Jets, Blazars and the EBL in the GLAST-*EXIST* Era

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06

Motivation

- GLAST key science of Blazars and GRBs: both incorporate time-variable studies of jets
- Common physics of relativistic shocks and lepton jets and synchrotron-IC emission
- *Both require broad-band X-ray and γ-ray spectra, high time resolution & positions for source identification and understanding emission model*

A wide-field all-sky hard X-ray imager needs to *EXIST*
(or at least overlap) in the GLAST time-frame …

Background for *EXIST*

(Energetic X-ray Imaging Survey Telescope)

- Deep all-sky (every orbit) hard X-ray (3-600 keV) survey mission to study/survey black holes on all scales
- Proposed in 1994 and recommended in 2000 Decadal Survey (like GLAST and Con-X)
- Well-studied candidate for *Black Hole Finder Probe* mission in Beyond Einstein program
- Now competing with two other *Einstein Probe* missions (JDEM and CMBPol) and LISA & Con-X for first-mission (2009 start) in Beyond Einstein Program in NRC-BEPAC review (decision by Sept. 2007)
- Very similar (but independently derived) mission profile (continuous-scanning very wide field imaging) to GLAST

Mission Overview of *EXIST* (on a single slide, ***next***…)

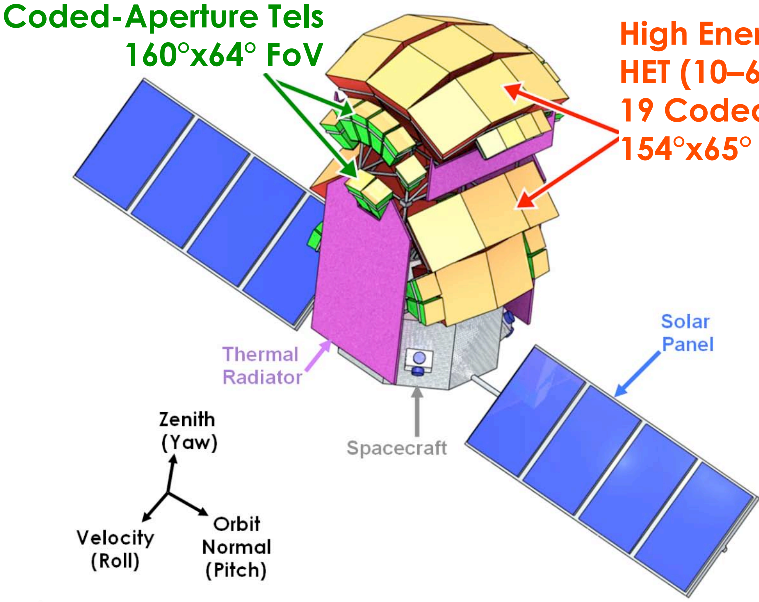
Energetic X-ray Imaging Survey Telescope (*EXIST*)

(as the *Black Hole Finder Probe* for the Beyond Einstein Program)

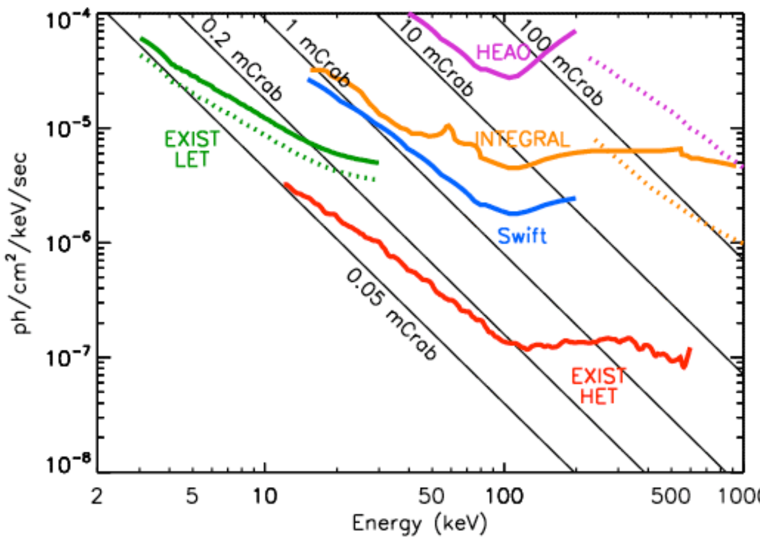
Hard X-ray (~3–600keV) all-sky imaging survey each 95 min orbit **to measure, as *Primary Objectives*:**

