



Simulating blazar SEDs using a spatially resolved SSC model

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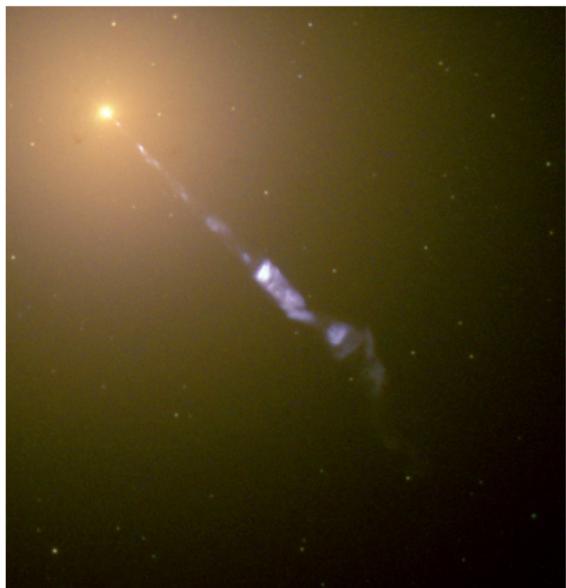
May 5, 2020



- luminosity of nuclei \gtrsim stellar luminosity
- jets on \sim kpc scales showing non-thermal emission
- super massive black holes, accreting interstellar gas
- high energetic outflows perpendicular to accretion disc

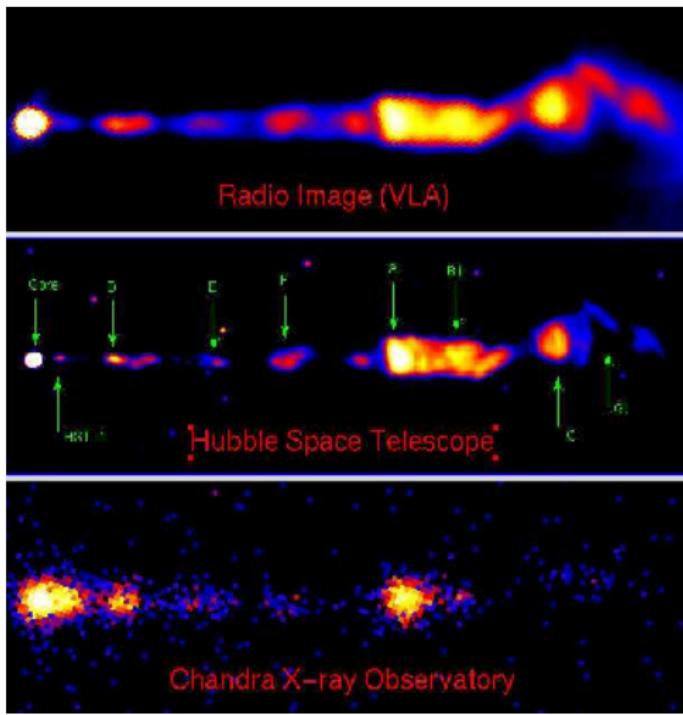
Blazars

- highly relativistic, i.e doppler boosted
- very broad and flat spectral energy distributions (SEDs)
- strong time variability on a wide range of timescales



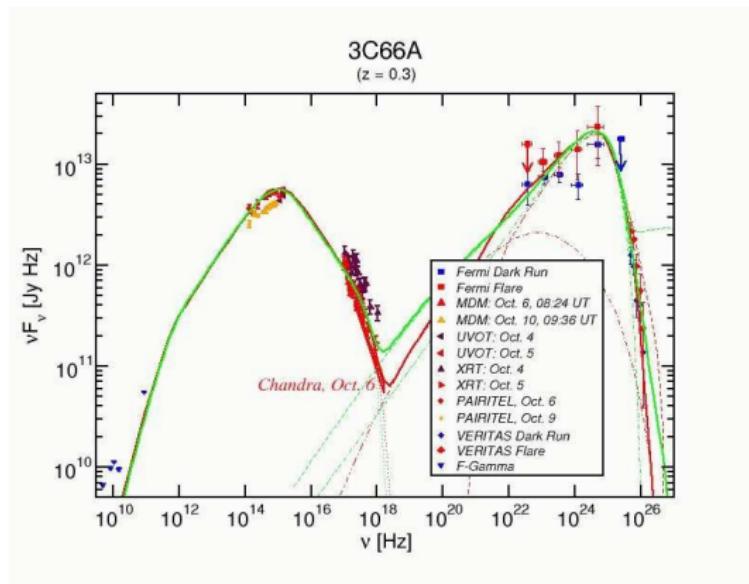
Jet of M87

from jets to blobs



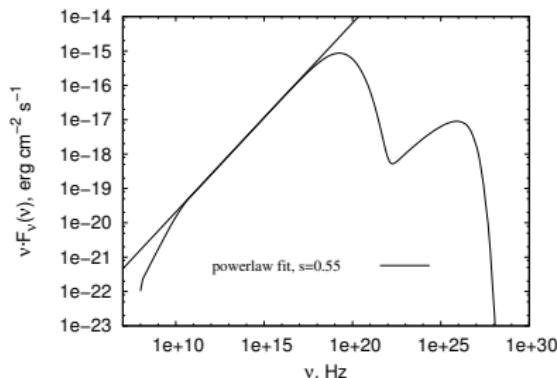
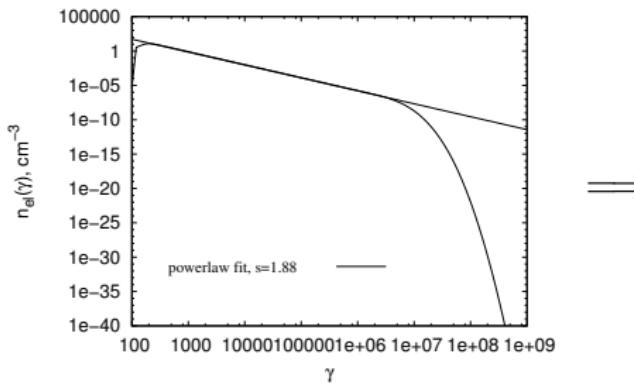
Jet of M87 - X-ray: NASA/CXC/MIT/H.Marshall et al., Radio: F.Zhou,
F.Owen (NRAO), Optical: NASA/STScI/UMBC/E.Perlman et al.

