

*Hard X-ray BH Surveys in Space & Time*  
*(going BATSS to DASCH to EXIST)*

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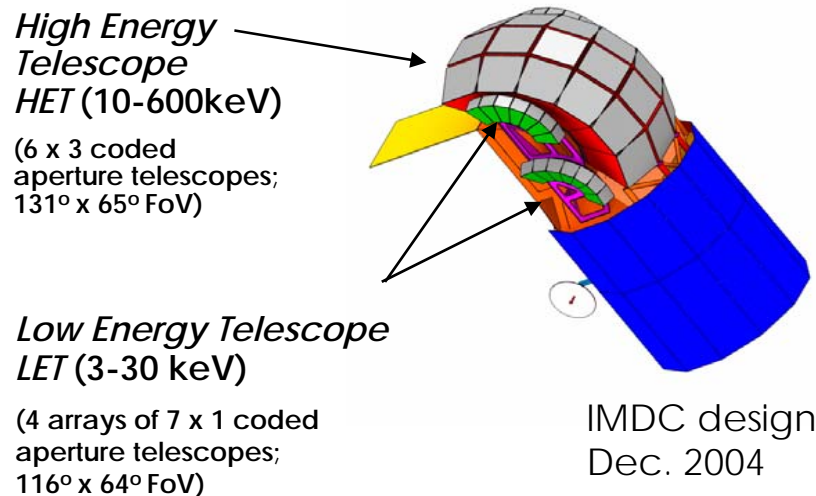
# Outline

- EXIST (Energetic X-ray Imaging Survey Telescope): Science Goals & Overview
  - HX survey of obscured AGN: Accr. Lum. of Universe
  - Tidal disruption of ms stars on dormant AGN
  - Blazars and EBL: Nucl. Lum. of Universe
  - Mission design
- BATSS: a (New!) slew survey for *Swift/BAT*
  - AGN flares
  - Long GRBs
- DASCH: AGN optical variability back in time

# Overview of *EXIST* Science and Design

**Hard X-ray (~3-600 keV) all-sky imaging *each orbit* to measure:**

- Obscured AGN and accretion (BHs) vs. nuclear (stars) luminosity of universe
- GRBs out to  $z \sim 20$  and *first stellar Black Holes* ( ~5-20X *Swift* sensitivity)
- Stellar Black Holes in Galaxy & IMBHs in Local Group & BHs as probes



e.g., EXIST measures Cen-A every orbit:  
*characteristic time variability (QPOs)*  
*constrain BH mass and spin!*

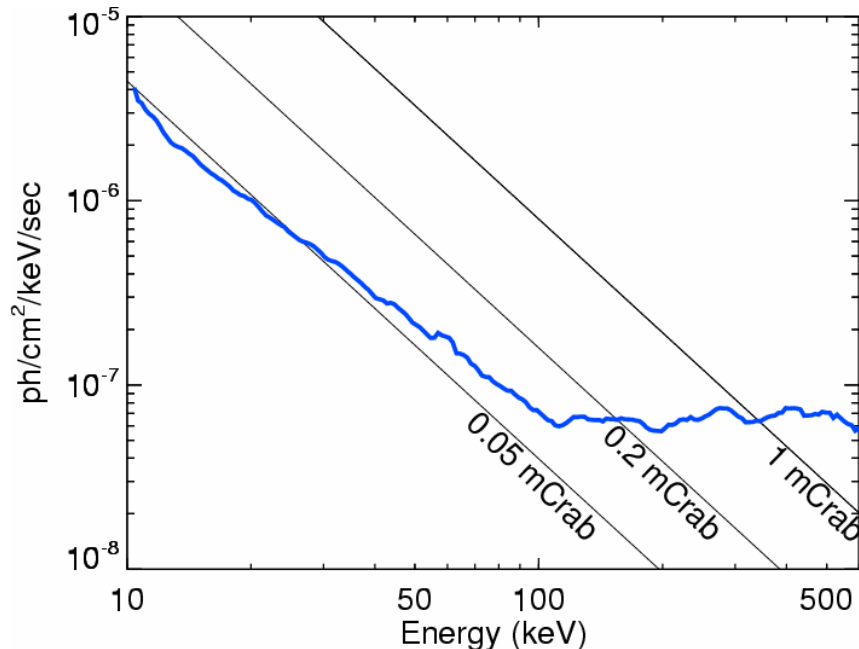
## **Mission Design parameters:**

- Extend ROSAT sens. ( $\sim 5 \times 10^{-13}$  cgs) to 3-150 keV with 0.9-5' resolution &  $\sim 10''$  positions
- Two wide-field coded aperture telescopes: 10-600 keV ( $6m^2$  CZT) & 3-30 keV ( $1.5m^2$  Si)

