SPECTRAL ANALYSIS OF S5 1803+784

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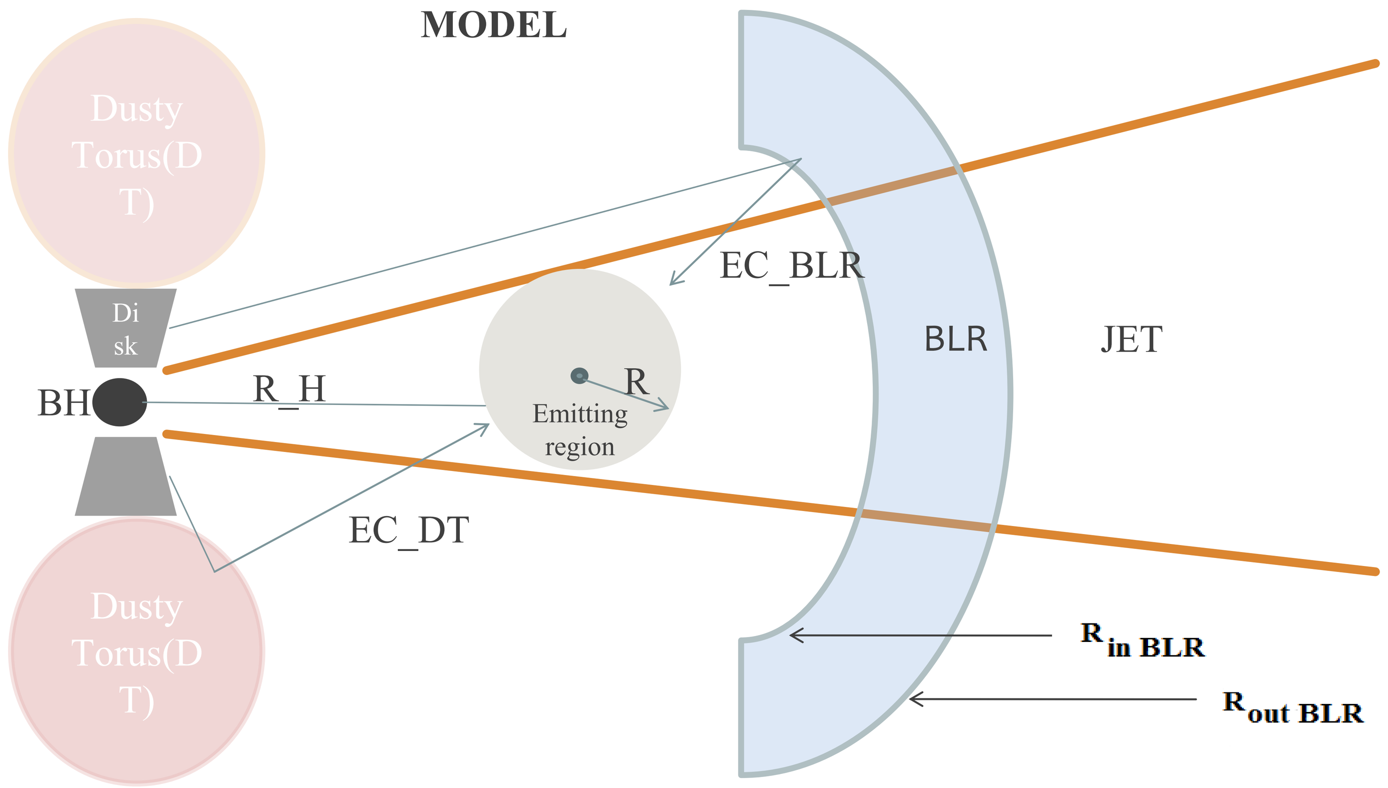
Confluence page link

Introduction

Mechanisms and processes responsible for relativistic jet launching, collimation and particle acceleration are not fully understood (Zhang et al. 2015; Bӧttcher 2019). However, there seems to be agreement on the most likely sources of power responsible for relativistic jets via gravitational potential of the accreting matter. In blazars, the structure of the relativistic jet, including the matter density and particle acceleration, the magnetic field evolution and the composition of the jet are needed to fully understand the physics of the gamma ray emission region and the evolution of the emission region in the jet. There is still no consensus on how these various components interact with each other and with the accretion disk of the black hole. Here we examined the spectral characteristic of S5 1803+784 in both the quiescent and flaring states of the blazar in the framework of a magnetic dissipation model.

