Magnetic Field Amplification and Blazar Flares

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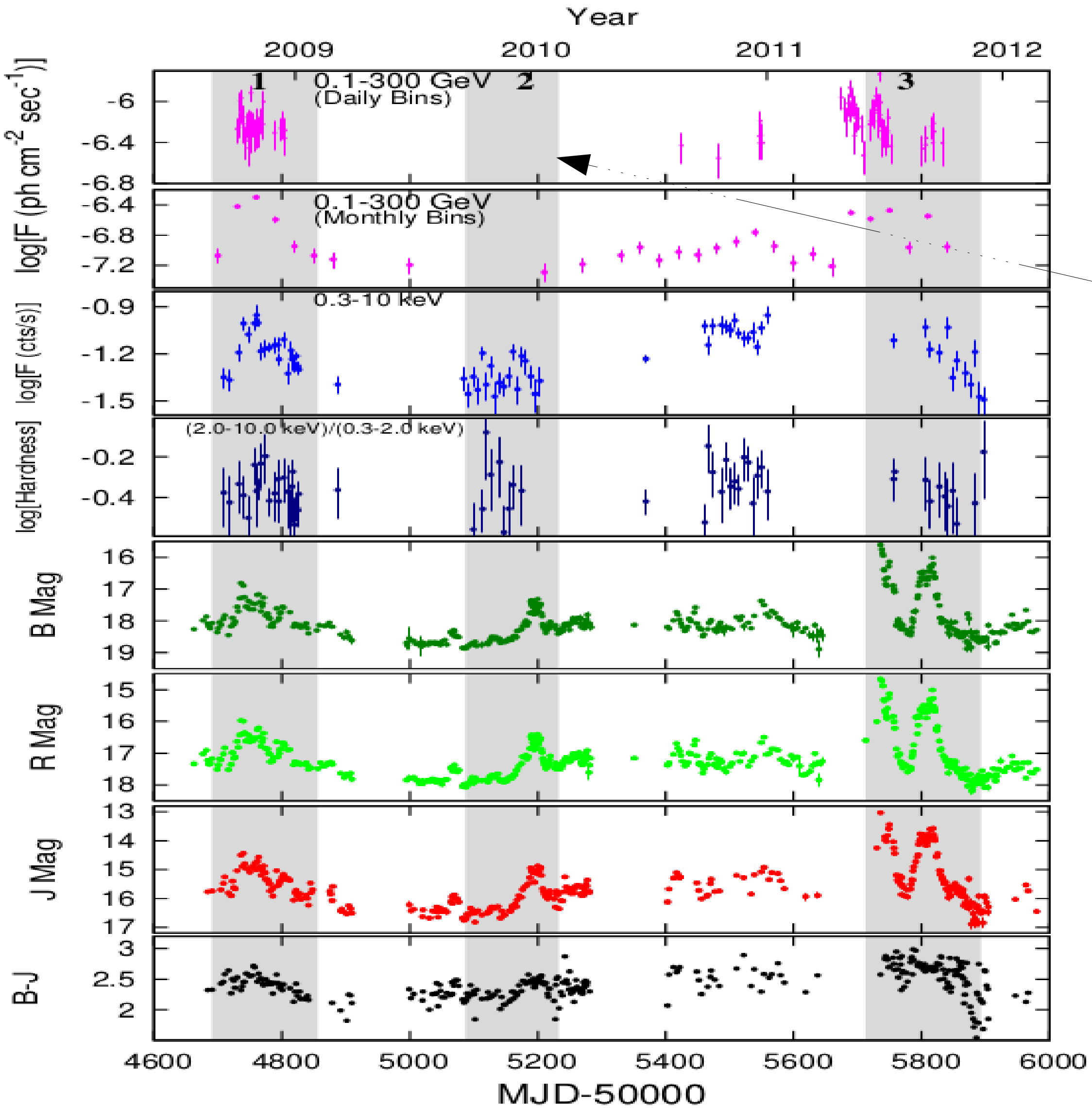
13.06.2013, Granada, Spain

Outline

- Observed odd flare of PKS 0208-512
- Inhomogeneous jet model
- Simulation of blazar flares
- Discussion

Observed light curves of PKS 0208-512



3 major optical flares in gray shaded sections.

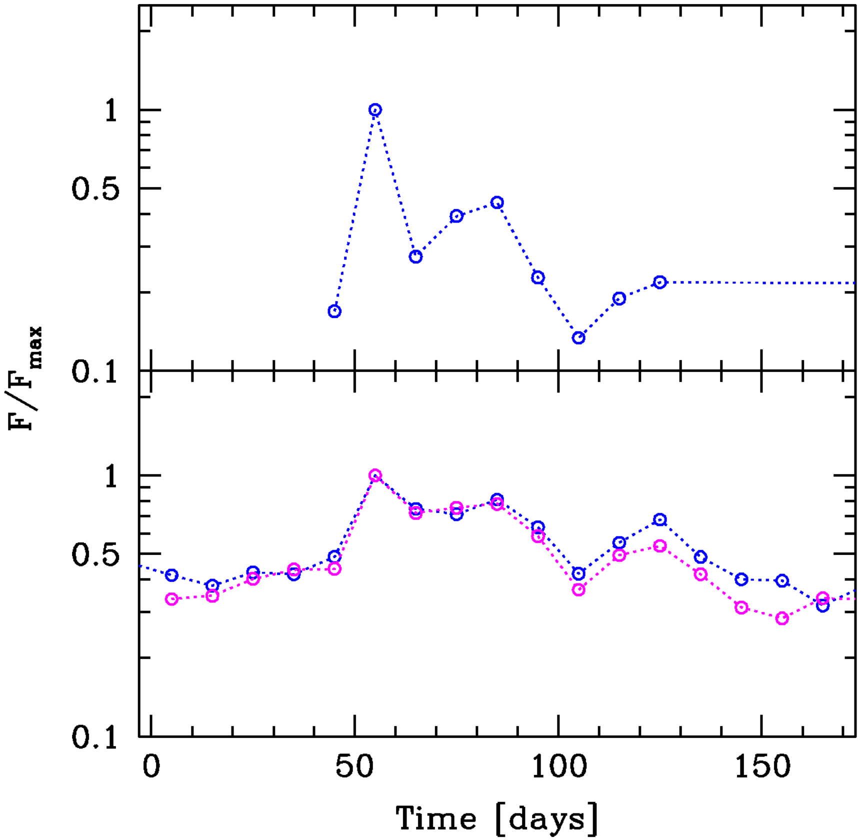
The 2nd one does not have an gamma-ray counterpart.

(Chatterjee et al. 2012)

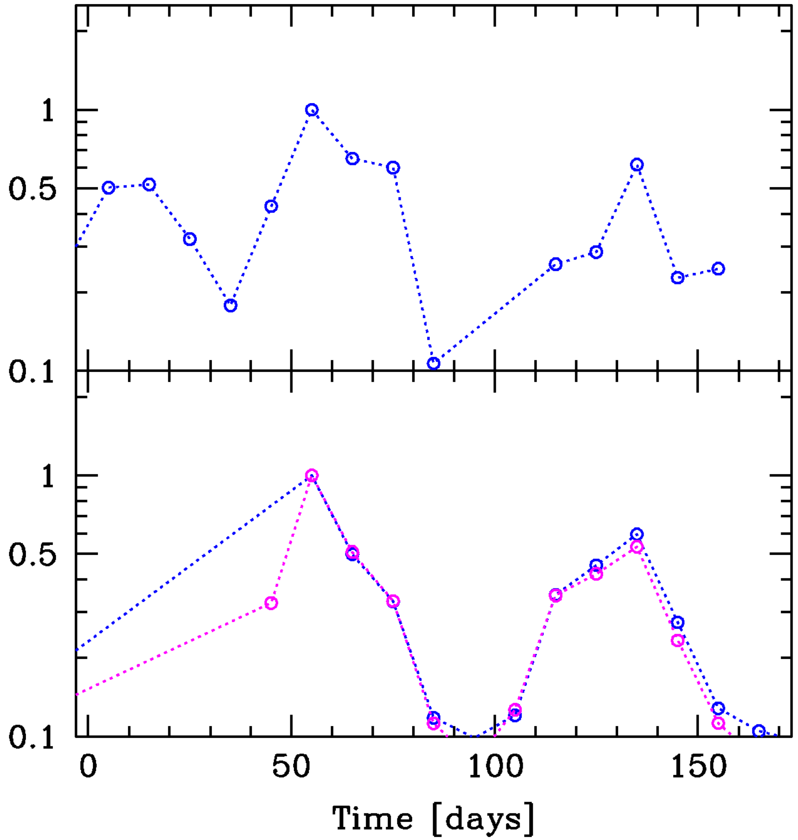
Optical and gamma-ray light curves show clear similarity