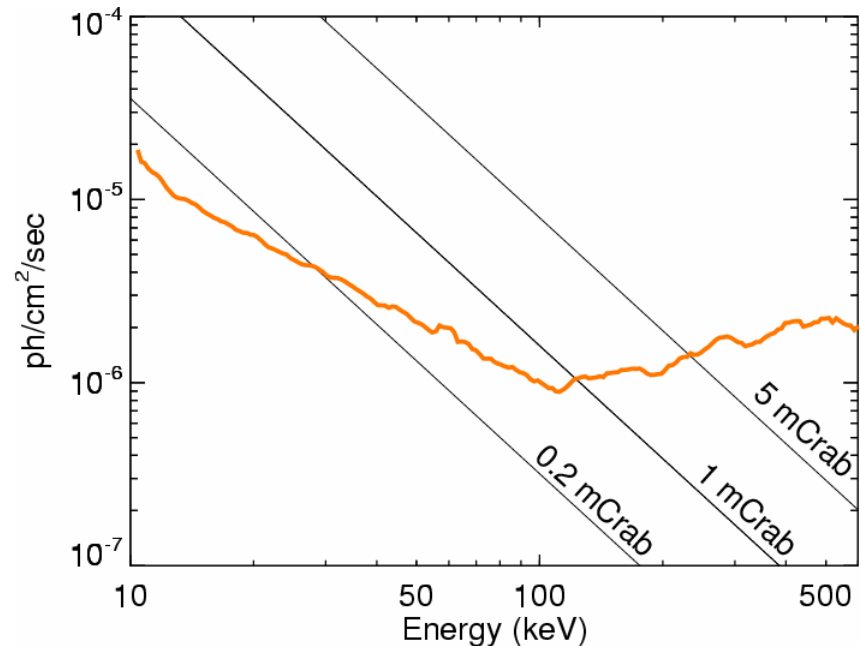
<http://EXIST.gsfc.nasa.gov>

# Expected EXIST Survey Sensitivity

## Continuum



## Narrow Line



LET 3-30 keV; HET 10-100 keV Sensitivities ( **~20X *Swift*/BAT**):

0.05mCrab =  $5 \times 10^{-13}$  cgs, (over any band  $E_{\text{low}} \rightarrow 2E_{\text{low}}$ )

vs. HET 100-600 keV: ~0.5mCrab =  $5 \times 10^{-12}$  cgs ( **~20X *INTEGRAL***)

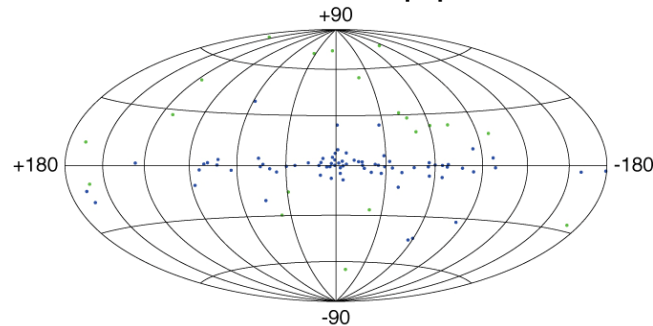
5 $\sigma$ , ~1yr, 20-40% duty cycle coverage of any source

# Hard X-ray Sky

- Hard X-ray (10-600 keV) sky not yet surveyed to ROSAT sensitivity. *EXIST* would be ~20X more sensitive than *Swift* or *INTEGRAL* and cover full sky
- *EXIST* will detect  $\geq 3 \times 10^4$  sources,  $\leq 10''$  positions, 3-600 keV spectra
- *EXIST* would provide unique temporal survey: *full sky imaging each orbit*

