The Beaming of External Compton Emission

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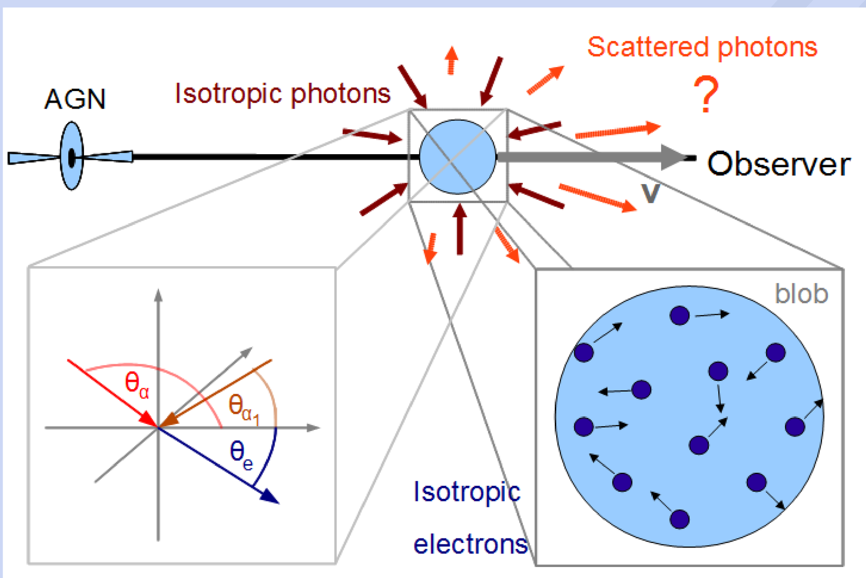
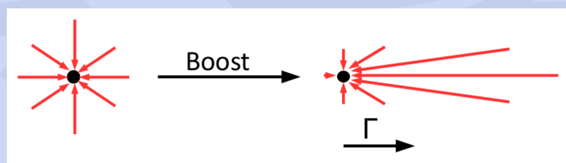
Blazars show very high energy emissions, in particular a double bump structure is found in the spectra. The lower energy bump is due to Synchrotron emission, while the bump at higher energies is caused by inverse Compton-scattering. Synchrotron Self Compton models (SSC) are used to explain those features. The Synchrotron photons are produced by the accelerated particles in the jet while photons in the higher energy regime arise from the Inverse Compton-scattered Synchrotron photons. However so called external photons - not produced within the jet - can also be scattered by the Inverse Compton effect and contribute to the emissions. In External Compton models (EC) photons from the accretion disk or the cosmic microwave background are considered. As variability of the blazar emissions can not be sufficiently fitted by conventional SSC models that assume homogeneous emission within the blob, spatially resolved models will obey angular dependent properties of the jet like the direction of magnetic fields and and consider spatial variations of electron and photon densities inside the blob.
An attempt to build spatially resolved SSC models with an EC component it is of particular interest to ascertain the angular radiation characteristics of the EC component. The resulting beaming pattern produced by a relativistic moving blob consisting of isotropic distributed electrons that Thomson-scatter photons from an external isotropic radiation field has been predicted by Dermer (1995). According to Dermer these isotropic external photons are boosted more strongly than an isotropic photon distribution in a blob within the jet. His calculations assume ultrarelativistic electrons and scattering in the Thomson regime. Hence a full consideration of all possible electron energies and obeying the Thomson as well as the Klein Nishina regime is given. The resulting distribution of scattered photons is computed numerically, the dependencies of physical parameters examined and the resulting instensity determined for an electron distribution described by a power law.

The Problem

A relativistic blob consisting of an isotropic electron distribution is moving with a Lorentz factor of Γ towards the observer. The electrons move with a Lorentz factor of γ in the blob frame. In the blob frame the incident external photons possessing an energy of α_1 (α_1^* in the observer's frame) and arising from an solid angle Ω_{α_1} are Inverse Compton scattered. The scattered photons are emitted into Ω_α and possess an energy of α. Values in the observer's frame are indicated by a star.