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

Flare #1

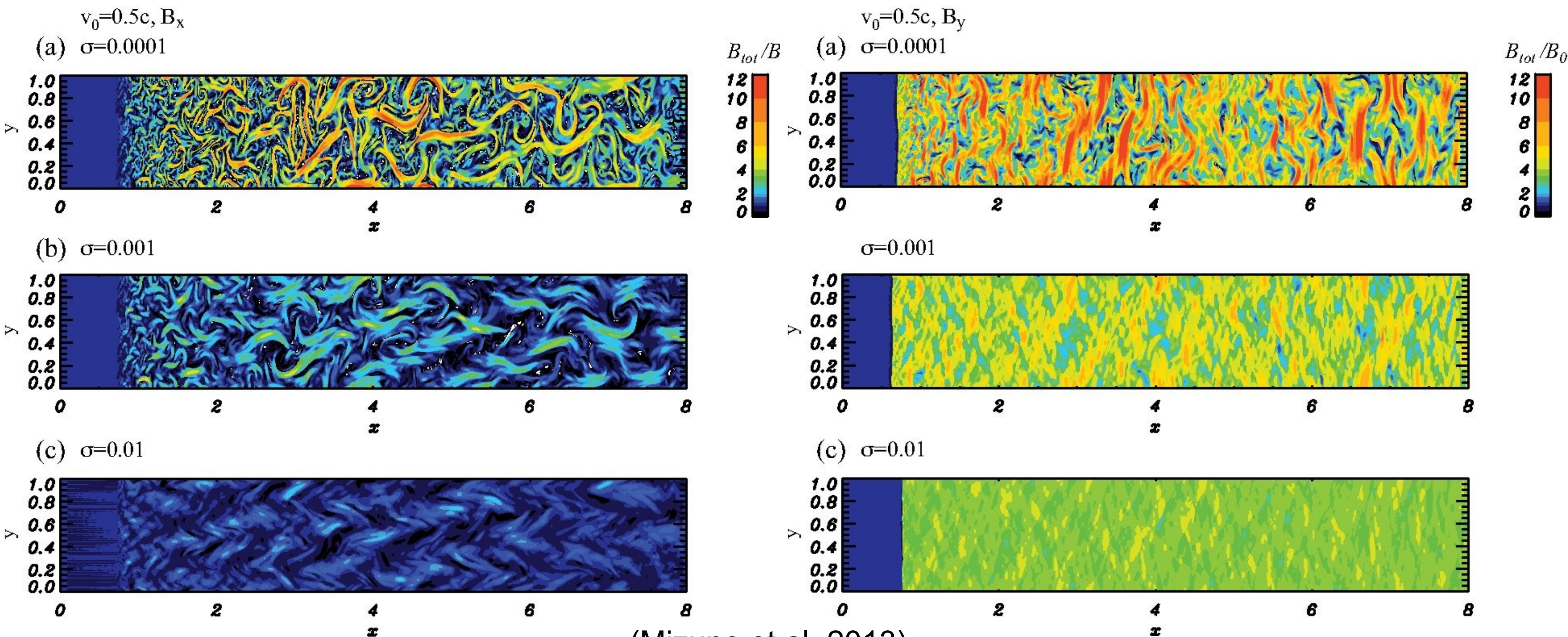


Flare #3



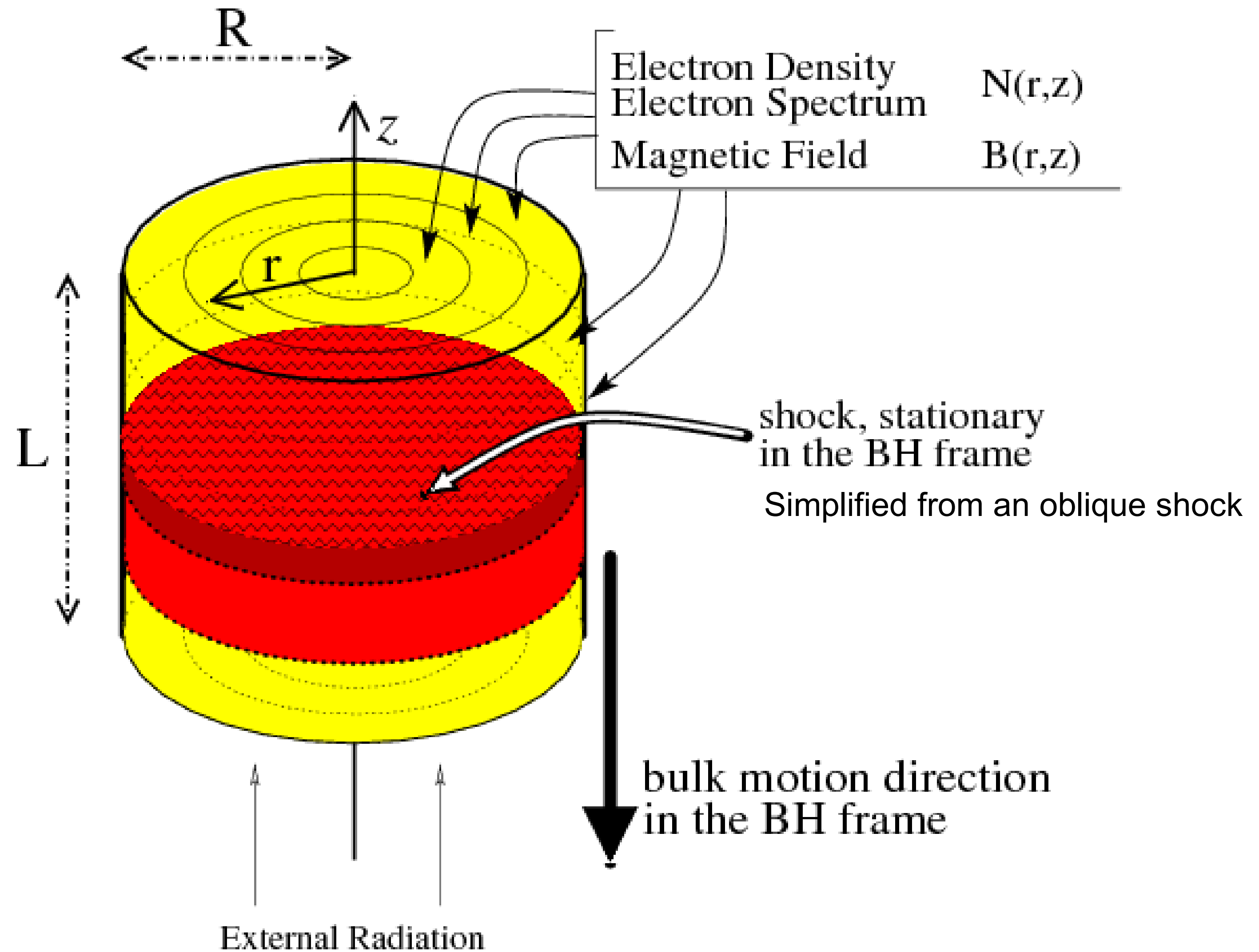
How could the source produce correlated flares sometimes, but optical-only flares at other times?

