Modeling Multiwavelength Blazar Spectra using a Particle Transport Equation

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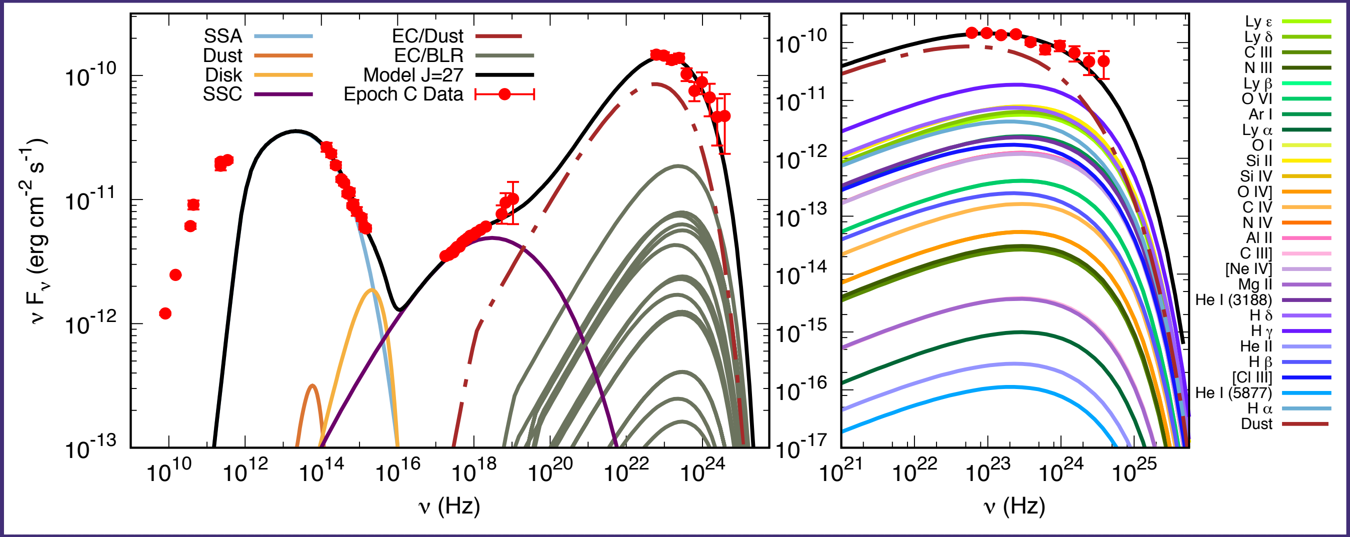

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We successfully model multiwavelength spectra for 3C 279 with a one-zone leptonic model. The solution to the particle transport equation provides the electron distribution with a shape defined by acceleration from both shocks and stochastic scattering with MHD waves, allowing us to compare them. We include radiation due to synchrotron, SSC, and full external Compton due to particle interactions with seed photons from the disk, dust torus, and 26 individual broad lines, improving the blob location prediction.

The Electron Distribution is the Solution to the Particle Transport Equation

Our transport equation for the electron distribution (N_e) with respect to the electron Lorentz factor (γ), includes stochastic acceleration due to MHD waves (D_0), shock acceleration & adiabatic expansion (a), synchrotron radiation (b_{syn}), full Compton radiation ($b_C H$), Bohm-diffusive particle escape with timescale τ, and monochromatic (γ_{inj}) particle injection with rate $\dot{N}_{inj}$. In the Thomson approximation, we can solve the transport equation analytically for both time dependent and steady-state cases (Lewis, Becker, & Finke, 2016). In Lewis Finke, & Becker (submitted), we include the full Compton cross-section, and solve the steady-state transport equation numerically, utilizing a new normalization technique we developed for this work.

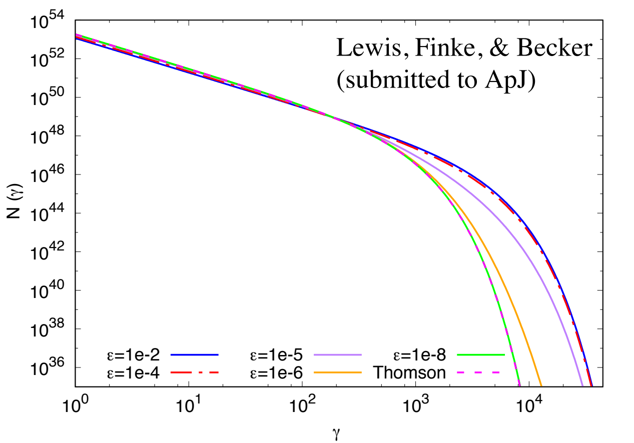
$$\frac{\partial N_e}{\partial t} = \frac{\partial^2}{\partial \gamma^2}\left[D_0 \gamma^2 N_e\right] - \frac{\partial}{\partial \gamma}\left[D_0 N_e \left(4\gamma + a\gamma - b_{\rm syn}\gamma^2 - \sum_j b_{{\rm C},j} H(\gamma\epsilon_j)\right)\right] - \frac{N_e \gamma D_0}{\tau} + \dot{N}_{\rm inj}\delta(\gamma - \gamma_{\rm inj})$$

$$H(y) = \frac{9}{32}\frac{1}{y^2} G_{\rm BMS}(y)$$

The function H describes the full Compton cross-section, which is dependent upon the incident photon energy ε in the Klein-Nishina regime, and such that $H(\gamma\varepsilon)$=1 in the Thomson limit. The effect of the incident photon energy on the electron distribution is shown at right, where j=1.

