On the spectral curvature of 1ES1011+496

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Brief Outline

- Introduction to 1ES1011+496
- Data analysis
- SED modelling
- Understanding the particle spectrum - the diffusive processes in the jet

Introduction

Observations

- High redshift VHE blazar
  $z = 0.212$
- VHE Spectral Index ~ 4.0
- Seen by MAGIC and VERITAS
- Detected by Fermi-LAT, not seen by EGRET
- SED not very well sampled, not simultaneous

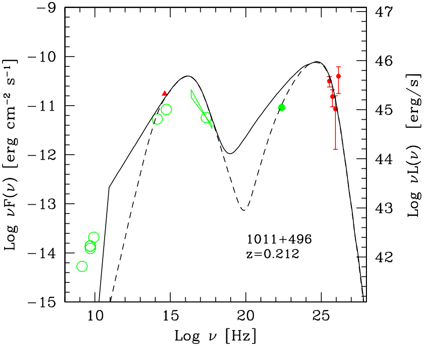
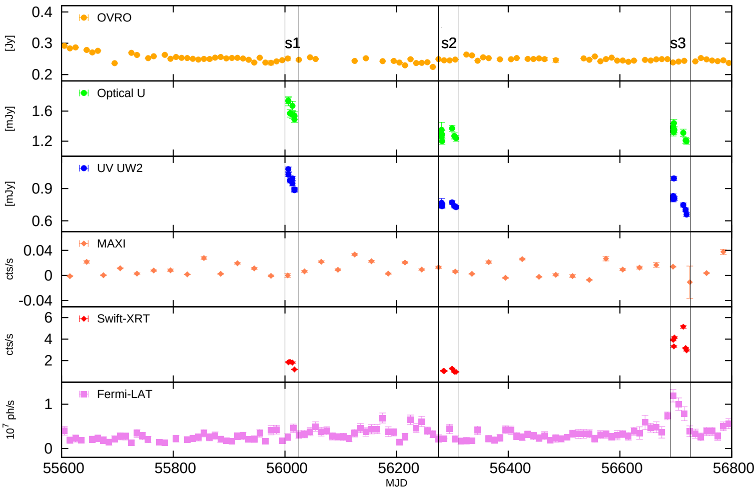


Figure : Published SED : Albert et al, ApJ, 667, 21

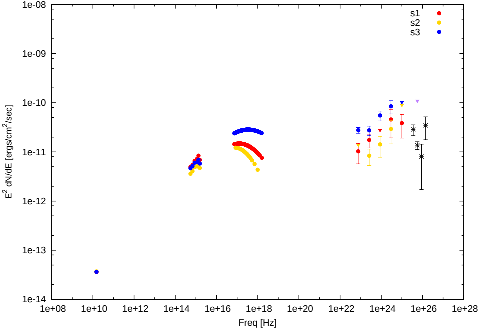
Lightcurve 2011 - 2014



Constructed SED

Instruments used

- Swift-UVOT
- Swift-XRT
- Fermi - LAT
- HAGAR : Just missed the flare due to moon time
- Archival MAGIC data



SED modelling

Synchrotron + Synchrotron Self Compton

(i) Emission region of radius R

(ii) Moving with doppler factor δ

(iii) Tangled magnetic field B

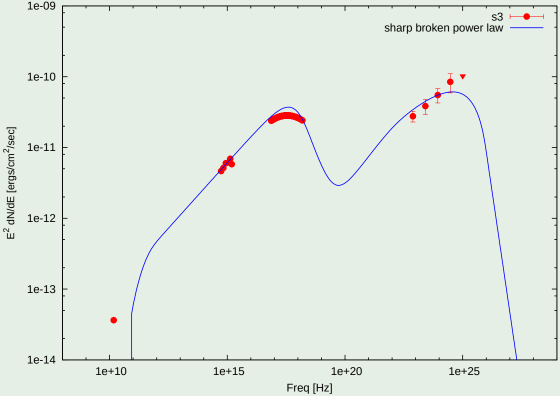
(iv) Equipartition assumed between electric and magnetic field density