Magnetic field amplification downstream of shock



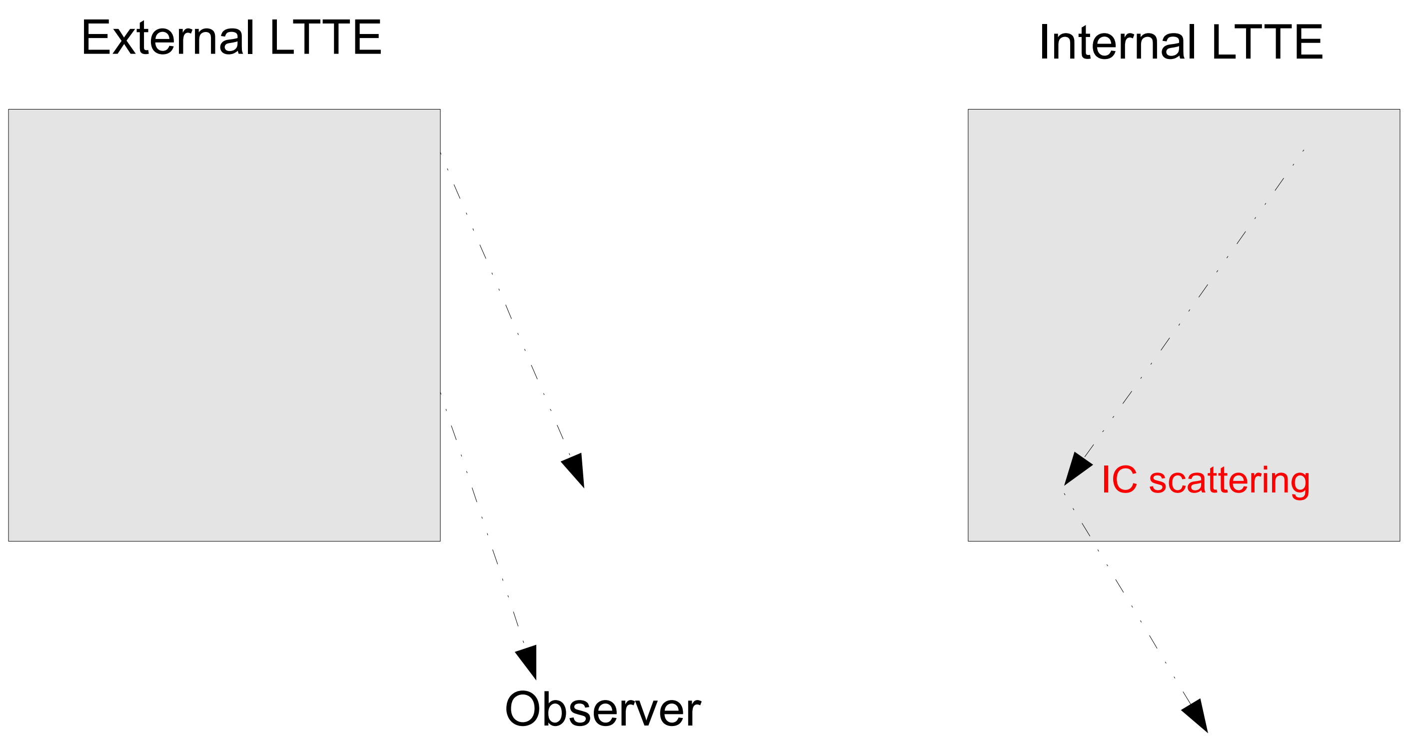
(Mizuno et al. 2013)

Geometry of our cylindrical jet model



Light Travel Time Effects (LTTE)

Symmetry of blazar light curves indicates that geometry and inhomogeneity are dominating the shape of the light curves. So, time dependent blazar models must consider inhomogeneity with light travel time effects (LTTE) included.



We use Monte Carlo simulation to track the LTTE of photons.

Electron evolution: Fokker-Planck equation

- Synchrotron & Inverse Compton cooling
- Stochastic particle acceleration
- Particle escape

$$\frac{\partial N(\gamma,t)}{\partial t} = -\frac{\partial}{\partial \gamma}\left[N(\gamma,t)\dot{\gamma}(\gamma,t)\right] + \frac{1}{2}\frac{\partial^2}{\partial \gamma^2}\left[N(\gamma,t)D(\gamma,t)\right] + Q(\gamma,t) - \frac{N(\gamma,t)}{t_{esc}}$$

Preliminary

Pure SSC scenario

Short increase of B causes the flare

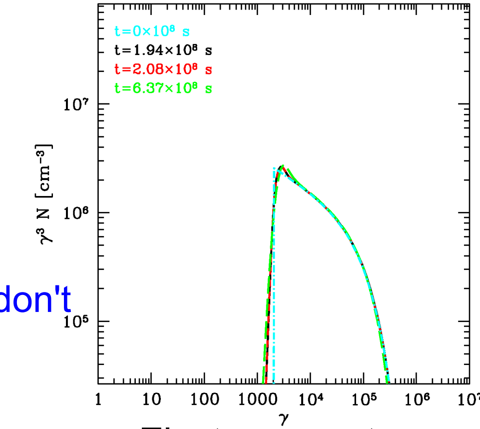
5 parameters:

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

Constrained by 5 observables:

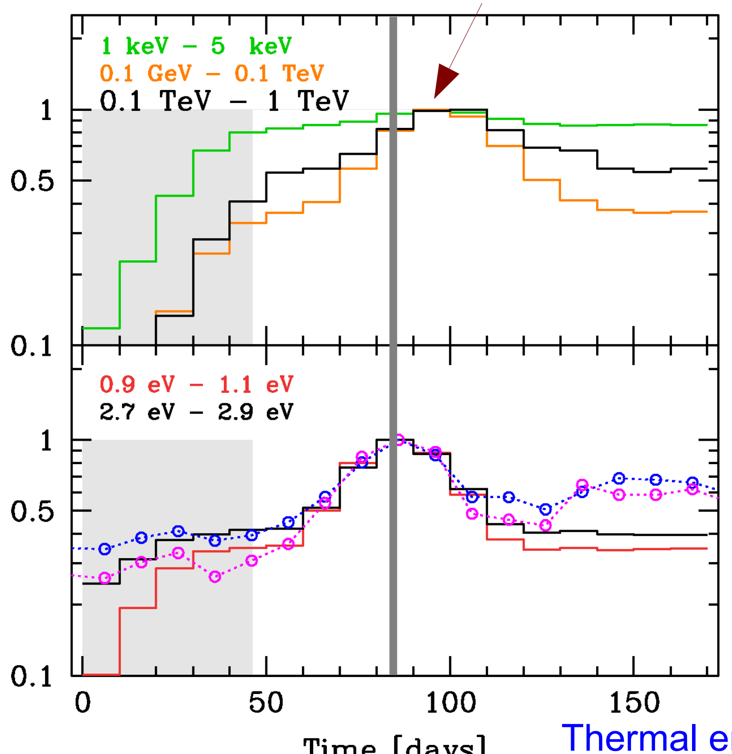
$\nu_{sy}, \nu_{ic}, L_{sy}, L_{ic}, t_{var}$

Electrons don't cool much

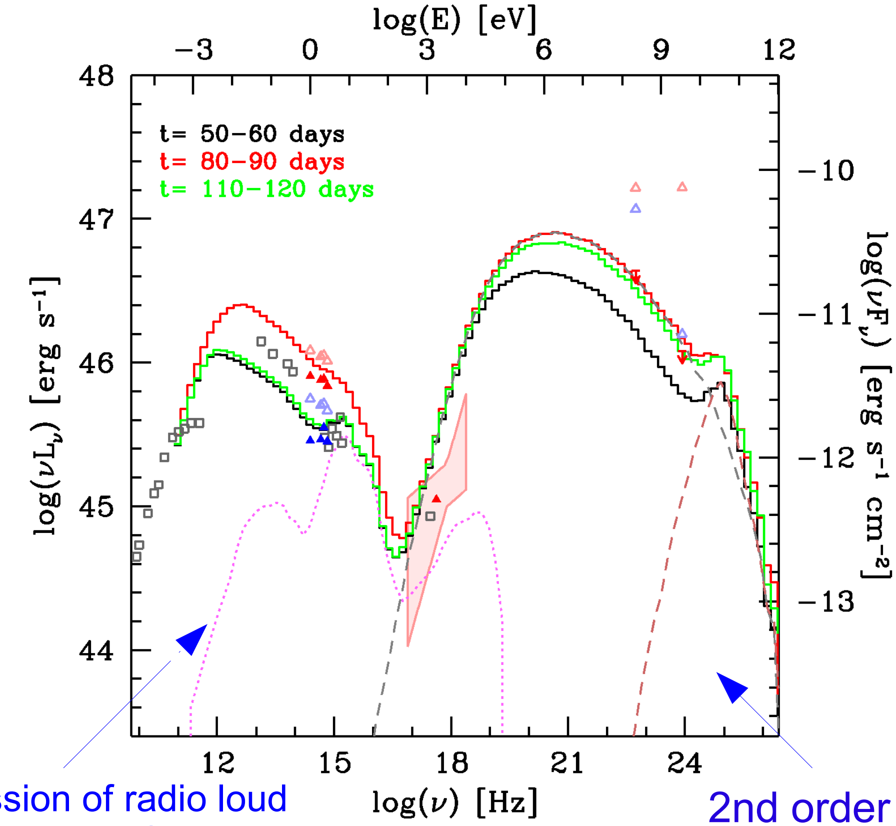


Electron spectrum

Delayed γ-ray flare



Light curves



SED

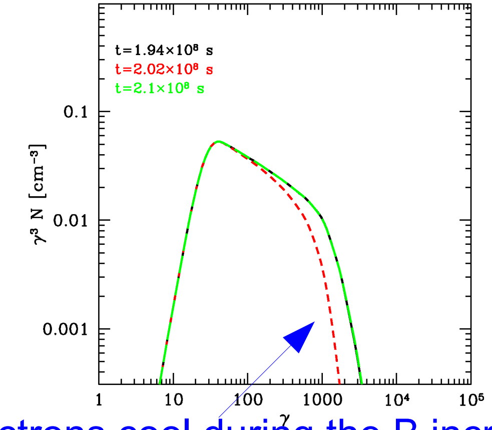
Thermal emission of radio loud quasars added to the SED as a posterior. (Elvis et al. 1994)

