Probing the Blazar zone through High Energy Flares of FSRQs

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Extracted from **L. Pacciani et al., 2014, ApJ, 790, 45**

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ABSTRACT

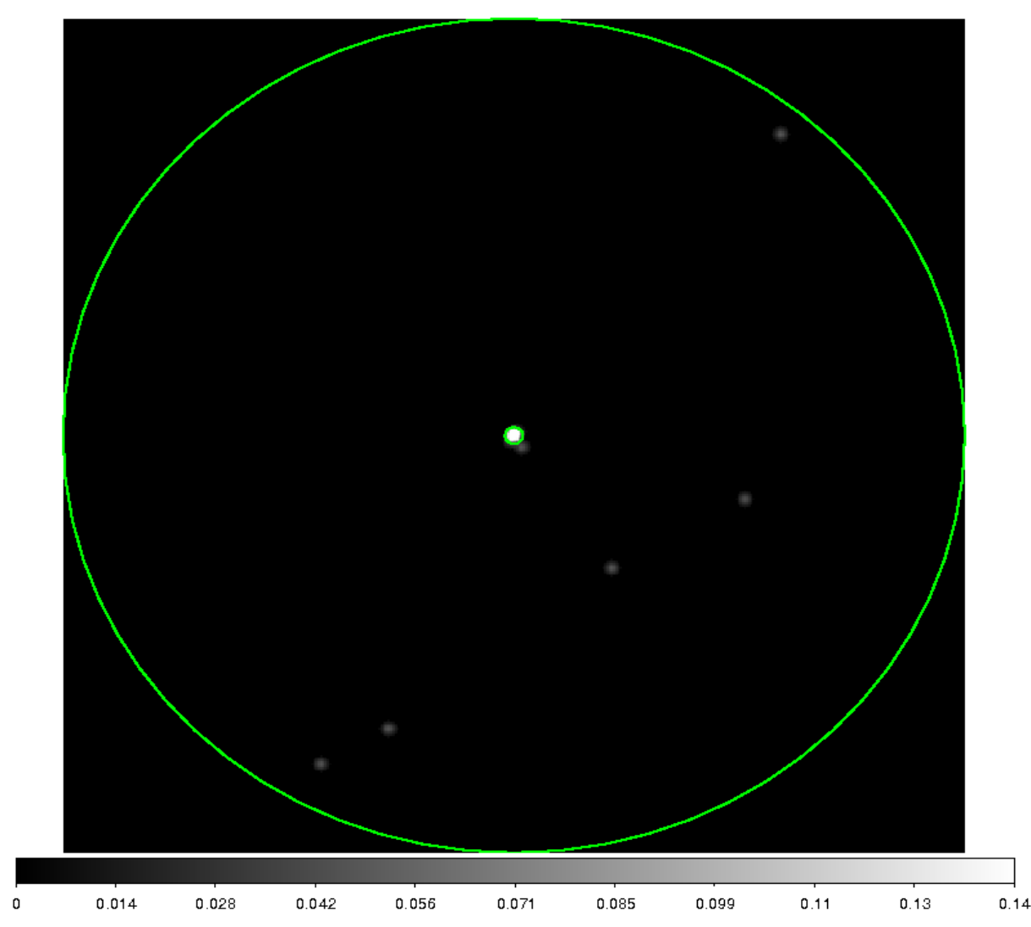
The gamma-ray emission offers a powerful diagnostic tool to probe jets and their surroundings in flat-spectrum radio quasars (FSRQs). In particular, sources emitting at high energies (>10 GeV) give us the strongest constraints.
This motivates us to start a systematic study of flares with bright emission above 10 GeV, examining archival data of the Fermi-LAT gamma-ray telescope. At the same time, we began to trigger Target of Opportunity observations to the Swift observatory at the occurrence of high-energy flares, obtaining a wide coverage of the spectral energy distributions (SEDs) for several FSRQs during flares. Among others, we investigate the SED of a peculiar flare of 3C 454.3, showing a remarkably hard gamma-ray spectrum, quite different from the brightest flares of this source, and a bright flare of CTA 102.
We modeled the SED in the framework of the one-zone leptonic model, using also archival optical spectroscopic data to derive the luminosity of the broad lines and thus estimate the disk luminosity, from which the structural parameters of the FSRQ nucleus can be inferred. The model allowed us to evaluate the magnetic field intensity in the blazar zone and to locate the emitting region of gamma-rays in the particular case in which gamma-ray spectra show neither absorption from the broad-line region (BLR) nor the Klein–Nishina curvature expected in leptonic models assuming the BLR as the source of seed photons for the External Compton scenario. For FSRQs bright above 10 GeV, we were able to identify short periods lasting less than one day characterized by a high rate of high-energy gamma-rays and hard gamma-ray spectra. We discussed the observed spectra and variability timescales in terms of injection and cooling of energetic particles, arguing that these flares could be triggered by magnetic reconnection events or turbulence in the flow.

