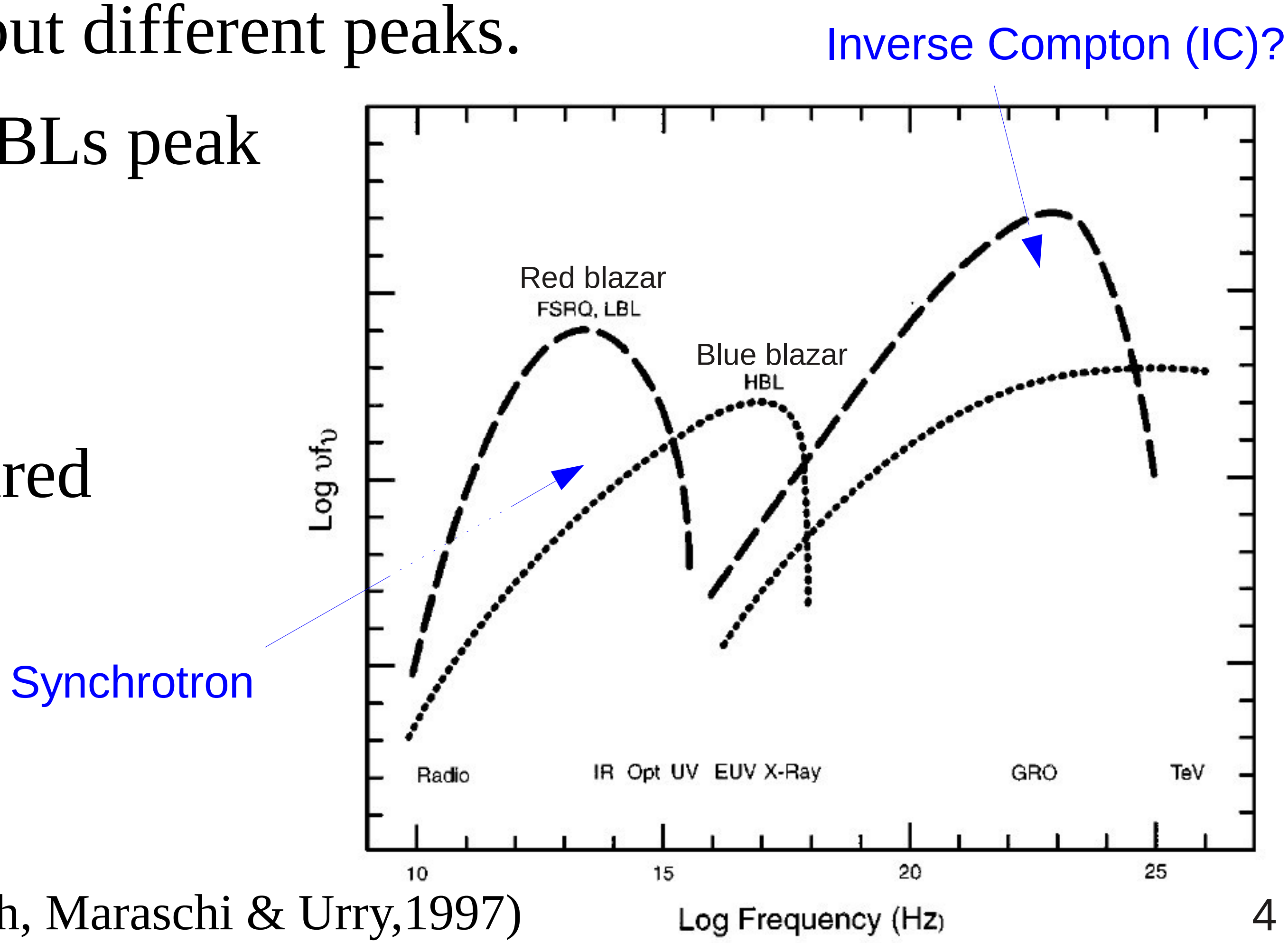
But, why does blazar vary like crazy?



BL Lacs & FSRQs

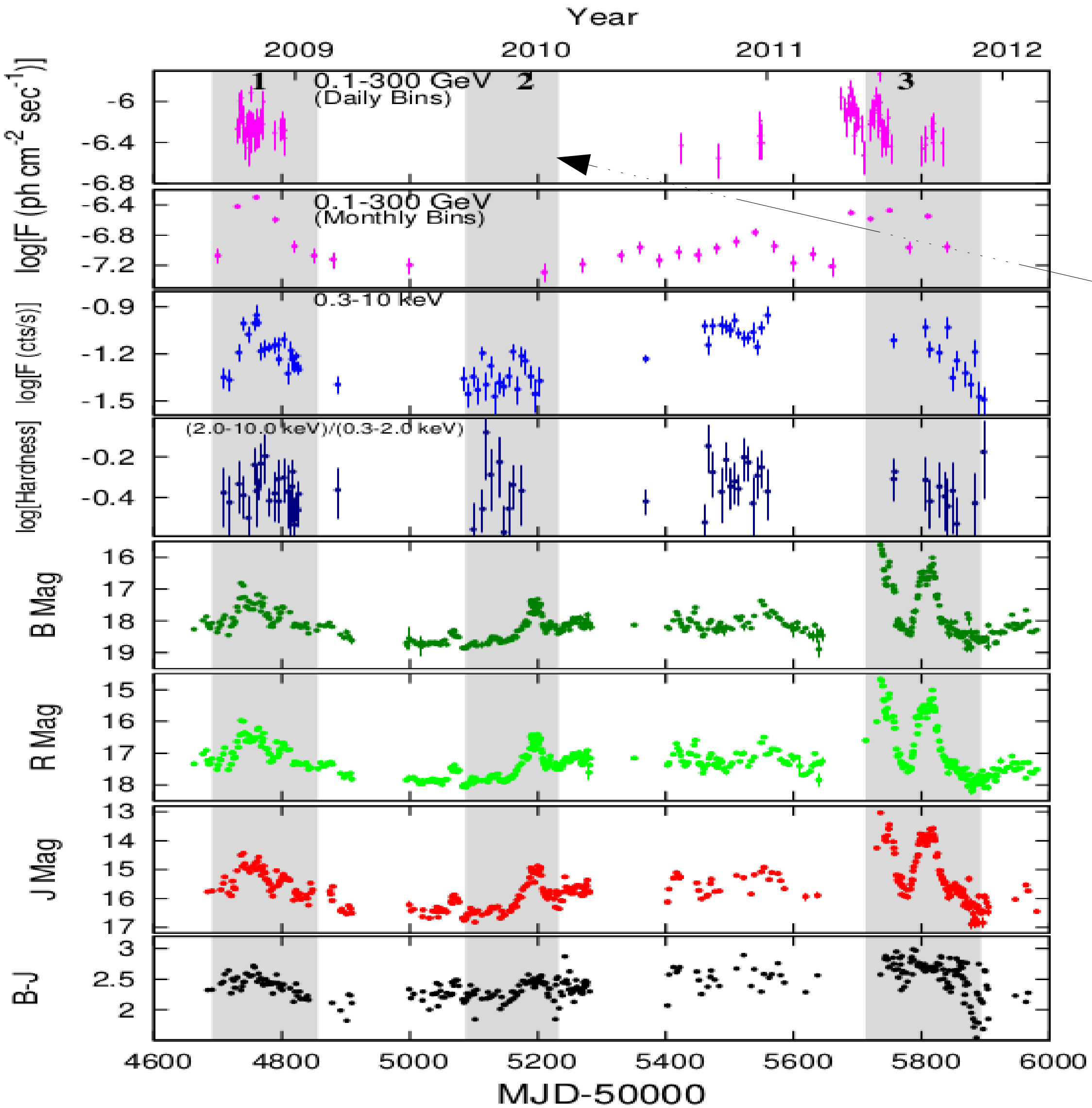
They have Spectral Energy Distribution (SED) with similar shape but different peaks.

- FSRQs and LBLs peak in UV/X-ray
- HBLs peak in Radio/infrared



(Ulrich, Maraschi & Urry,1997)

