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

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(and the EXIST Team)
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

Low Energy Telescope  
LET (3–30 keV)  
32 Coded-Aperture Tels  
160°x64° FoV

High Energy Telescope  
HET (10–600 keV)  
19 Coded-Aperture Tels  
154°x65° FoV

- All-sky image ea. orbit with 1.2' (3-30keV) & 6.8' (10-600keV) resol. & ≤11" positions, 10usec timing, ~20% duty cycle
- Two wide-field scanning coded aperture telescopes: HET:10–600 keV (6m² CZT) & LET: 3–30 keV (1.3m² 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-\(\Gamma\) jets

- \(EXIST\) imaging (HET & LET telescopes + active shield) measure GRB spectrum at highest time resolution (10\(\mu\)s) for jet microphysics and “photo–z” redshift from \textit{Firmani relation} (correlation of GRB lum. with \(E_{\text{pe}}\) and \(T_{45}\), both measured by GRB \textit{prompt emission} from broad–band, high–statistics GRB spectrum measured by \(EXIST\))

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

- \(EXIST\) measures \textit{polarization} of GRB spectrum vs. time by azimuthal distribution of Compton scattering into neighboring pixels in imaging detector: constr
Most distant stars & galaxies probed by GRBs

- *Swift* GRB at $z = 6.3$ & Spitzer galaxies at $z \sim 8$ show **GRBs must be detectable out to at least $z \sim 8-10$**

- Broader energy band, higher sensitivity & FoV needed for large sample at $z \geq 8-10$

- IR from space (**JWST**) needed for $z \geq 10$

**Record redshift vs. time:** GRBs nearly max!

**GRB Luminosity correlates with spectrum:** gives $z$!

- **EXIST** measures $E_{pk}$ and $T_{0.45}$ and Firmani reln. gives “photo-z” with uncertainties typically $\Delta(\log(1+z)) \sim 0.1$.

- **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 $z \geq 10$

**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.
GLAST + EXIST: Using GRBs as cosmic probes

- Photo-z’s from EXIST ($\Delta z \sim 0.1 - 0.2$) 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 ($z \sim 15-20$ & Pop III GRBs)

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 (~5–200 keV) 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

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

**Complements GRB science: star formation vs. redshift from** $L_{\text{GRBs}}$ 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 fluctuations

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 $\nu_{peak}$ 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 ($8 \times 10^{-6}$ 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 ($\langle \alpha_{μx} \rangle = 1.07$).
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)