HE Trigger

We started to search for relevant signal at E > 10 GeV in the FERMI-LAT archive from FSRQs and in new upcoming data.

High energy (HE) activity period is defined as the period of time in which the HE photon rate is > 3 x mean HE rate

3C 454.3, Sept. 2013 HE flare



Search within the FERMI-LAT FSRQs sample

We obtained > 40 candidates with detections with TS significance 26 < TS < 136 (E > 10 GeV) and High Energy activity periods lasting from 1 to 12 days in the host galaxy frame.
We selected for flares with MWL coverage, for sources with available Broad lines luminosities (to infer the disk luminosity using the mean ratios of Broad Lines luminosities in Francis 1991 and in Celotti 1997).

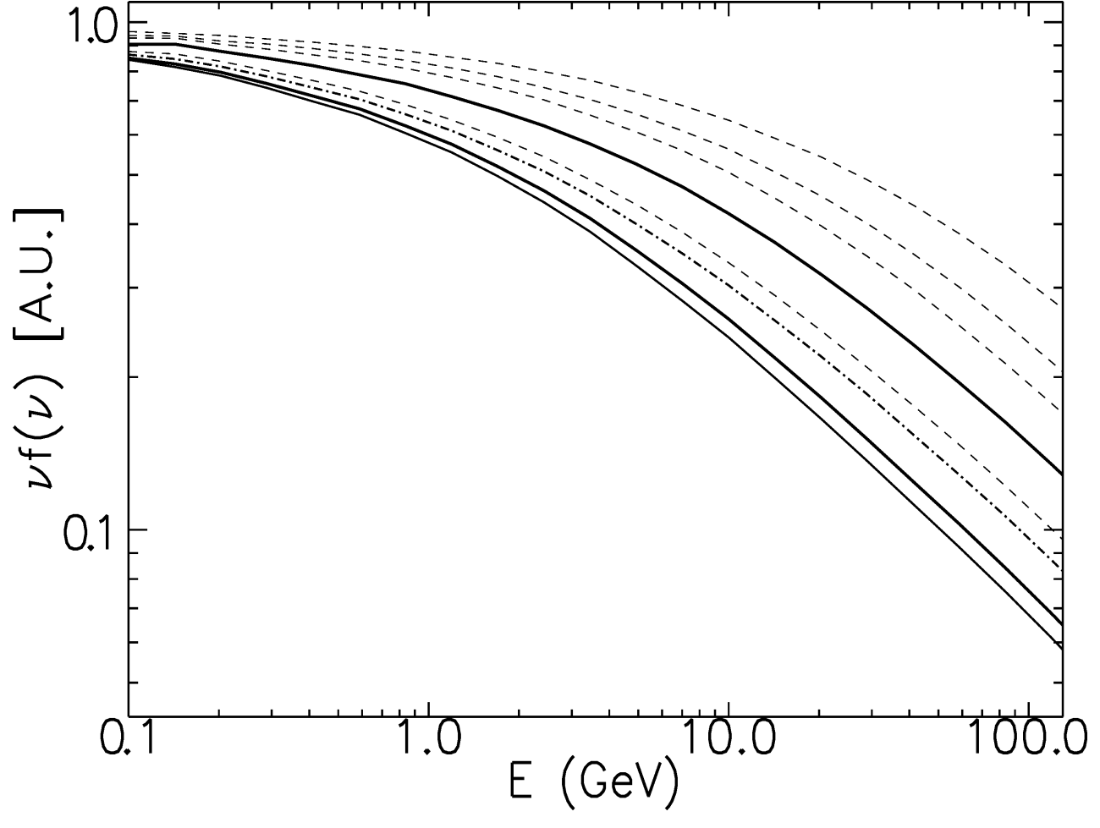
we obtained 10 sources

apart GB6 J1239+0443 (Pacciani et al., 2012), PKS B1424-418 (Tavecchio, Pacciani et al., 2013), 3C 279, 4C +21.35, PKS 1510-08

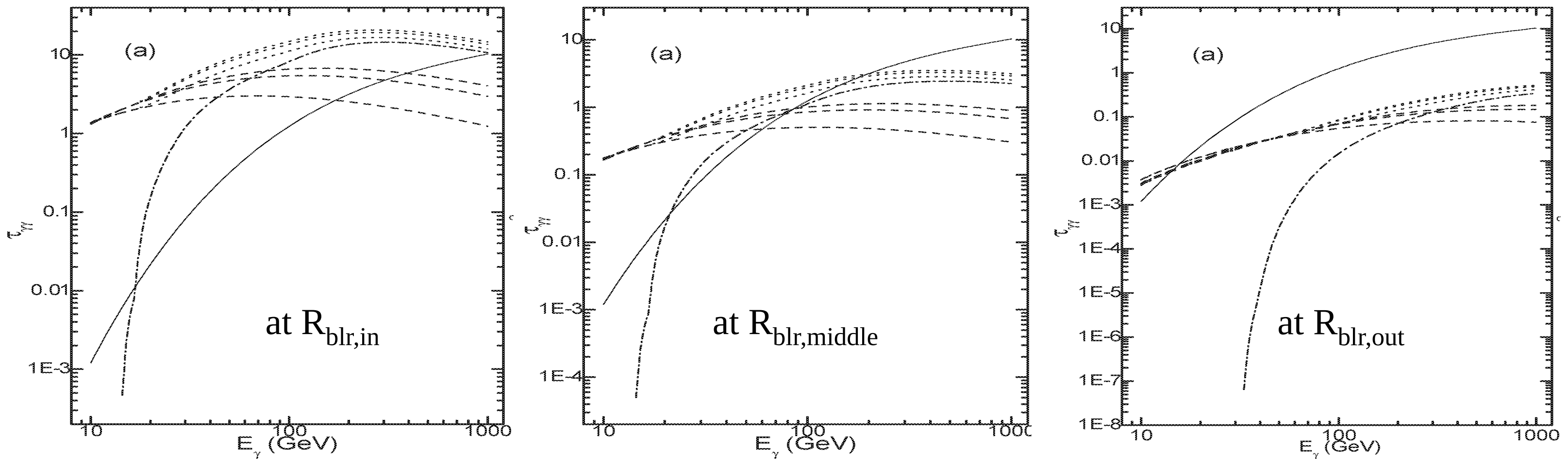
localization of the blazar zone

- **Lack of absorption features in the Gamma-ray spectrum from $\gamma\gamma \rightarrow e^+e^-$ (model independent)**
- **No Klein-Nishina curvature (assuming a leptonic Model)**
- **External seed-photon Fields intensity modeling assuming a spherical shell geometry for the BLR, and typical BLR radii scaling as $L_{disk}^{1/2}$.**

KN suppression (EC on BLR)