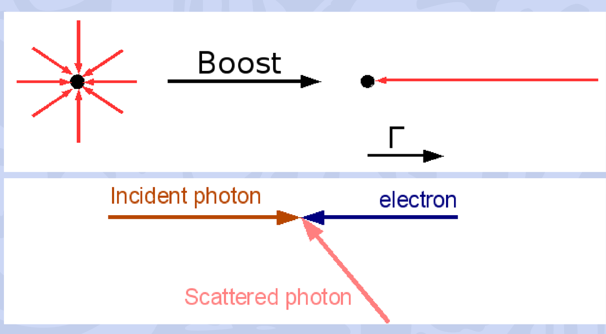


The incident external isotropic photon distribution in the oberver's frame n^*_{ph} is boosted into the blob frame, Compton-scatters with the istropic electron distribution in the blob frame n_e and is reboosted into the observer's frame.

Dermer's Results

Assumptions in the blob frame:

- Incident photons' direction is opposite to blob direction
- Head on Collisions



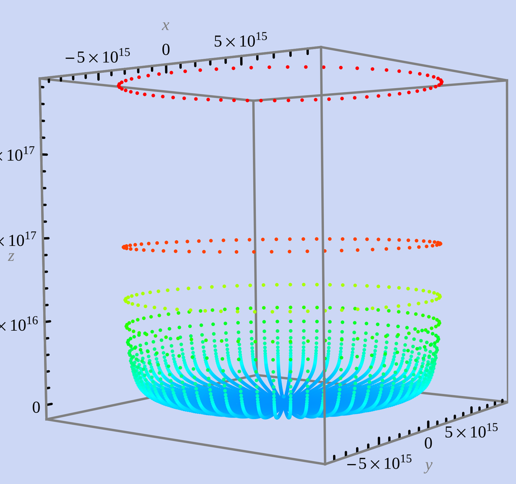
Assuming an electron distribution describing a power law $n_e(\gamma) = \gamma^{-p}$ and defining $a = (p-1)/2$, the resulting beaming pattern goes with the Doppler factor as D^{4+2a}. In comparison the beaming pattern of an isotropic radiation in the blob frame goes as D^{3+a}.

The Calculation

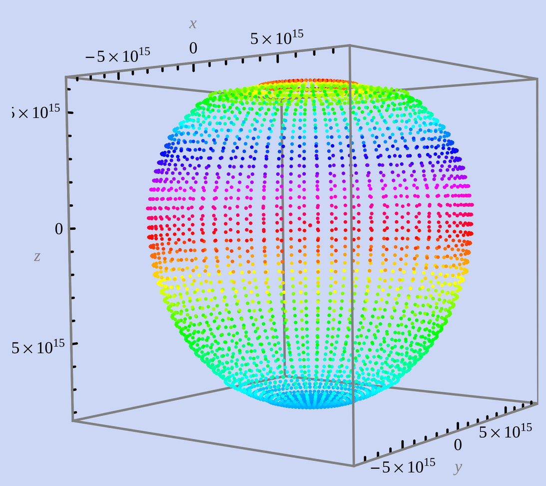
For the exact calculation of the Compton scattering of a peaked photon distribution in the blob frame (corresponds to an isotropic distribution in observer's frame) the full Compton cross section is used. The differential number of scattered photons in the blob frame is evaluated.

$$\frac{dn}{dt\,d\alpha\,d\Omega_\alpha} = \int d\gamma \int d\Omega_e \int d\alpha_1 \int d\Omega_{\alpha_1} n_{ph}(\alpha_1, \Omega_{\alpha_1}) n_e(\gamma)\, \sigma(\alpha_1, \Omega_{\alpha_1}, \gamma, \Omega_e; \alpha, \Omega_\alpha)$$