SSC-models



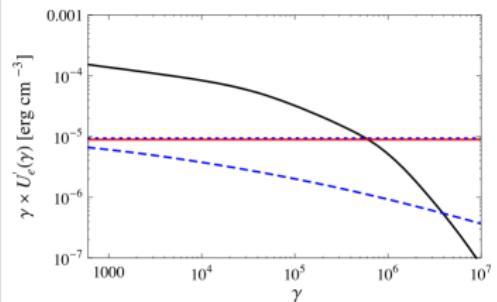


- leptonic model explaining first peak by synchrotron emissions of electrons
- high energy photons are produced by inverse Compton scattering
- scattering by the very same electron population that emitted the photons



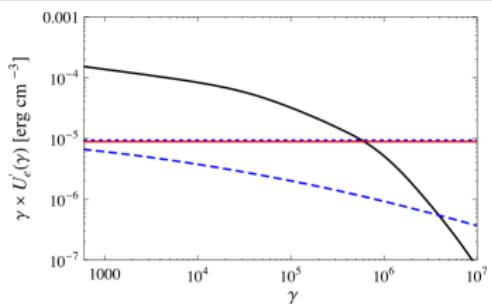
very basic approach

- assume some (multiple) broken powerlaw
- parameters are $\gamma_{max}, \gamma_{min}, \gamma_{break}^i, s^i$



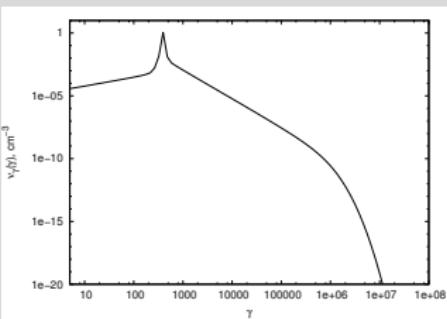
very basic approach

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self consistent approach (e.g. Weidinger et al. 2010)

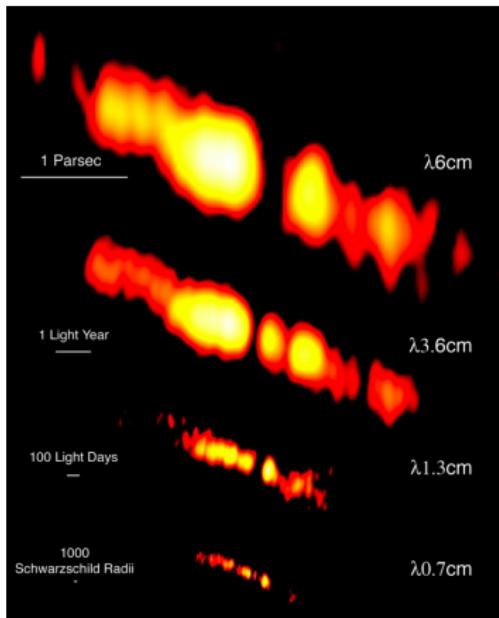
- injection of particles at some γ_{inject}
- self consistent acceleration and cooling



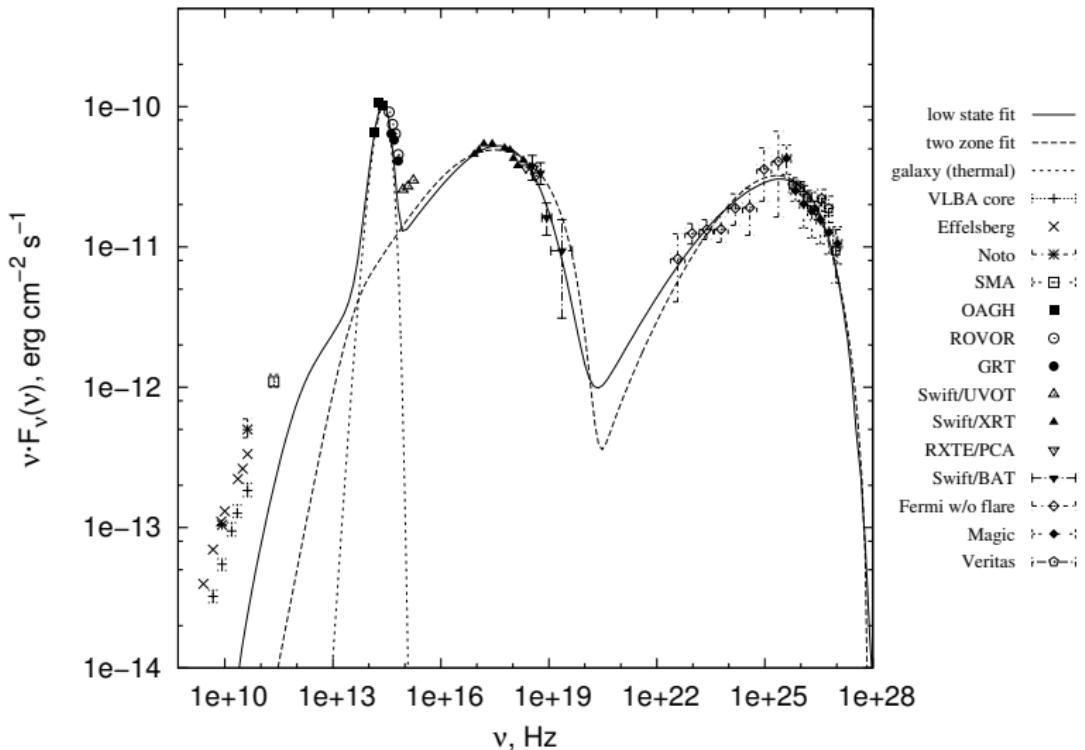


Spatially resolved model

Spatially resolved model



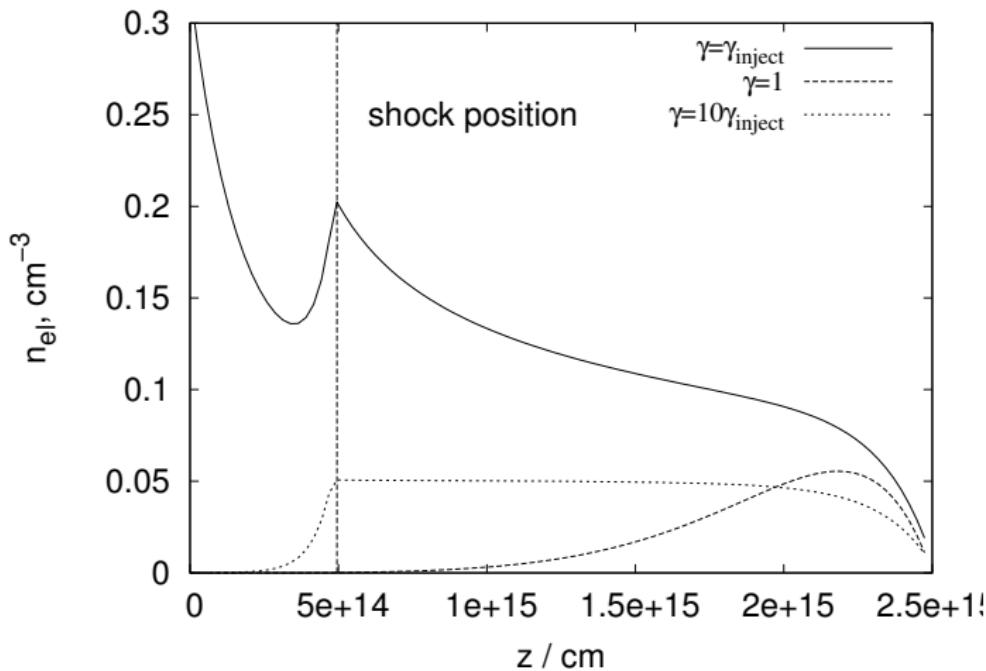
VLBI image of the jet of NGC1052; M. Kadler, Universität Wuerzburg