2nd order SSC

Preliminary

Dusty torus EC scenario

Short increase of B causes the flare

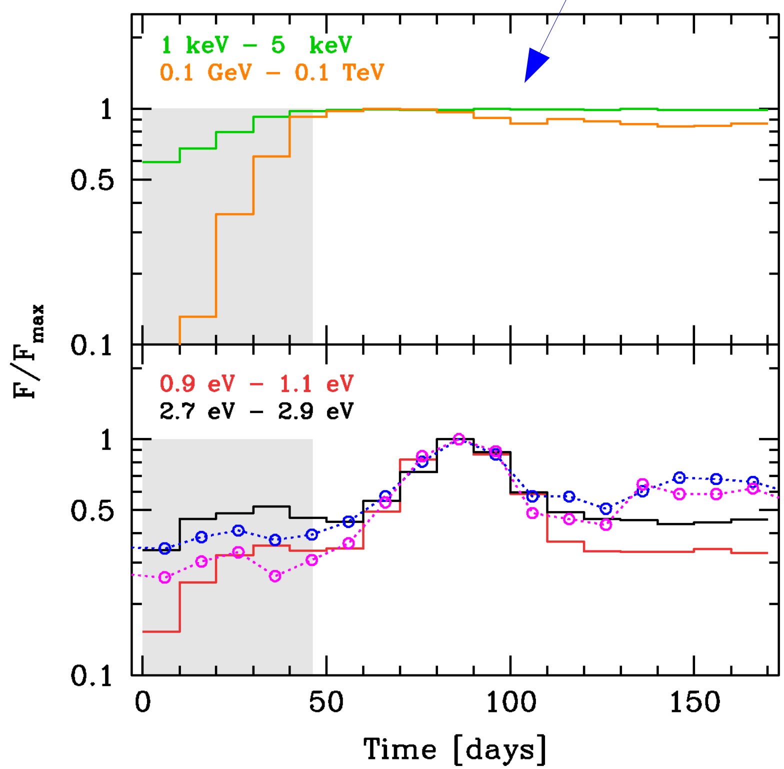


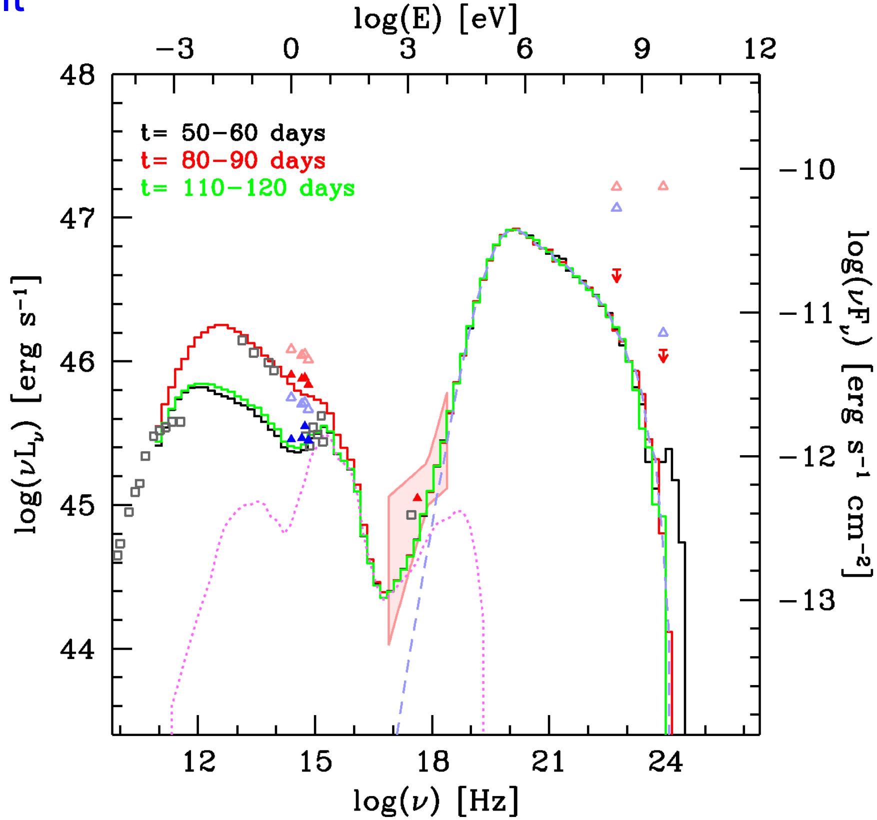
Electrons cool during the B increase

6 variables but 5 observables;

So we choose to fix δ=40 based on the fastest superluminal motion in FSRQs obtained with VLBI observation (Jorstad et al. 2005)