- **Obscured or dormant SMBHs** to probe SMBH properties & evolution, CXB origin & accretion luminosity of the universe
- **The birth of stellar BHs from cosmic GRBs** to probe GRB origins, derive photo-z's & cosmic structure/evol. out to z >6-10
- **Non-thermal jets from BHs** to constrain BH-jet physics, cosmic IR background & nuclear luminosity of the universe
- **Stellar and IMBHs in the Galaxy & Local Group** to constrain BH numbers, properties, formation & evolution

***Plus Secondary Objectives*: 511keV from BHs & novae; SGRs/magnetars out to 150Mpc; ^{44}Ti survey & SN rate in Galaxy**



Survey	No. Obj.
AGN	>3. E4
GRBs	700/y
Flux lim dE=E/2 in:	**Full sky 1y (cgs)**
3-100 keV	5 E-13
≤600 keV	5 E-12
Time Res.	**Units**
ea. Photon	0.1msec
GRB pos.	10sec
Mission dur	5y
En. Resol.	**dE/E (%)**
3-600 keV	2 – 6%



EXIST **1yr survey continuum sensitivity (5σ source, dE/E=1)**

- **All-sky image ea. orbit with 1.2' (3-30keV) & 6.8' (10-600keV) resol. & ≤11" positions,10μsec timing, ~20% duty cycle**
- **Two wide-field scanning coded aperture telescopes: HET:10–600 keV ($6m^2$ CZT) & LET: 3– 30 keV ($1.3m^2$ Si); 5Mbs cont**
- **Recommended by 2000 Decadal Survey; strong synergy with GLAST, JWST, LSST, Con-X & LISA if launched in 2015**

http://EXIST.gsfc.nasa.gov

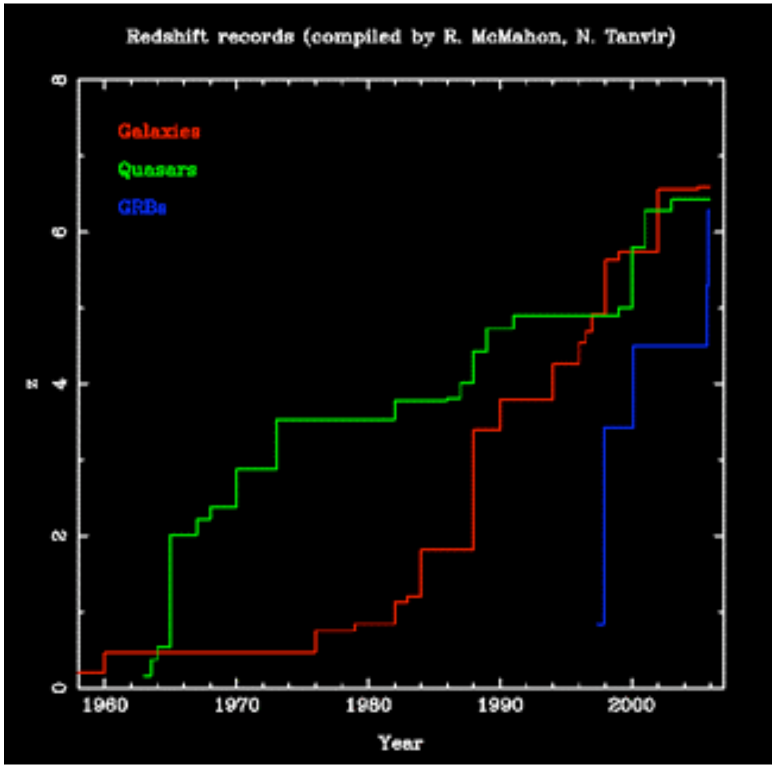
Unravelling GRBs and high-Γ jets

- *EXIST* imaging (HET & LET telescopes + active shield
s) measure GRB spectrum at highest time resolution
(10μs) for jet microphysics and “photo–z” redshift fro
m *Firmani relation* (correlation of GRB lum. with E_{pe}
$_{ak}$ and $T_{45,}$, both measured by GRB *prompt emission* f
rom broad–band, high–statistics GRB spectrum m
easured by *EXIST*)