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



spatial distribution



Jet morphology. z along jet axis.



synchrotron radiation of a single electron

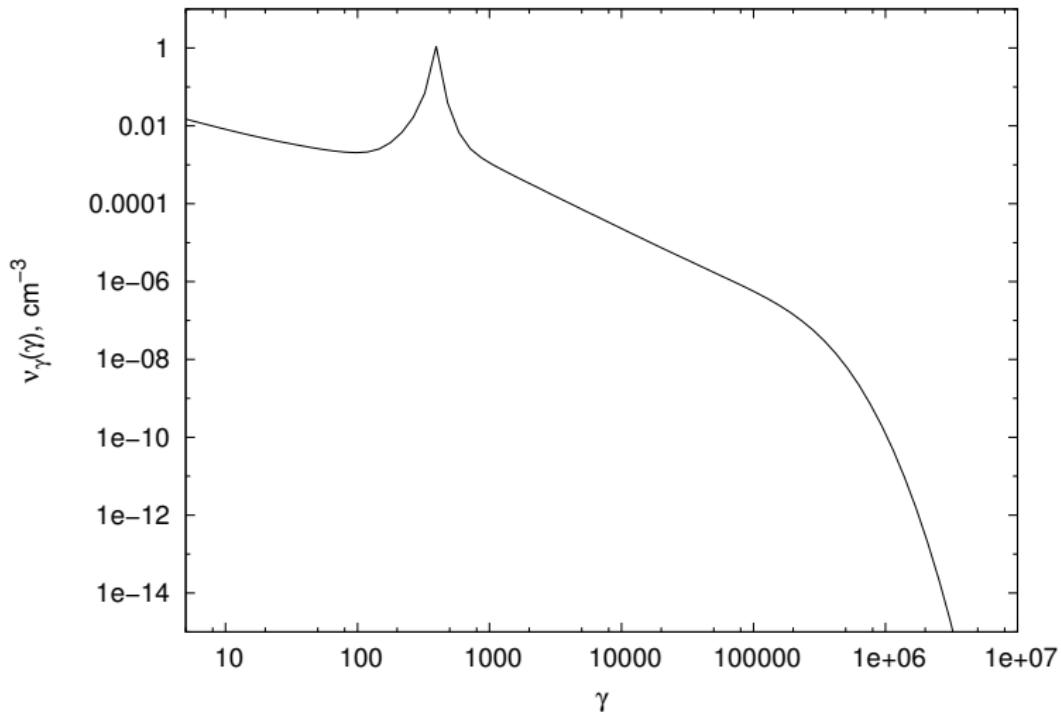
using $\nu_c = \frac{3\gamma^2 qB}{4\pi mc}$:

$$P_\nu(\gamma, \nu) = \frac{\sqrt{3} q^3 B}{m c^2} \cdot \frac{\nu}{\nu_c} \int_{\frac{\nu}{\nu_c}}^{\infty} d\eta \ K_{\frac{5}{3}}(\eta) \underset{\text{small } \nu}{\propto} \nu^{\frac{1}{3}}$$

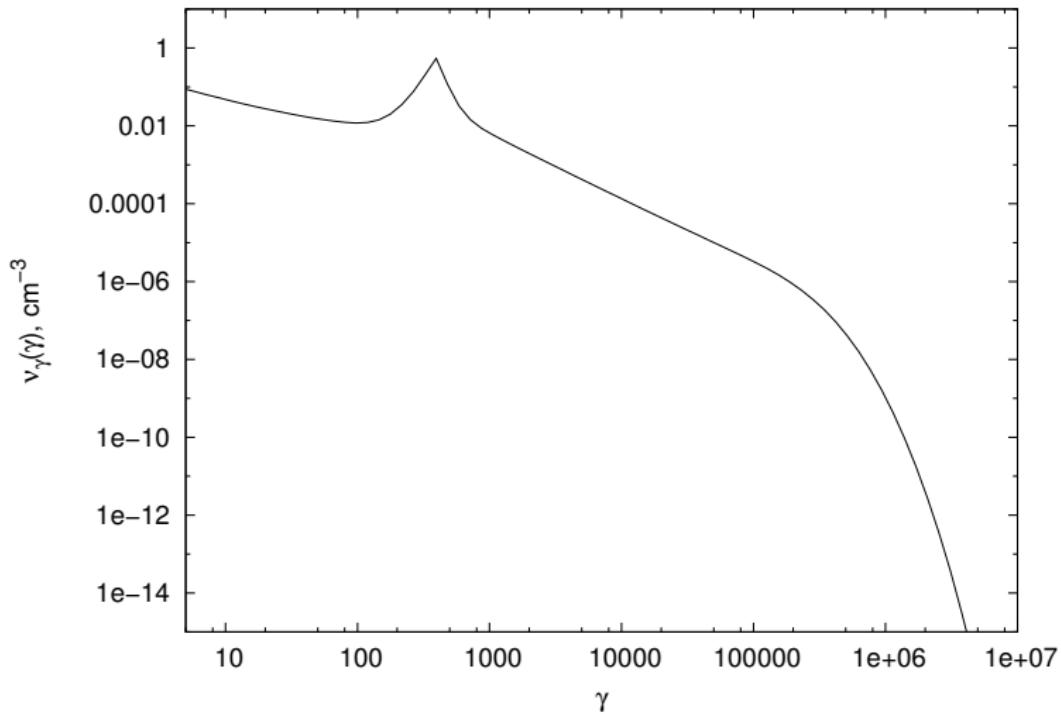
synchrotron self absorption by a powerlaw distribution

