Numerical calculation of blazar spectra. Application to 1 ES 1218+30.4

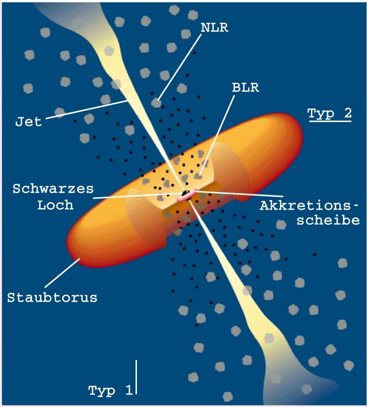
Michael Rüger, Universität Würzburg

Astroteilchenschule Obertrubach-Bärnfels 2007

2007/10/8

Outline

AGN scheme

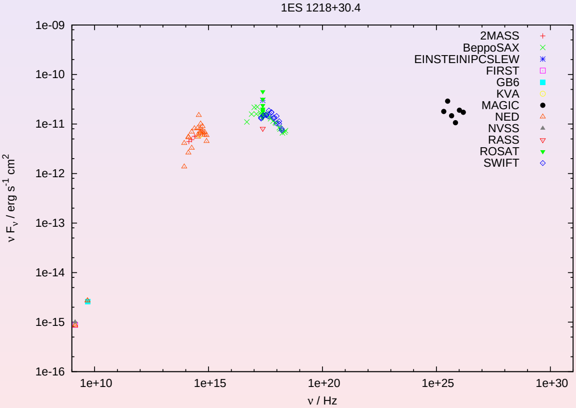


from Urry&Padovani 1995

BL Lac Objects

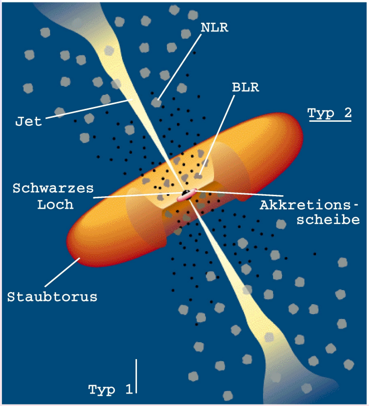
- Prototype BL Lacertae
- Absence of emission lines
- Emission from radio- to TeV-regime $\rightarrow$ observable by IACTs
- Example: 1 ES 1218+30.4 high-peaked BL Lac object (HBL)

1 ES 1218+30.4 high-peaked BL Lac object



Synchrotron Self-Compton Model

- 1. peak (from radio to X-rays):
  Synchrotron radiation from electrons due to the magnetic field
- 2. peak (gamma rays):
  inverse Compton scattering of these photons by the same electron population
- We consider the comoving frame of a spherical zone in the jet with radius R (one zone model)
- particle distributions are homogeneous and isotropic


NLR
BLR
Typ 2
Jet
Schwarzes
Loch
Akkretions-
scheibe
Staubtorus
Typ 1

Synchrotron Self-Compton Model

- 1. peak (from radio to X-rays):
  Synchrotron radiation from electrons due to the magnetic field
- 2. peak (gamma rays):
  inverse Compton scattering of these photons by the same electron population
- We consider the comoving frame of a spherical zone in the jet (one zone model)
- particle distributions are homogeneous and isotropic

Equation for photon distribution

$$\frac{dn(\nu)}{dt} = R_S(\nu) - c\,\alpha_\nu(\nu)n(\nu) + R_C(\nu) - \frac{n(\nu)}{t_{ph,esc}}$$

- R_S: synchrotron emission
- α_ν synchrotron self absorption coefficient
- R_C: inverse compton emission
- $t_{ph,esc}$: photons escape time

Equation is solved numerically

Solution of the photon equation

- Discretizing the time derivative:

$$\frac{\partial n}{\partial t} \to \frac{n(t_{n+1}) - n(t_n)}{\Delta t}$$
$$\Rightarrow n(t_{n+1}) = n(t_n) + \Delta t \cdot (\dots)$$

$n(t_{n+1})$ is computed by using the Crank-Nicholson-Scheme

Crank-Nicholson-scheme

Example: flux-conservative equation

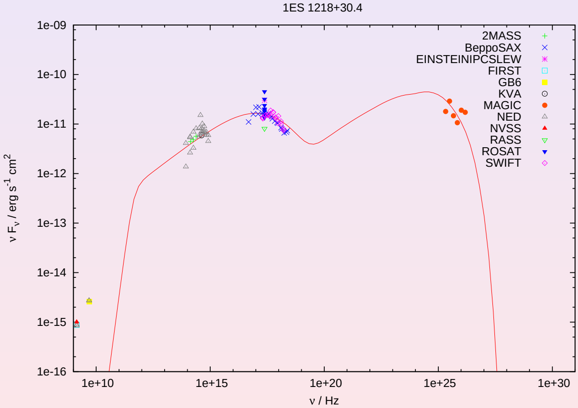
$$\frac{\partial f}{\partial t} = -\frac{\partial F(f)}{\partial x}$$