Observed light curves of PKS 0208-512

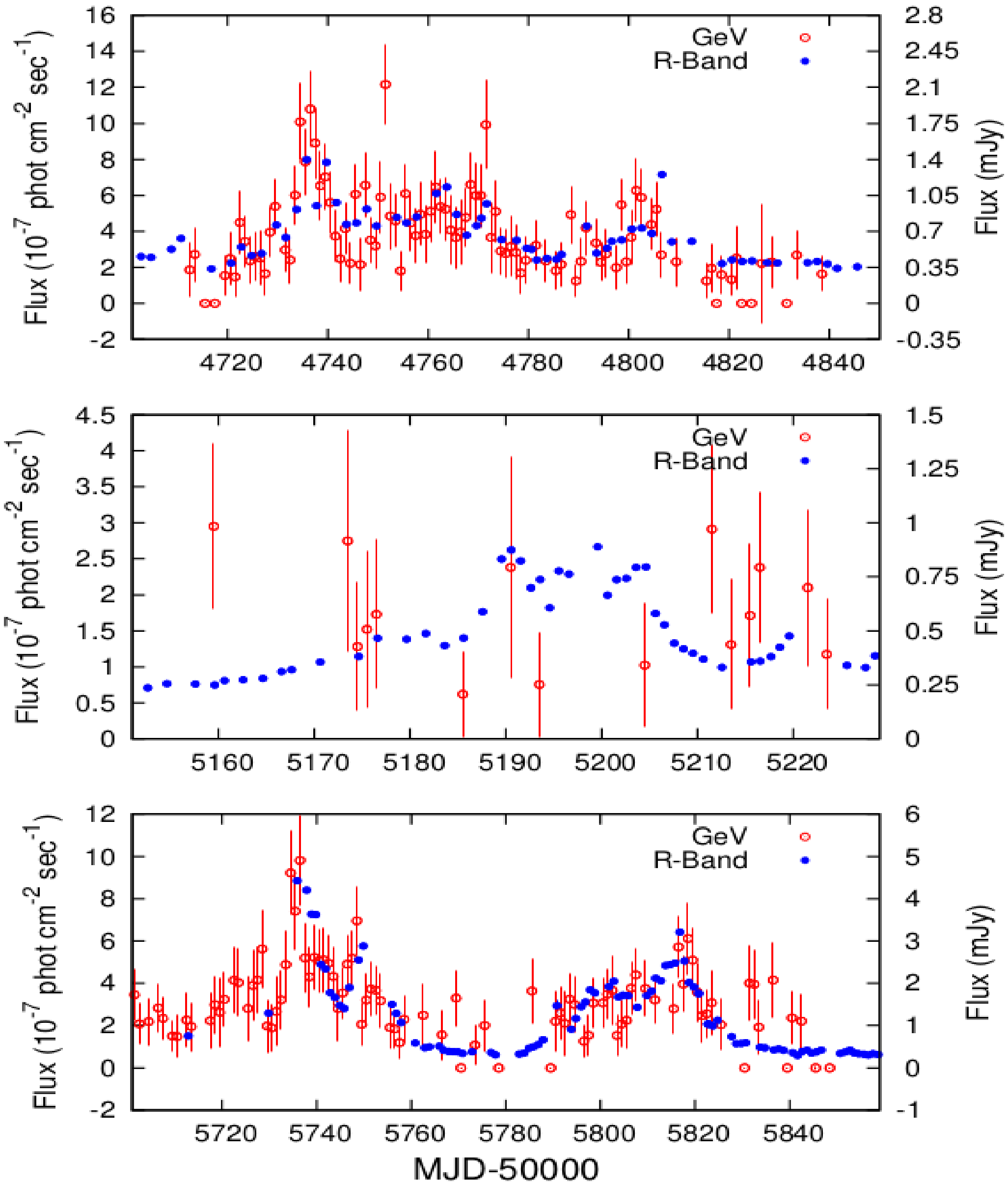


3 major optical flares in gray shaded sections.

The 2nd one does not have an gamma-ray counterpart.

(Chatterjee et al. 2012)

Daily light curves of the three flares enlarged

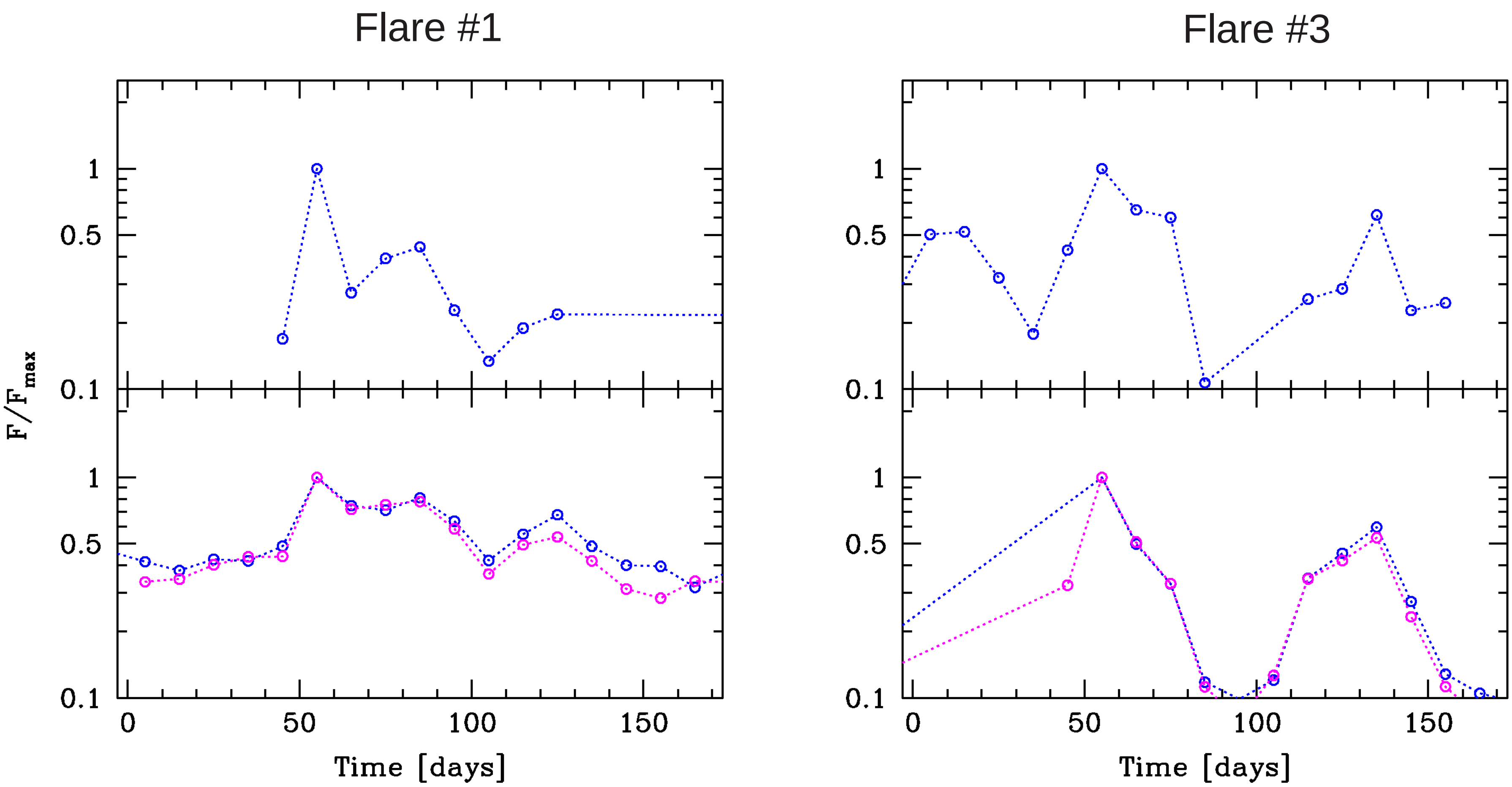


Points with low test statistics (TS>4) included

(Chatterjee et al. 2012)

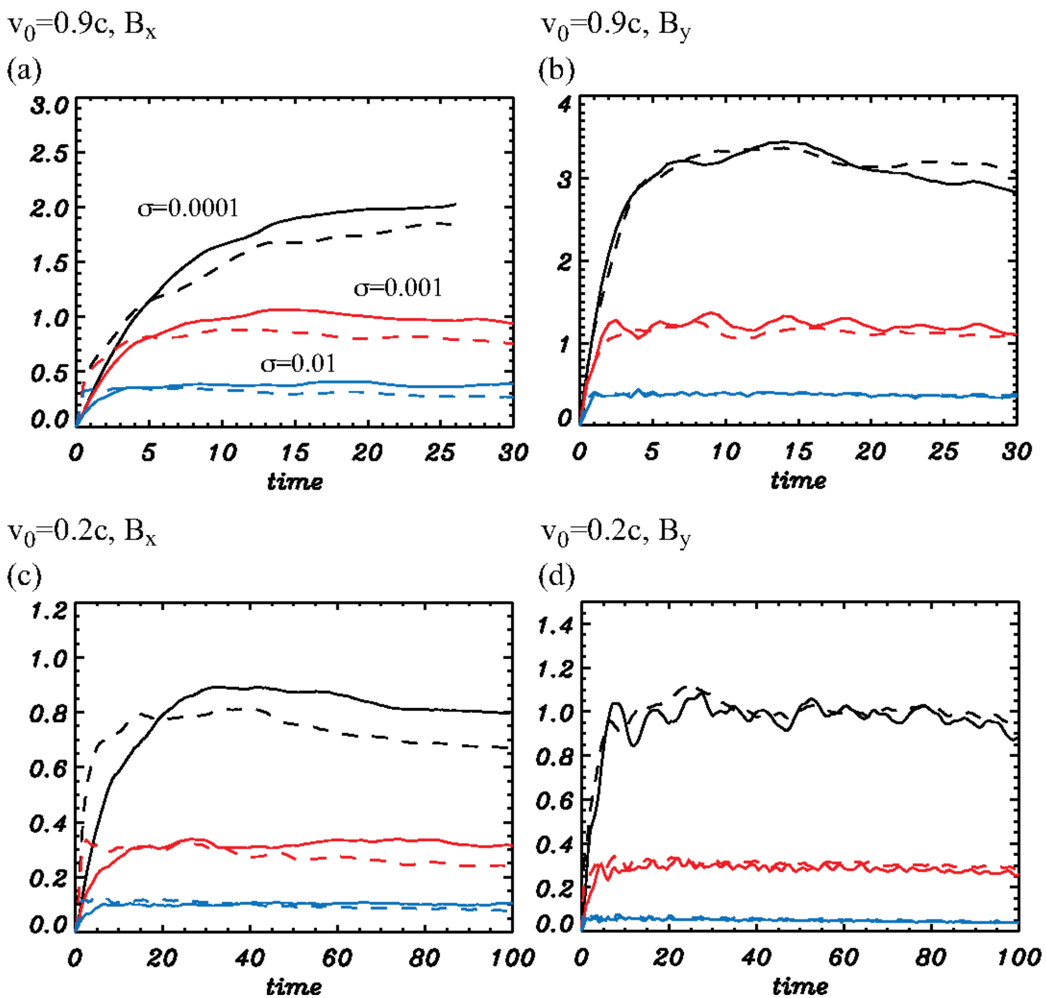
Optical and gamma-ray light curves show clear similarity

Light curves binned in 10 day bins
Upper panels show gamma-ray,
Lower panels show B and J band infrared