equivalence of brightness and kinetic temperature leads to a flux

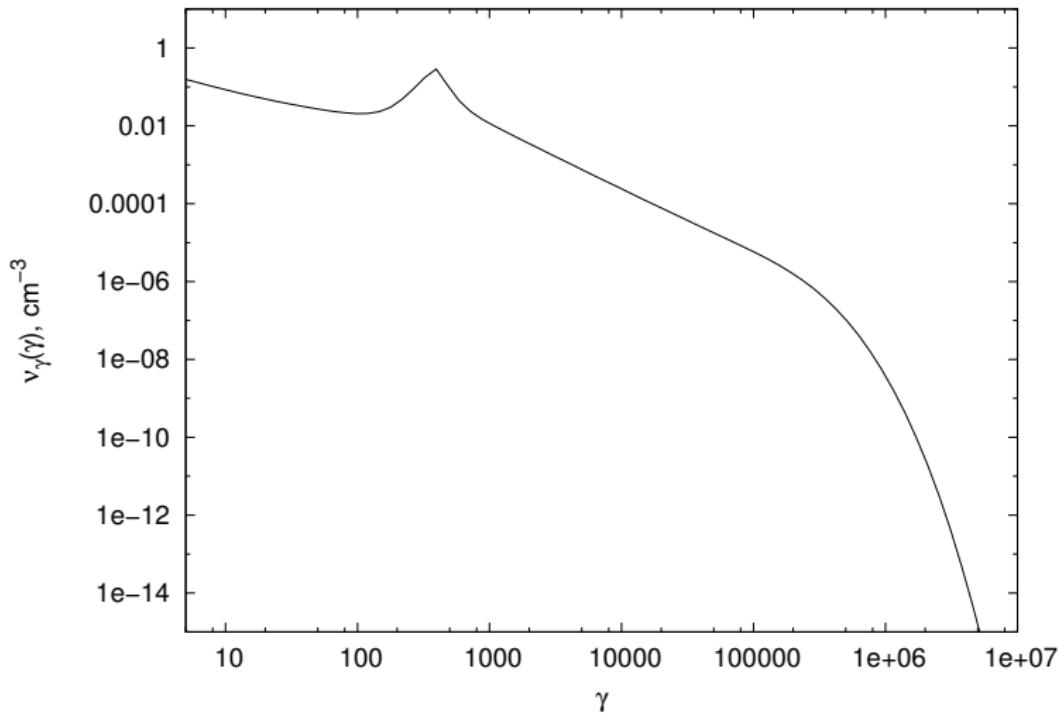
$$F_\nu \propto \nu^{\frac{5}{2}}$$



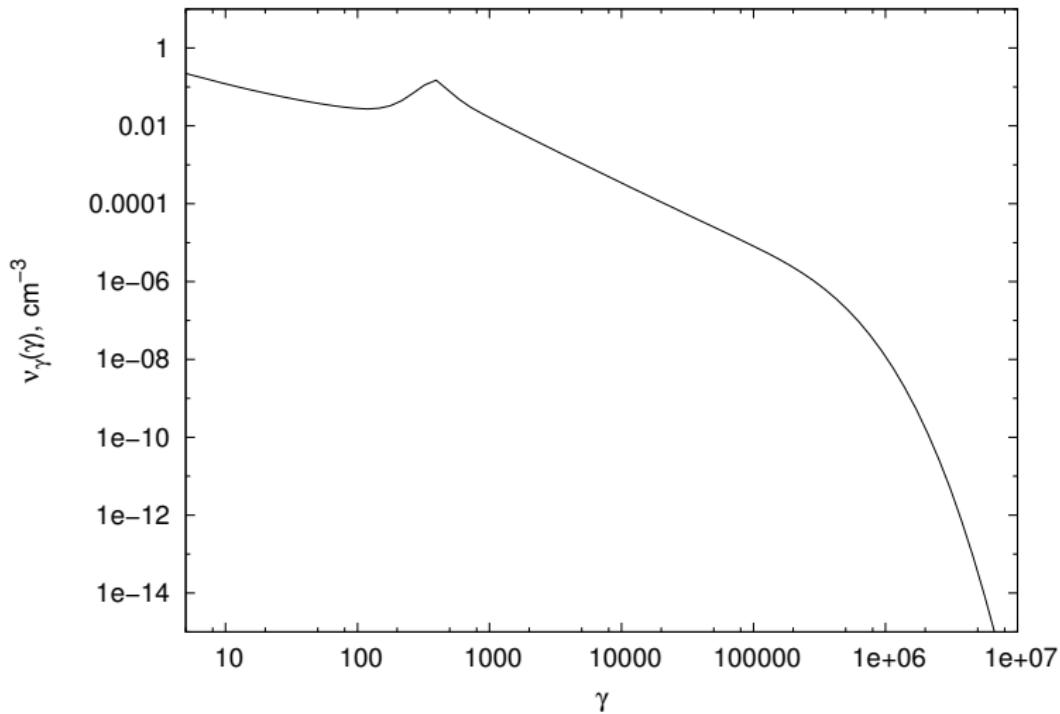
Electron distribution at different distances to the shock.