S5 1803+784, a low synchrotron peak (LSP) blazar is categorized as a BL LAC (Ghisellini et al. 2010). Evidence abounds in literature that LSP blazars do not fit well with single zone SSC model without contributions of seeded photons from sources external (EC) to the jet (Paggi et al. 2011). Here we present the results of phenomenological spectral model fits of the four observed flaring states of S5 1803+784 in the framework of a leptonic jet model using a single zone SSC + EC model. The implication of the SED parameters to acceleration and emission processes is also discussed.

ONE ZONE LEPTONIC JET MODEL



Schematic diagram of the general view of the model (not to scale)

model description

$U_e = m_e c^2 \int Q(\gamma)\, d\gamma$

$U_p = m_p c^2 \int Q(\gamma)\, d\gamma$

$U_{rad} = \frac{L\_tot}{4\pi R^2 c D^4}$

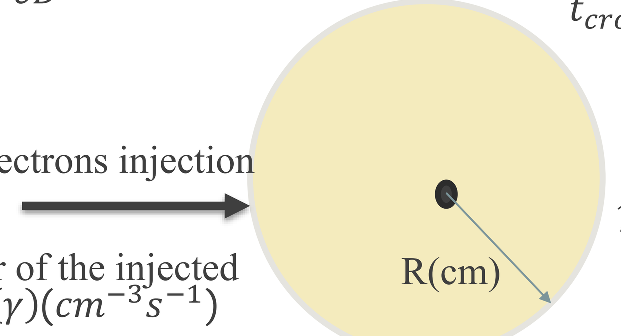
$U_B = \frac{B^2}{8\pi}$

Emitting particles energy – distribution at $t_{cross} = N(\gamma)\,(cm^{-3})$

$t_{cross} = \frac{R}{c}(s)$

$N(\gamma) = Q(\gamma)\, t_{cross}$

$\gamma_{cool} = \frac{3 m_e c}{4\sigma_T R U_i}$



Total power of the injected electrons $Q(\gamma)(cm^{-3}s^{-1})$

$Q(\gamma) = Q_0 \frac{(^{\gamma}/_{\gamma_b})^{-p}}{1+(^{\gamma}/_{\gamma_b})^{-p+p\_1}}$

$(cm^{-3}s^{-1})$

Broken power law

(Energy densities of the photons sources)

$U_i = U_{BLR}(\gamma) + U_{DT}(\gamma) + U_{Sync}(\gamma)$

Volume of the emitting region $V = \frac{4\pi}{3} R^3, (cm^3)$

(Ghisellini & Tavecchio, 2009)