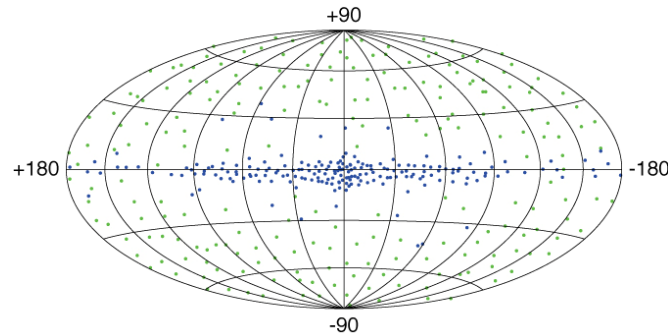
## Previous Hard X-ray Sky

HEAO-1, BeppoSAX



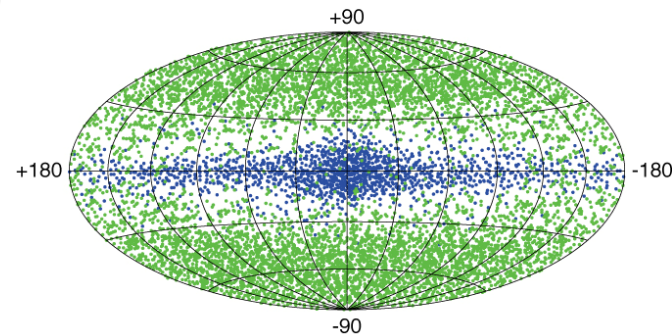
## $\leq 2010$ Hard X-ray Sky

Swift & INTEGRAL

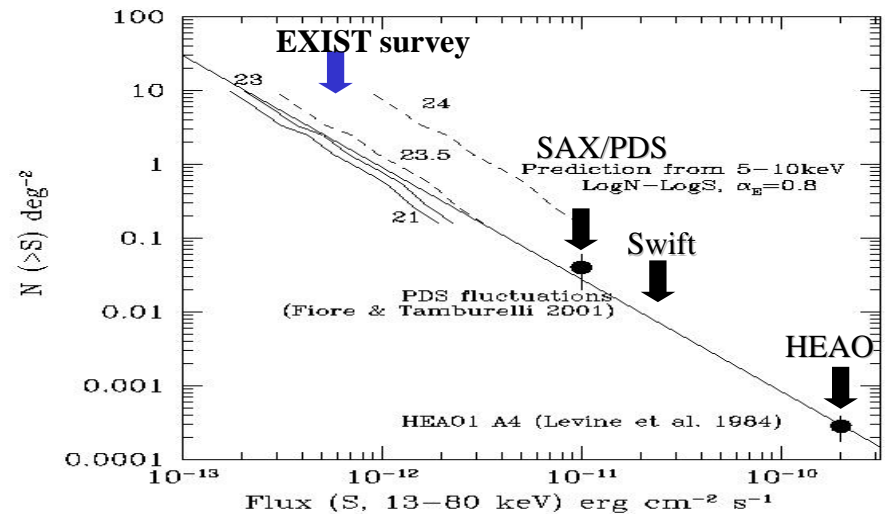
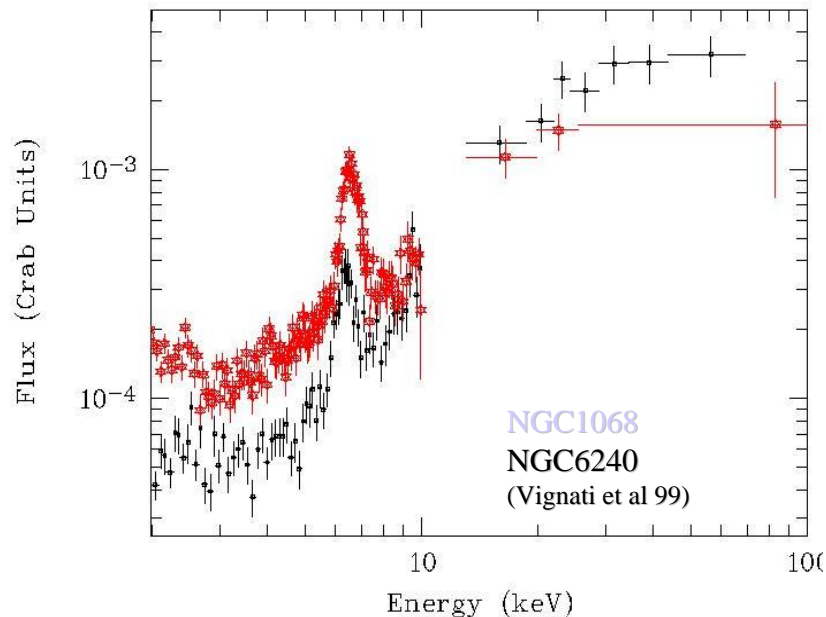


## 2015(?) Hard X-ray Sky

EXIST



# Obscured AGN and origin of the CXB



**Chandra & XMM** surveys find >40% unresolved CXB from obscured AGN but at peak of CXB,  $E \sim 20\text{-}30 \text{ keV}$ , only  $\sim 10\%$  of CXB is resolved!