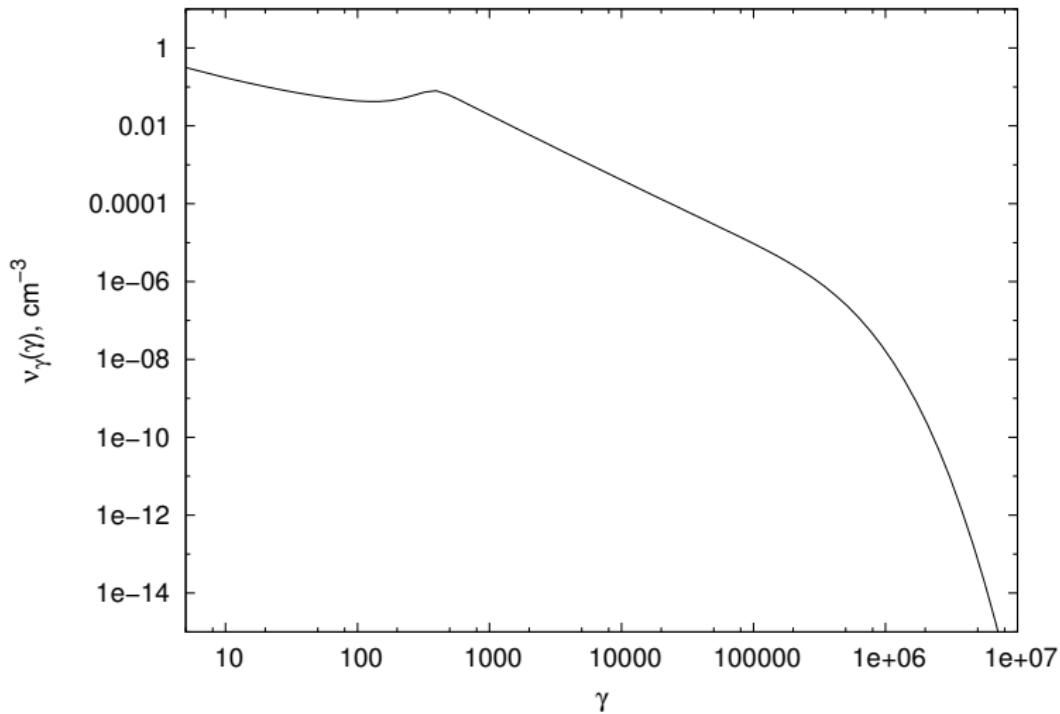
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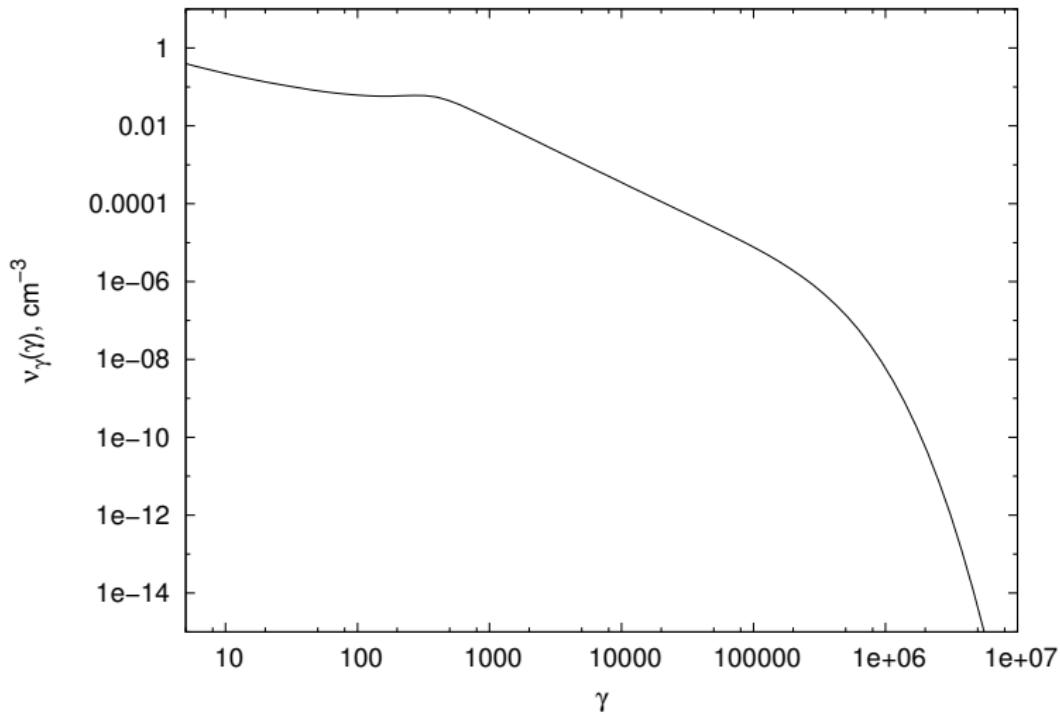
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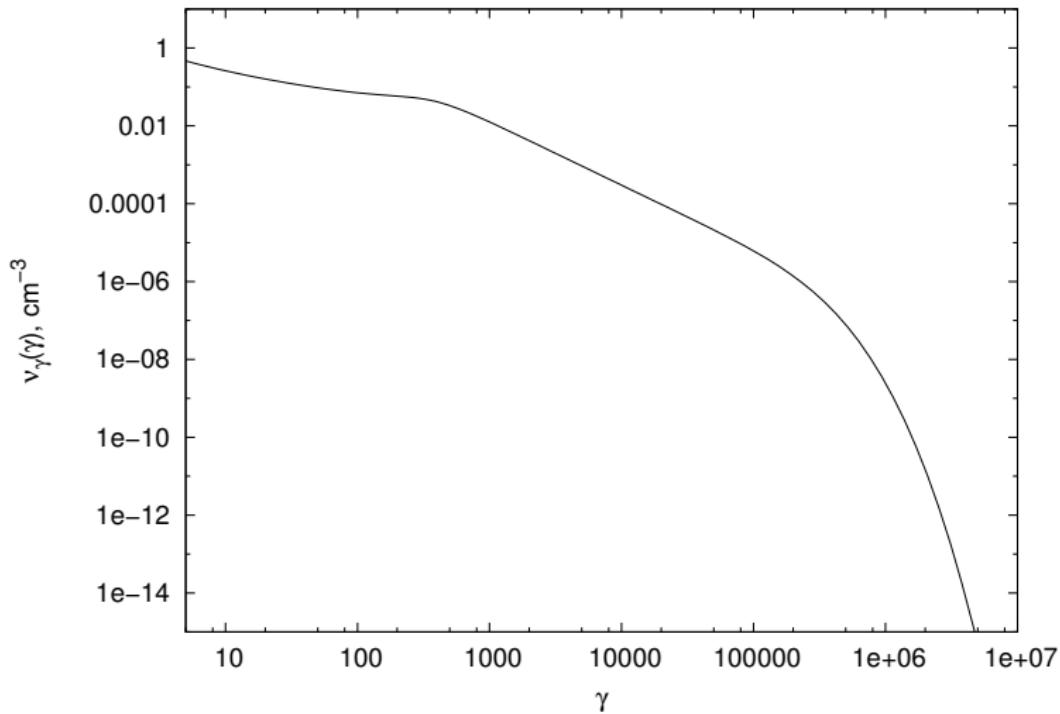
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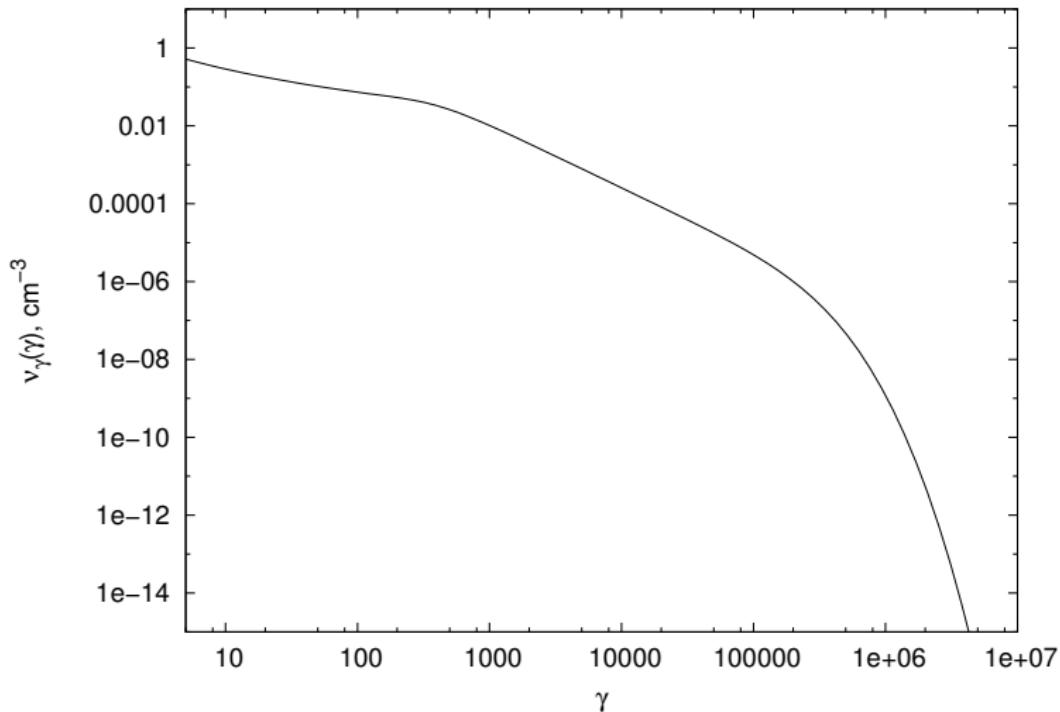