(v) Model with different particle distributions

1. Broken power law (BP)

$$N(\gamma)d\gamma = \begin{cases} K\gamma^{-p_1}d\gamma, & \gamma_{min} < \gamma < \gamma_b \\ K\gamma_b^{(p_2-p_1)}\gamma^{-p_2}d\gamma, & \gamma_b < \gamma < \gamma_{max} \end{cases} \quad (1)$$

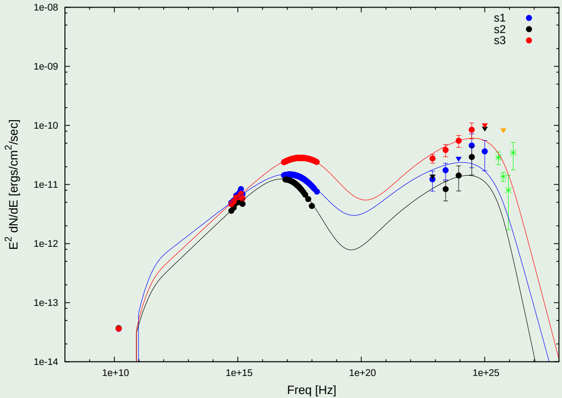
Does not work - REQUIRES SMOOTH CURVATURE !!!



2. Smooth broken power law (SBPL)

$$N(\gamma)d\gamma = K\frac{(\gamma_b)^{-p}}{(\gamma/\gamma_b)^p + (\gamma/\gamma_b)^q}d\gamma \qquad (2)$$

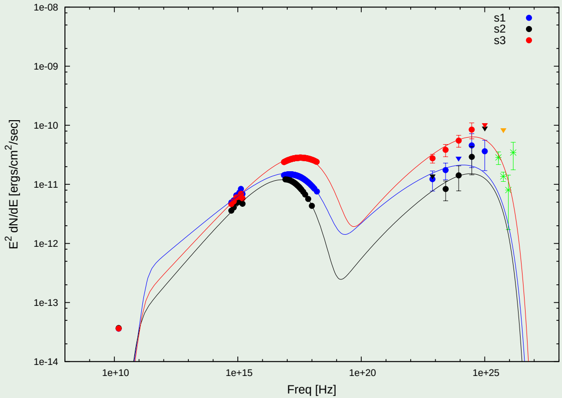
Well explains the data



3. Power law with exponential cutoff (CPL)

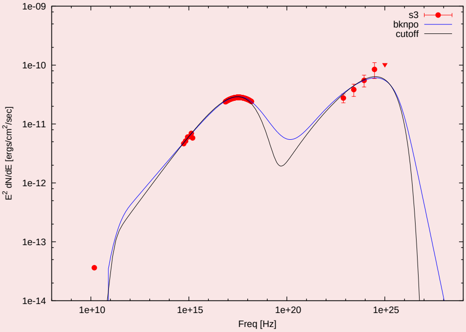
$$N(\gamma)d\gamma = K\gamma^{-p}exp(\frac{\gamma}{\gamma_{max}})d\gamma \quad (3)$$

Well explains the data



Comparison of CPL and SBPL

Take away message (1) : Need a smooth curvature in the particle spectrum to explain the data



- Need high energy X-ray (**ASTROSAT**/**NuSTAR**) to be able to distinguish between the SBPL and the CPL.

WHY IS IT IMPORTANT

It can tell us about the diffusive processes in the jet.

Solving the kinetic equation

- Assume that an accelerating region (AR) supplies electrons to the radiating (cooling) region (CR).
- Kinetic equation in the CR given by

$$\frac{\partial N}{\partial t} - \frac{\partial}{\partial \gamma}(P(\gamma)N) + \frac{N}{t_{esc}(\gamma)} = Q \tag{4}$$

- $P(\gamma) = -\frac{\partial \gamma}{\partial t}$: Energy loss rate
- Assume
  1. One shot injection process $Q = K\gamma^{-p}\delta(t - t_0)$
  2. Energy dependant escape timescale $t_{esc} \propto \gamma^{\xi}$
- Energy independant case ($\xi = 0$) well studied (eg : Kirk et al 1998)

