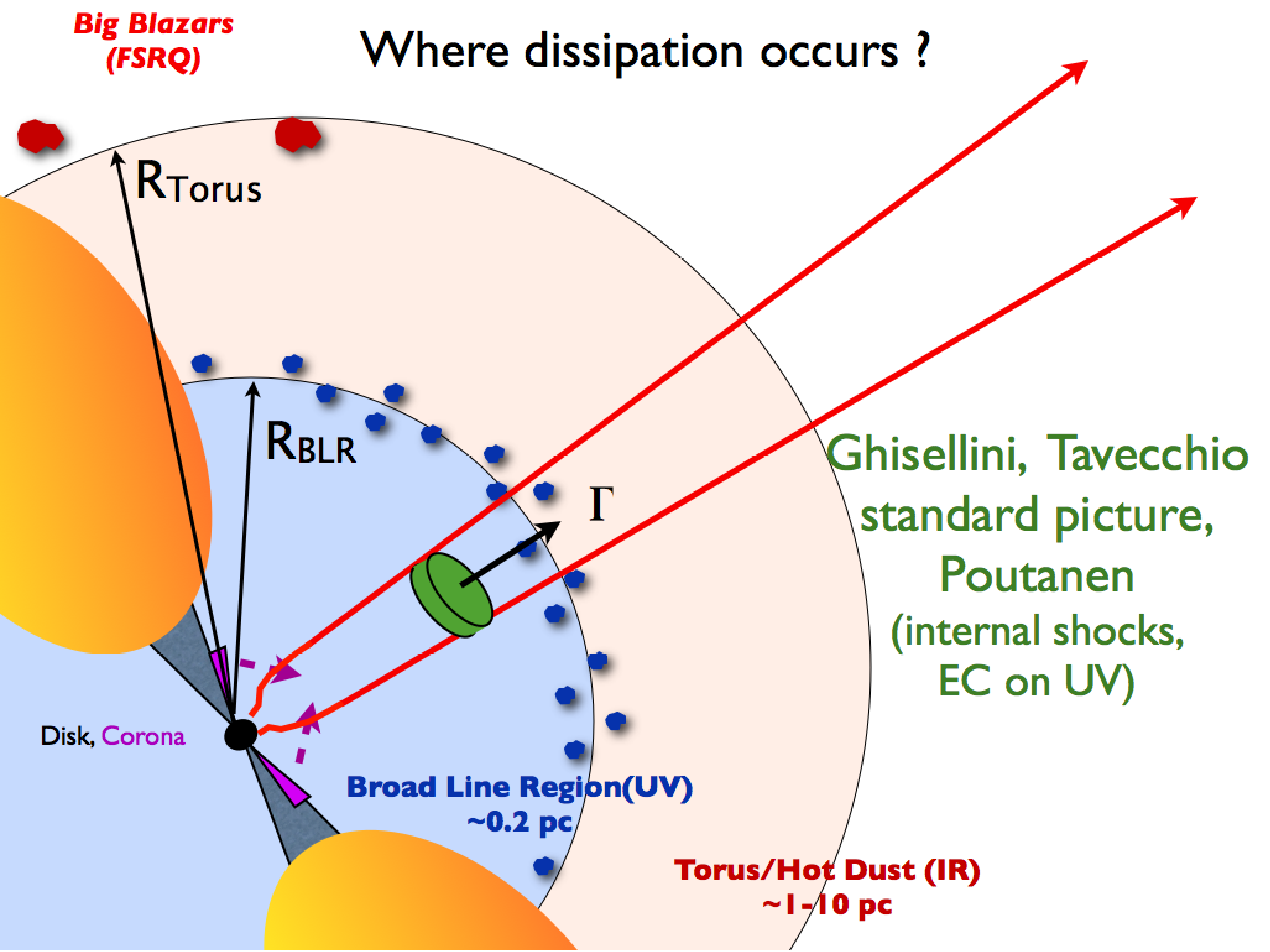
On the origin of gamma-rays in Fermi blazars: beyond the broad line region?