➡ **EXIST** will find >1-10 obscured AGN/square degree and obtain first *all-sky* measure of Seyfert 2 ➡ QSO 2 luminosity function and constrain obscuration vs.  $z$  for supermassive BHs.

Provide required all-sky survey for rare (Type 2 QSOs) and  $L_x$  dependence of NH

# AGN variability on all scales...

- Brightest (3C273, Cen-A, NGC 4151) measured every 95min (20% duty cycle)
- Constrain BH mass (PDS breaks) and spin (for “known” mass &  $L_x/L_{\text{edd}}$ )
- Provide continuous monitoring for full-sky AGN @ 10X below Swift/INTEGRAL every 1-3d
- Spectral variability 3-600 keV
- QPOs from brightest AGN to compare with galactic BH-LMXBs

# Dormant SMBHs revealed by Tidal disruption

(and triggers for LISA gravitational wave inspiral)

*Tidal disruption of stars spiraling into Dormant SMBHs with mass  $\sim 10^7 M_\odot$ : if 1% of  $L_{acc}$  in HX band,  $\sim 10^{-5}$  events/year/Mpc<sup>3</sup> allow EXIST to see  $\sim 10$ -30 flares/yr out to  $\sim 200$  Mpc! (Grindlay 2004).*

HX spectral comp. "confirmed" with PL spectral decay of RX1242 measured with Chandra/XMM!

*Sub-giants with WD cores are gravitational wave **LISA** triggers.*



Artists conception of tidal disruption of star in RXJ1242-1119 detected with ROSAT (1991) and confirmed with Chandra (Komossa et al 2004).

*Possible soft ( $\sim 3$  keV) prompt ( $\sim 1$  d) burst detectable out to  $\sim 30$  Mpc directly with EXIST (LET) and with MAXI or LOBSTER; **LISA** trigger*

**Measure  $10^{6-7} M_\odot$  SMBH content/evolution of nearby galaxies**  
**(understand BH-Bulge mass relation & BH-galaxy evolution!)**

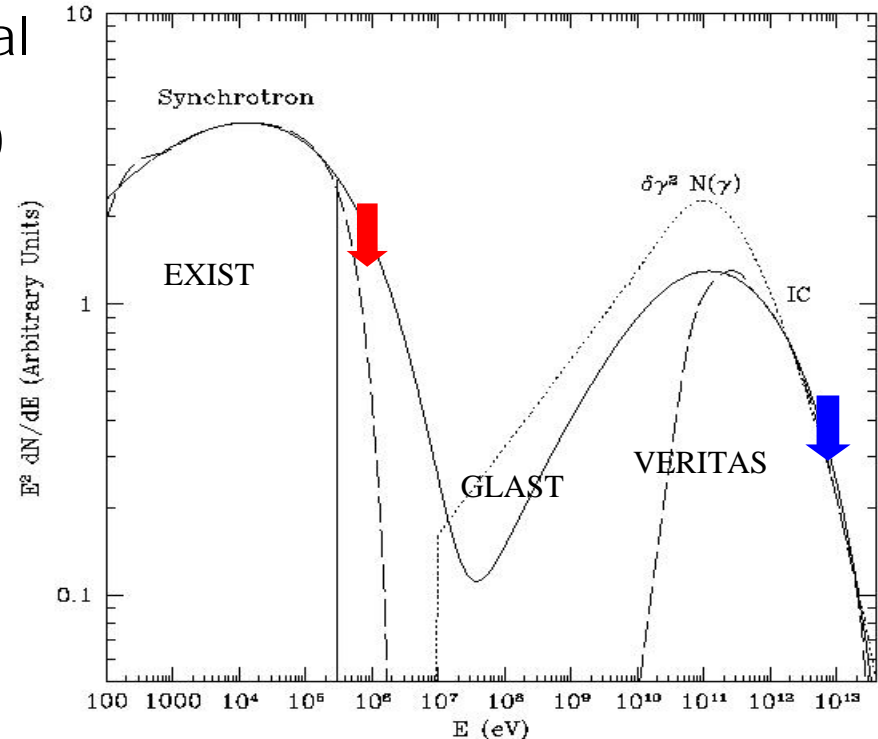


# Blazar Spectral variability:

## 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* and *HESS/VERITAS* to constrain origin of diffuse IR background

