Simulating blazar SEDs using a spatially resolved SSC model

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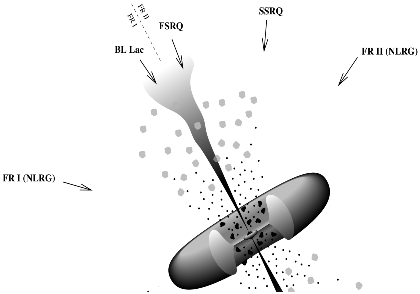
Outline

Blazars

Blazars - An AGN subclass

- many observed AGNs show collimated jet structures
- those transport high energy particles away from the host galaxy
- due to the size of the observed jets, effective acceleration mechanisms have to exist within the jet



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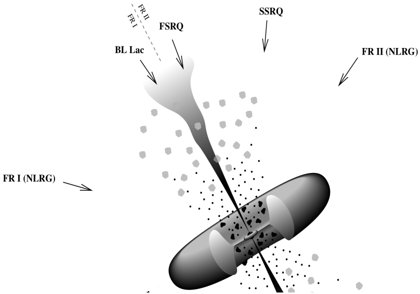
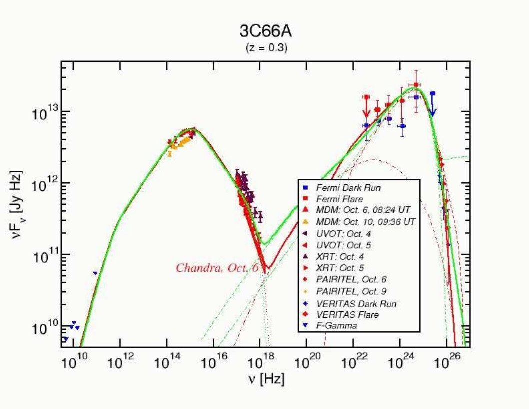


- depending on viewing angle $\rightarrow$ different properties
- Blazars have very small angles $\rightarrow$ emissions dominated by jet

Blazars - Typical SEDs

double peak structure



SSC-model

SSC - Model

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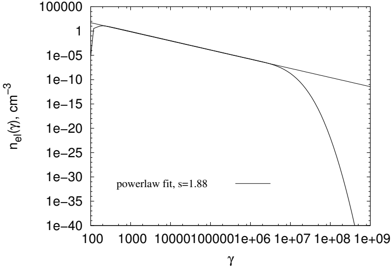
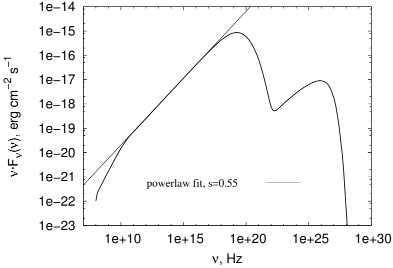
- high energy photons are produced by inverse Compton scattering
- scattering by the very same electron population that emitted the photons



$\Longrightarrow$



SSC - Inconsistencies

single zone SSC

- the electron distribution producing the SED isn't explained physically $\rightarrow$ merely mapping of breaks and spectral indices onto SED
- light travel times have to be checked by hand
- light travel time $\simeq$ homogenisation time?

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two zone SSC (e.g. Weidinger et al. 2010)

- time variation can only be introduced by injection of particles or arbitrary variations of parameters
- hard to explain softlags
- ultra short variation timescales still need small emission regions and/or high doppler factors