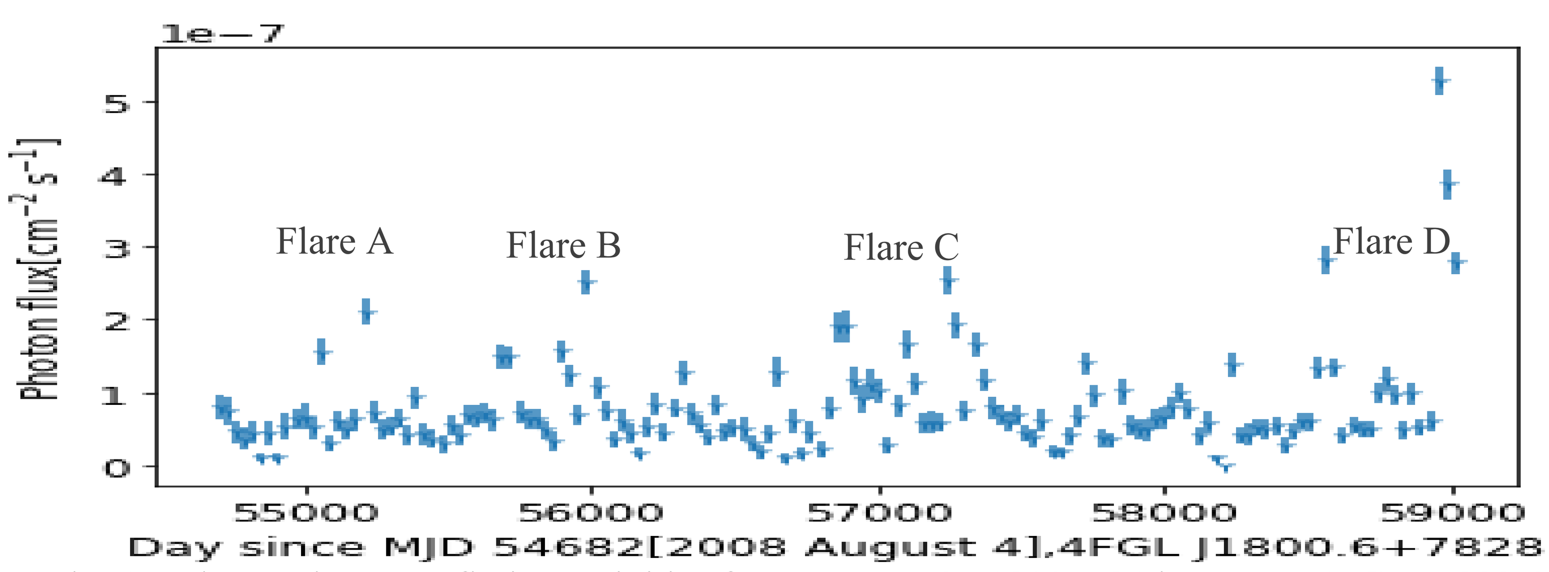
Data and Analysis

NED: The archival data of the blazars from radio up to X – ray was obtained from NASA/IPAC Extragalactic Database (NED). We use this same archival NED data for the quiescent and the flaring states changing only the gamma-ray data for the different states of the blazar.

Fermi–LAT: The reprocessed Pass 8 data sets with the P8R3_SOURCE_V2 instrument response functions were used. The data were analysed following the standard procedures implemented in the *Fermi* ScienceTools software package version 1.2.23 using Fermipy python package 0.19 (Wood et al., 2017).