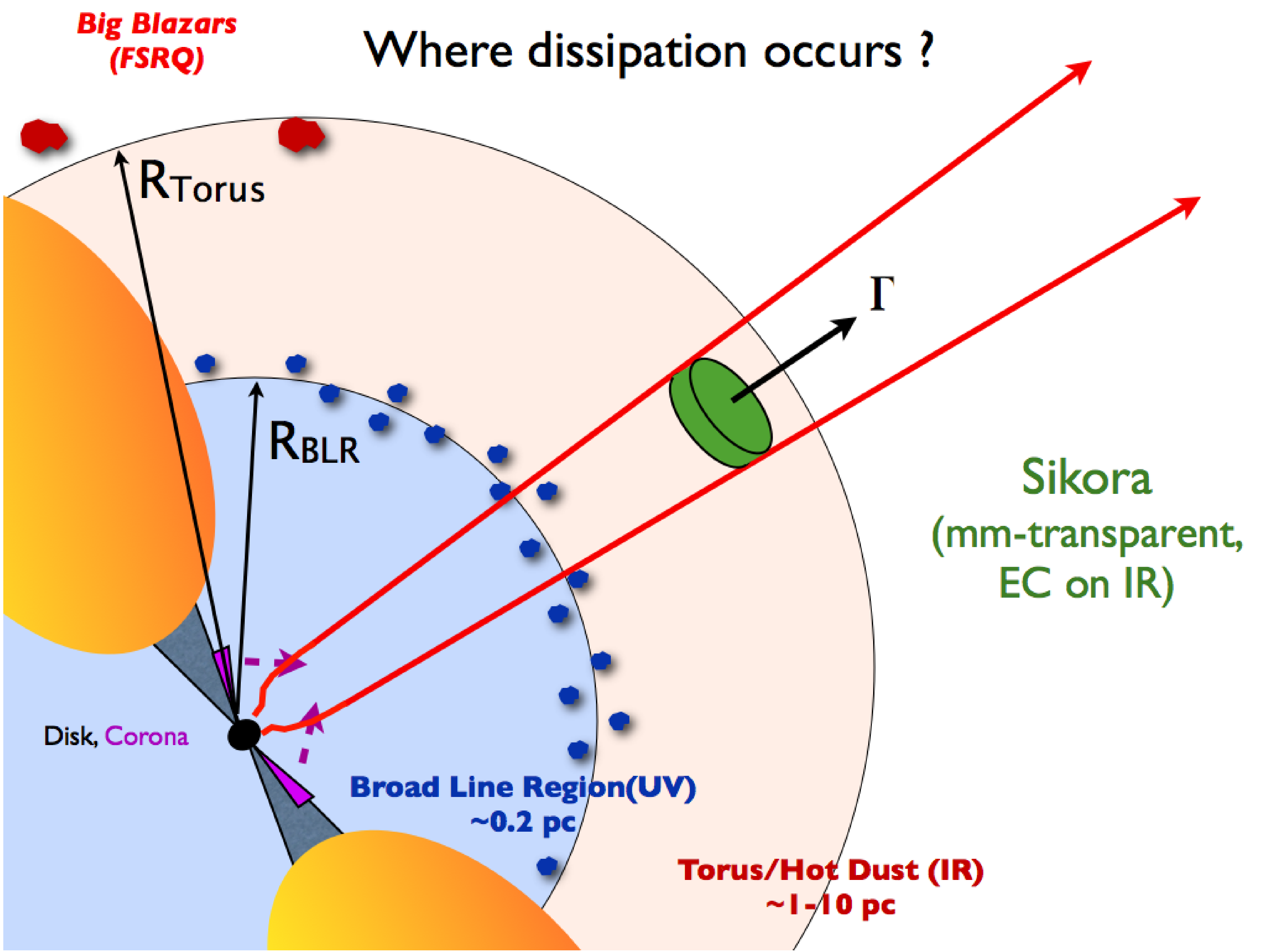
Sara Cutini

INFN Perugia

Costamante, Cutini, Tosti, Antolini & Tramacere
MNRAS, 2018, V. 477, Issue 4, p.4749-4767



Big Blazars (FSRQ)
Where dissipation occurs ?
R Torus
R BLR
Γ
Ghisellini, Tavecchio standard picture, Poutanen (internal shocks, EC on UV)
Disk, Corona
Broad Line Region(UV) ~0.2 pc
Torus/Hot Dust (IR) ~1-10 pc