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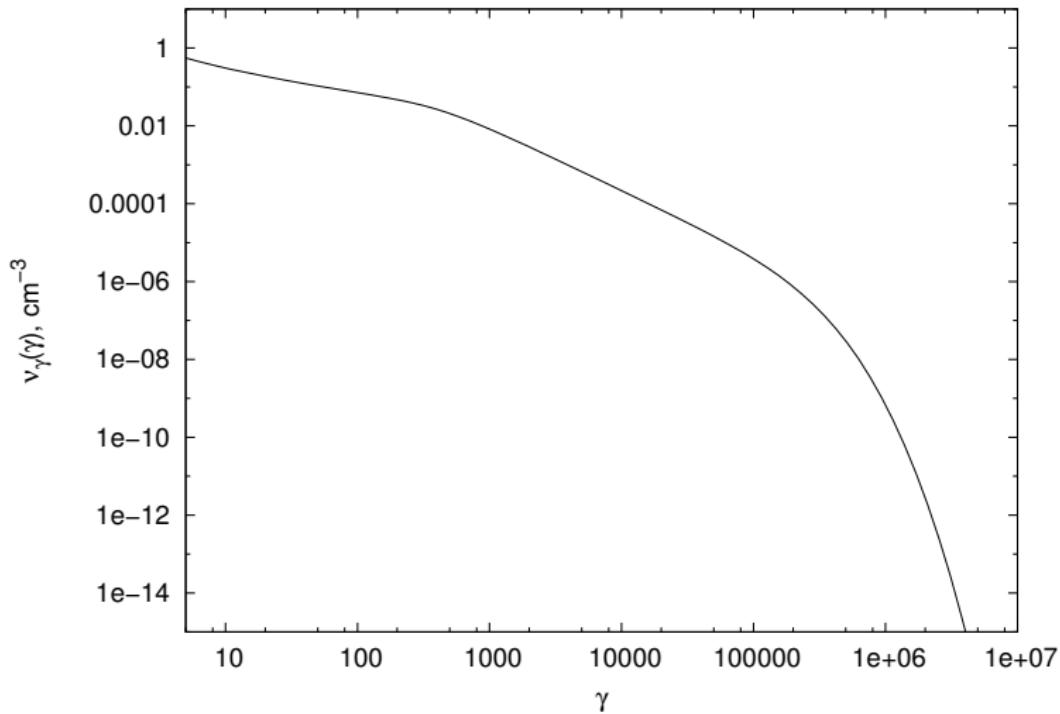
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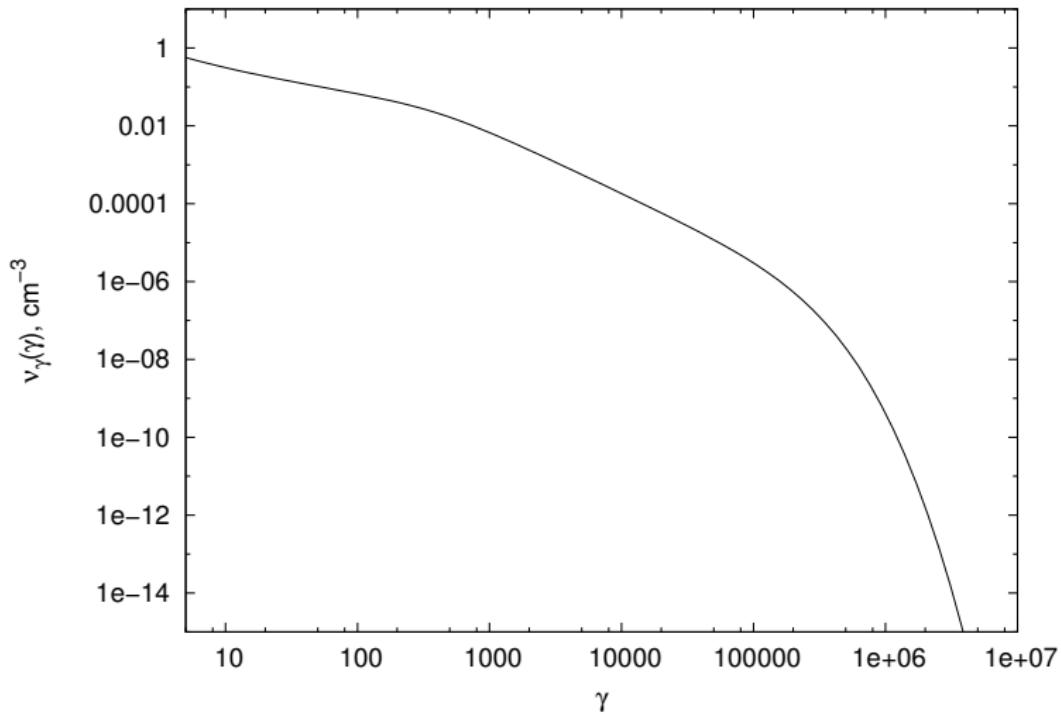
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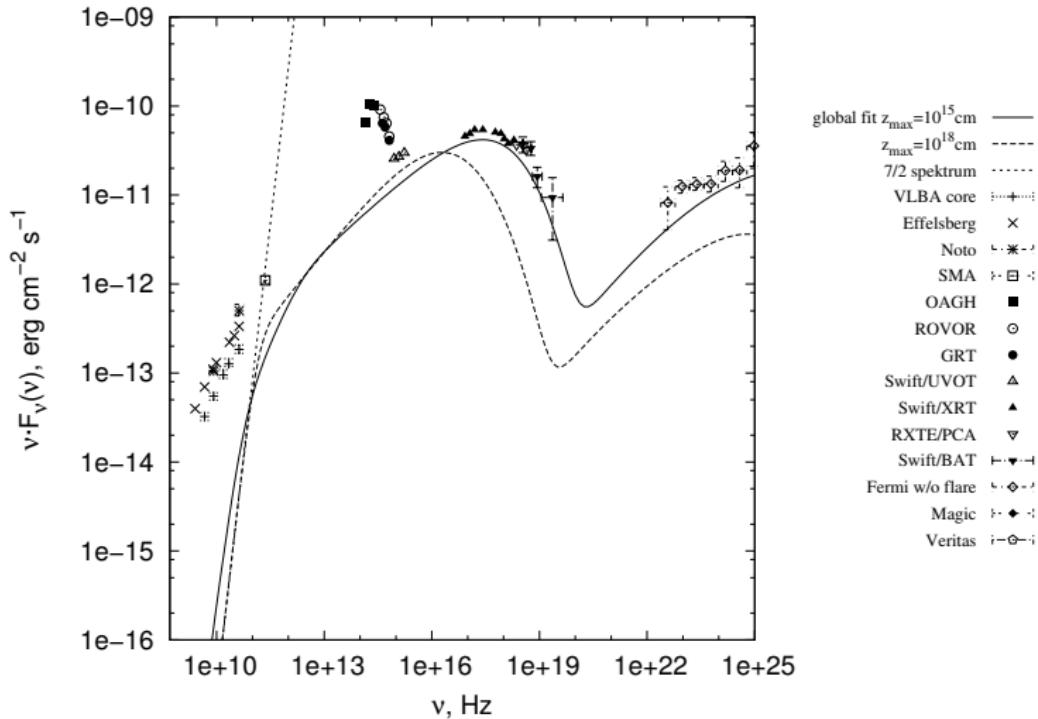
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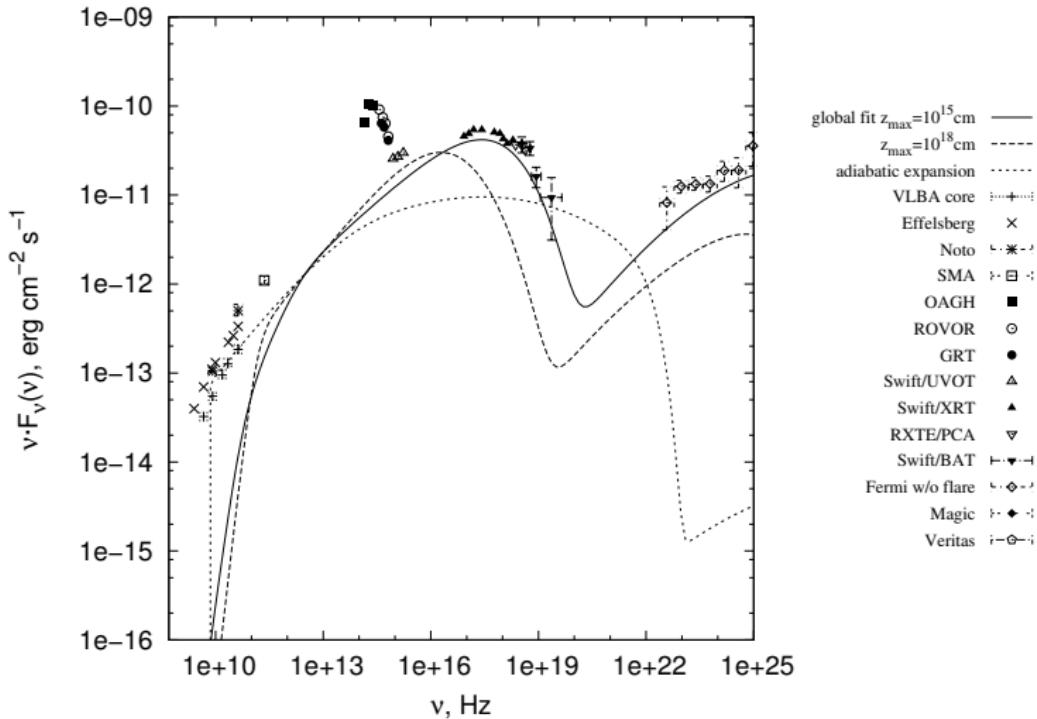