γ-ray level remains fairly constant

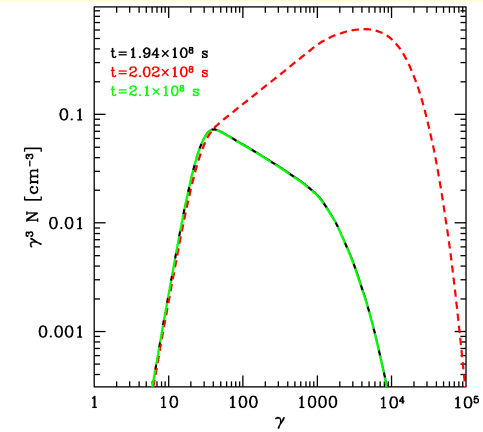




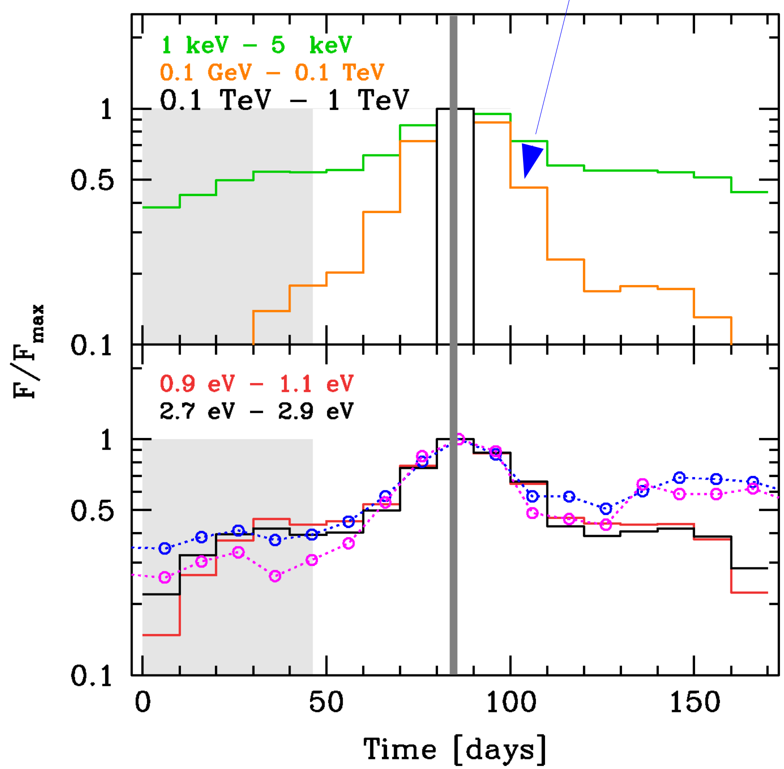
Preliminary

Dusty torus EC scenario

Short increase of acceleration causes the flare

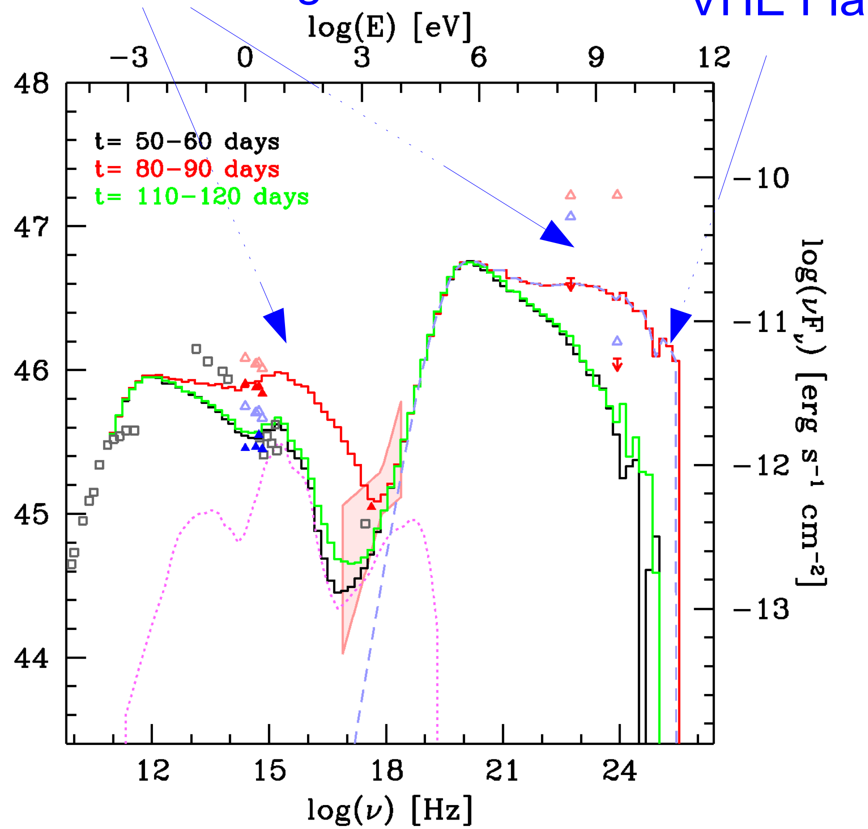


γ-ray varies similarly as optical



Spectral hardening

VHE Flare



Discussion

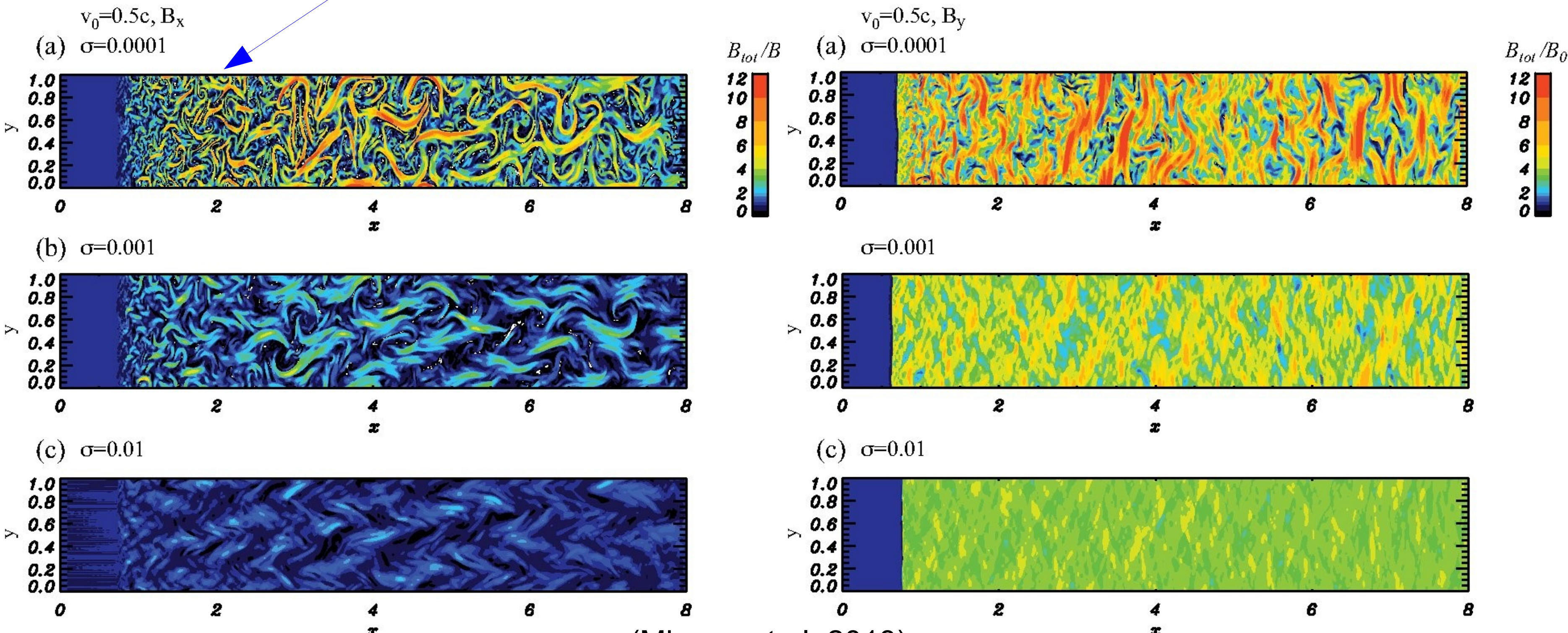
1) The lack of time delays between optical and γ-ray flares, and the occurrence of optical flares without γ-ray counterpart, support the EC model as opposed to pure SSC model;

2) 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.

3) Whether a blazar optical flare has an γ-ray counterpart may depend on the allocation of the shock energy between magnetization and turbulence; This allocation may depend on the initial orientation of magnetic field in the emission blob;

MHD simulation of magnetic field amplification

Strong turbulence at the beginning



(Mizuno et al. 2013)

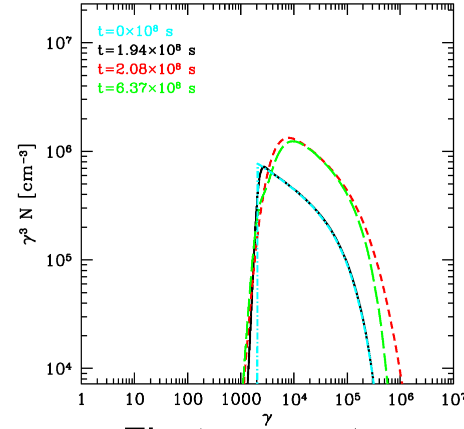
The postshock magnetic field is more ordered with perpendicular magnetic field (right).

Thank you!

The Innermost Regions of Relativistic Jets and Their Magnetic Fields
Theory, simulations, and observations of AGN jets from radio to gamma-rays
Granada (Spain), June 10th-14th, 2013
Topics Covered:
Jet formation
Black hole, accretion disk, jet connection
Multi-spectral-range emission
Magnetic fields and polarization
Jet dynamics and stability
Unification models, microphysics, particle acceleration
Relativistic stellar jets
Scientific Organizing Commitee:
Ivan Agudo (IAA-CSIC, Spain)
Margo Aller (UMICH, USA)
Markus Boettcher (Ohio Univ., USA)
Denise Gabuzda (UCC, Ireland)
Markos Georganopoulos (UMBC, USA)
Gabriele Giovannini (IRA-INAF, Italy)
Jose L. Gómez (Chair, IAA-CSIC, Spain)
Robert Laing (ESO, Germany)
Matthew L. Lister (Purdue Univ., USA)
Andrei Lobanov (MPIfR, Germany)
Alan Marscher (Boston Univ., USA)
José-Maria Marti (Univ. Valencia, Spain)
Josep M. Paredes (Univ. Barcelona, Spain)
Gregory Taylor (UNM, USA)
Nektarios Vlahakis (Univ. Athens, Greece)
CSIC
RadioNet
http://jets2013.iaa.es