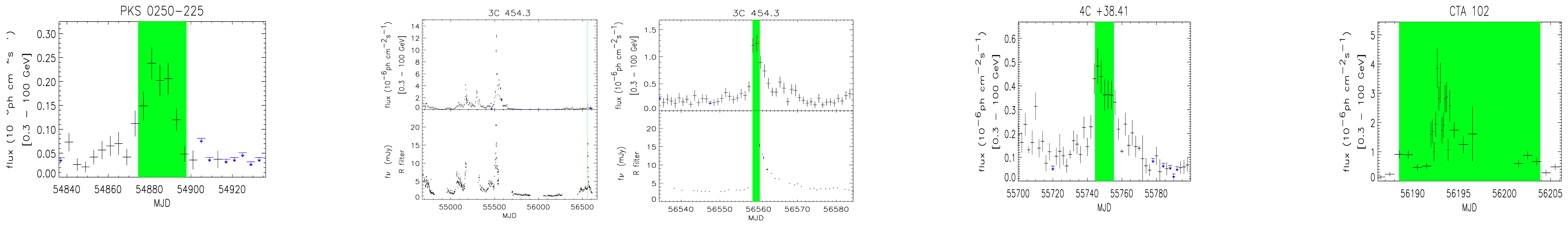


γγ absorption from BLR (Liu & Bai 2006, Liu, Bai, Ma 2008)