Spatially resolved model

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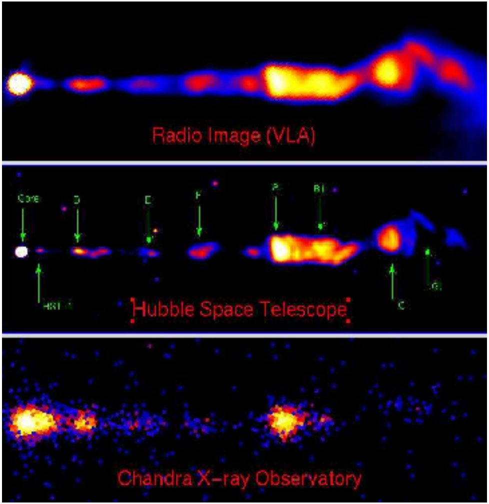
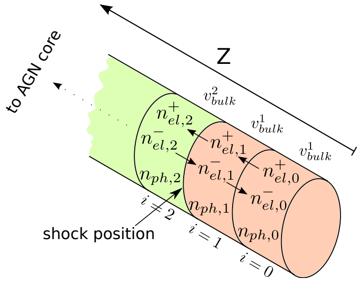


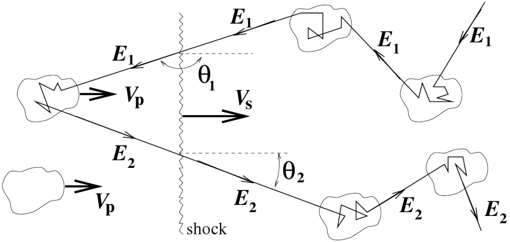
Figure: Jet of M87 - X-ray: NASA/CXC/MIT/H.Marshall et al., Radio: F.Zhou, F.Owen (NRAO), Optical: NASA/STScI/UMBC/E.Perlman et al.

Spatially resolved model

- expanding the two zone to a N-zone model
- modelling the jet propagating through the zones
- describing acceleration via scattering around the shock (Fermi I process)
- calculating the SEDs in each zone and sum up taking into account light travel times



Spatially resolved model - Fermi-I



- shock is represented by jump in bulk velocity u between neighboured zones
- in shock frame: $u_u = -V_S$, $u_d = V_P - V_S$, $R = \frac{u_u}{u_d}$
- scattering is controlled via the probability for an electron to change its propagation direction

Spatially resolved model - Properties

- electron distribution
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solving the Vlasov equation

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  - advection through the zones
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  } mimics Fermi I

  - additional acceleration by Fermi II process
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  } solving the Vlasov equation
- photon distribution
  - production of photons via synchrotron radiation
  - energy gain via inverse Compton scattering
  - losses because of synchrotron self absorption

Spatially resolved model - Results

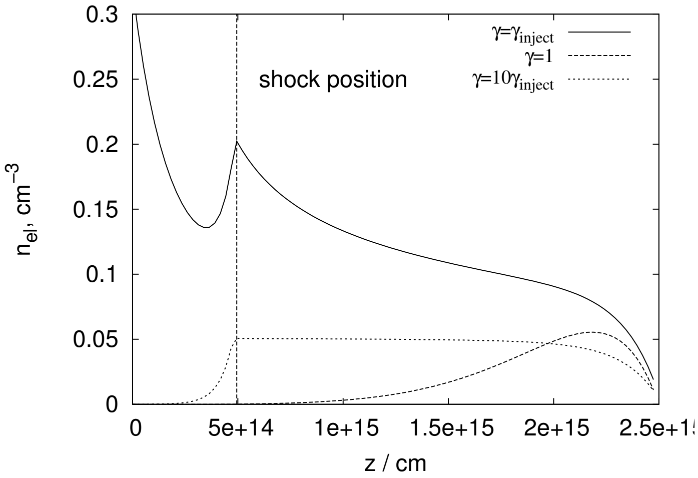

Figure: Jet morphology.