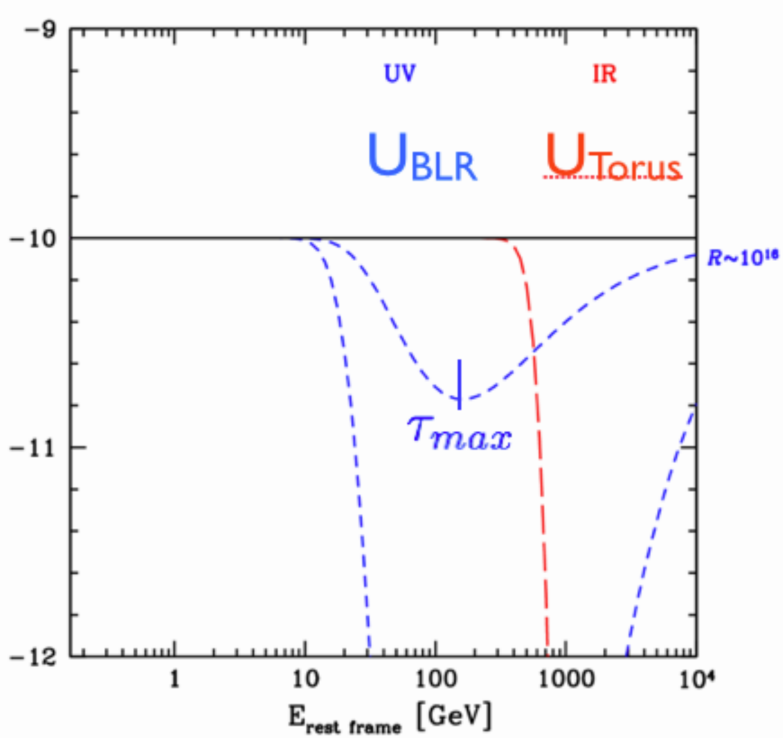


Big Blazars
(FSRQ)
Where dissipation occurs ?
R_{Torus}
R_{BLR}
Γ
Sikora
(mm-transparent,
EC on IR)
Disk, Corona
Broad Line Region(UV)
~0.2 pc
Torus/Hot Dust (IR)
~1-10 pc

Inside or outside?

» BLR opacity implies an optical depths >>1

» **In FSRQ we expected no VHE detection, cut-off features around 10-20 GeV for external compton on BLR and around 1 TeV for external compton on dusty torus**



e.g. on BlackBody target field (good approximation to BLR attenuation)

Inside or outside?
Aim

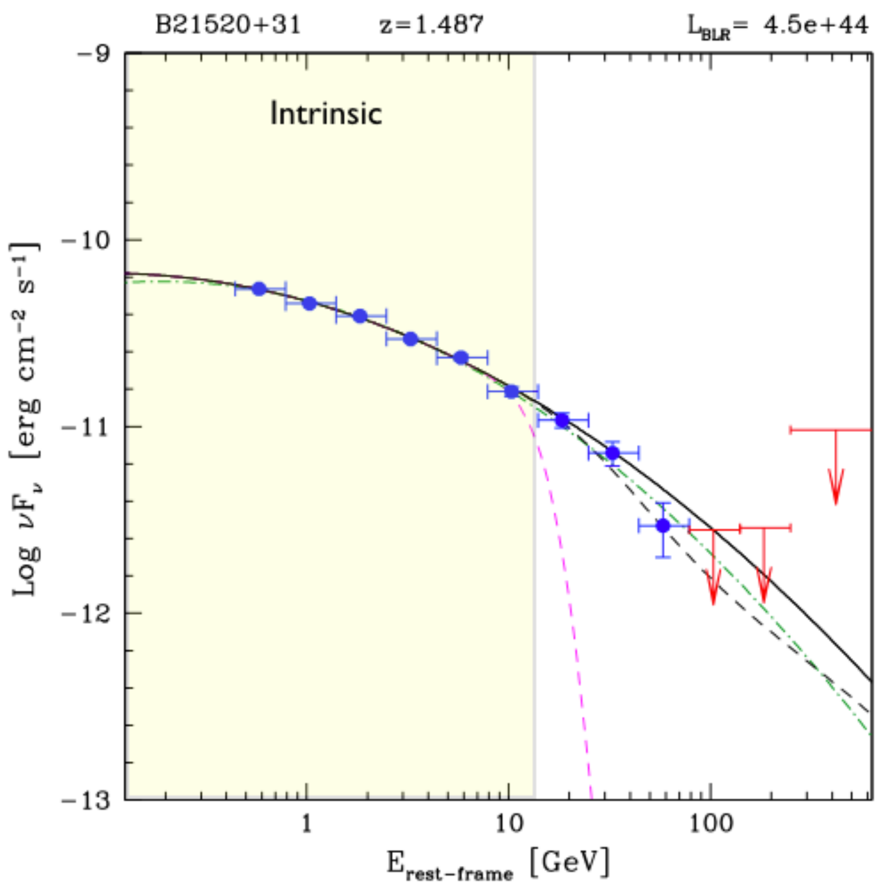
» **The aim of this paper is to find out the typical behavior of the population of gamma-ray detected FSRQs, by looking for the presence or absence of BLR-induced cut-off features in the so called BLR External Compton scenario.**

» **We want to address the following issues:**
a) BLR absorption is a common phenomenon in Fermi-LAT FSRQ? and at which optical depth?
b) The measured absorption is consistent with the photon densities used by external Compton models?
c) There is a difference in the location of dissipation region between high (flaring) and low states. That is, if the “persistent” (low-flux) emission is mostly produced outside the BLR and the flaring emission inside?