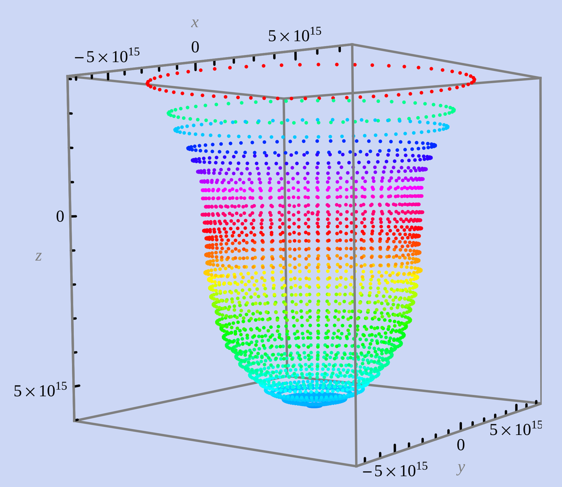
Step 1: The differential number of scattered photons in the blob frame for one incident photon direction on an isotropic homogeneous electron distribution is $\propto 1/(\alpha_1 \gamma^2)$



$\alpha_1 = 10^{-9}$
$\alpha = 10^{-9}$
$\gamma = 10$



$\alpha_1 = 10^{-9}$
$\alpha = 10^{-8}$
$\gamma = 10$



$\alpha_1 = 10^{-9}$
$\alpha = 10^{-7}$
$\gamma = 10$

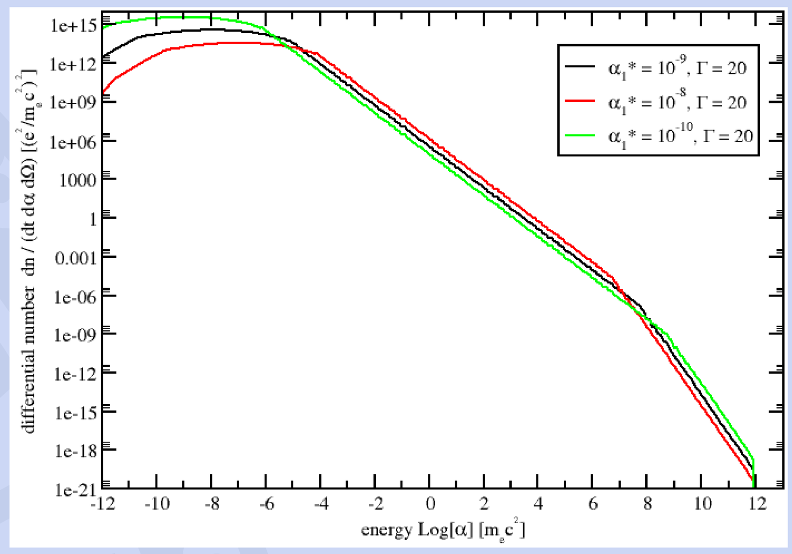
Step 2: Integration over all incident photon energies, directions and electron energies in the blob frame

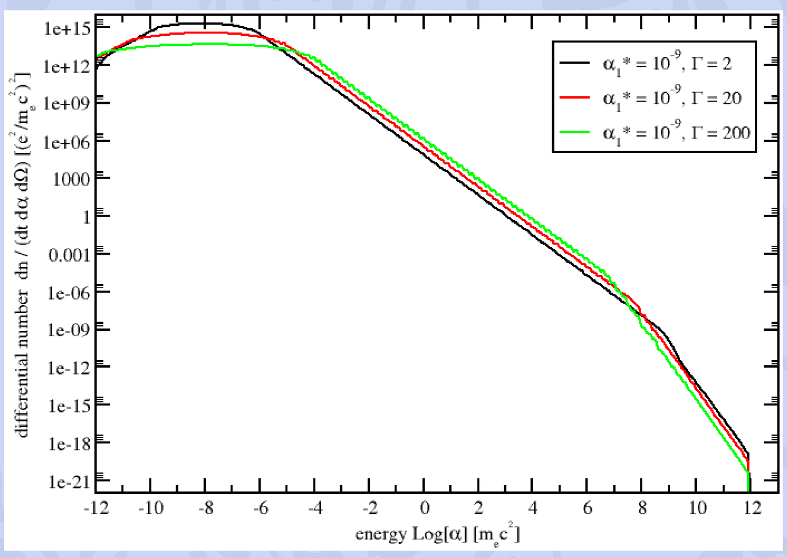
Step 3: Boost into observer's frame

Blob Frame: Results for $n_e(\gamma) = \gamma^{-2.2}$

The plot of the differential number of scattered photons displays the transition from the Thomson to the Klein Nishina regime which is the point of discontinuity. The energy-cutoff at $\alpha = 10^{12}$ is due to a chosen maximum value of $\gamma = 10^{12}$.