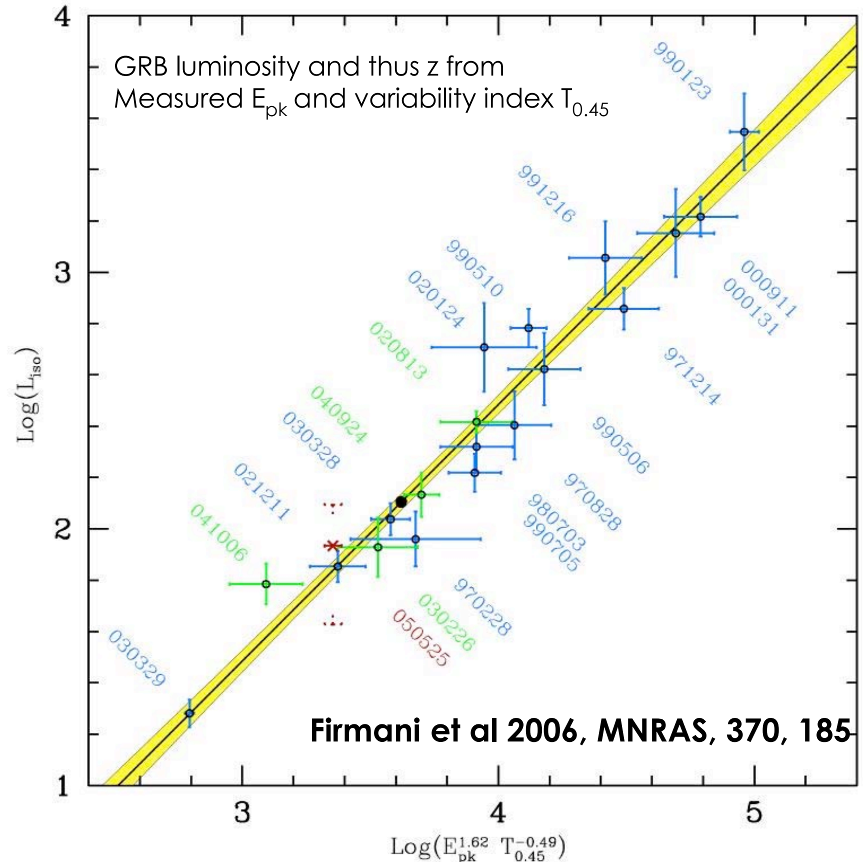
- GLAST (GBM + LAT) measures broad–band spectrum
and max. internal γ in jet for total particle energy of je
t

- *EXIST* measures *polarization* of GRB spectrum vs. tim
e by azimuthal distribution of Compton scattering int
o neighboring pixels in imaging detector: constr

Most distant stars & galaxies probed by GRBs



Record redshift vs. time: GRBs nearly max!