Inside or outside? procedure

- **We selected the 100 brightest FSRQ of the 3FGL + 6 further objects characterized by particularly large values of L_{BLR}**
- FSRQ are objects with strong broad lines in their optical spectrum, the external compton on BLR photons was the standard scenario to model SEDs of the large majority of gamma-ray detected FSRQ (Ghisellini & Tavecchio 2008, 2009)
  - The external optical/UV photons used to produce γ-rays (IC) represent targets for γ- γ annihilation ➔ GeV-TeV photons interact with UV photons
- The LAT data used were collected from 2008 August 5 (MJD 54683) to 2014 December 01 (MJD 56992) with PASS8
  - We extracted 106 time integrated SEDs
  - For 18 sources with well defined flaring state we extracted also the high and low state SEDs

Inside or outside? Metodology



Intrinsic band model: Power-law or Log-parabolic

— Intrinsic extrapolated

--- Fitted free tau_BLR

--- Expected tau_BLR (deep in BLR, ~$R_{BLR}/2$)

-.- Log-parabolic Full band (no BLR)

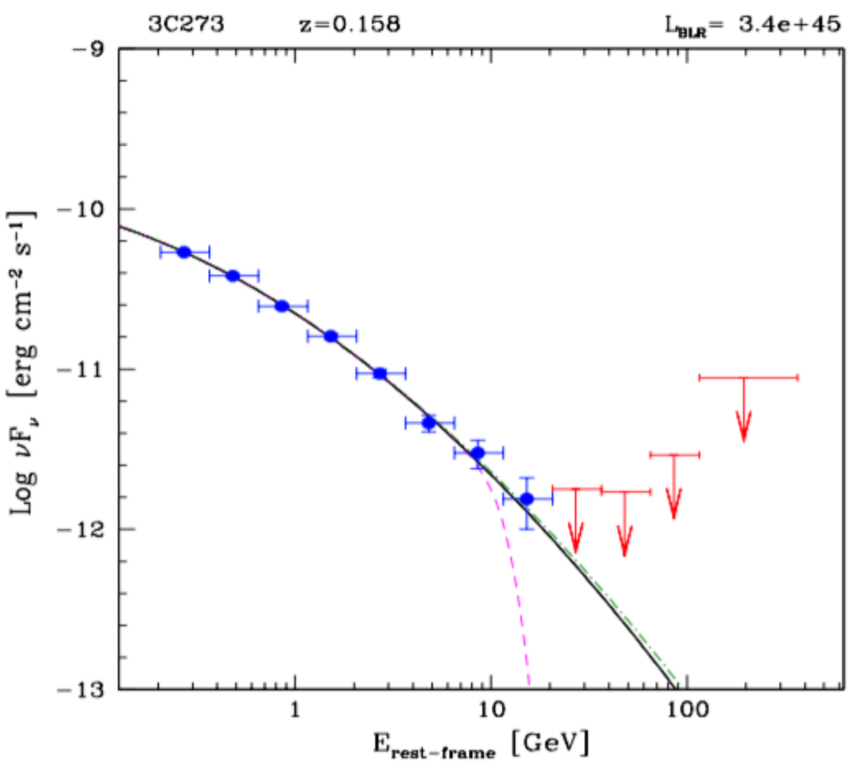
Upper limit if:
TS <4 or
Npred <3 or
Err >50%