As the energy of the incident photons in the observer's frame is boosted to lower and higher energies in the blobframe, the limit of the Thomson regime is dependent on the initial energy in observer's frame, i.e. lower energies obeying $\alpha_{1,min}\gamma_{T,max} < 1$ Thomson-scatter with higher γ and the Thomson Limit is $\alpha_{T,max} \approx \alpha_{1,min}\gamma^2_{T,max}$



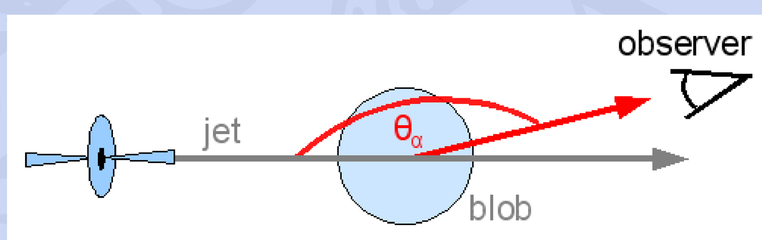


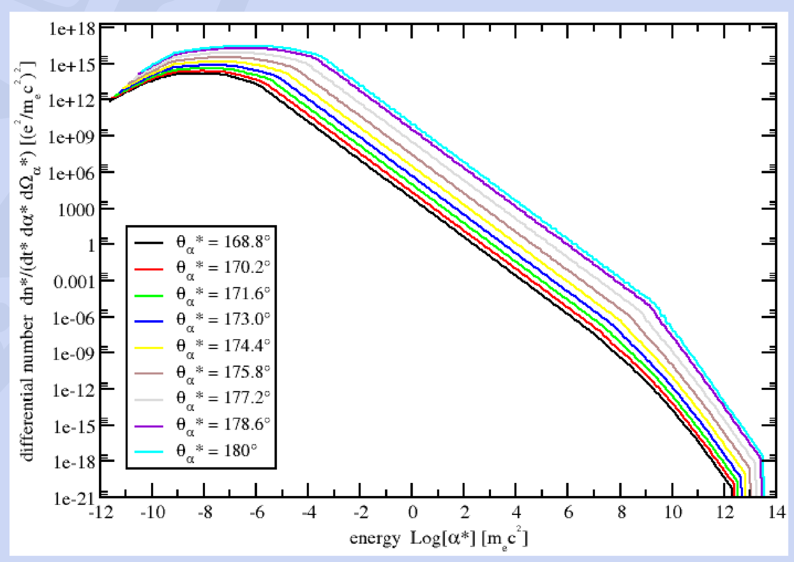
The higher Γ

- the more the incident photon distribution is peaked
- the higher is maximum energy $\alpha_{1,max} \approx \Gamma\alpha_1^*$
- the lower is $\gamma_{T,max}$
- the lower the Thomson limit (s.a.)

Observer's Frame: Results for $n_e(\gamma) = \gamma^{-2.2}$

Amplified by the boosting the differential number of scattered photons decreases with larger inclination between the blob's moving direction and the observer's line of sight.





Comparing the exact calculation with Dermer's results displays conformance of the physical behaviour in the Thomson regime, $a = 0.6$.
The calculated intensity is lower than in Dermer's computation which is due to the exact angular dependent incident photon distribution; the number of photons boosted to higher energies is higher in Dermer's computation.
Dermer's approximated result seems to be valid in the interval $[\alpha_{1,max}\gamma_{min}, \alpha_{1,max}\gamma_{T,max}]$