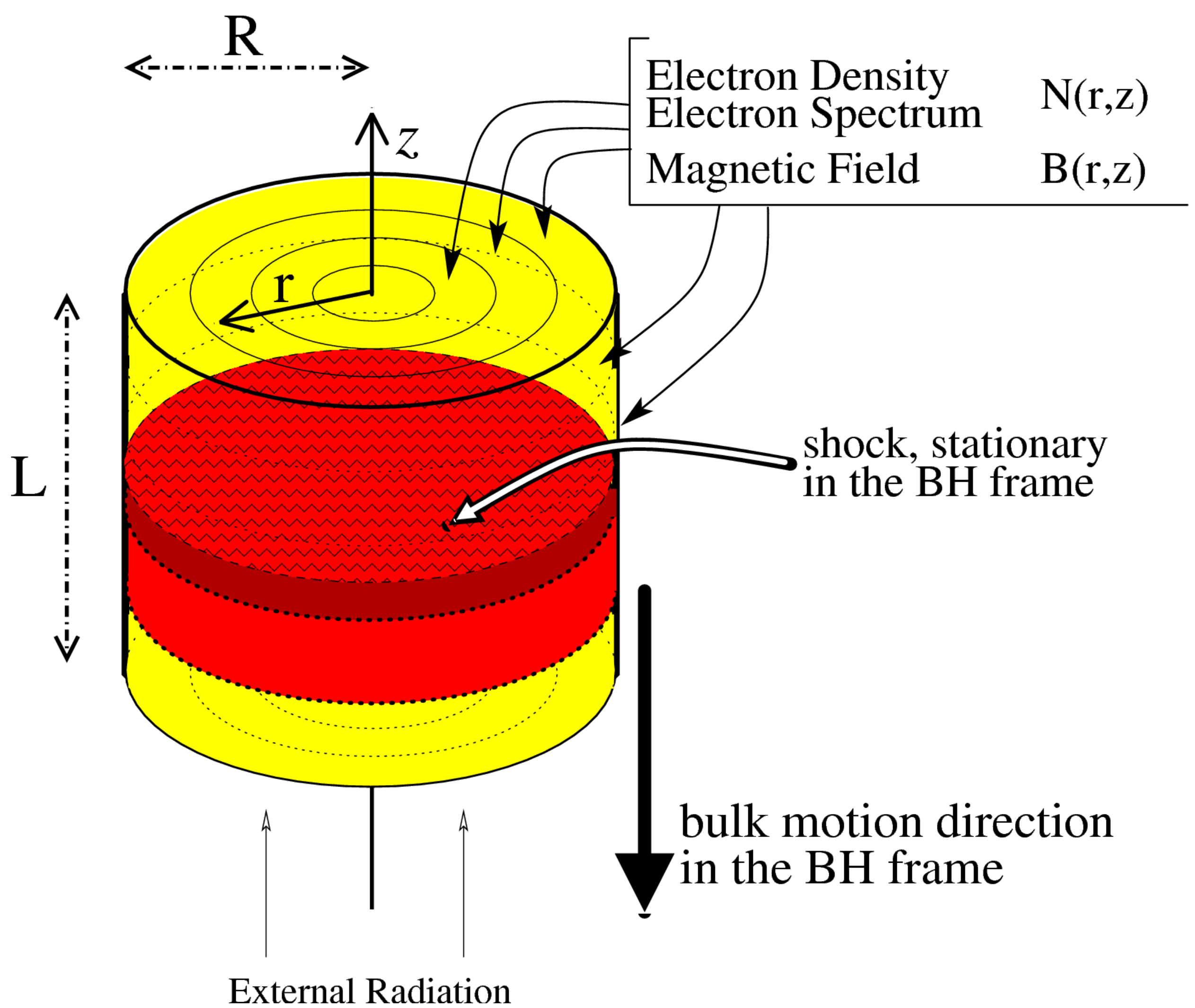
How could the source produce correlated flares sometimes, but optical-only flares at other times?

Magnetic field growth in MHD simulation



(Mizuno et al. 2013)

Geometry of our cylindrical jet model



6 cases are studied

Emission mechanism	Cause of flare
Pure SSC	Burst change of magnetic field
	Burst change of acceleration efficiency
Dusty torus EC	Burst change of magnetic field
	Prolonged change of magnetic field
	Burst change of acceleration efficiency
	Prolonged change of acceleration efficiency

Pure SSC scenario

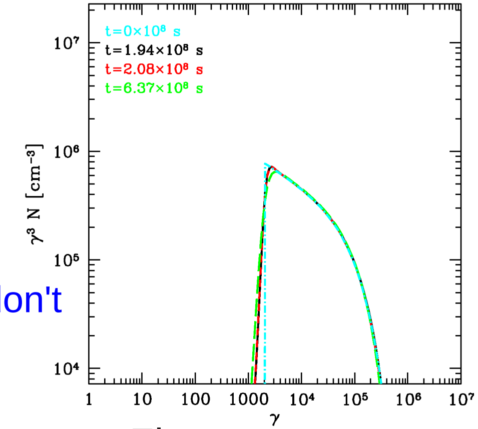
Burst increase of B causes the flare

5 parameters:

$B, n_e, R, \gamma_{min}, \delta$

Constrained by 5 observables:

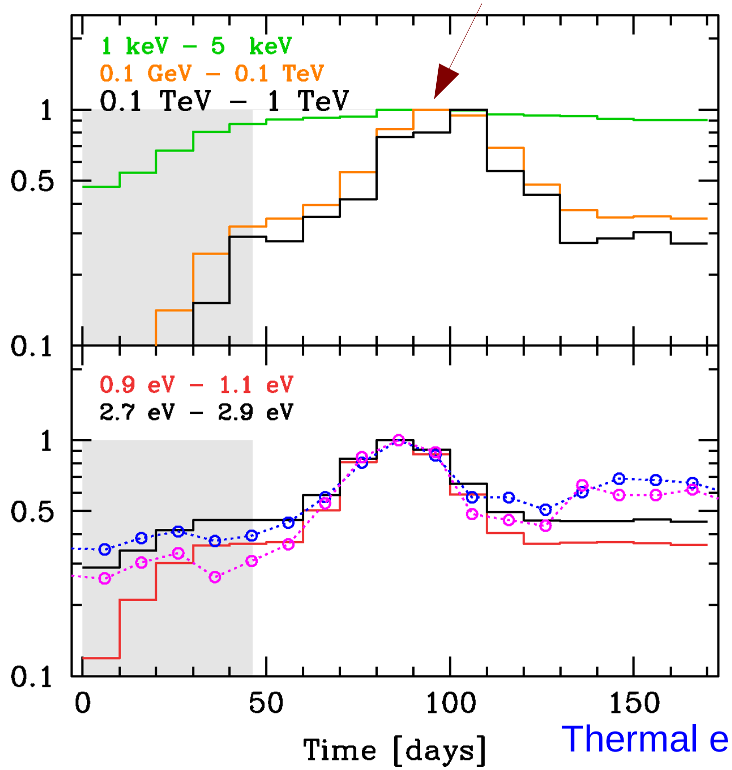
$\nu_{sy}, \nu_{ic}, L_{sy}, L_{ic}, t_{var}$



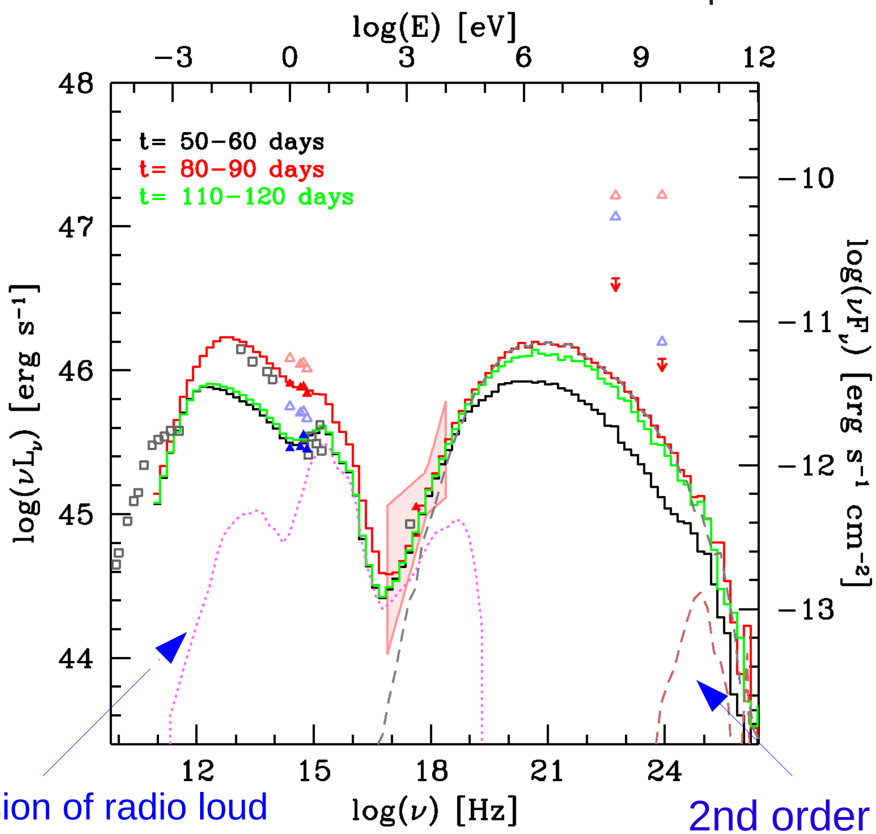
Electrons don't cool much

Electron spectrum

Delayed γ-ray flare



Light curves



SED

Thermal emission of radio loud quasars added to the SED as a posterior. (Elvis et al. 1994)

2nd order SSC

Pure SSC scenario

Burst increase of B causes the flare

5 parameters:

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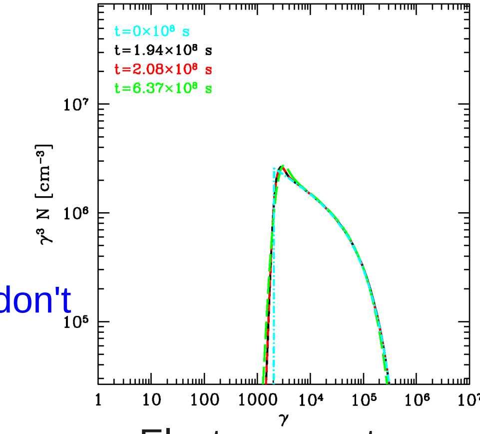
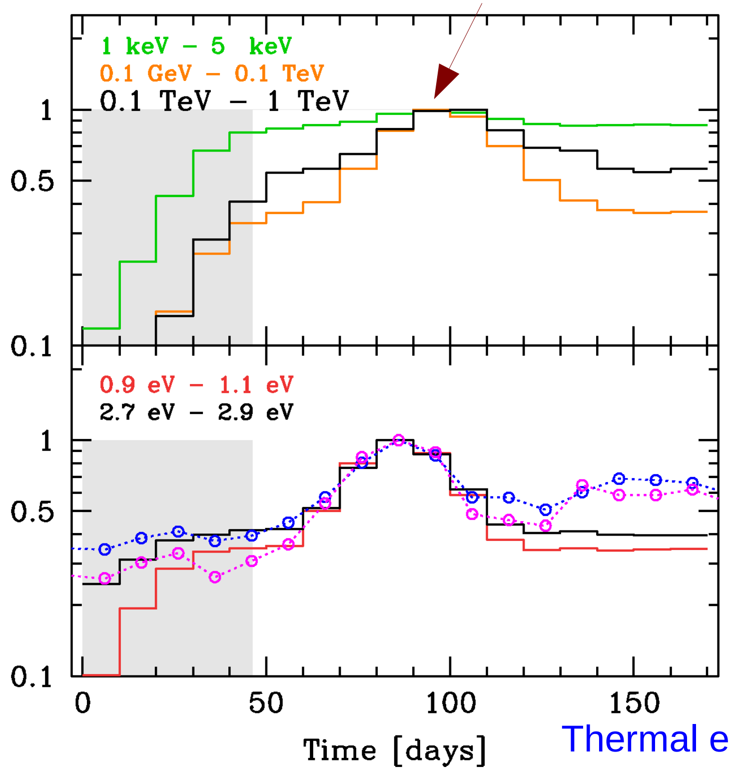
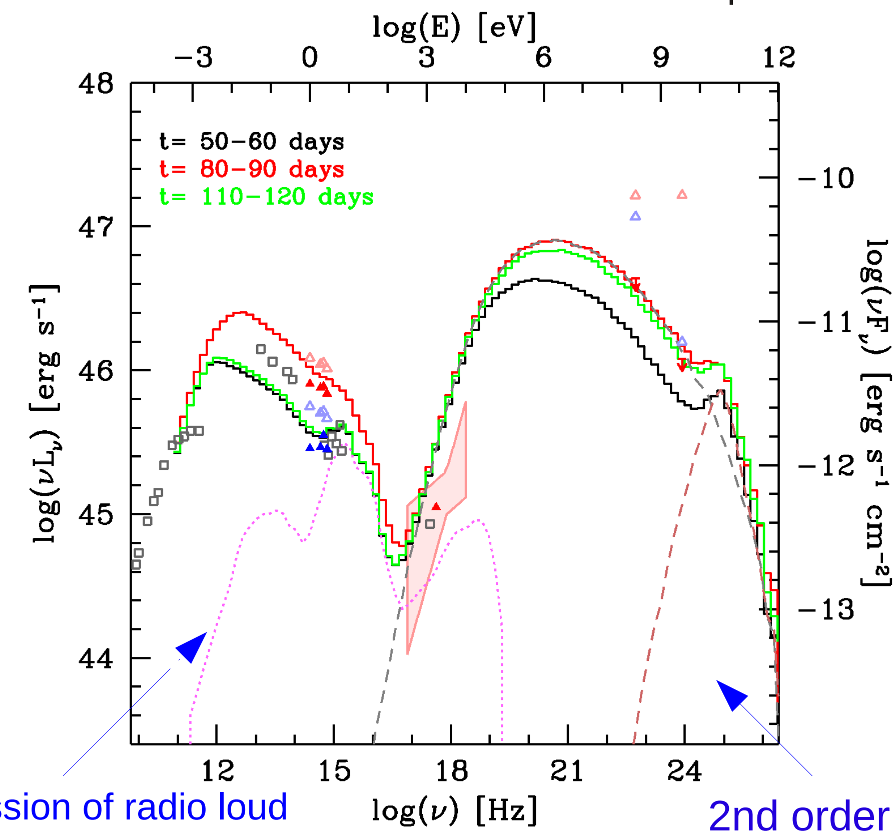


Electron spectrum

Delayed γ-ray flare



Light curves



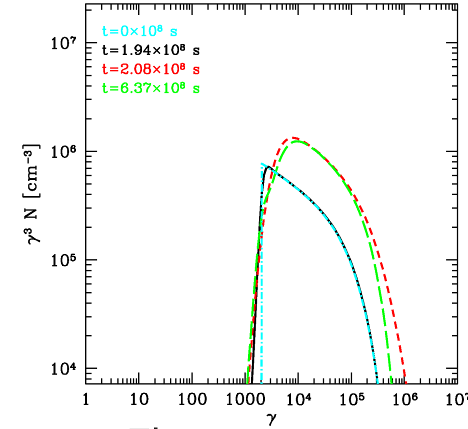
Thermal emission of radio loud quasars added to the SED as a posterior. (Elvis et al. 1994)