Electron distribution at different distances to the shock.



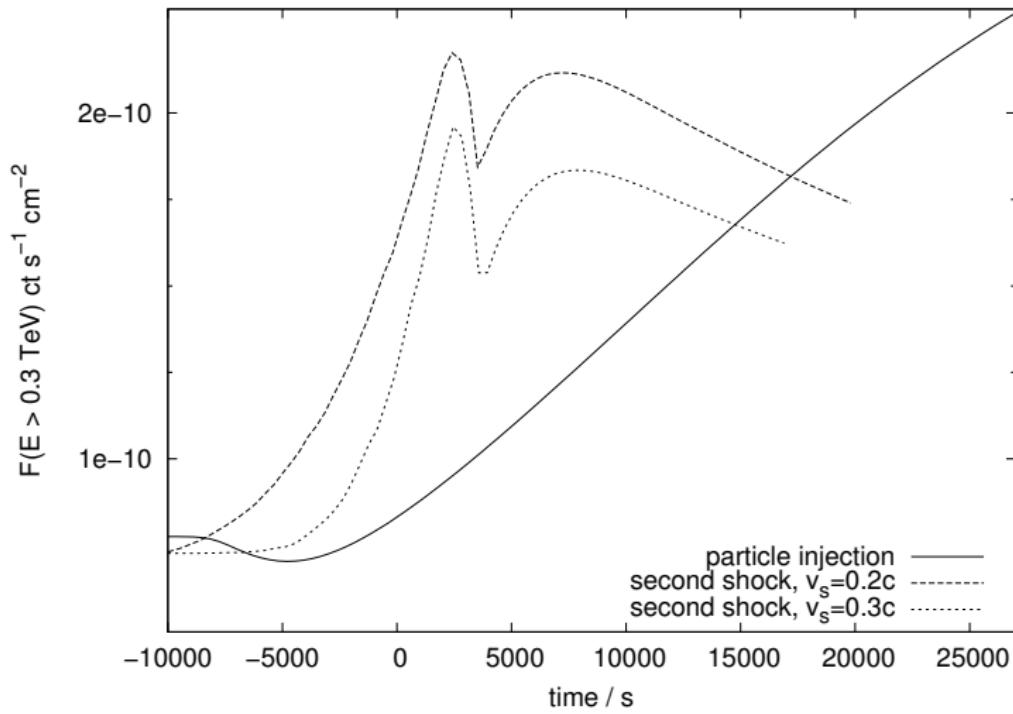
Effect of significant larger simulation region.