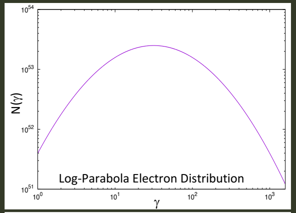
$$\begin{aligned} G_{\rm BMS}(\gamma\epsilon) =& \frac{8}{3}\gamma\epsilon \frac{1+5\gamma\epsilon}{(1+4\gamma\epsilon)^2} - \frac{4\gamma\epsilon}{1+4\gamma\epsilon}\left(\frac{2}{3} + \frac{1}{2\gamma\epsilon} + \frac{1}{8(\gamma\epsilon)^2}\right) \\ &+ \ln(1+4\gamma\epsilon)\left(1 + \frac{3}{\gamma\epsilon} + \frac{3}{4(\gamma\epsilon)^2} + \frac{\ln(1+4\gamma\epsilon)}{2\gamma\epsilon} - \frac{\ln(4\gamma\epsilon)}{\gamma\epsilon}\right) \\ &- \frac{5}{2\gamma\epsilon} - \frac{\pi^2}{6\gamma\epsilon} - 2 + \frac{1}{\gamma\epsilon}\sum_{n=1}^{\infty} \frac{(1+4\gamma\epsilon)^{-n}}{n^2} \end{aligned}$$

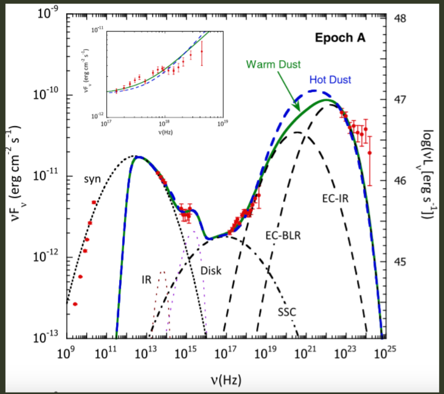
Boettcher, Mause, & Schlickeiser (1997)

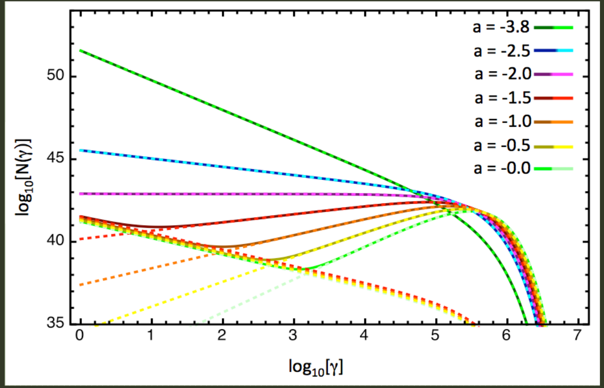


Stochastic Acceleration Dominates Positive Contributions to the Particle Energy Budget

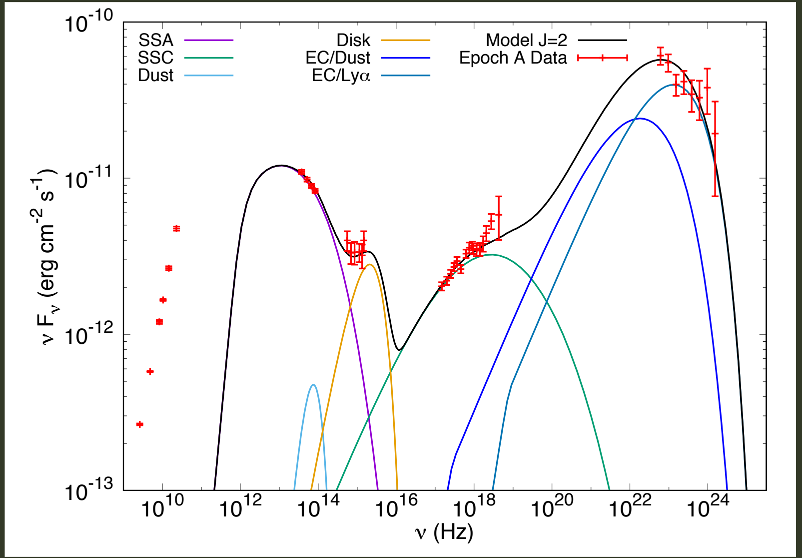
The transport equation-based electron distribution can change shape. In the central figure below, the dark green line (very similar to most of our data comparisons) is due to the balance between stochastic acceleration (D_0) and shock acceleration/adiabatic expansion (a) with an exponential cut-off (due to non-thermal cooling). In this case the adiabatic expansion overwhelms any shock acceleration, making a negative, and stochastic acceleration the dominant contributor to the particle acceleration. The change to the shape of the electron distribution from an ad hoc function to a self-consistent solution to the transport equation is the main difference between the methods to produce the figures at the bottom left and right, where the latter matches the *Fermi*LAT data. Assuming adiabatic expansion is roughly constant, increasing *a* increases the shock acceleration contribution, which can pull more electrons to higher energies before they radiate, and change the SED shape also.