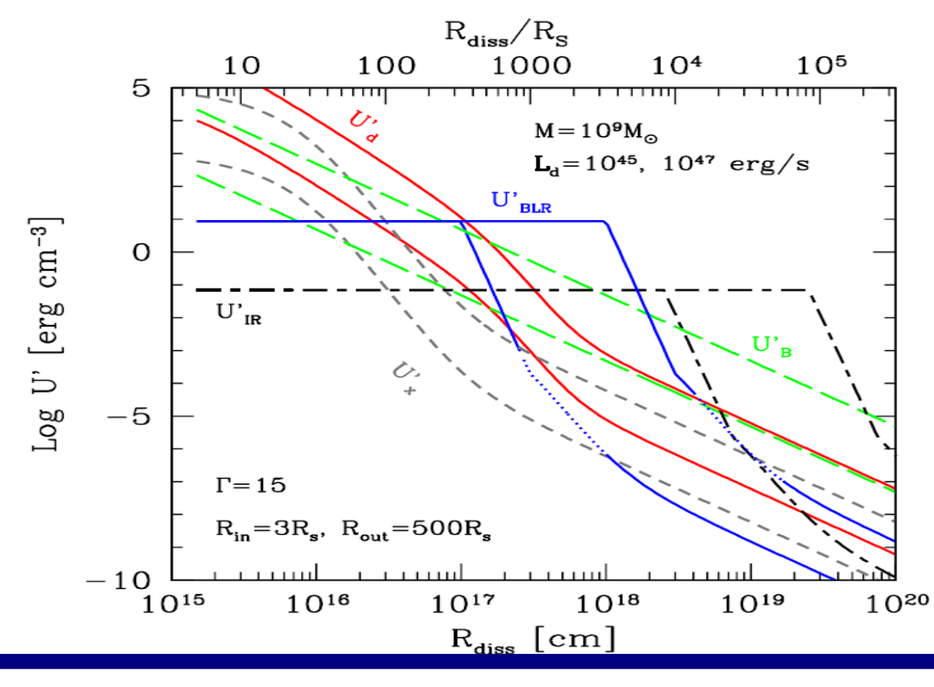


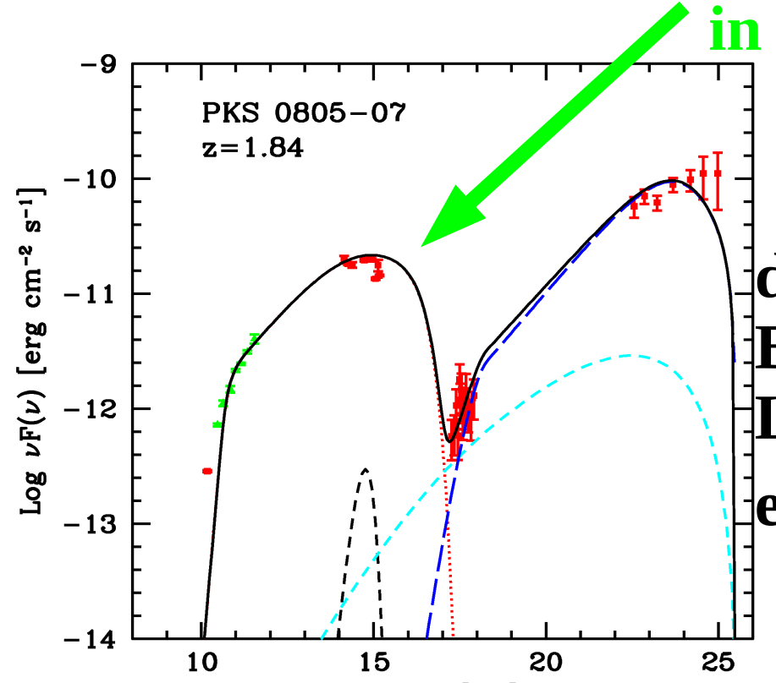
L_{BLR}=2.6x10^{44} erg/s **$\tau_{\gamma\gamma}$ scales as $L_{BLR}^{1/2}$**