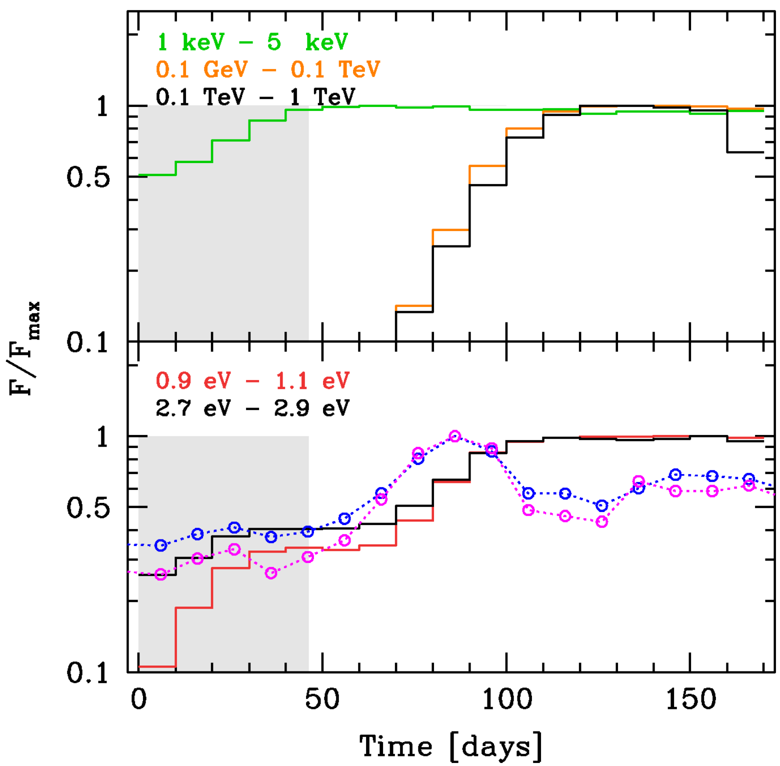
Pure SSC scenario

Burst increase of acceleration efficiency causes the flare

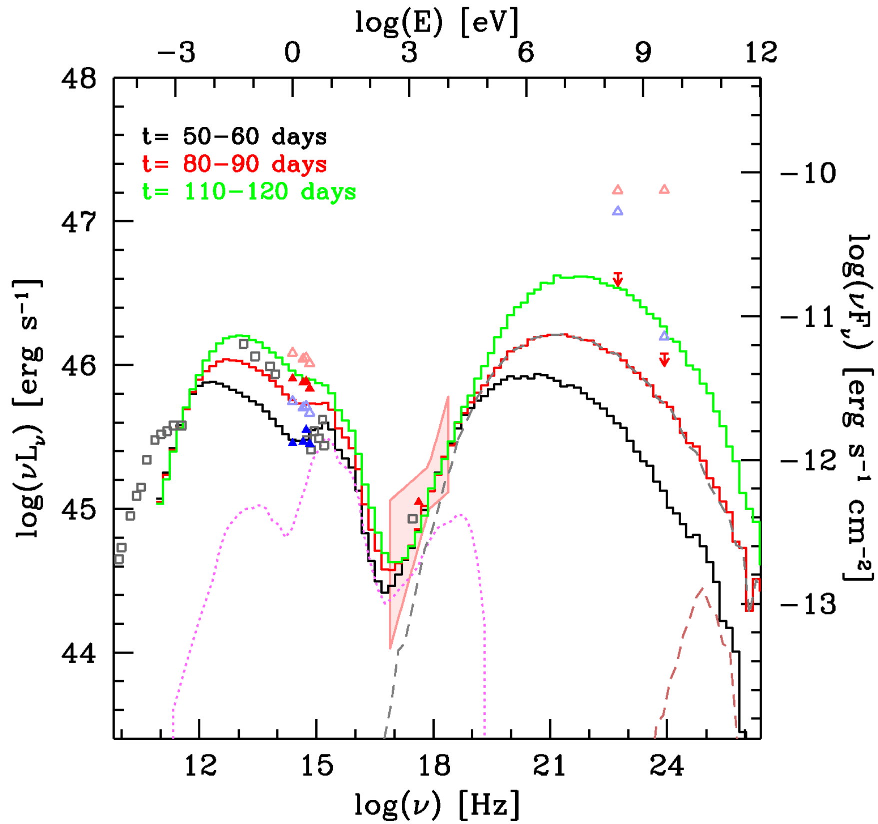


Electron spectrum

The electrons accelerated, but cooling is too slow



Light curves

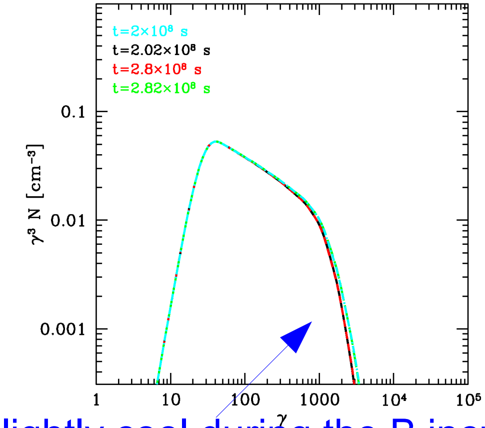


SED

Dusty torus EC scenario

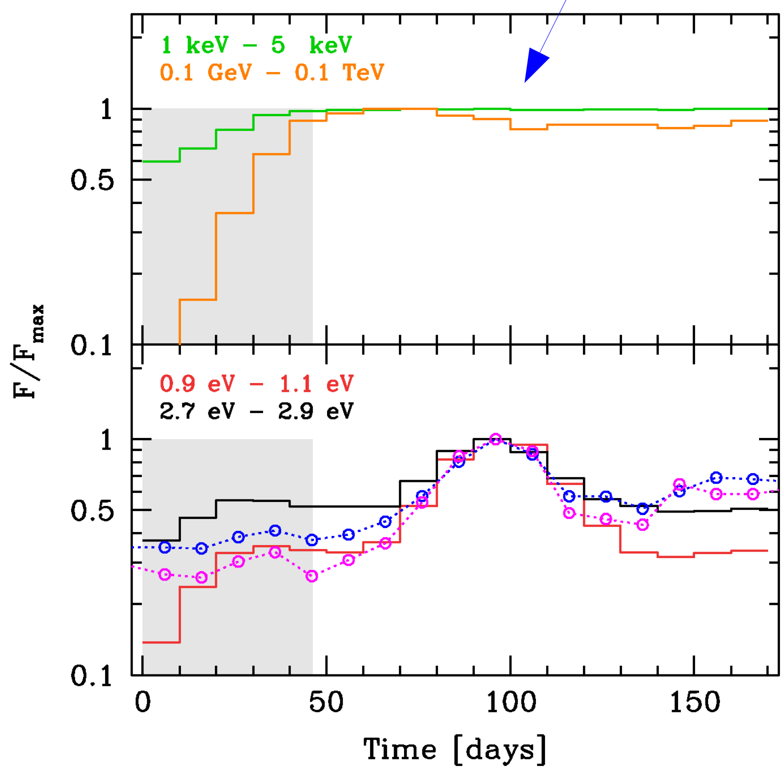
Prolonged increase of B causes the flare

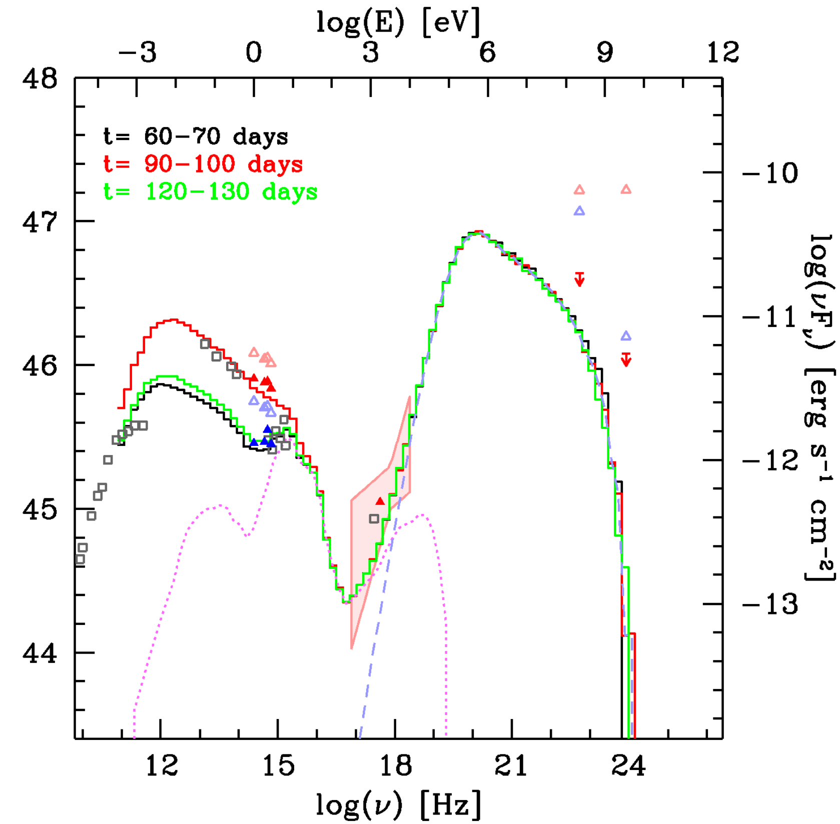
6 variables but 5 observables;
So we choose to fix δ=40 based on VLBI observation of superluminal motion in FSRQs