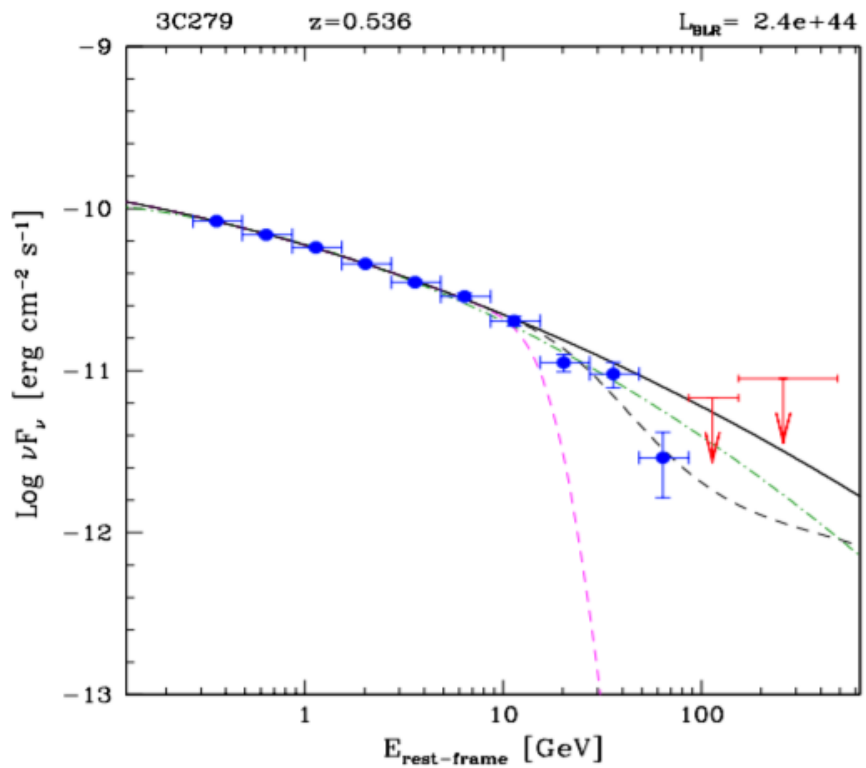
NB: Rest-Frame Energies ! E*(1+z)

(*) The value relative to the L_{BLR} is extracted from literature (Ghisellini et al 2011, 2015)

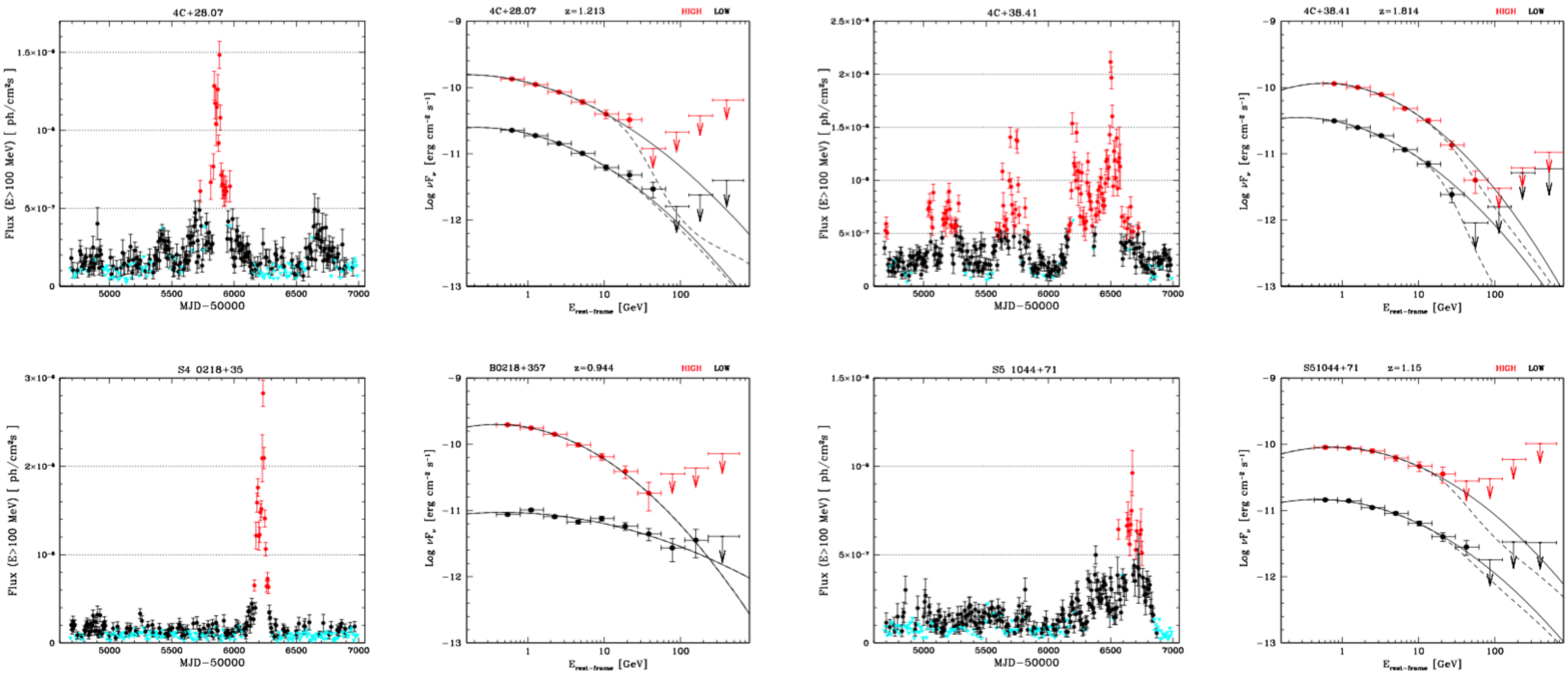
Inside or outside?
Time integrated SED

No evidence of BLR absorption cut-offs!