Idea: taking the average of the right hand side at current and next time step

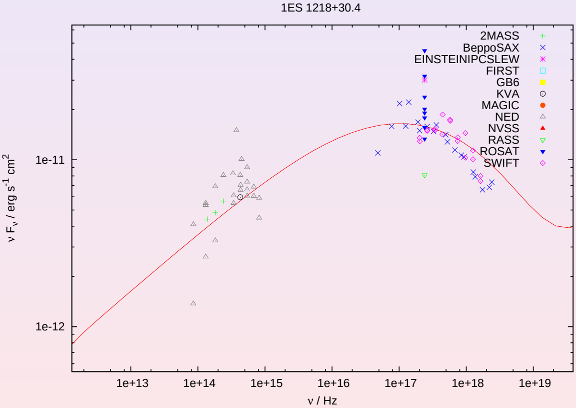
$$\frac{f_j^{n+1} - f_j^n}{\Delta t} = \frac{1}{2}\frac{F_{j+1}^{n+1} - F_j^{n+1}}{\Delta x} + \frac{1}{2}\frac{F_{j+1}^n - F_j^n}{\Delta x}$$

$\rightarrow$ implicit method, need to solve tridiagonal matrix equation

Best fit for 1 ES 1218+30.4



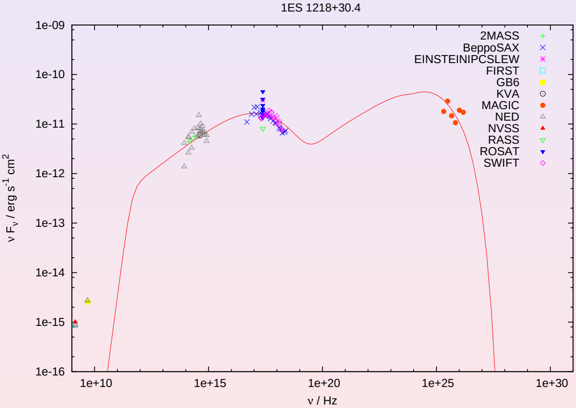
Zoom into the synchtron peak



Conclusion

- One zone SSC-modell is able to explain the multi-wavelength spectrum of 1 ES 1218+30.4
- More simultaneous data are necessary to confirm or rule out model

Best fit for 1 ES 1218+30.4



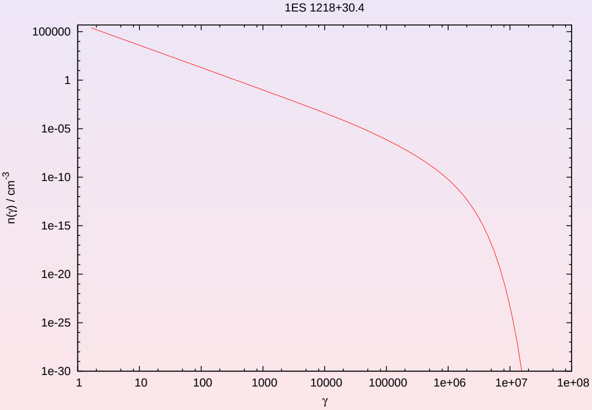
Electron distribution

- No variability during the observation
  $\Rightarrow$ steady-state distribution sufficient
- smoothed broken power law distribution with cut-off

Tavecchio et al. 2001

$$n(\gamma) = K\gamma^{-s_1}\left(1+\frac{\gamma}{\gamma_b}\right)^{s_1-s_2}\exp\left(-\frac{\gamma}{\gamma_{max}}\right)$$

Electron distribution



best fit parameters

First estimation using Kataoka et. al. 2000
Small modifications yield best fit

- $\gamma_b = 6 \times 10^4$
- $\gamma_{max} = 4 \times 10^5$
- $s_1 = 2.3$
- $s_2 = 3.3$
- $B = 0.568 \mathrm{~G}$
- $K = 8 \times 10^5 \mathrm{~cm}^{-3}$
- $\delta = 13$

$$
\begin{aligned}
R_S &= \frac{4\pi}{h\nu} j_\nu(\nu) \\
&= \frac{1}{h\nu} \int d\gamma n_{e^-}(\gamma) P_\nu(\nu, \gamma) \\
&= n(\gamma_0) P_S(\gamma_0) \frac{2\pi mc}{3eB} \frac{1}{\gamma_0} \\
\text{with } \gamma_0 &= \sqrt{\frac{4\pi mc\nu}{3eB}}
\end{aligned}
$$

$$
\begin{aligned}
R_C(\nu) &= \int d\gamma \, n_{e^-}(\gamma) \times \\
&\times \int d\alpha_1 \left[n_{ph}(\alpha_1) \frac{dN(\gamma, \alpha_1)}{dt d\alpha} - n_{ph}(\alpha) \frac{dN(\gamma, \alpha)}{dt d\alpha_1} \right]
\end{aligned}
$$

$$
\begin{aligned}
R_S &= \frac{4\pi}{h\nu}\, j_\nu(\nu) \\
&= \frac{1}{h\nu}\int d\gamma n_{e^-}(\gamma) P_\nu(\nu,\gamma) \\
&= n(\gamma_0) P_S(\gamma_0) \frac{2\pi mc}{3eB}\frac{1}{\gamma_0} \\
\text{with } \gamma_0 &= \sqrt{\frac{4\pi mc\nu}{3eB}}
\end{aligned}
$$

$$
\begin{aligned}
R_C(\nu) &= \int d\gamma\, n_{e^-}(\gamma) \times \\
&\times \int d\alpha_1 \left[n_{ph}(\alpha_1)\frac{dN(\gamma,\alpha_1)}{dtd\alpha} - n_{ph}(\alpha)\frac{dN(\gamma,\alpha)}{dtd\alpha_1} \right]
\end{aligned}
$$