Electrons slightly cool during the B increase

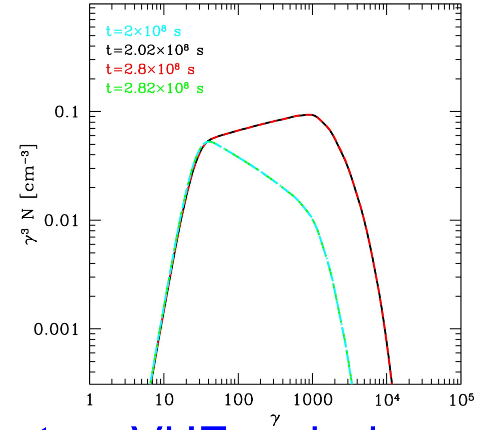
γ-ray level remains fairly constant



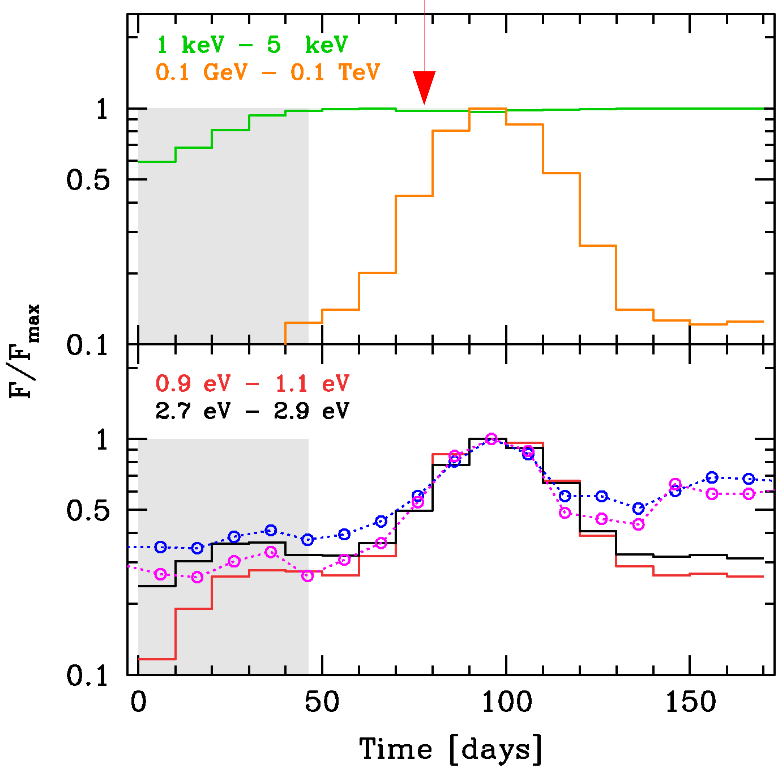


Dusty torus EC scenario

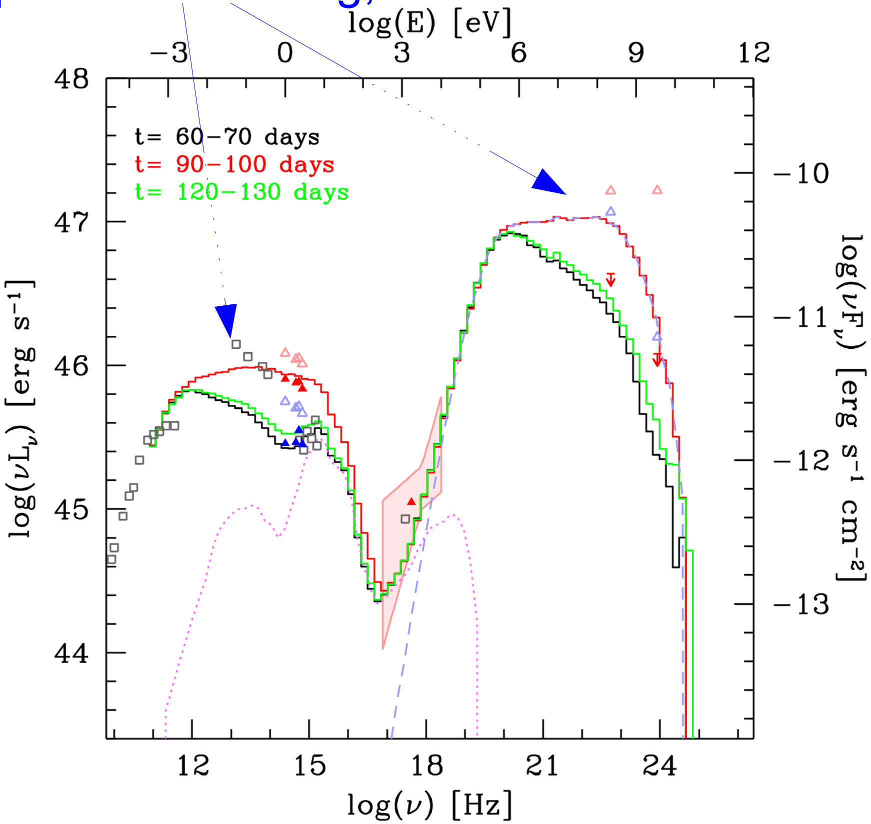
Prolonged increase of acceleration causes the flare



X-ray too quiet

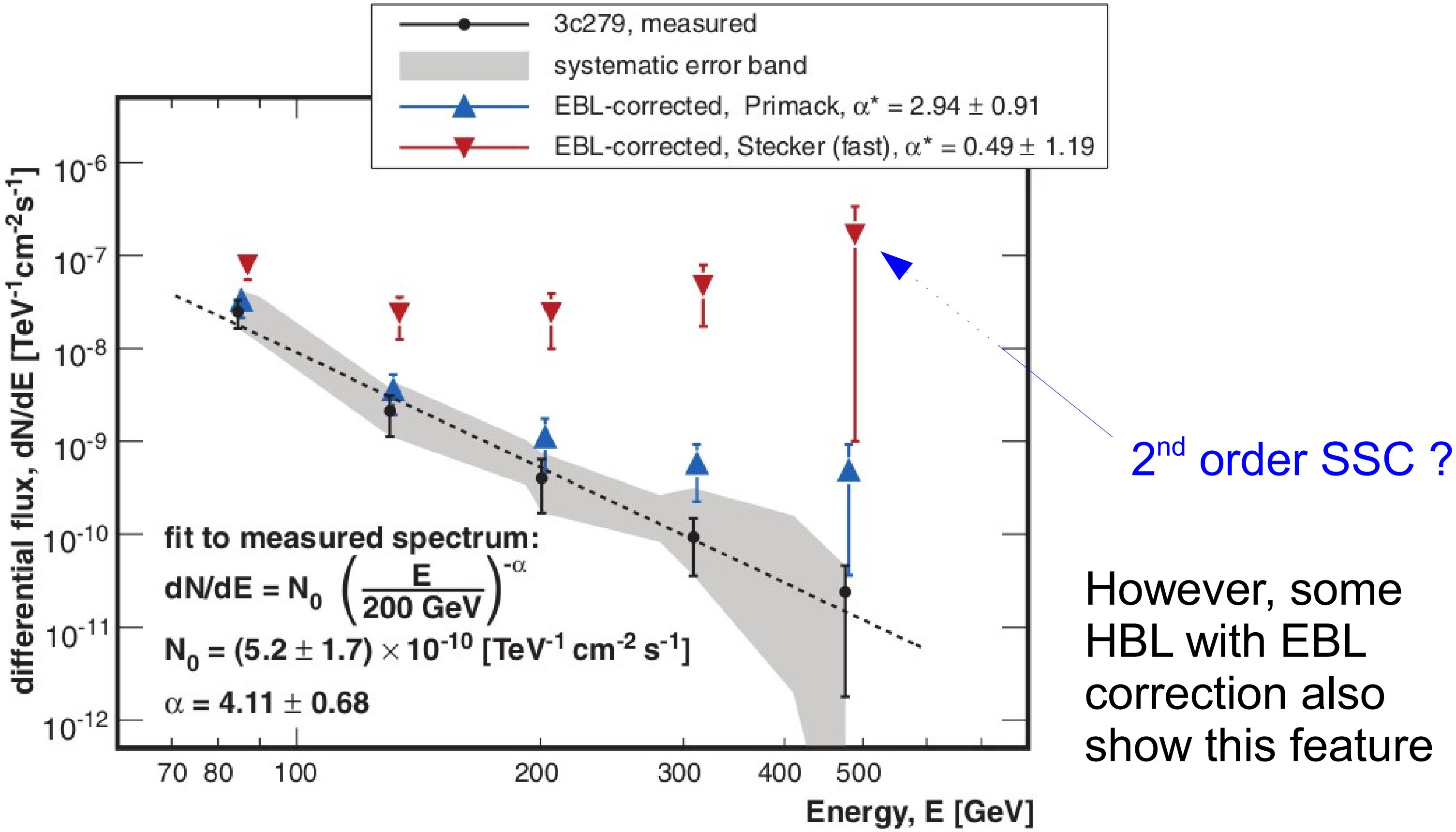


Spectral hardening, but no VHE emission



VHE emission detected in 3C279

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

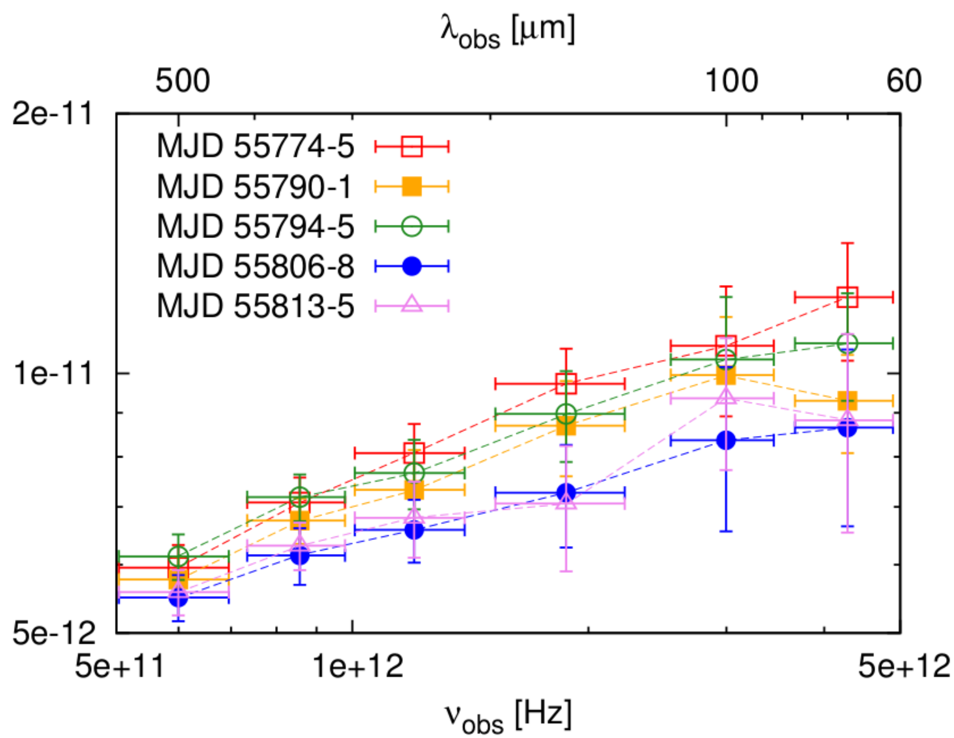


However, some HBL with EBL correction also show this feature

(MAGIC collaboration, 2008)