Inside or outside? low and high state



Spectra: full lines show the spectrum with parameters determined below 13 GeV, dashed lines show the result of the fits with free BLR absorption.

Inside or outside? Results

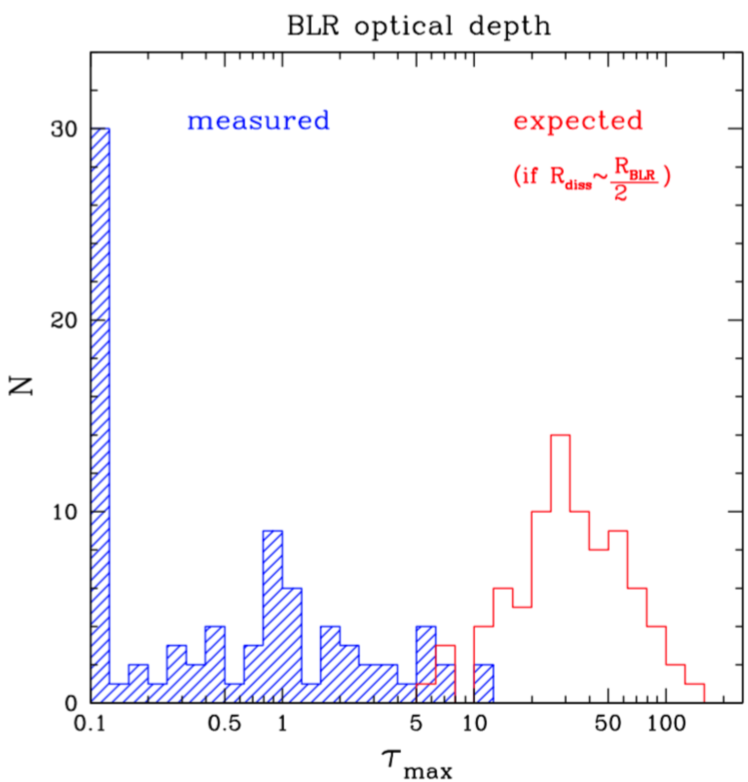


Figure 1. Histogram of the distribution of the measured vs expected maximum optical depths τ_{max}, for the 83 objects for which L_{BLR} is available. Histograms are calculated with 10 bins per decade, in logarithmic space. Where $\tau_{max} \leq 0.1$, objects have been counted in the first bin. The LAT data indicate that the allowed optical depth due to BLR photons is at most a factor $\sim 30 - 100\times$ *l*ower than typically assumed and used in EC(BLR) models, and only for about 1/3 of the sample.

The Fermi-LAT spectra indicate that for ~70% of our FSRQ sample there is no evidence of BLR absorption (tau_{max} < 1),

The remaining ~30% of the objects the possible optical depths are a factor ~100 x lower than expected in EC on BLR models.

Inside or outside? Discussion

If the External Compton on Broad Line Region scenario is correct and the blazars zone is well within the BLR ➔ **We expect to detect strong cutoff above 10-20 GeV, but we have no seen it**

No evidence of cutoff in the GeV spectra in several FSRQ ➔ Also in FSRQ with strong line and disk luminosities, characterized by quite large BLR sizes.

Most of the case NO absorption from Broad Line Region (8% of FSRQ showed an optical depth >5)➔ **In the high state mild possibility of absorption**