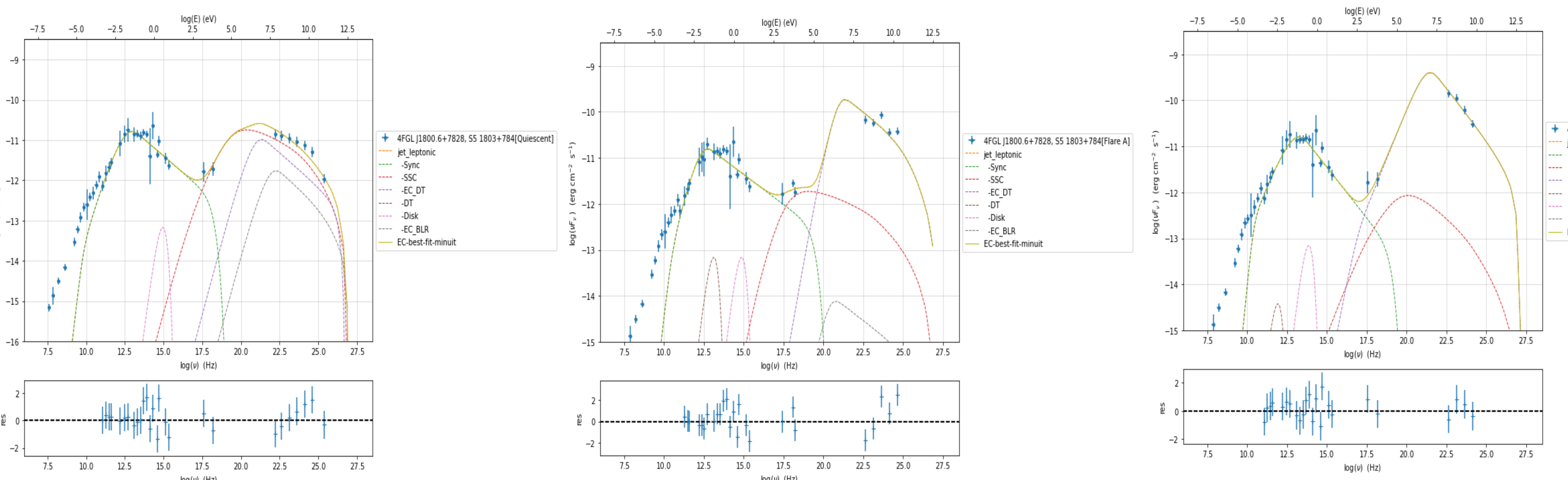
We have included all 4FGL – DR2 (fourth *Fermi*-LAT 10-year source catalogue) gll_psc_v26.xml point sources within 15^0 from the ROI centre as well as Galactic diffuse model gll_iem_v07 and extragalactic isotropic emission templates (iso_P8R3_SOURCE_V2_v1.txt) in the source model file for the background subtraction.

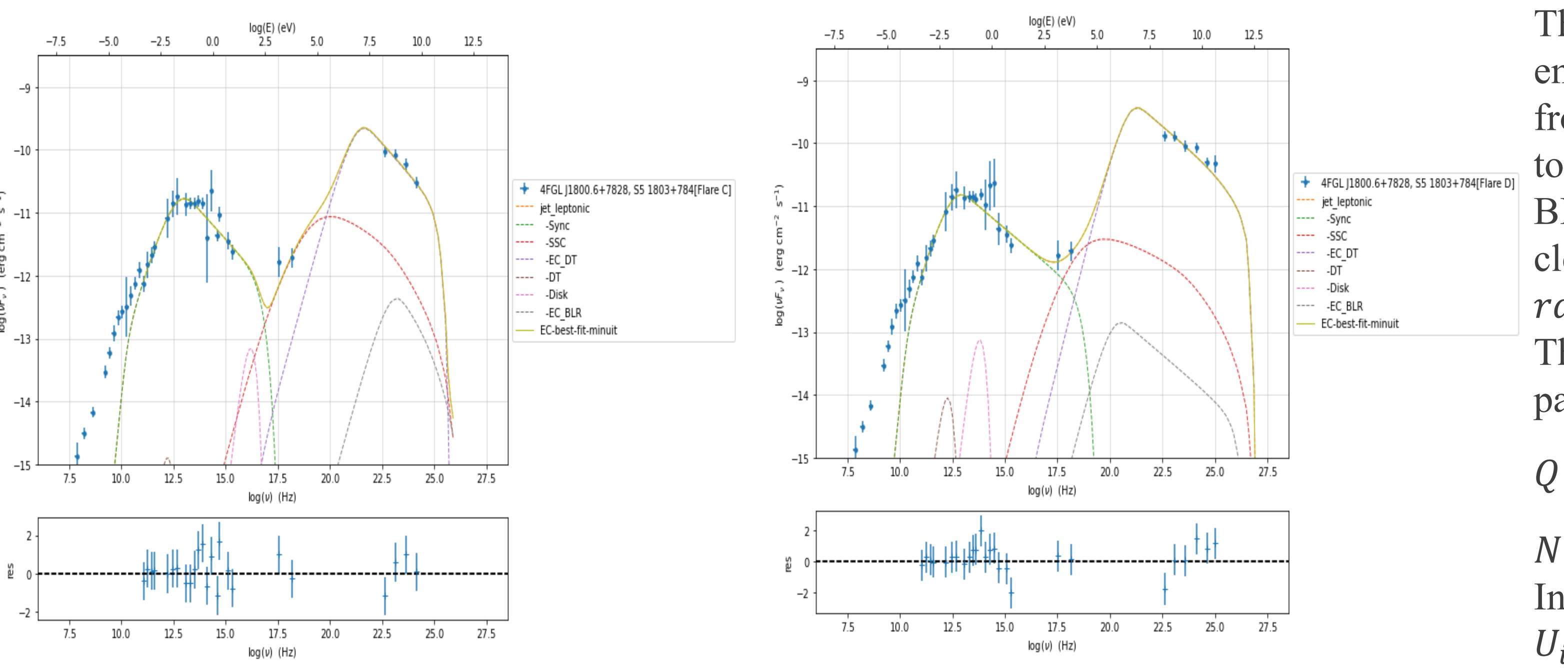
Jetset: JetSeT (version 1.1.2) is an open-source C/Python framework; a numerical modelling and SED fitting tool for relativistic jets (Tramacere 2020)