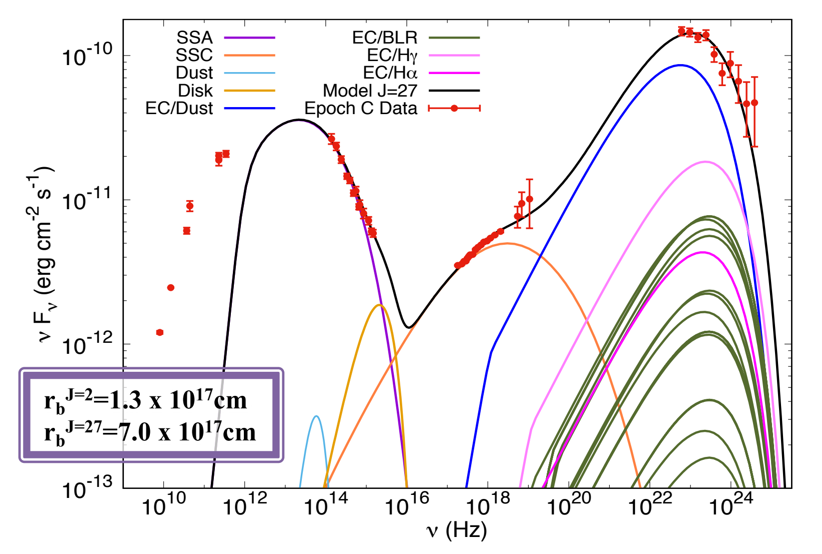


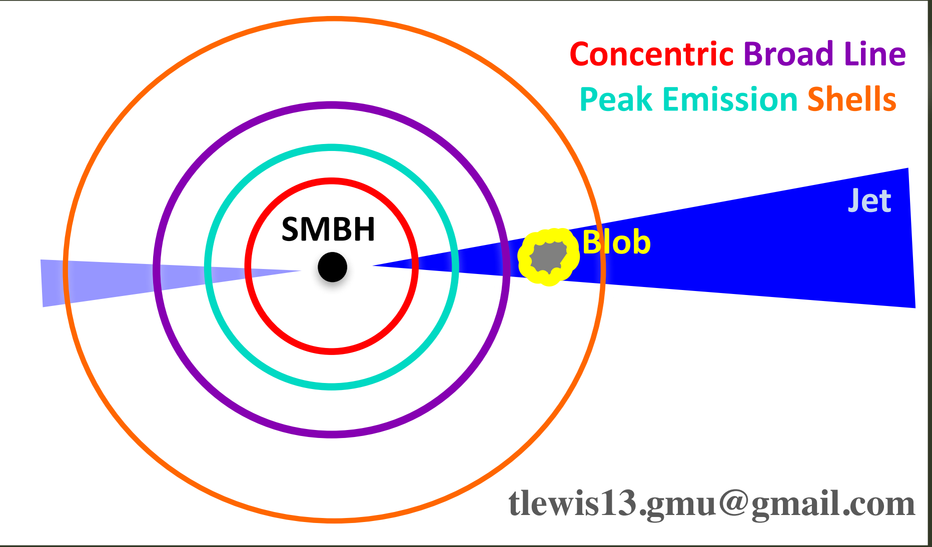
Shown on the left: Dermer et al. (2014) examined the same multi-wavelength data, but were unable to model the *Fermi*LAT γ-rays above 5 GeV (~10^{24} Hz), having chosen an ad hoc log-parabola electron distribution (top left).



The Stratified Broad Line Region Model Predicts That the Emitting Region Is Further From the Black Hole

We model radiation due to self-absorbed synchrotron, synchrotron self-Compton, and external Compton, with seed photons from the accretion disk (which are unimportant), the dust torus, and 26 individual broad lines. We adopt the stratified broad line region from Finke (2016) shown at right. It states that each emission line has a unique energy density and peak emission distance from the central black hole. Furthermore, these properties are related by ratios common across AGN according to reverberation mapping. Therefore the values for one emission line can set the values for all of them, meaning that the inclusion of more than 1 line does not increase the number of free parameters in the model. To achieve a similar comparison to the data, each individual line contributes less flux than if one is considered alone, but the aggregate contribution from the BLR is approximately the same whether we use one line or many. Additionally, the predicted location of the emitting region is at least a factor of 2 larger when we consider 27 external Compton sources (dust & 26 broad lines) than when we consider only 2 (dust & Lyman α)





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