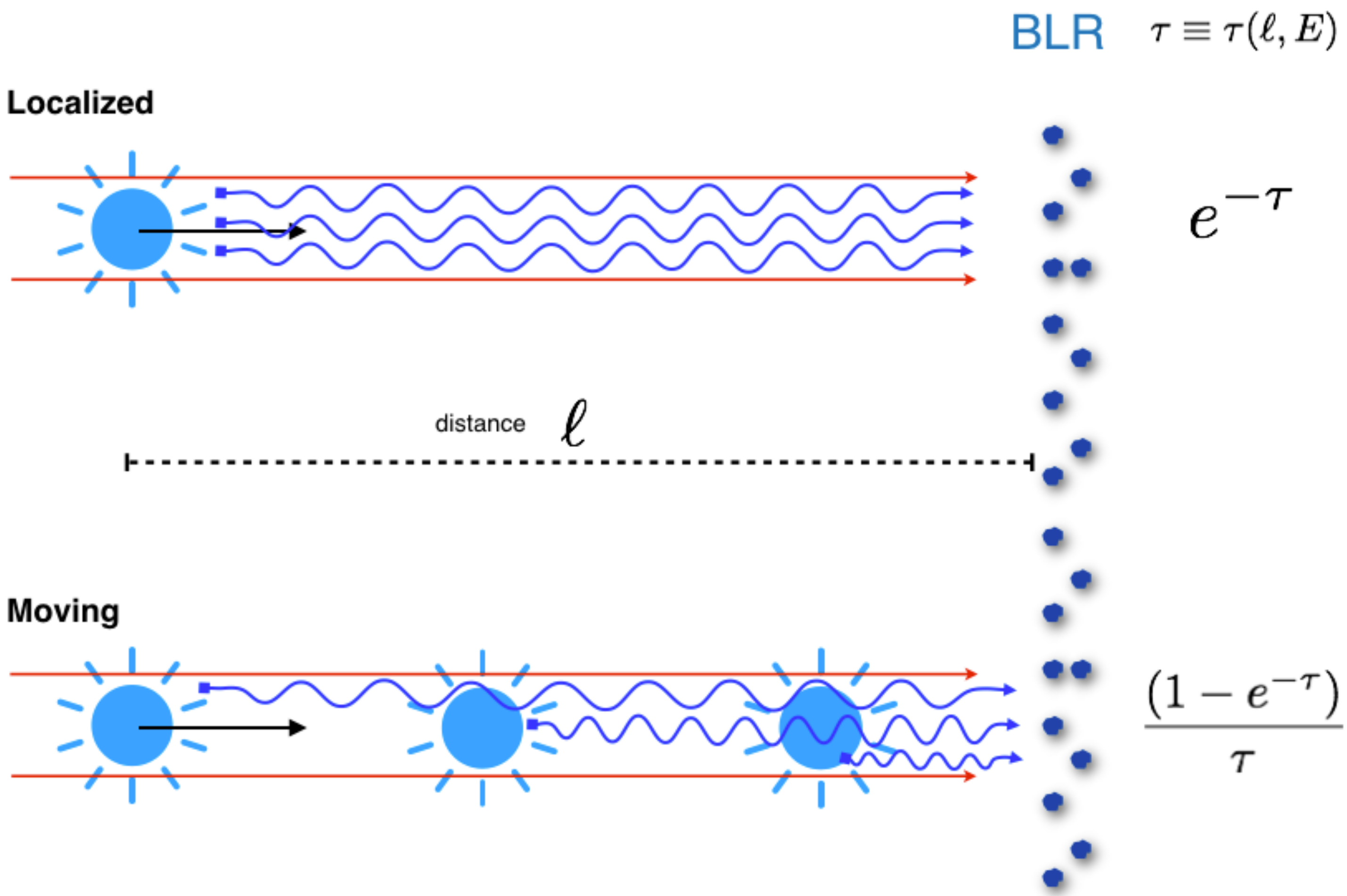
Inside of outside? Implications

- **External Compton on BLR photons is disfavoured as main mechanism for the gamma-ray emission in Fermi FSRQs.**
  - This conclusion holds also in the alternative scenario of a BLR much larger (100×) than given by reverberation mapping, requiring 10× higher bulk motion Lorentz factors of the plasma to reach an equivalent energy density in the jet frame.
  - A viable alternative for the **EC mechanism is provided by the IR photons** from the dusty torus (Sikora et al. 2009).
- The mild, smooth cut-off often seen between **few GeV to few tens GeV is most likely intrinsic due to the end of the accelerated particle distribution.**
- Without suppression by the BLR, the gamma-ray emission in FSRQ can reach the VHE band with potentially very high luminosities, as demonstrated by the flares of 3C 454.3. **Therefore also FSRQs can be good targets for VHE telescopes!**

Thank you!!!