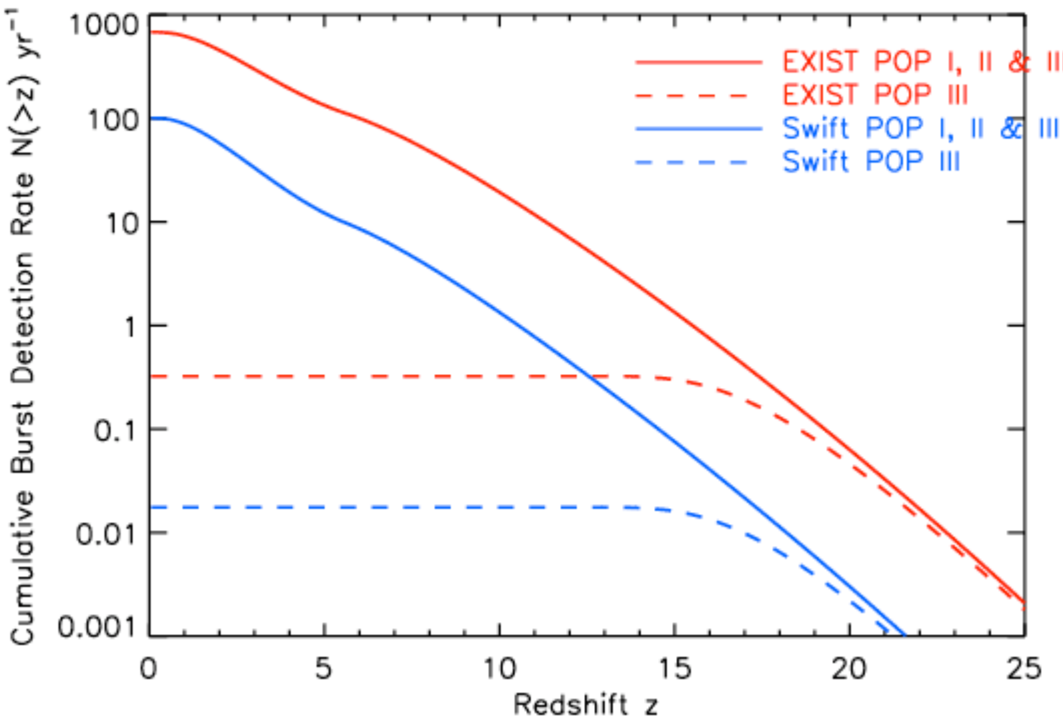


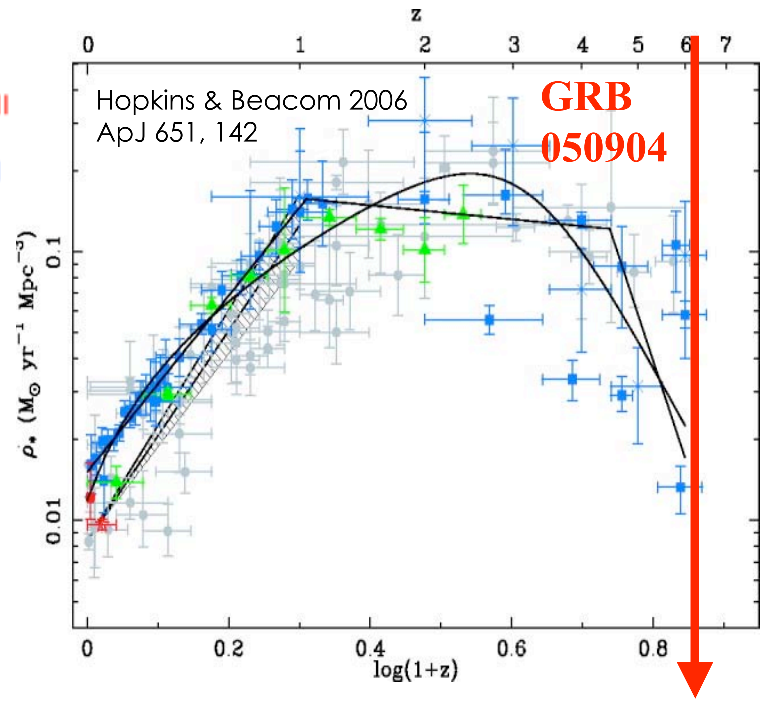
GRB Luminosity correlates with spectrum: gives z !

- *Swift* GRB at z = 6.3 & Spitzer galaxies at z ~8 show *GRBs must be detectable out to at least z ~8–10*
- Broader energy band, higher sensitivity & FoV needed for large sample at z ≥ 8–10
- IR from space (*JWST*) needed for z ≥10!

