Inverse Compton Scattering of Cosmic Microwave Background Photons in Blazars

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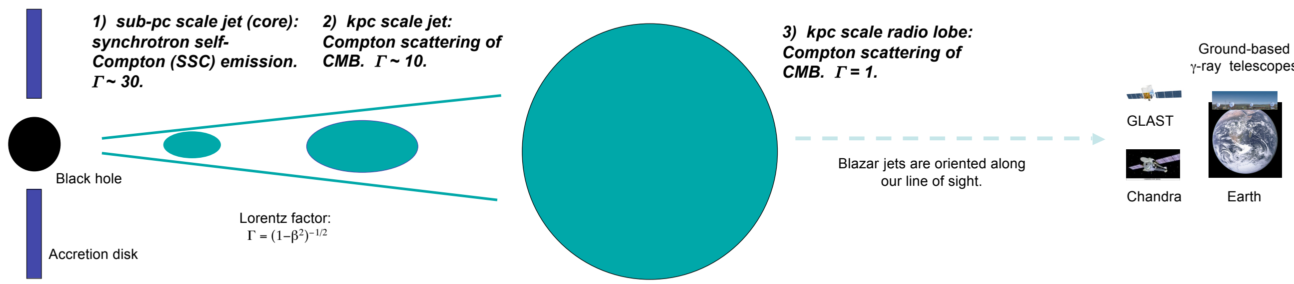
Abstract: Blazars are thought to be Fanaroff-Riley galaxies viewed along their jets. Recent observations of very high energy (VHE) gamma-rays from blazars (e.g., 1ES 1101-232 or 1ES 0229+200), when corrected for absorption by the extragalactic background light (EBL) are quite hard ($\Gamma < 2$) and difficult to explain with the conventional synchrotron self-Compton model. We explore the possibility instead that the hard VHE γ-ray spectra are produced by Compton scattering of cosmic microwave background (CMB) photons by shock-accelerated electrons in a relativistically moving extended jet. Furthermore, Compton scattering of CMB photons in (non-relativistically moving) radio lobes in blazars may be a source of GeV photons that could be detectable with the Gamma-ray Large Area Space Telescope (GLAST). *Detection of these photons can help put constraints on the magnetic field in radio lobes.*

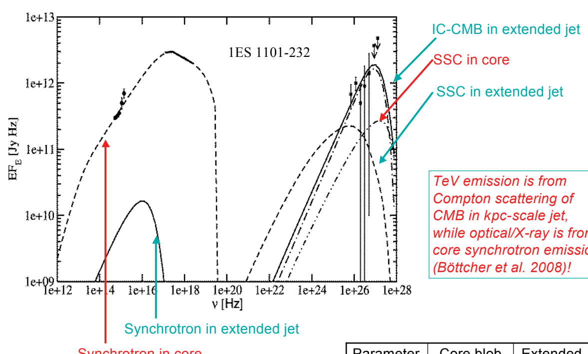
Three possible γ-ray emission regions in blazars:



BL Lacs with hard VHE γ-ray spectra: Comptonization of CMB in an extended jet?

Some BL Lacs such as 1ES 1101-232 or 1ES 0229+200 have been observed with very hard TeV spectra consistent with no variability on timescales of months (contrasting with rapidly varying BL Lacs such as PKS 2155-304 or Mrk 501). This implies either a lower extragalactic background light (EBL) energy density than previously thought, or very hard intrinsic spectra ($\Gamma < 1.5$) than previously thought possible with the SSC model (see however, Stecker et al 2007).

Or a new alternative . . .



TeV emission is from Compton scattering of CMB in kpc-scale jet, while optical/X-ray is from core synchrotron emission (Böttcher et al. 2008)!

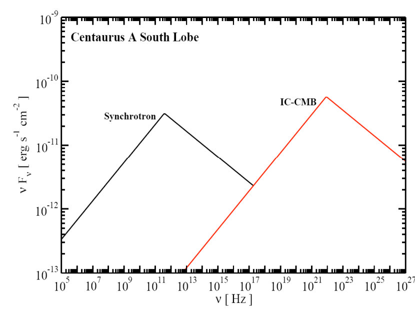
Parameter	Core blob	Extended jet blob
B' [G]	0.05	1 x 10^{-5}
Γ	25	15
δ_D	25	15
L_{jet} [erg s^{-1}]	1.5 x 10^{40}	1.5 x 10^{41}
q	2.5	1.5
γ_1'	1.8 x 10^5	100
γ_2'	1.5 x 10^6	6 x 10^6

Above data from 1ES 1101-232 are from HESS, RXTE and the ROTSE 3c telescope, an optical telescope at the HESS site (Aharonian et al 2007). HESS data was de-absorbed with baseline Stecker et al. (2006) EBL model (Aharonian et al. 2007).

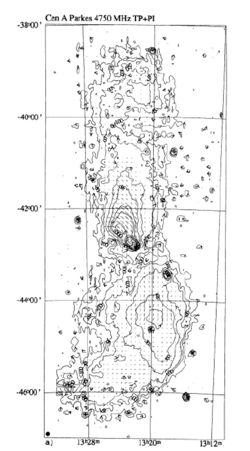
- Power injected into jet must be greater than observed power in the radio lobe. For 1ES 1101-232, P(1.5 GHz) = 3.8 x 10^{40} erg s^{-1} (Laurent-Muehleisen et al. 1993).
- Cooling timescales are on the order of 10^3 years for the extended jet. Thus, if significant variability is detected, it would rule out this model.
- *GLAST* will give further information on the γ-ray spectrum and variability, which could rule out or provide further evidence for this model!

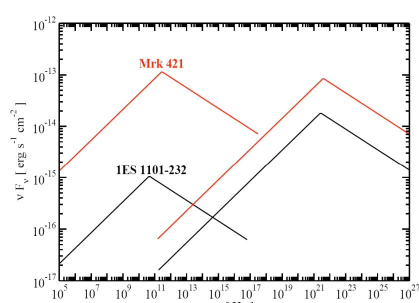
GeV γ-rays from radio lobes

Inverse Compton scattering of CMB photons by radio lobes of FR galaxies (e.g., Centaurus A) will create γ-ray photons in *GLAST*'s energy range. *GLAST* should observe Cen A at 5σ in an exposure of about a day (Cheung 2007). Could *GLAST* detect radio lobes of blazars in γ-rays?



Left: The SED of a Cen A radio lobe assuming a lobe age of 10^7 years. *Below*: Radio lobes of Cen A (Junkes et al. 1993).





GLAST should take tens of years to see IC-CMB from radio lobes in blazars such as Mrk 421 and 1ES 1101-232. Even worse, it won't be able to resolve them from the core for E < 20 GeV.

Parameter	Cen A	Mrk 421	1ES 1101-232
z	d=3.5 Mpc	0.03	0.186
R_{lobe} [kpc]	60	60	260
B_{eq} [μG]	2.4	3.9	1.1
α_1 [$F_\nu \propto \nu^{-\alpha}$]	-0.7	-0.7	-0.7
P(1.5 GHz) [erg s^{-1}]	8.9 x 10^{39}	4.9 x 10^{40}	3.7 x 10^{40}

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