adiabatic expansion

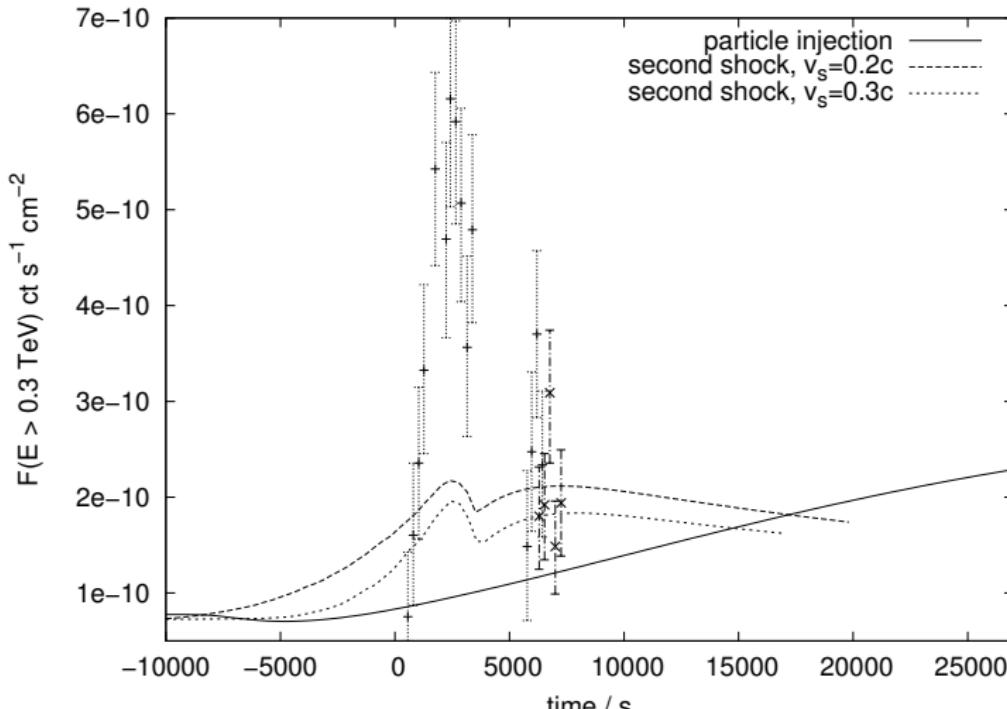


Effect of additional adiabatic expansion.

short time variability



shock vs. particle injection



model vs. data



talked about:

- self consistent spatially resolved SSC modell
- access to radio information via adiabatic expansion
- modelling of time variability with different approaches treating light travel times correctly

not talked about:

- implementation of shock acceleration
- possibility of including realistic scattering parameters obtained from PIC simulations
- compare predicted morphology to VLBI observations

spatial resolution brings new opportunities, but new problems, too



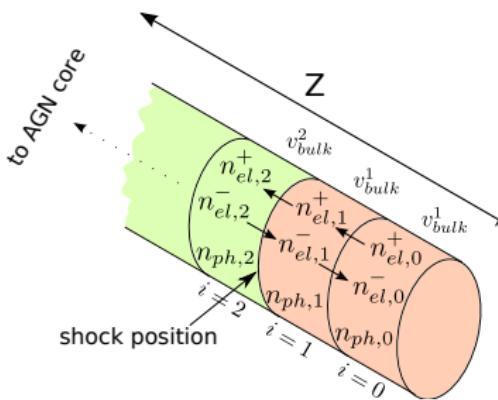
Thank you



- A. A. Abdo, M. Ackermann, M. Ajello, A. Allafort, L. Baldini, J. Ballet,
G. Barbiellini, M. G. Baring, D. Bastieri, K. Bechtol, and et al. et al.
Insights into the High-energy γ -ray Emission of Markarian 501 from
Extensive Multifrequency Observations in the Fermi Era. *Astrophys. J.*, 727:
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- M. Weidinger, M. Rüger, and F. Spanier. Modelling the steady state spectral
energy distribution of the BL-Lac Object PKS 2155-30.4 using a
selfconsistent SSC model. *Astrophysics and Space Sciences Transactions*, 6:
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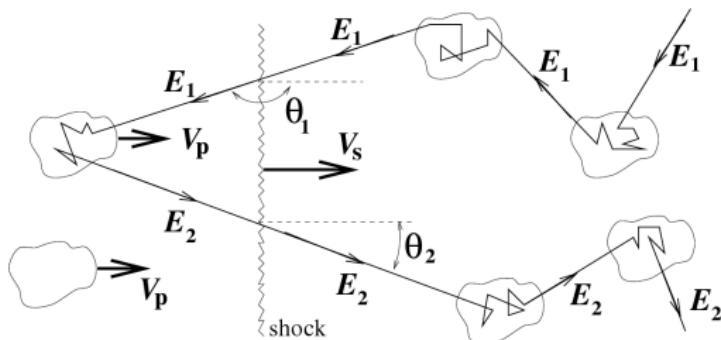


- expanding the two zone to a N-zone model
- modelling the jet propagating through the zones
- describing acceleration via scattering around the shock (Fermi I process)
- calculating the SEDs in each zone and sum up taking into account light travel times





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
 - advection through the zones
 - potentially change of direction due to scattering
- } mimics Fermi I



- electron distribution

- advection through the zones
 - potentially change of direction due to scattering
 - additional acceleration by Fermi II process
 - losses due to synchrotron radiation and invers compton scatering
- } mimics Fermi I
- } solving the Vlasov equation



- electron distribution
 - advection through the zones
 - potentially change of direction due to scattering
 - additional acceleration by Fermi II process
 - losses due to synchrotron radiation and invers compton scatering
 - photon distribution
 - production of photons via synchrotron radiation
 - energy gain via inverse Compton scattering
 - losses because of synchrotron self absorption
- } mimics Fermi I
- } solving the Vlasov equation