SED

2nd order SSC

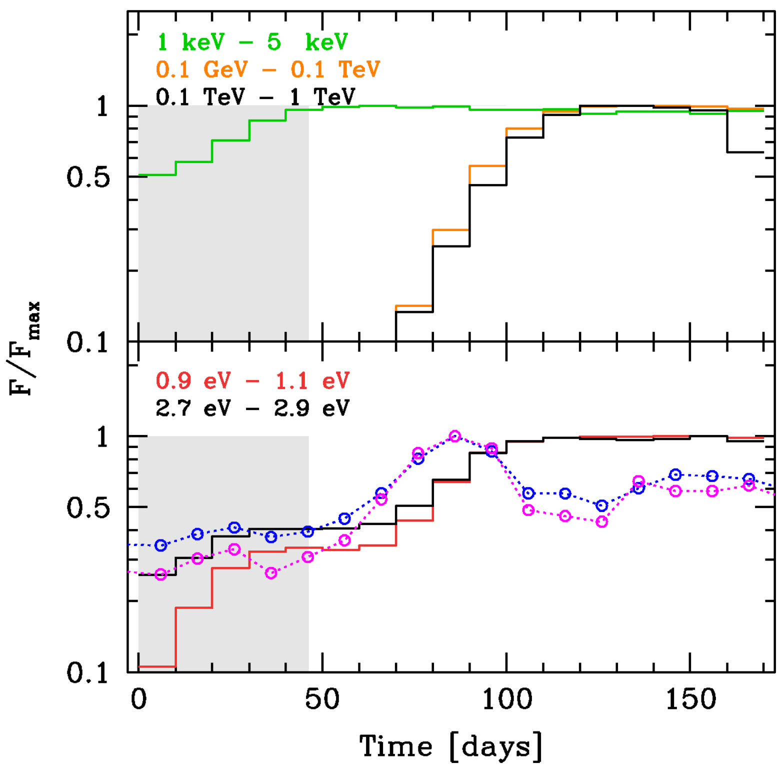
Pure SSC scenario

Burst increase of acceleration efficiency causes the flare

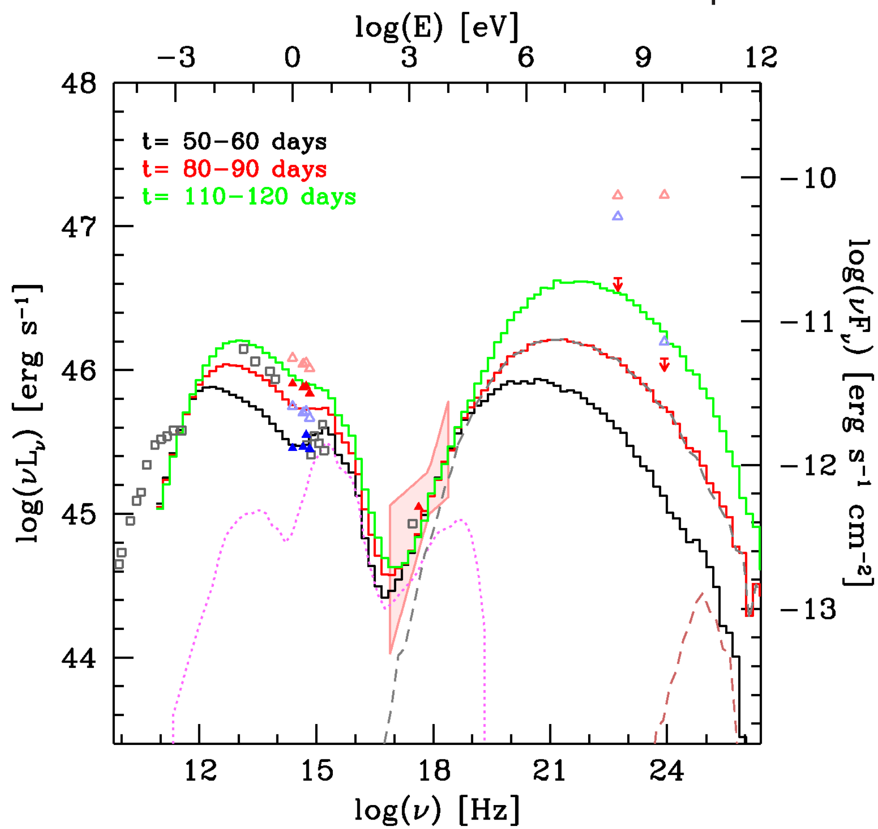


Electron spectrum

The electrons accelerated, but cooling is too slow



Light curves

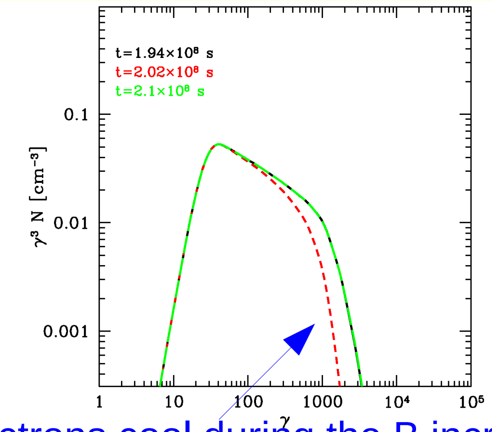


SED

Dusty torus EC scenario

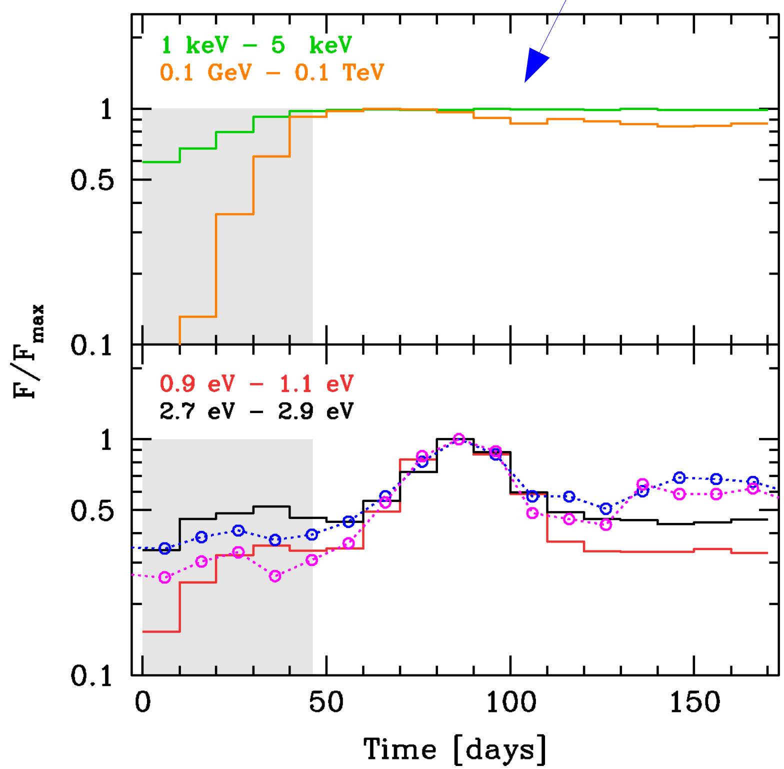
Brief increase of B causes the flare

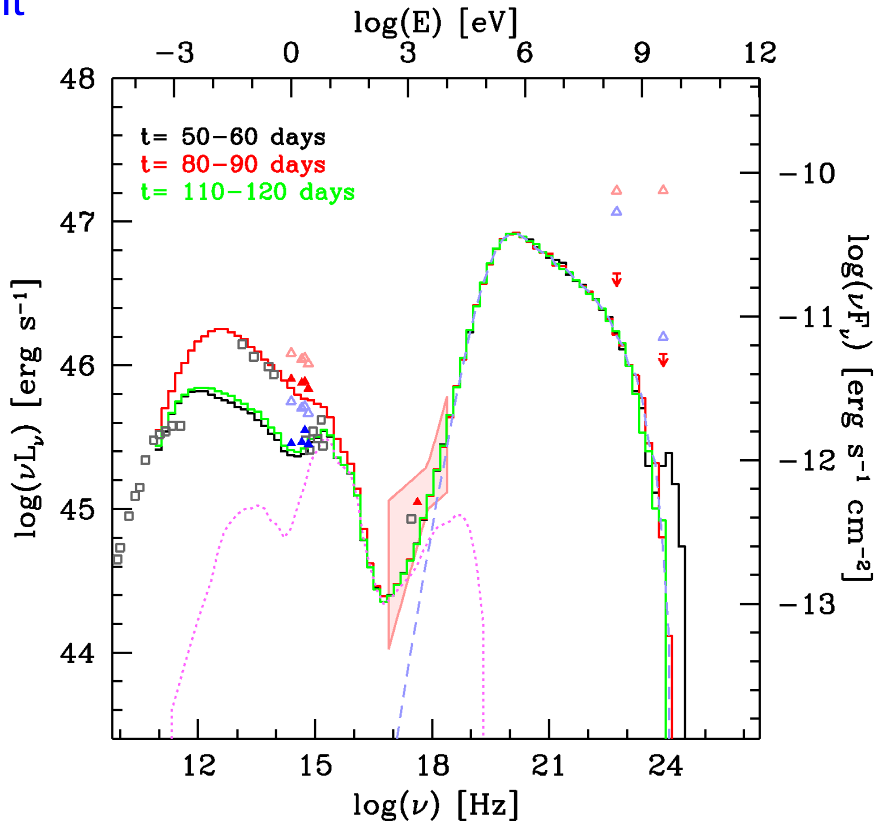
6 variables but 5 observables;
So we choose to fix δ=40 based on VLBI observation of superluminal motion in FSRQs



Electrons cool during the B increase

γ-ray level remains fairly constant

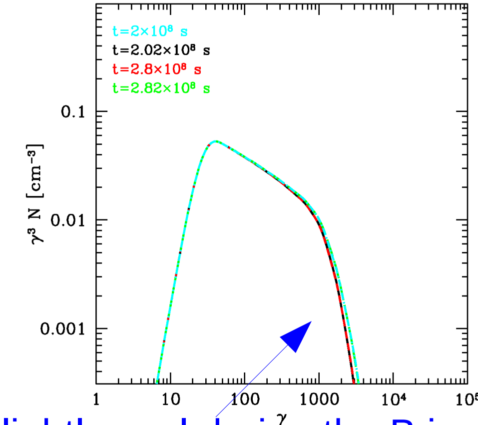




Dusty torus EC scenario

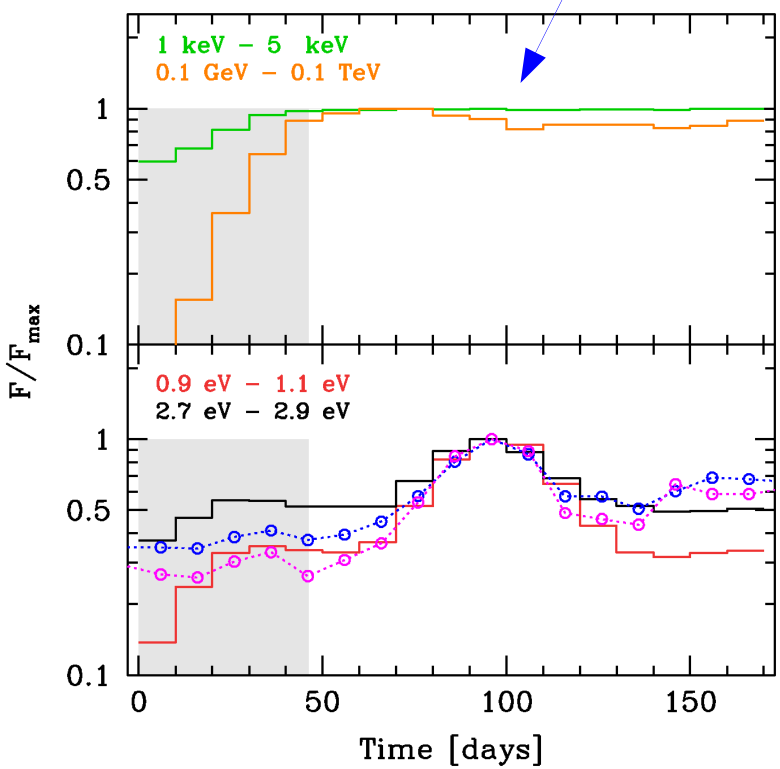
Prolonged increase of B causes the flare

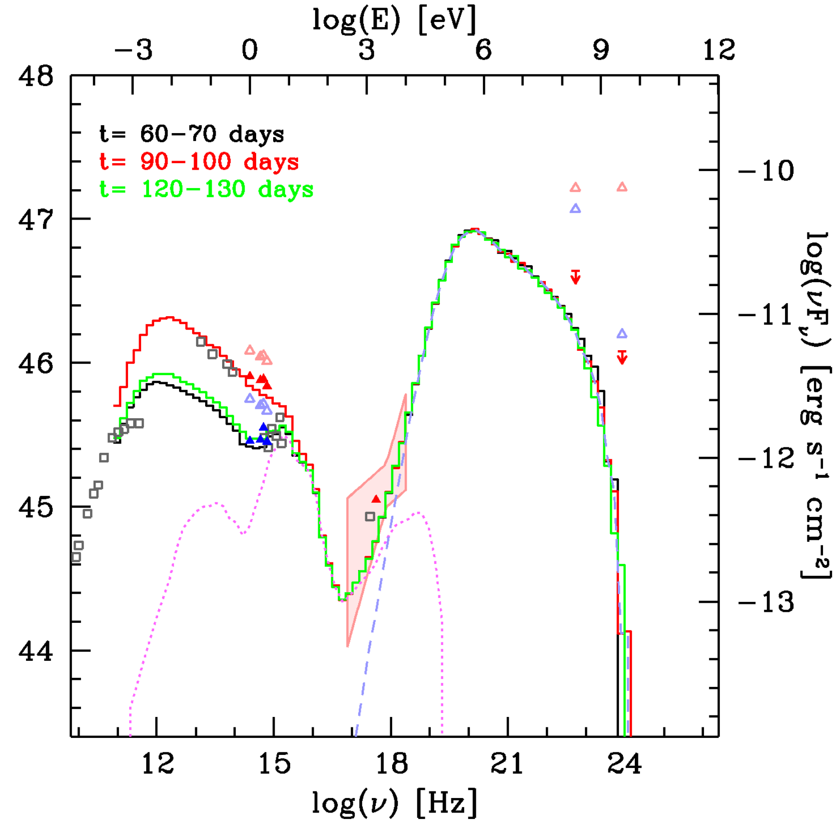
6 variables but 5 observables;
So we choose to fix δ=40 based on VLBI observation of superluminal motion in FSRQs