Some of the Light Curves. Green area represents the period of HE activity

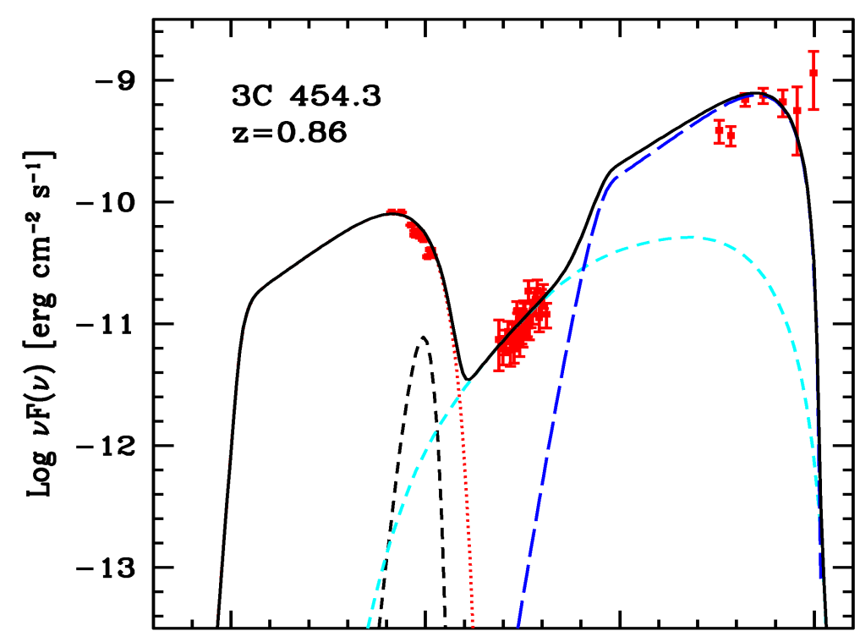


Some of the SEDs and their modeling assuming a spherical shell BLR

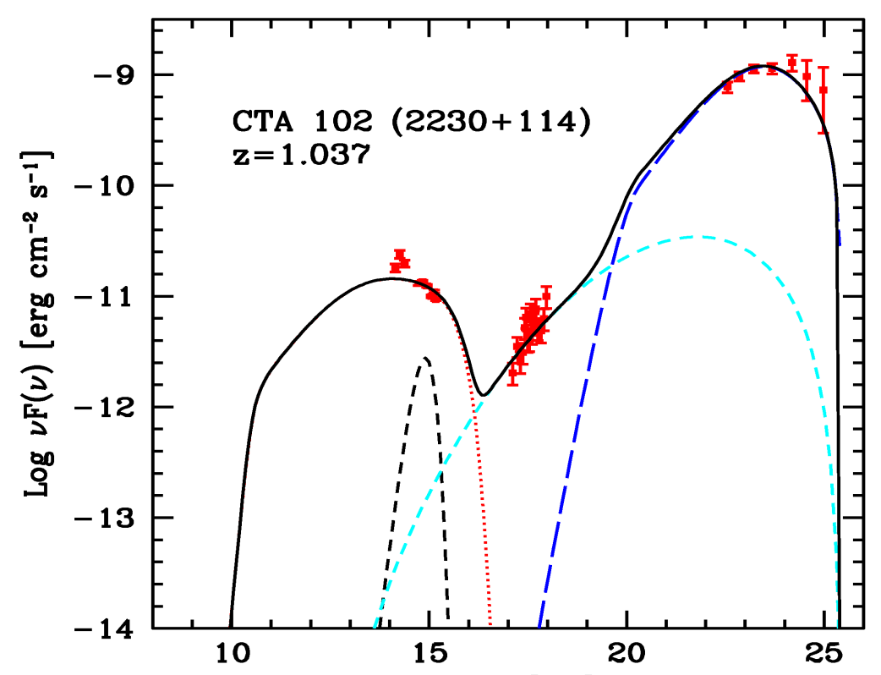




dist=0.8 pc
B=315 mG
L_{disk}=24x10^{45} erg/s



dist=0.5 pc
B=230 mG
L_{disk}=33x10^{45} erg/s

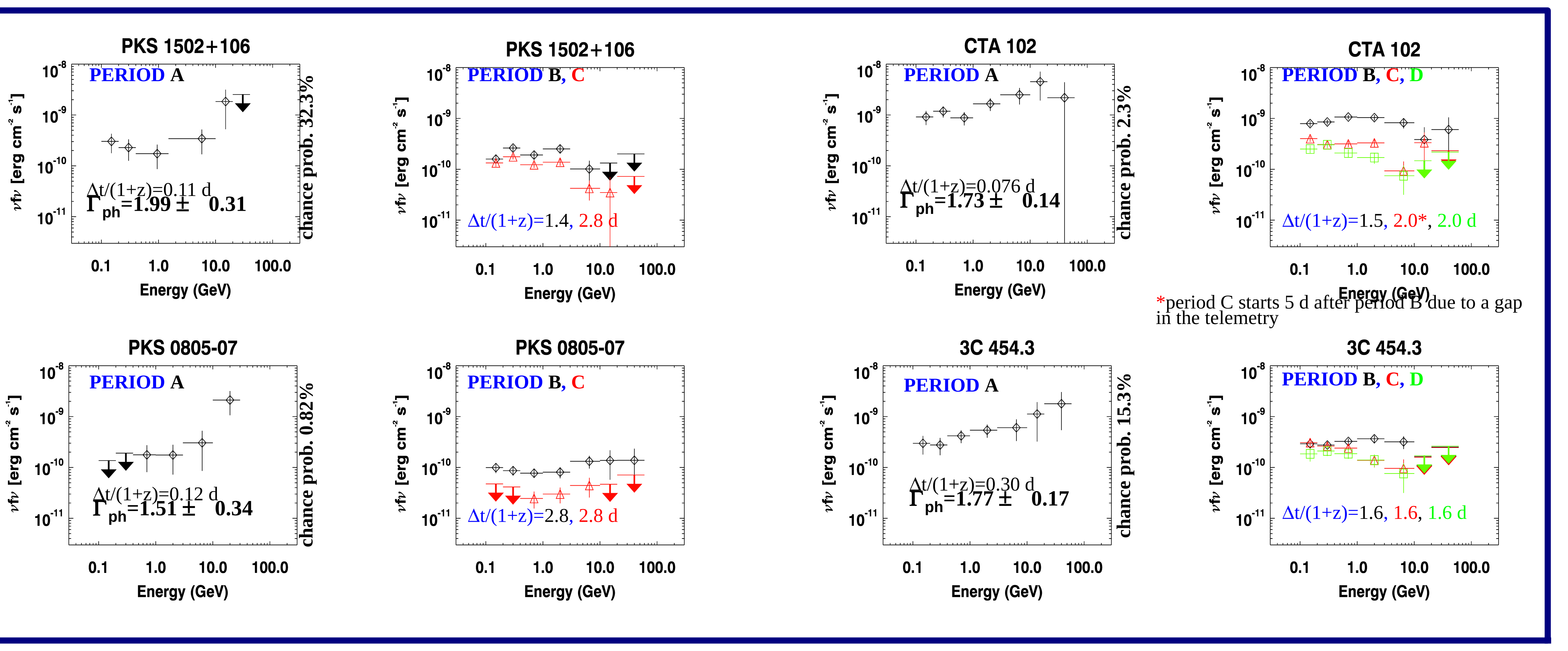


dist=0.3 pc
B=140 mG
Ldisk=41x10^{45} erg/s

Fast HE flares and spectral evolution

From the 4 brightest HE flares we searched for fast variability at HE (E> 10 GeV).
For all these 4 sources we found short periods (period A) lasting from 1.5 hours to less than 6 hours of very bright HE emission and hard spectra.

NB: in the following, the gamma-ray photon index of periods A (Γ_{ph}) are evaluated in the energy range 0.2-10 GeV (they are not biased by the selection criteria, i.e. the search for bright emission at HE, E>10 GeV)