Final Solution

[Using Green's function method, following Atoyan and Aharonian, 1999]

$$N(\gamma, t) = \frac{K\Gamma_0^{2-p}}{\gamma^2} \exp\left[-\int_0^t \frac{dx}{\tau(\Gamma_x)}\right] \quad (5)$$

where

$$\boxed{t - x = \int_{\gamma}^{\Gamma_x(\gamma,t)} \frac{d\gamma}{P(\gamma)}}$$

is the trajectory of the particle in energy space.
And the final solution is given by,

$$N(\gamma) = \frac{K\Gamma_0^{2-p}}{\gamma^2} \exp\left[-\frac{\gamma_b \gamma_c^{\xi}}{(\xi+1)} \left\{ \left(\frac{1}{\gamma}\right)^{\xi+1} - \left(\frac{1}{\gamma} - \frac{1}{\gamma_b}\right)^{\xi+1} \right\}\right] \text{ for } \xi \neq -1 \quad (6)$$

$$N(\gamma) = \frac{K\Gamma_0^{2-p}}{\gamma^2} \left(1 - \frac{\gamma}{\gamma_b}\right)^{\frac{\gamma_b}{\gamma_c}} \qquad \text{for } \xi = -1 \quad (7)$$

Comparing with the data

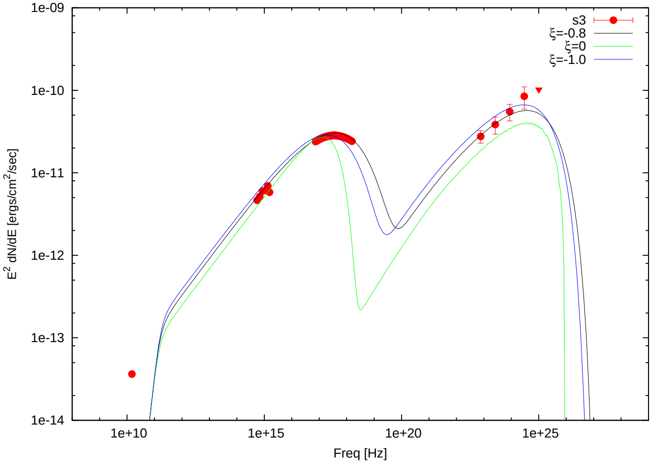


Figure : $\xi = -0.8$ well repoduces the data;
$\xi = -1.0$ corresponds to the well known case of Bohm diffusion, and is a reasonable match to the data.

The particle spectrum

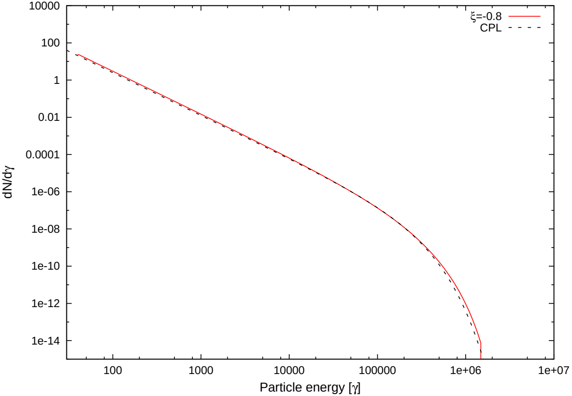


Figure : $\xi = -0.8$ gives rise to a power law with an exponentially falling tail

Conclusions

1. A smooth curvature in the particle spectrum is required to explain the data
2. Can be obtained by a SBPL or a CPL
3. An energy dependent escape mechanism gives rise to a smooth curvature in the particle spectrum.
4. An energy dependency of $\xi = -0.8$ mimics a CPL (for one shot injection).
5. An energy dependency of $\xi = -1.0$ corresponds to the case of the well known Bohm diffusion scenario, where the mean free path $\lambda \propto r_g$
6. **The particles escape from the cooling region closely resembling a Bohm diffusion mechanism**

THANK YOU !!!