Electrons slightly cool during the B increase

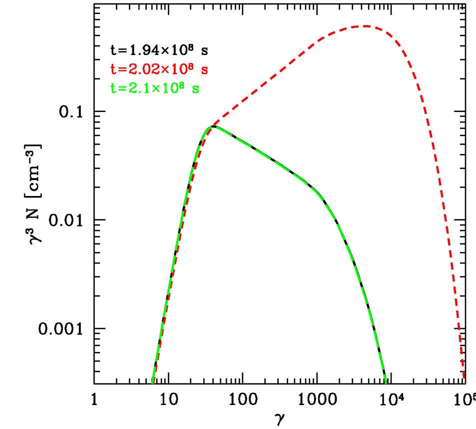
γ-ray level remains fairly constant





Dusty torus EC scenario

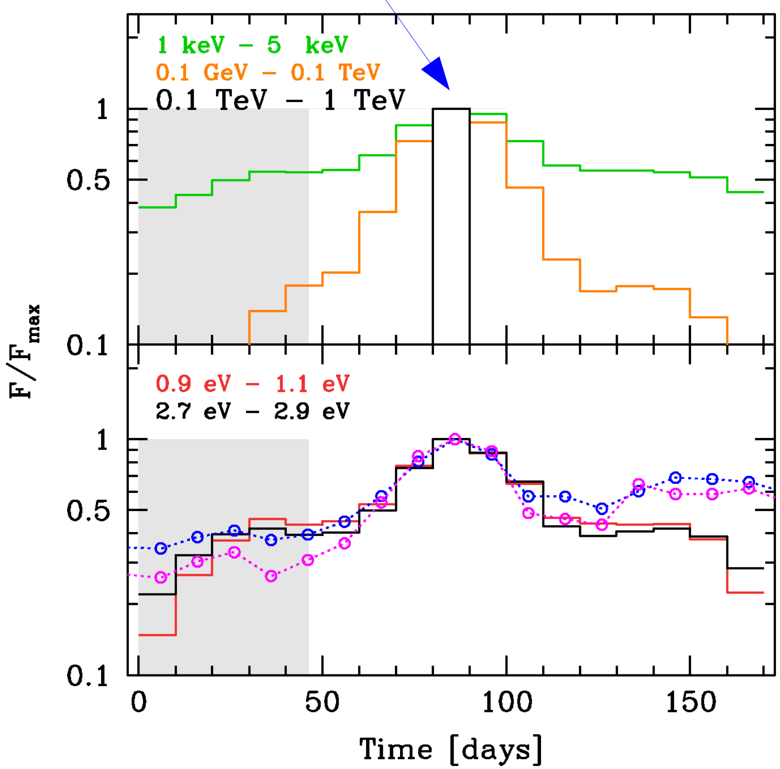
Burst increase of acceleration causes the flare

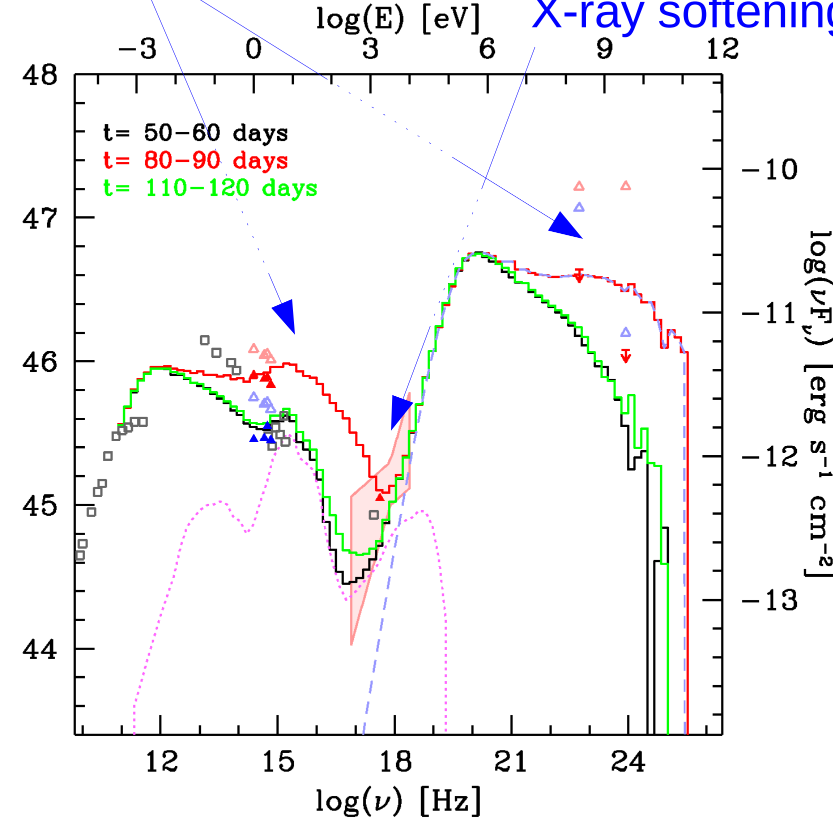


VHE emission begins to show up

Spectral hardening

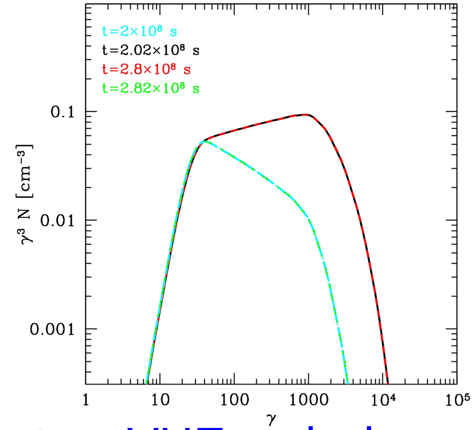
X-ray softening

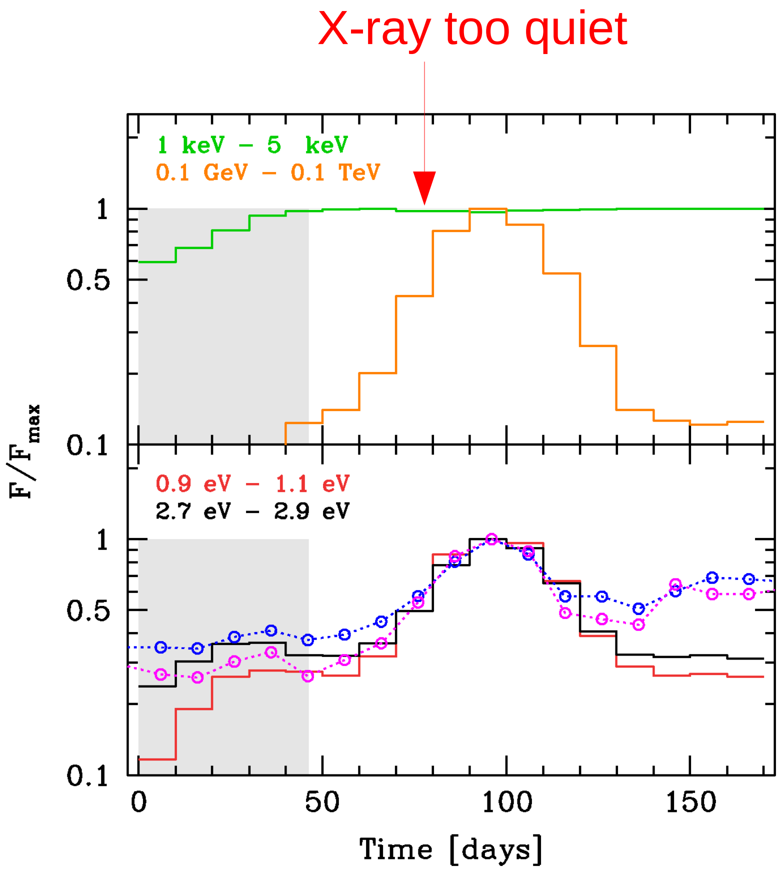


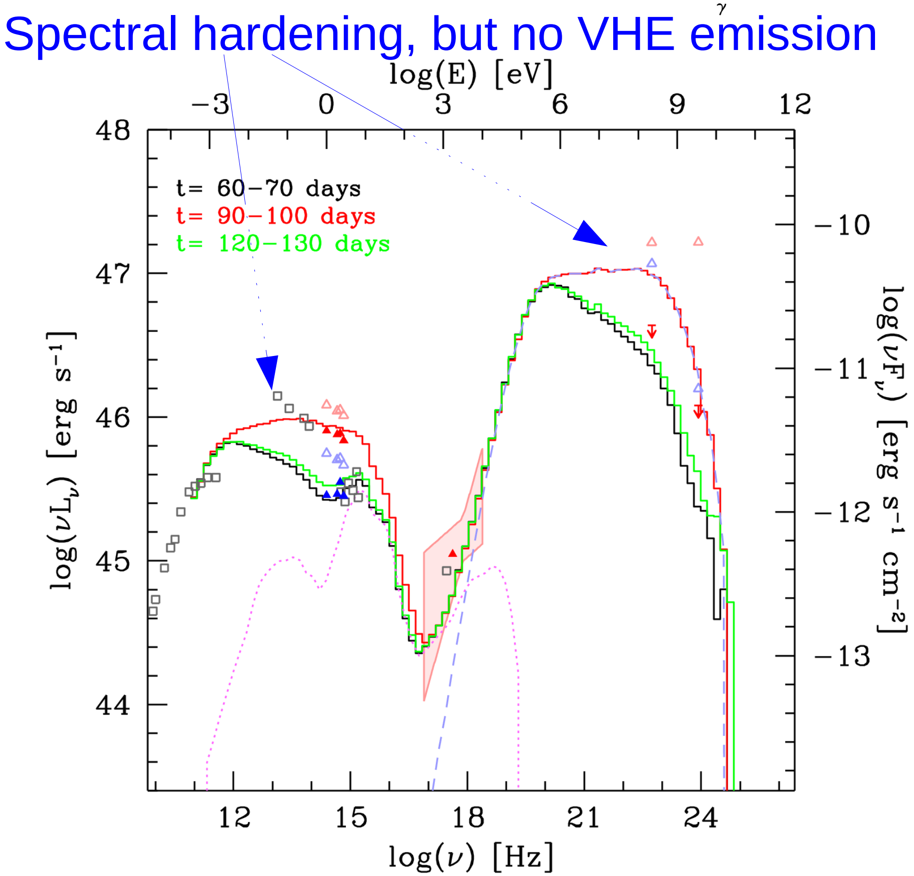


Dusty torus EC scenario

Prolonged increase of acceleration causes the flare







Discussion

1) The lack of time delays between optical and γ-ray flares, and the occurrence of optical flares without γ-ray counterpart, support the EC model as opposed to pure SSC model; However, this depends on the association of the flares with magnetic field amplification;

2) Whether a blazar optical flare has an γ-ray counterpart may depend on the allocation of the shock energy between magnetization and turbulence;