*period C starts 5 d after period B due to a gap in the telemetry

Magnetic reconnection

at ~1 TeV:

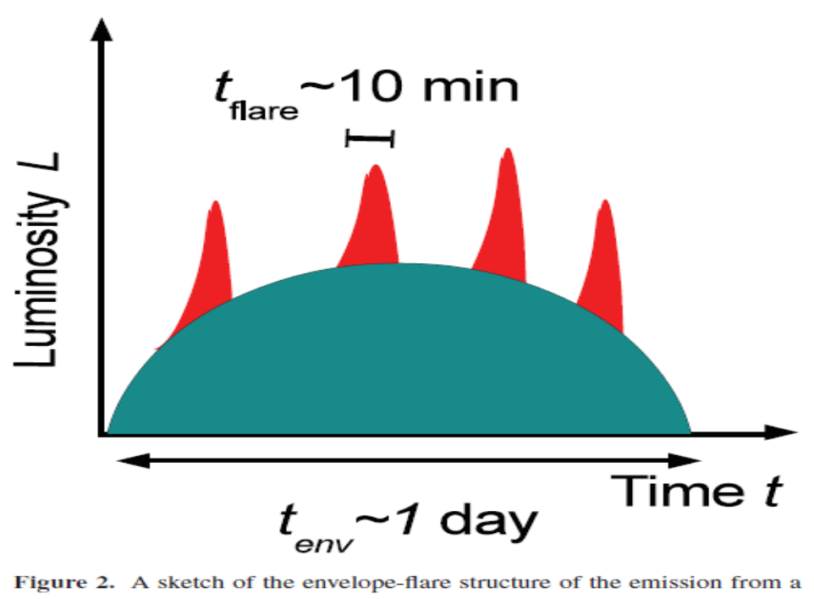


Figure 2. A sketch of the envelope-flare structure of the emission from a reconnection layer. The envelope duration corresponds to that of the reconnection event: $t_{env} = l'/\Gamma_j \epsilon c$. Monster plasmoids power fast flares which show exponential rise and last for $t_{flare} = 0.1 l'/\delta_p c$. For an envelope of ~1 d blazar flaring, the model predicts that monster plasmoids result in ~10-min flares.

Giannios 2013

Variability time scale from the SED modeling is ~30 d, comparable with long term modulation of the light curve, but we observe also sub-daily variability.