- *EXIST* measures E_{pk} and $T_{0.45}$ and Firmani reln. gives "photo-z" with uncertainties typically $\Delta(\log(1+z))$ ~0.1.
- *EXIST* measures E_{pk} up to 3 MeV using active shields
- GRBs provide "back-light" for IR spectroscopy of IGM, gas, & galactic structure back to re-ionization

Predicted *EXIST* GRB rate opens universe to z ≥ 10





EXIST GRBs vs. z will probe the star formation rate (SFR) vs. z at highest redshifts, and constrain/measure Pop III.

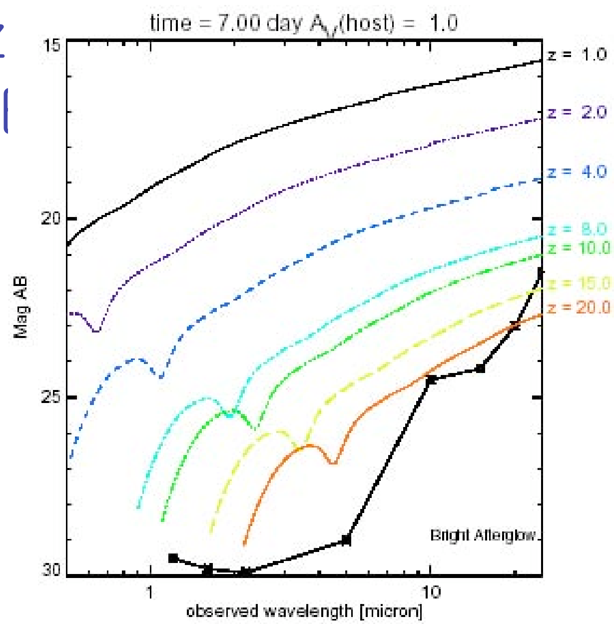
Predicted GRB rates vs. z based on Bromm and Loeb (2005). *EXIST* will detect many GRBs at z >7 and may detect Pop III GRBs for which models are uncertain.

GRBs allow cosmology at highest redshifts (non-CMB), and *EXIST* will open this window.

***EXIST will* probe:**

GLAST + *EXIST*: Using GRBs as cosmic probes

- Photo-z's from *EXIST* (Δz ~0.1 – 0.2) and high energy spectral breaks observed by GLAST-LAT: constrain EBL
- Followup afterglow high-resolution ground-based spectra (V,R,I,J,H,K bands) and *JWST mid-IR spectra* for GRBs with photo-z's >6 use "back-light" of GRB afterglows to measure cosmic structure and metallicity vs. z universe (z ~15–20 & PopIII GRI



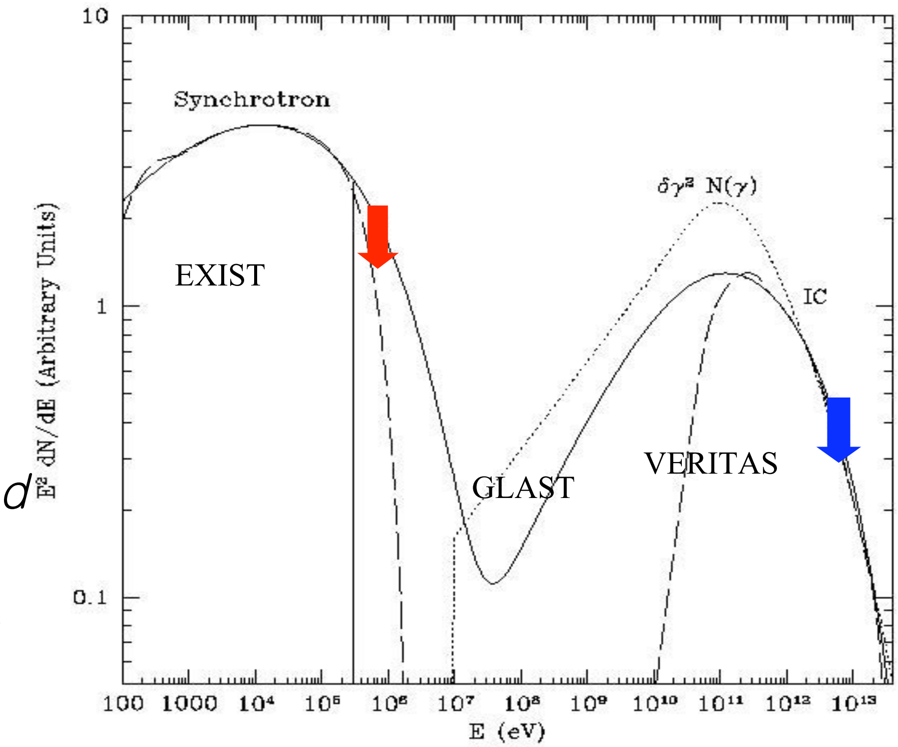
JWST detectability of spectrum of afterglow of GRB060206 scaled to z values shown at 7d after GRB and with foreground Av=1 (Bloom et al 2007, in prep.)