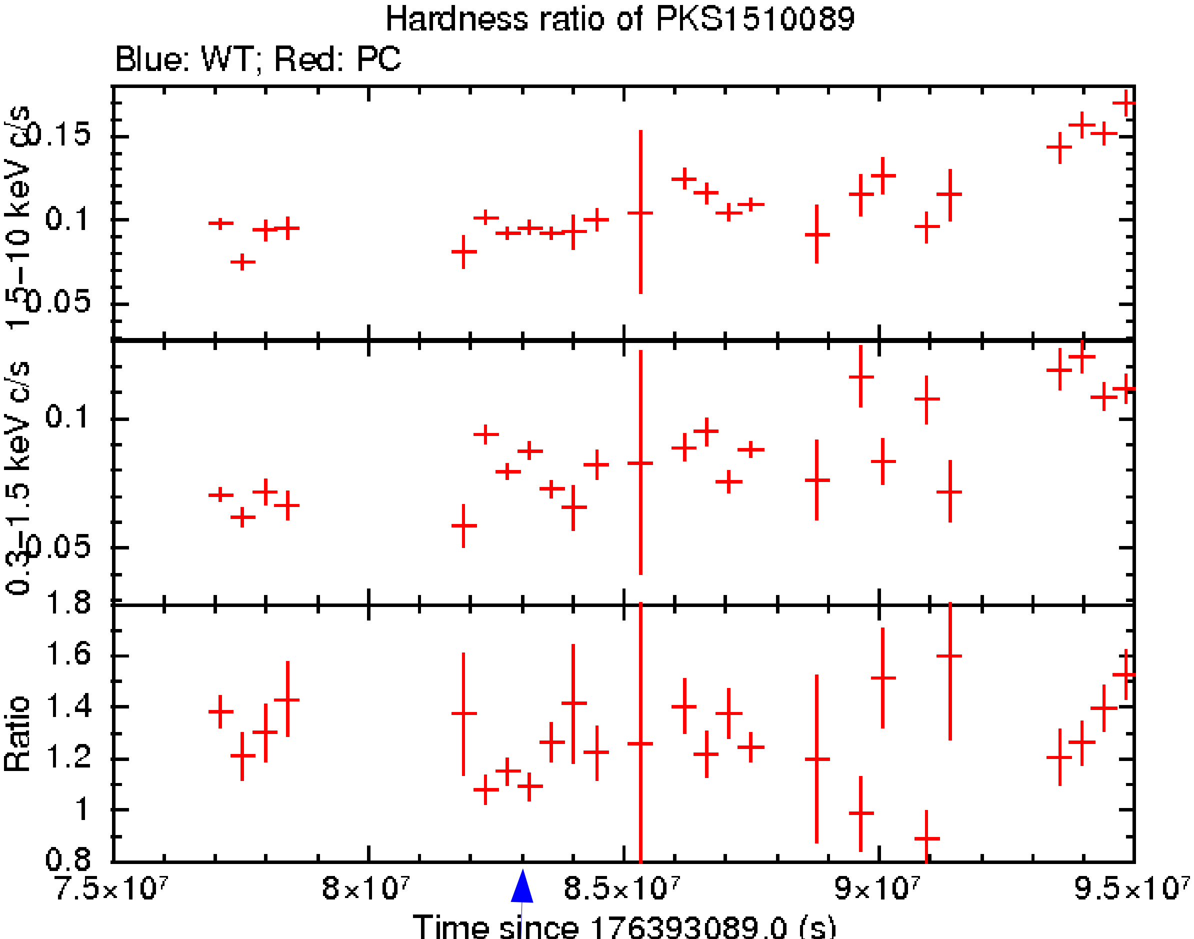
Herschel Observation of PKS 1510-089

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

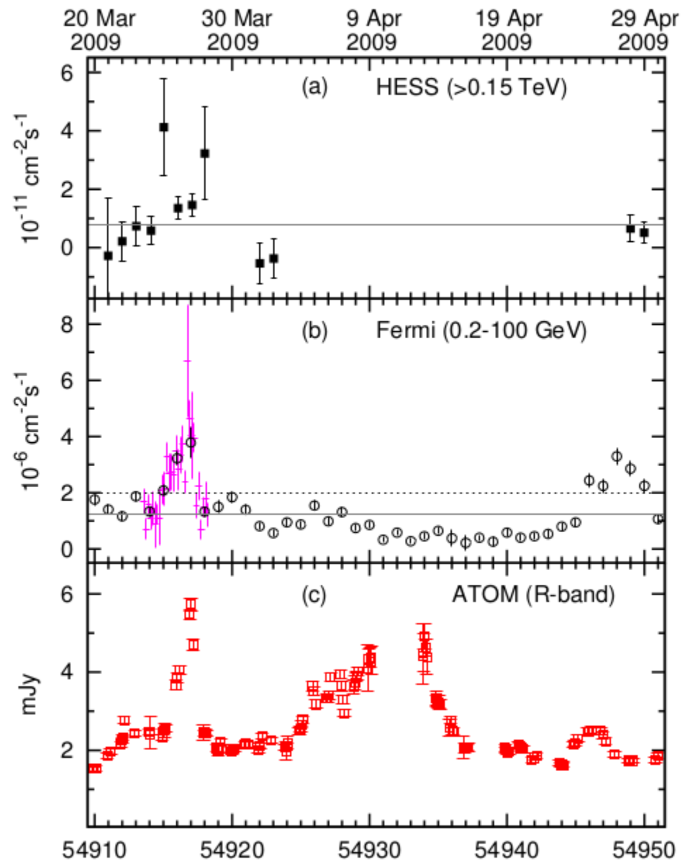


(Nalewajko et al. 2012)

X-ray light curves and Hardness ratio



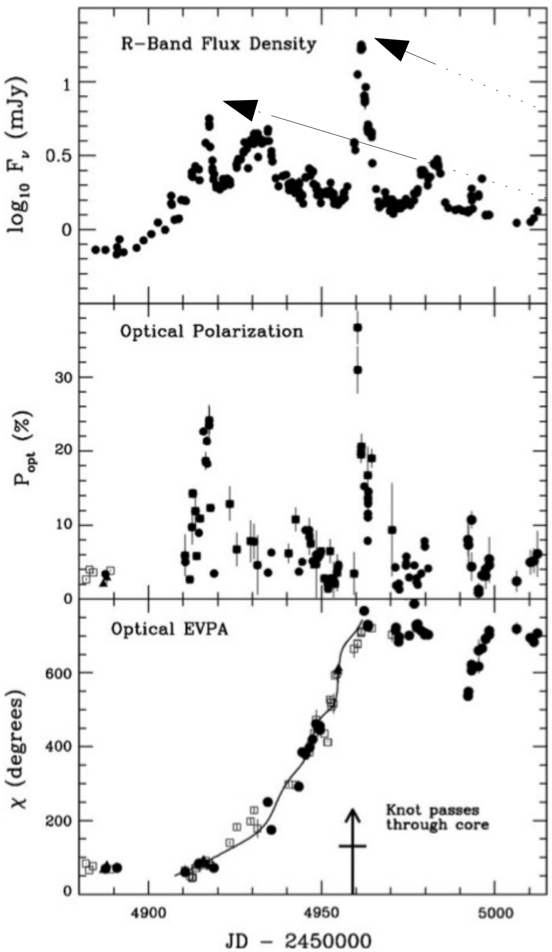
HESS detection of PKS1510-089



(HESS collaboration, 2013)

Polarization change during blazar flares

PKS 1510-089



(Marscher et al. 2010)

These two flares also have strong γ-ray counterparts