**Time-variability:** spectral breaks required from simultaneous HX measurements. Wide-field HX imaging needed to match *GLAST*



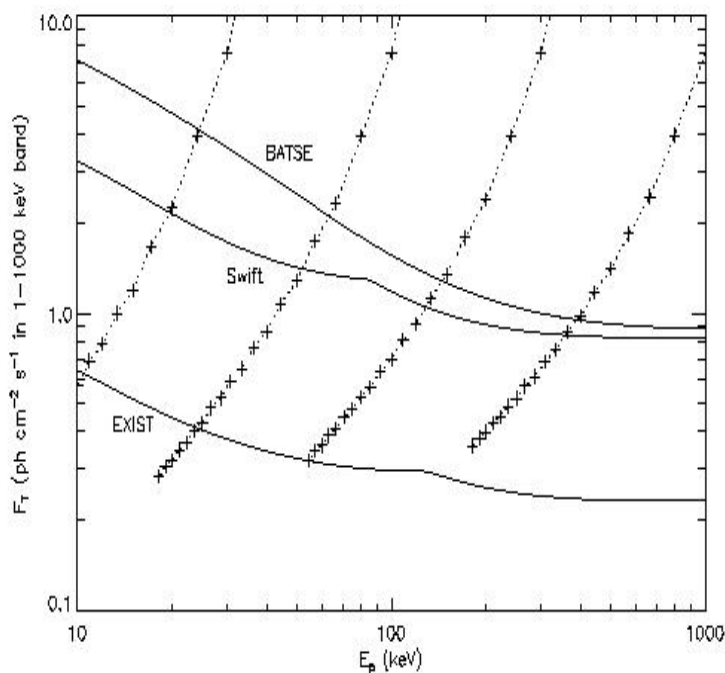
SSC model for Mkn 501 (Coppi & Aharonian 1999)

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

**Complements GRB science: star formation vs. redshift from LGRBs vs.  $z$**

# Birth of Stellar BHs at $z \sim 5-20$

- “**Long**”-**GRBs** are from SNIb,c & likely due to stellar BH formation
- Likely that first stars were  $\sim 100M_{\odot}$  and collapse to BHs  $\Rightarrow$  GRBs
- “**Short**”-**GRBs** from merging NSs in globulars (Grindlay et al 2006) suggests Short GRBs enhanced at  $z$  of globular cluster formation?



Flux vs. detected  $E_{\text{peak}}$  for GRBs from  $z=1$  (top +) to 10 (bottom +) for  $E_{\text{peak}} = 30, 100, 300, 1000\text{keV}$  if emitted at  $z=1$  vs. sensitivities (Band 2004).