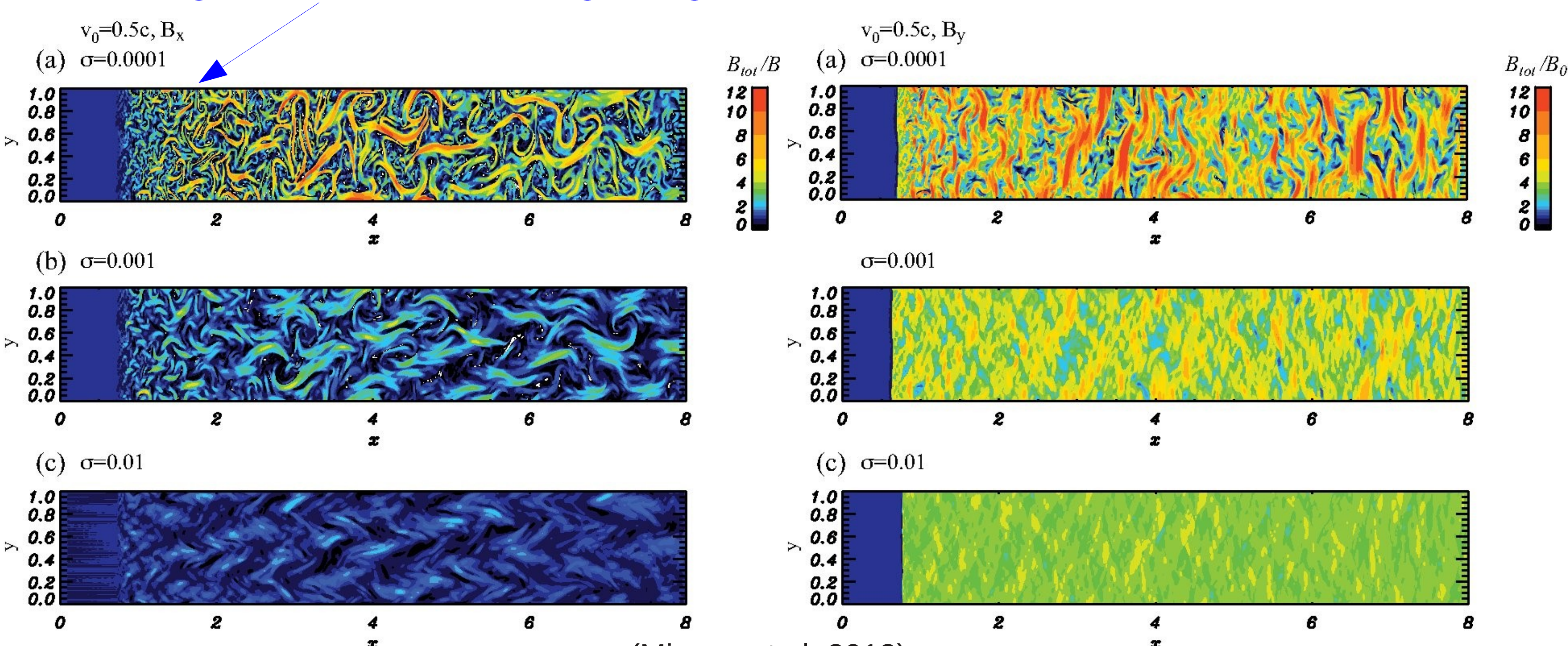
3) This allocation may depend on the initial orientation of magnetic field in the emission blob;

4) The change of acceleration efficiency can explain the spectral hardening of γ-ray blazars during flares, as well as the rare detection of FSRQs in VHE.

5) The softening of the X-ray during acceleration induced flares may be instructive for the VHE detection of FSRQs.

MHD simulation of magnetic field amplification

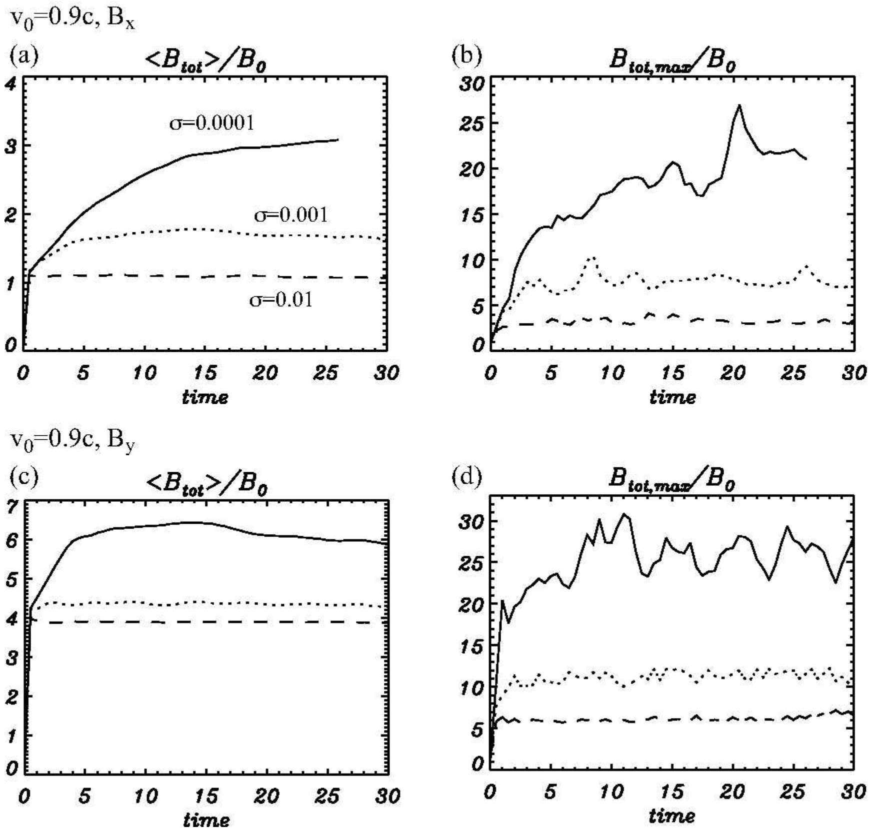
Strong turbulence at the beginning



(Mizuno et al. 2013)

The postshock magnetic field is more ordered with perpendicular magnetic field (right).
How is the level of turbulence connected to the efficiency of acceleration?

Magnetic field growth in the MHD simulation

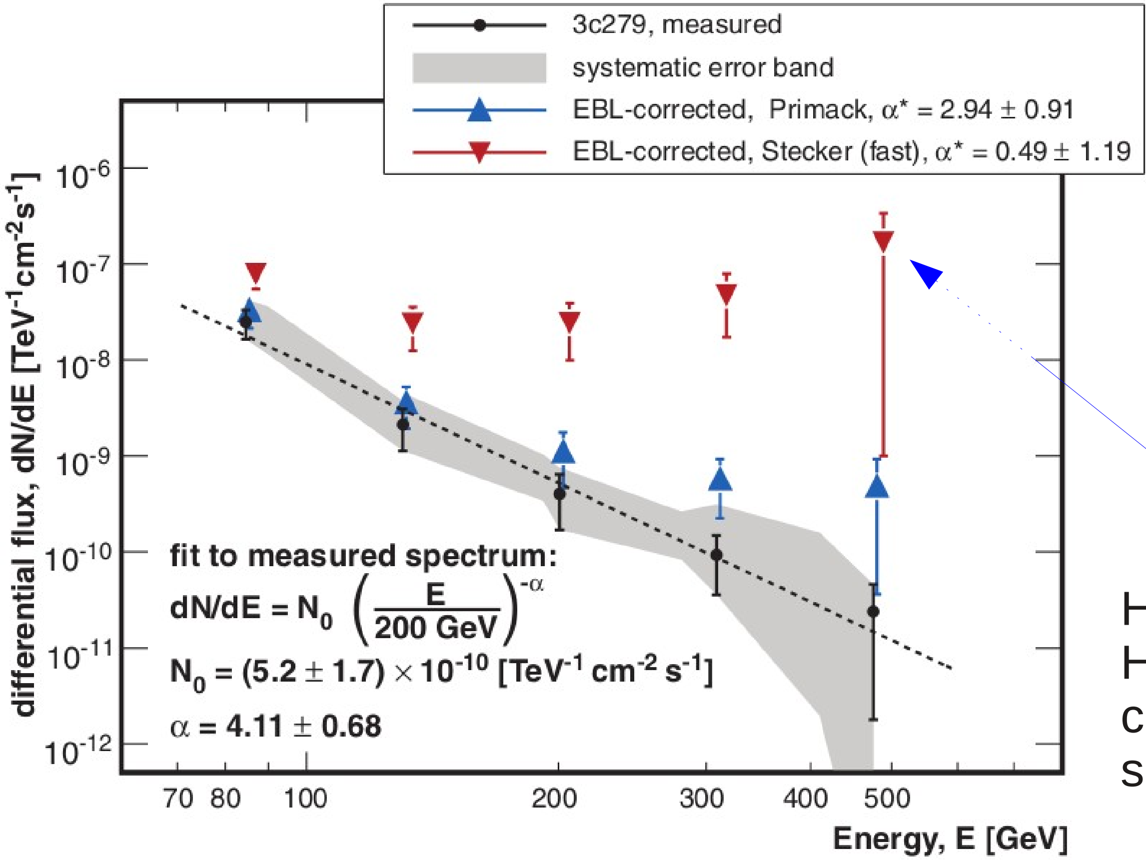


(Mizuno et al. 2013)

Perpendicular magnetic field case (bottom ones)
has less field growth beyond compression.