EXIST/GLAST Blazar Spectral variability: **Jets to EBL**

Extragalactic Background Light (EBL): Stellar vs. Accretion Luminosity of Universe

EBL: Hard x-ray (synchrotron) spectral breaks (~5-200keV) for *Blazars* at known redshift allow SSC gamma-ray (~10 GeV - 10 TeV) spectral breaks measured by *GLAST & HESS/VERITAS* to constrain poorly known diffuse IR background from total stellar light of universe *absorbing gammas to* e^+-e^-

Time-variability: spectral breaks *required* from *simultaneous* HX + γ measurements. Wide-field HX imaging needed for simultaneous X,Gamma-ray observations of Blazars to monitor and *measure large samples to overcome cosmic variance*



SSC model for Mkn 501 (Coppi & Aharonian 1999)

EXIST will provide the *continuous HX spectral-monitoring* to study Blazars and non-thermal AGN to constrain diffuse IR (~10-100μ) background from obscured AGN and thus ***nuclear vs. accretion luminosity of the universe***

Complements GRB science: star formation vs. redshift from L_{GRBs} ***vs. z***

EXIST measures Blazar flares vs. GeV–TeV

- Variability of Blazars must be accounted for in unfolding SSC model (synch HX vs. IC GeV–TeV) to derive intrinsic spectrum

- Simultaneous with GLAST allows unique unfolding of spectrum to derive intrinsic spectrum & thus measure EBL from observed cutoff