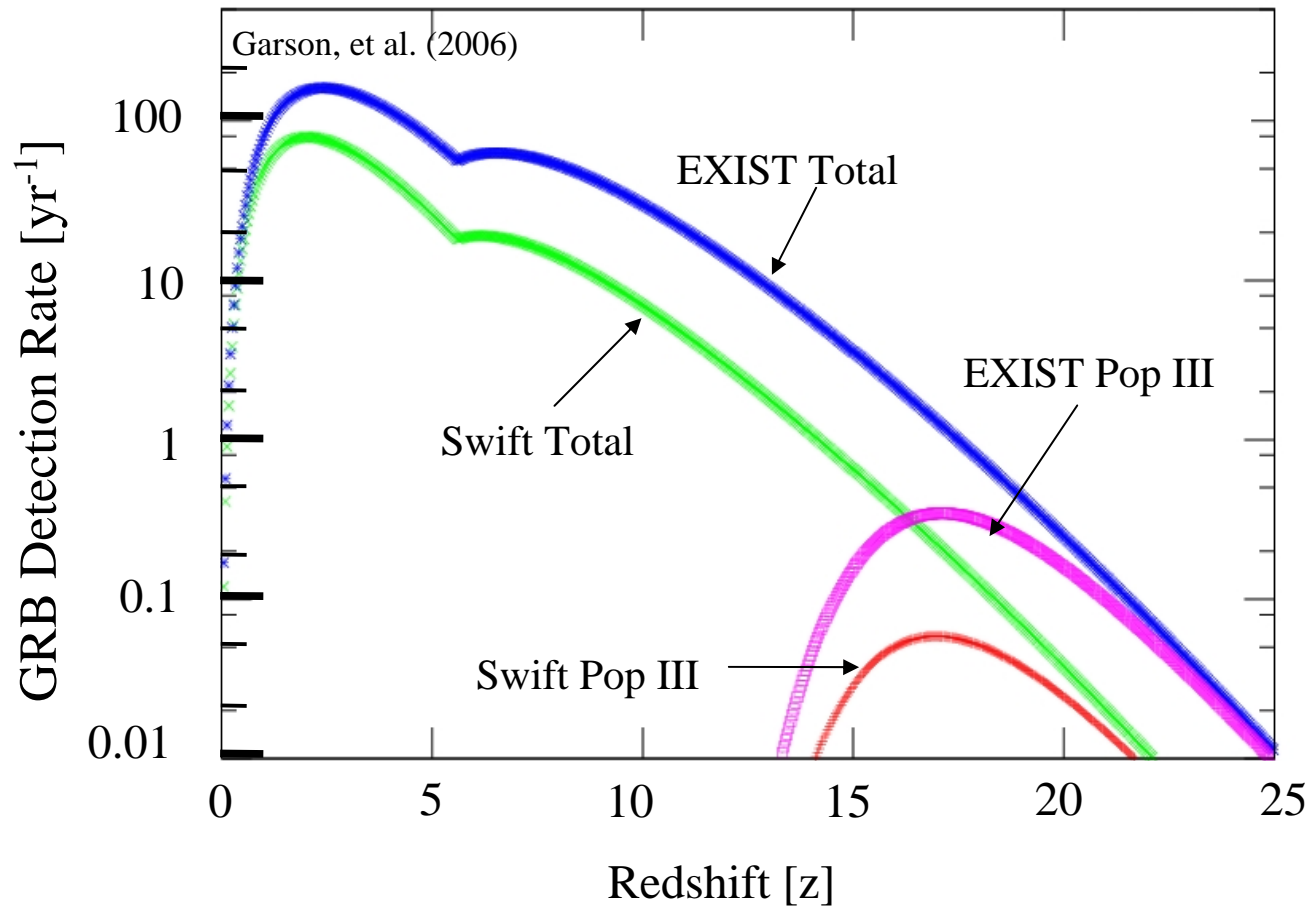
**EXIST** detects GRBs to  $z \sim 20$  from PopIII BHs at re-ioniz. epoch suggested by WMAP.

Photometric  $z$  from Lum- $E_{\text{peak}}$  (Amati)  $\Rightarrow$  need response to  $E > 300\text{keV}$ ,  
And from Lum-Variability (Paczynski Relation)  $\Rightarrow$  need large area det.

X-ray flashes and high  $z$  GRBs  $\Rightarrow$  need response to  $E \sim 3\text{ keV}$

$\sim 5\text{sr}$  instantaneous GRB coverage  
And increased sensitivity:  
**Rare (high  $z$ ?) events; 3-5GRBs/d!**

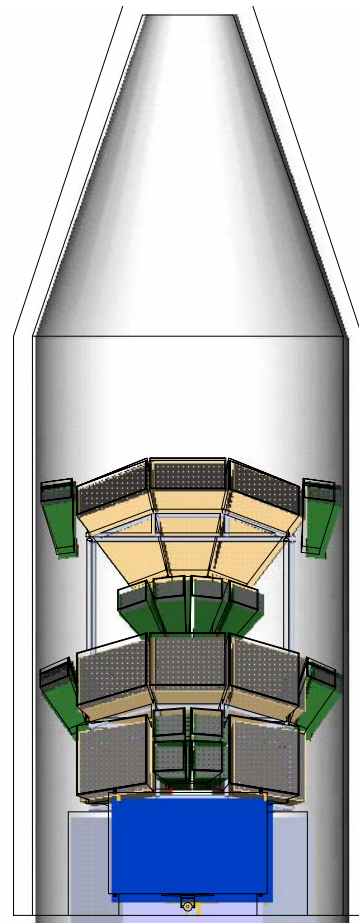
# Preliminary High- $z$ GRB Sens. Estimate