VHE emission detected in 3C279

Other two FSRQs detected in VHE: 3C273 and PKS1222-216

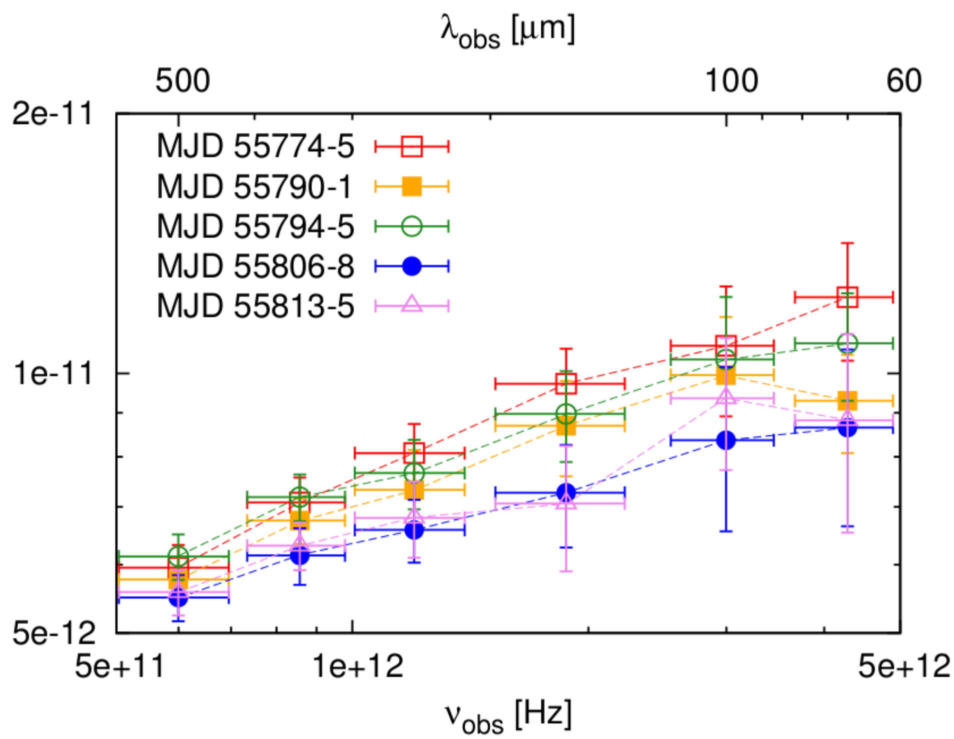


However, some HBL with EBL correction also show this feature

(MAGIC collaboration, 2008)

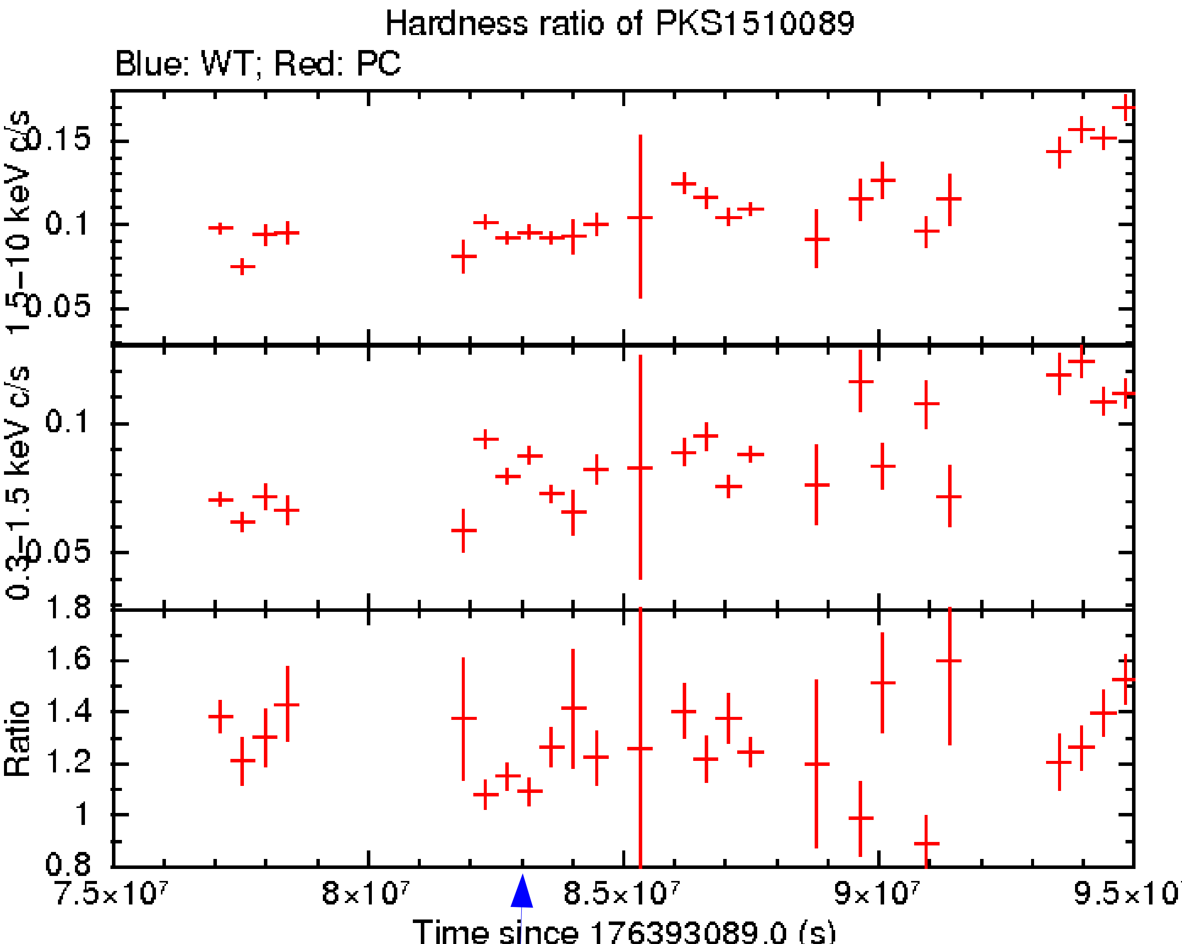
Herschel Observation of PKS 1510-089

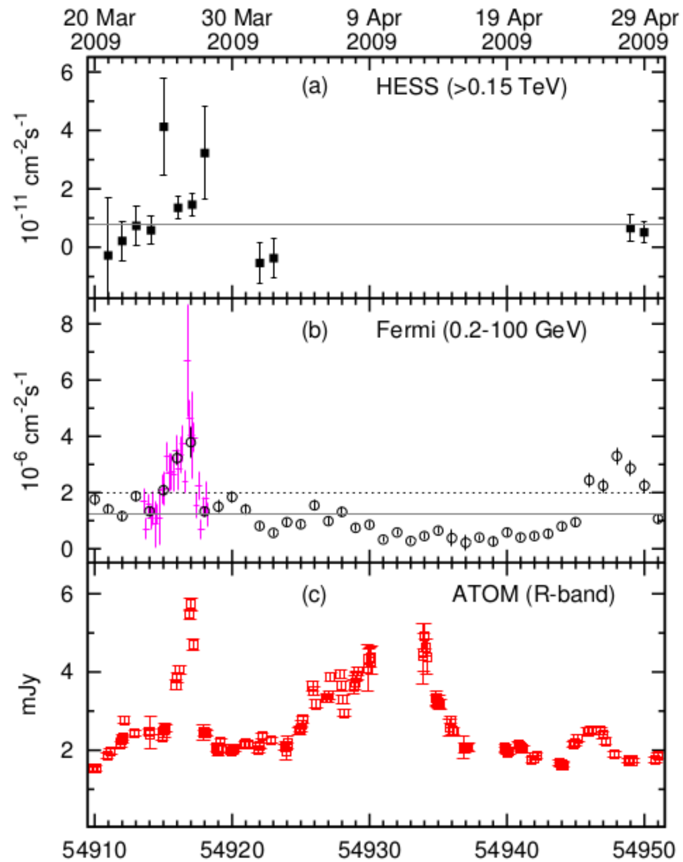
The high energy points are more variable than the low energy points



(Nalewajko et al. 2012)

X-ray light curves and Hardness ratio





(HESS collaboration, 2013)

HESS detection of PKS1510-089

Potential Loopholes

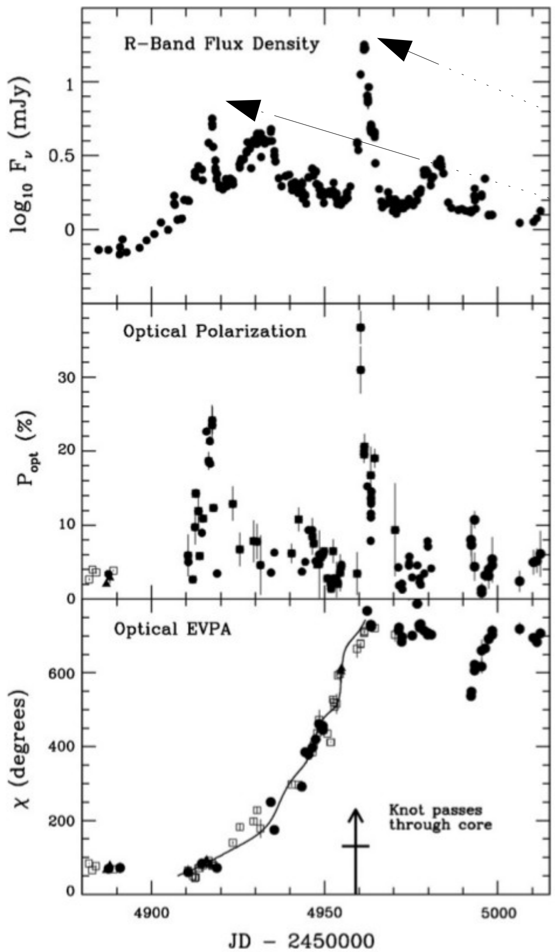
- Escape and acceleration time scales are on the order of 10^{-5} light crossing time of the blob. These fast particle acceleration and escape can be explained by turbulent cells scattered across the emission region;

- Relative size: Z=2.4x10^{18}cm, R_torus=3.5x10^{18}cm; This can be reconciled considering the relativistic abbreviation;

- This model currently finds difficulty in explaining the increase of optical polarization during correlated flares.

Polarization change during blazar flares

PKS 1510-089



(Marscher et al. 2010)

These two flares also have strong γ-ray counterparts

This increase of polarization is not easily explained by turbulent magnetic field amplification

Change of polarization angle

Conclusion

Magnetic field amplification in relativistic shocks, along with its associated stochastic particle acceleration can well explain most features of blazar flares.