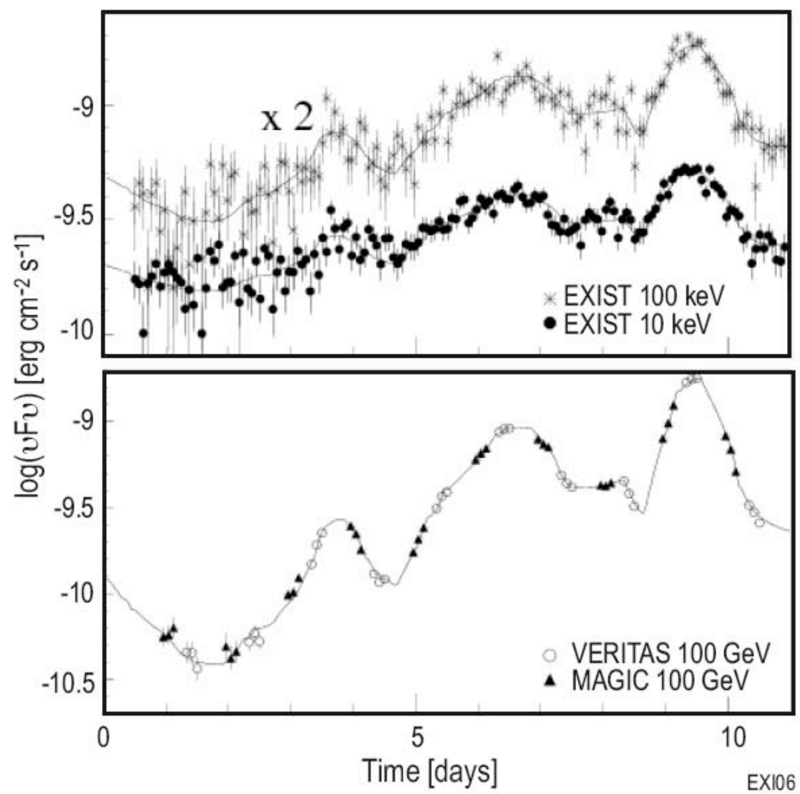


Figure 4: Simulated blazar light curve for the EXIST reference mission vs. TeV light curve as recorded by VERITAS.

Blazars contribute to CXB & CMB fluctuatio ns

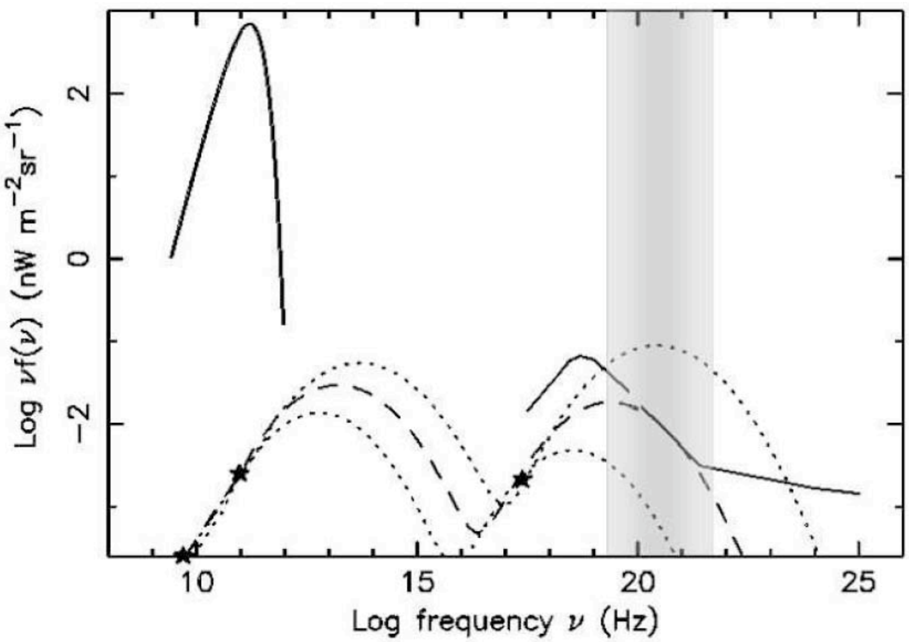


Fig. 10. The possible contribution of LBL Blazars to the Hard X-ray/soft γ-ray Background (shaded area). The three SSC curves corresponds to different ν_{peak} values ($\log\ \nu_{peak} = 12.8, 13.5 and 13.8$) and are constrained to go through the three star symbols representing 1) the total contribution of Blazars at 94 GHz (8×10^{-6} of the CMB intensity), 2) the average 5 GHz to 94 GHz slope ($\alpha_{5-94GHz} = 0.2$) and 3) the average spectral slope between 94 GHz and 1 keV ($\langle\ \alpha_{\mu x}\ \rangle = 1.07$).

Blazars contribute to CXB (increasingly Important above 100 keV) and CMB Fluctuations… (Giommi et al 2005)

Combination of EXIST + GLAST Needed…

Synergy of *EXIST* & GLAST: ≥2015 together?

(and now a paid political advertisement…)

- Incredible synergy and complementarity of GLAST and *EXIST*: both wide-field, full sky, broad energy/timing…
- GRBs and Blazars for relativistic jets as probes of high-z universe: enabled by *both* missions
- Time variability and broad-band spectra of AGN, pulsars, binaries and transients: need *both*
- *Support Black Hole Finder Probe (EXIST…) at upcoming BEPAC Town Mtgs.:*

  Cambridge (Feb. 12), Baltimore (Mar. 14), Chicago (Apr. 4)