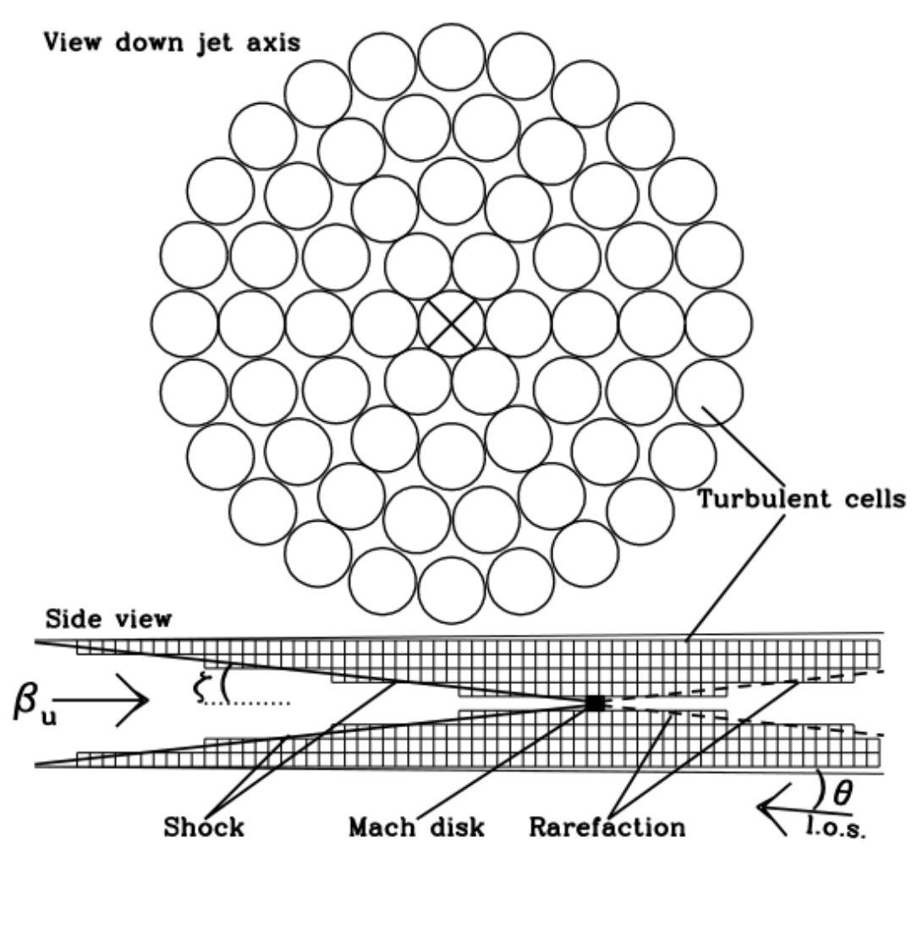
Recent scenario for magnetic reconnections proposed for strongly magnetized jets (Giannios 2013) includes an envelope emission (lasting ~1 day) powered by plasmoids, together with fast flares (lasting ~10 min) generated by grown "monster plasmoids".

In low magnetized plasma (such as at several parsec), reconnection time scales are longer and longer flares (days to weeks) could arise (Giannios 2013).

"Monster plasmoids" contain energetic particles freshly injected by the reconnection event (Uzdensky et al. 2010)

Turbulence in the jet (Narayan & Piran 2012, Marcher 2014)

Electron acceleration is caused by standing conical recollimation shocks. Flux and polarization variability originates from turbulence in the flow, approximated as cilindrical cells



CONCLUSIONS

We obtained 10 flare candidates with MWL data

Gamma-ray spectra, MWL SED modeling, and spectral evolution are consistent with a dissipation region at parsec scale

we identified short periods lasting 1,5-6 hours characterized by hard gamma-ray spectra.

the following period corresponds to a cooling phase?

recollimation and turbulence models could account for the acceleration at pc scale

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