Fermi-LAT observed γ – ray flaring activities from BL Lac S5 1803+784 known as 4FGL J1800.6+7828 in Fermi – LAT 4FGL catalog (The Fermi–LAT collaboration 2020, ApJS, 247,1) with coordinates R.A (Right ascension) = 270.1891° and Declination = + 78.4678 and redshift z = 0.684 with flux peaks on January 11, 2010 (MJD 55207, Flare A), May 2, 2011(MJD 55683, Flare B), August 24, 2015 (MJD 57258, Flare C) and 12 April 2020 (MJD 58951, Flare D). The 30 – day bin light curve is shown above.

Results





The bulk of external photons for the gamma ray emission observed during the flaring states emanate from the reflected infrared photons from the dusty torus. This agrees with the fact that S5 1803+784 is a BL Lac with a very weak BLR and often shows no clear cross-correlation between the radio and the $\gamma - ray$ emission (Nesci et al. 2021).

Therefore, the electron injection and the emitting particle distribution are described as

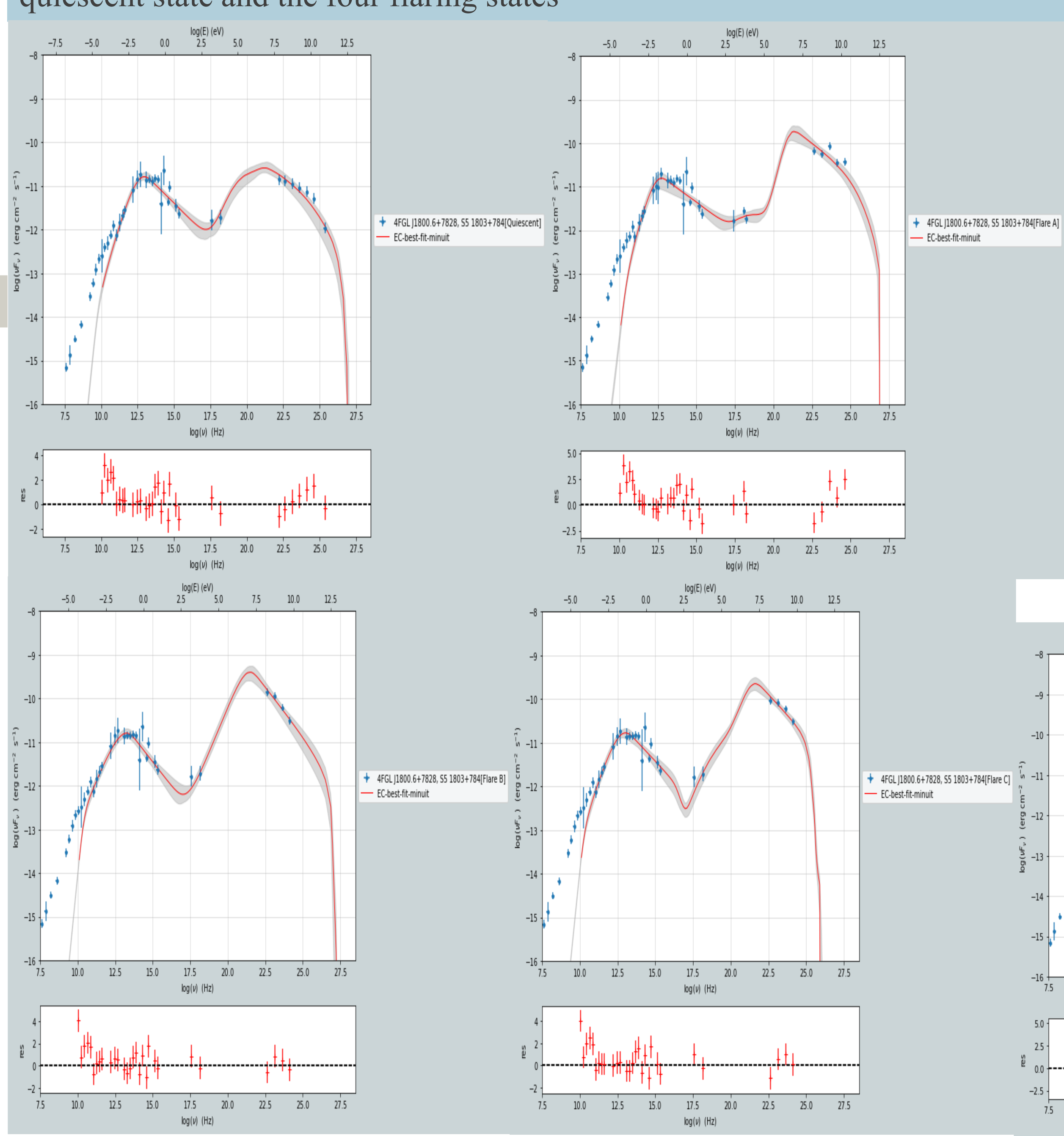
$Q(\gamma) = Q_0 \frac{(^{\gamma}/_{\gamma_b})^{-p}}{1+(^{\gamma}/_{\gamma_b})^{-p+p\_1}} \quad (cm^{-3}s^{-1})$ and

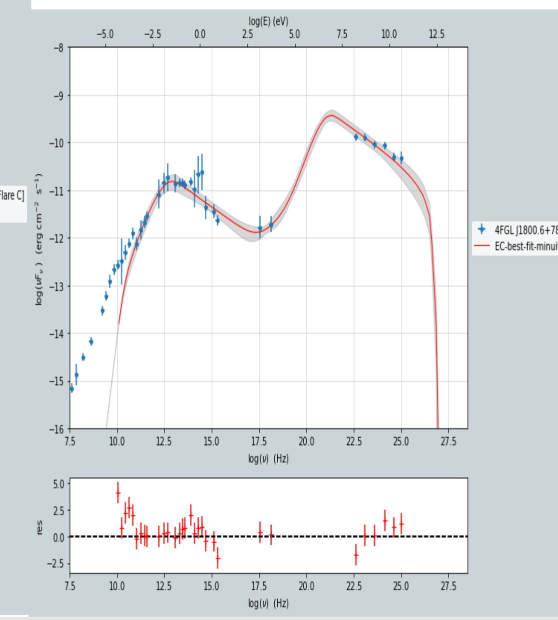
$N(\gamma) = Q(\gamma)\, t_{cross}\ (cm^{-3})$ respectively,