Spatially resolved model - Results

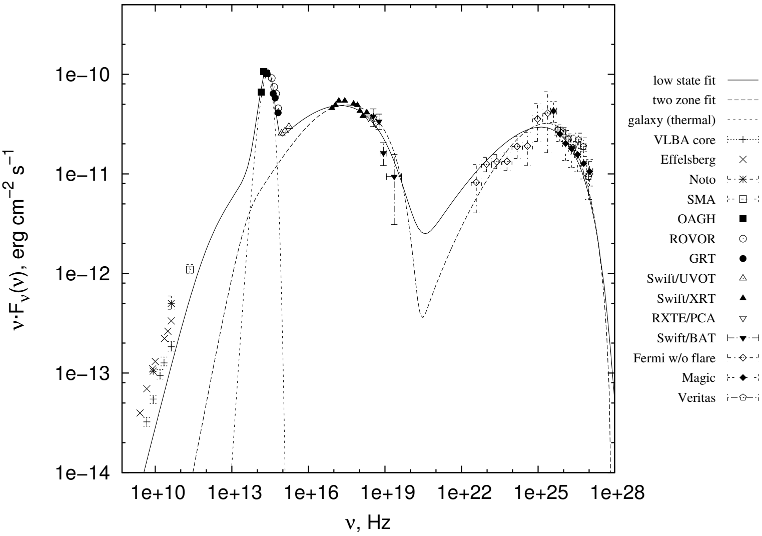

Figure: Low state fit of Mrk501. Multifrequency data from Abdo et al. (2011).

Spatially resolved model - Results

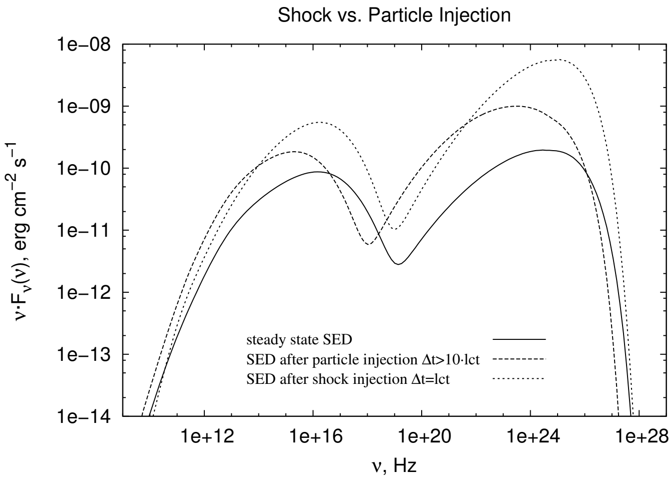

Figure: Comparison of variability due to particle and shock injection, respectively.

Outlook

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further model development

- electron positron pair interactions
- inclusion of hadronic components and using the model of Hümmer, Rüger, Spanier, and Winter (2010) to calculate secondary fluxes
- angle resolved external Compton of photons from the host galaxy, employing the model by Hutter and Spanier (2010)

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further applications

- fitting high states and (short time) variability
- explaining observed time lags between flare lightcurves of different bands $\rightarrow$ due to morphology of emission region ?
- compare predicted morphology with VLBI observations?

Conclusion

- self consistent and causal model
- explain radio part of the SED much better
- produce variation via particle injection **as well as** additional shocks
- resemble light curves and observed time lags?
- compare predicted morphology to VLBI observations

Bibliography I

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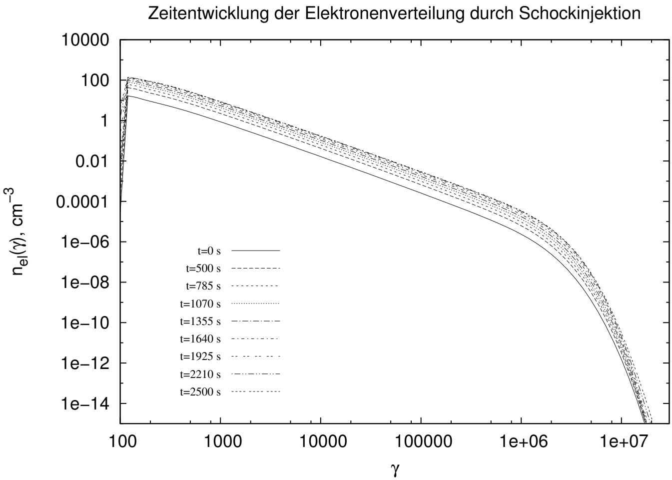
Variability due to shock injection



Variability due to particle injection