Backup slides

Case of moving blob



Case of moving blob

We can gain a factor ~3 in path length

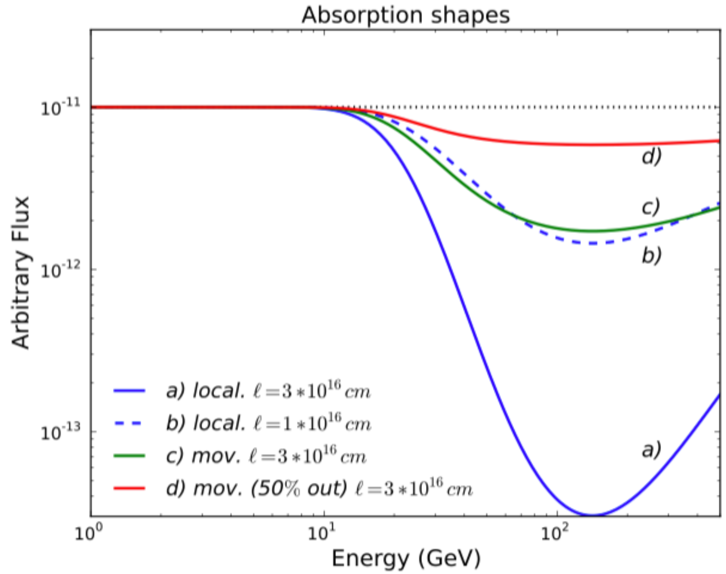
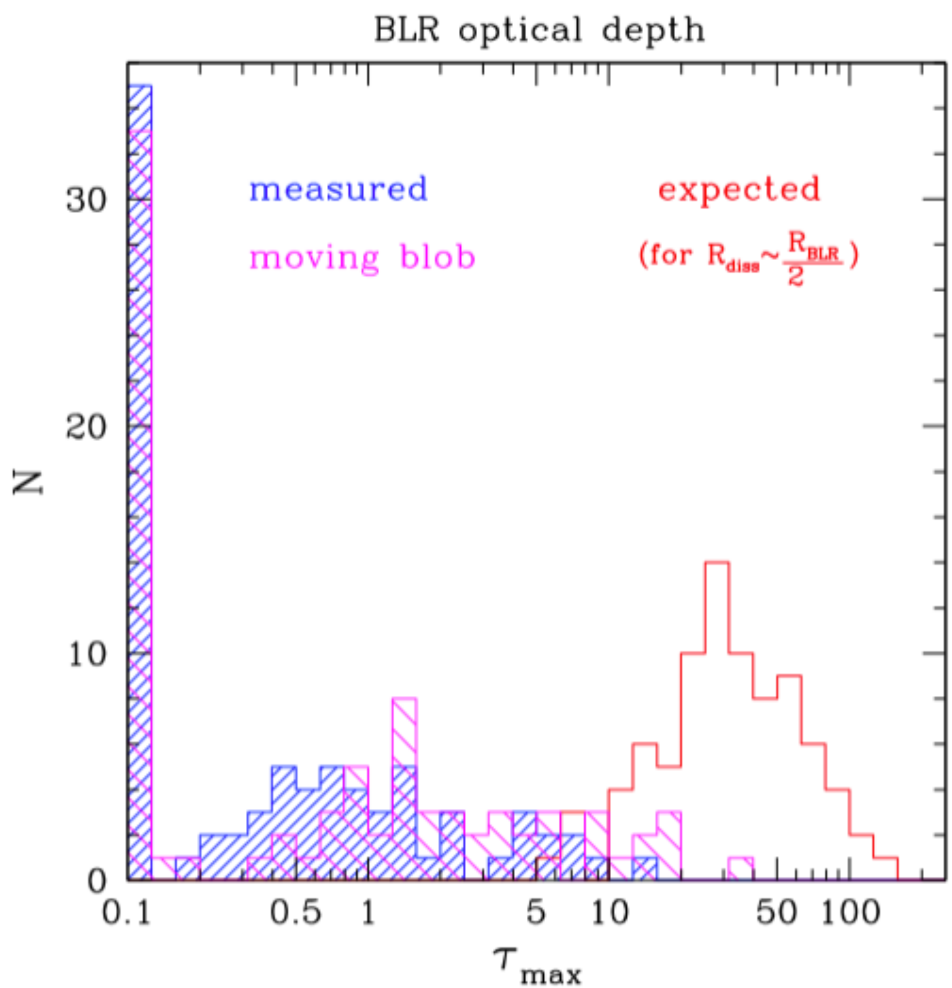


Figure 5. Absorption shapes for three emission scenarios: *a)* localized emission, with the same path ℓ for all photons ($e^{-\tau}$ absorption); *b)* constant emission from moving blob fully inside the BLR, up to $R_{\rm BLR}$ (Eq. 4); *c)* constant emission from moving blob, with 50% of the flux from outside the BLR. Scenarios b) and c) present shallower attenuation features than scenario a), for the same overall path ℓ inside the BLR. The absorption shape from scenario a) is almost indistinguishable from the shape of scenario b) with slightly higher τ (compare lines for localized emission at $\ell = 1 * 10^{16}$ cm with moving-blob at $\ell = 3 * 10^{16}$ cm).

if we assume that the observed flux is dominated by the emission of a single relativistic blob over a relatively long time -> the actual travel of the blob in that timeframe can be quite large due to Doppler effect.

Gamma-rays can originate from different locations inside the BLR, and the net absorption effect can be different.

Case of moving blob



It does ***NOT*** *change the main result*