In this case:

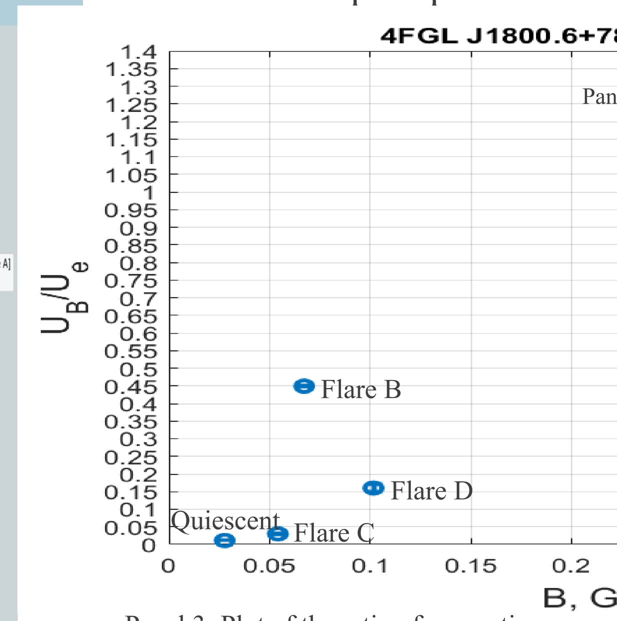
$U_i = U_{DT}(\gamma) + U_{Sync}(\gamma)$ where the external photons from the dusty torus (EC_DT) dominate the inverse Compton process.

Phenomenological spectral best fit jet energetics of S5 1803+784 in both the quiescent state and the four flaring states

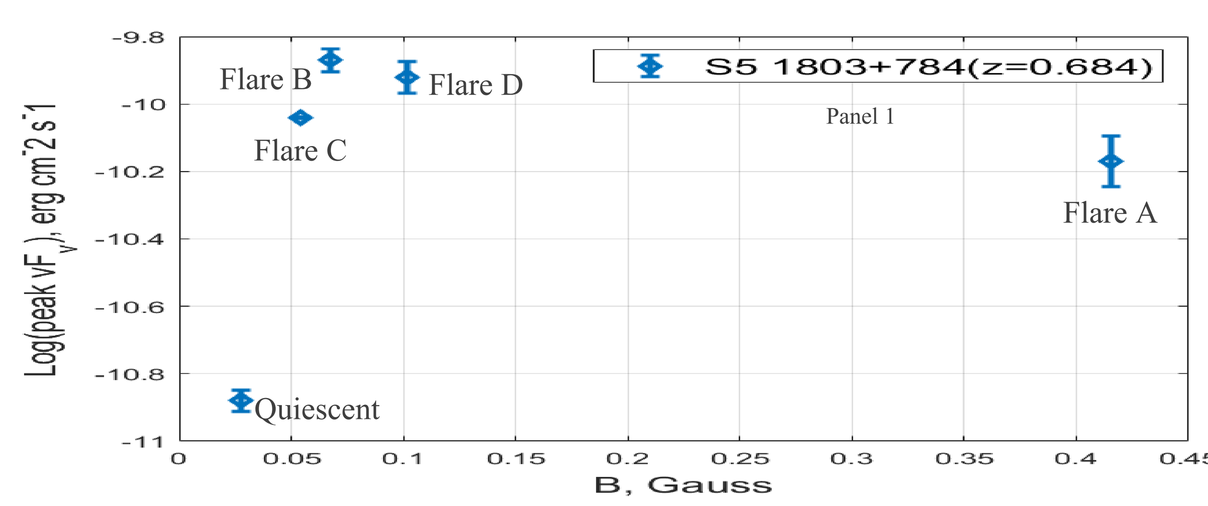


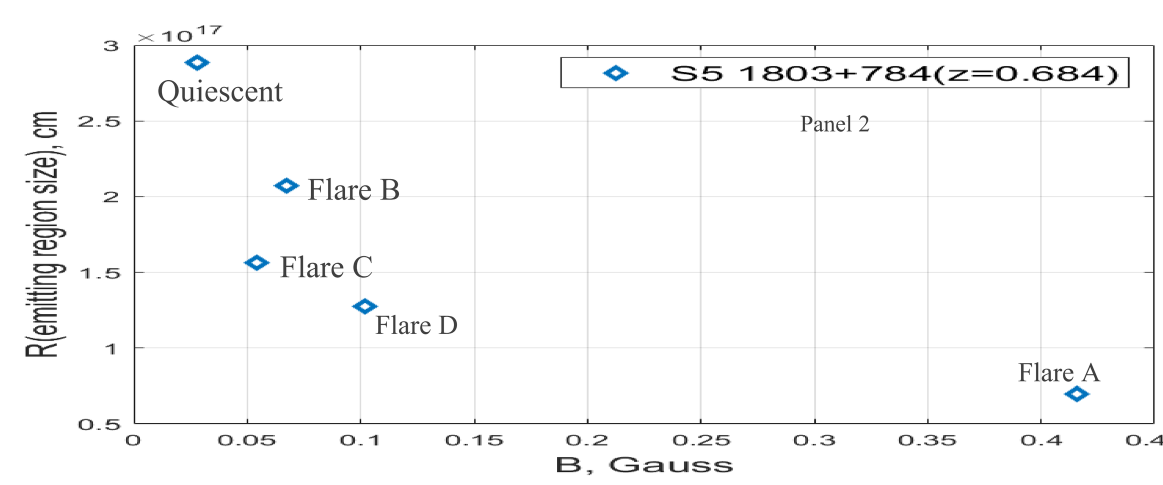


Phenomenological spectral best fits using JetSeT to obtain the 50th percentile the lower and the upper bounds of the uncertainty are the differences to 16th and 84th percentiles (Tramacere A. et al. 2011, Tramacere A. et al. 2009, Massaro E. et al 2006)



Panel 3: Plot of the ratio of magnetic energy density and the particle energy density (U_B/U_e) and magnetic field during the flaring states and quiescent state





Panel 1: Plot of the peak νF_ν and the magnetic field during the flares and quiescent states

Panel 2: Plot of the emitting region size and the magnetic field during the flares and quiescent states

Brief Discussion

From plots in panel 1, 2 & 3 it is clear that the flares from S5 1803+784 have distinct characteristics. From panel 1 , 2 & 3 we can infer that the four flaring states of S5 1803+784 shows evidence of magnetic dissipation (Zhang et al. 2015), which hints at the possible mechanism of particle acceleration. The low magnetization observed from flare C hints at shock acceleration as a possible mechanism (panel 3, Bӧttcher 2019). The magnetic field has an inverse relation with the emitting region size (panel 1) which could imply that powerful flares from this source (e.g. flare A) come from a compact region of the jet and the higher magnetization of flare A (panel 3) hints at the possibility of magnetic reconnection enhancing particle acceleration during the flare.

Conclusion

From the SED the bulk of the external photons for the inverse Compton process of this blazar come from the dusty torus.

Our result agrees with the conclusion of Lei & Wang 2015 that the location of the $\gamma - ray$ dissipation may be distinct in different states of the source. The mechanism of particle acceleration may be distinct also in different states of the source.

We suggest particle acceleration as a result of magnetic dissipation (and magnetic reconnection in the case of flare A Omojola et al. in prep).

If the $\gamma - ray$ emission is as a result of magnetic dissipation by reconnection then the emission region should be close to or within a region of magnetic turbulence. This would place the emission region of flare A further out from the central engine although the $\gamma - ray$ dissipation region, size and position is still hotly debated.

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