- Use SN and PopIII Rates from Bromm & Loeb (2006)
- Use only HE telescope; rate higher including LET

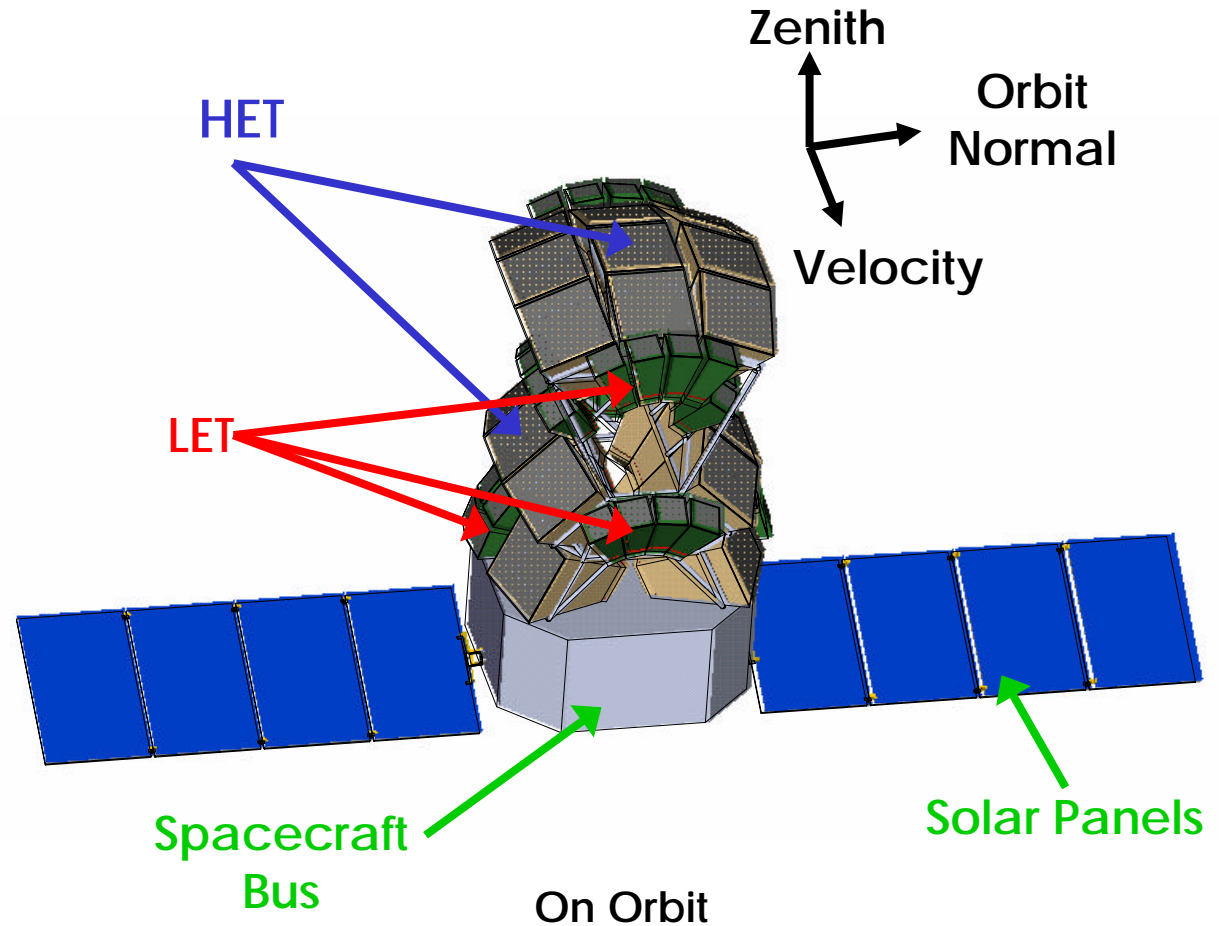
# New (*General Dynamics*) Design Concept

Symmetric, smaller solar panels & increased LET Area & FoV



Stowed

Atlas V (5m Fairing)



On Orbit

*NRC Review to recommend 1<sup>st</sup> Beyond Einstein Mission: EXIST in 2015?*

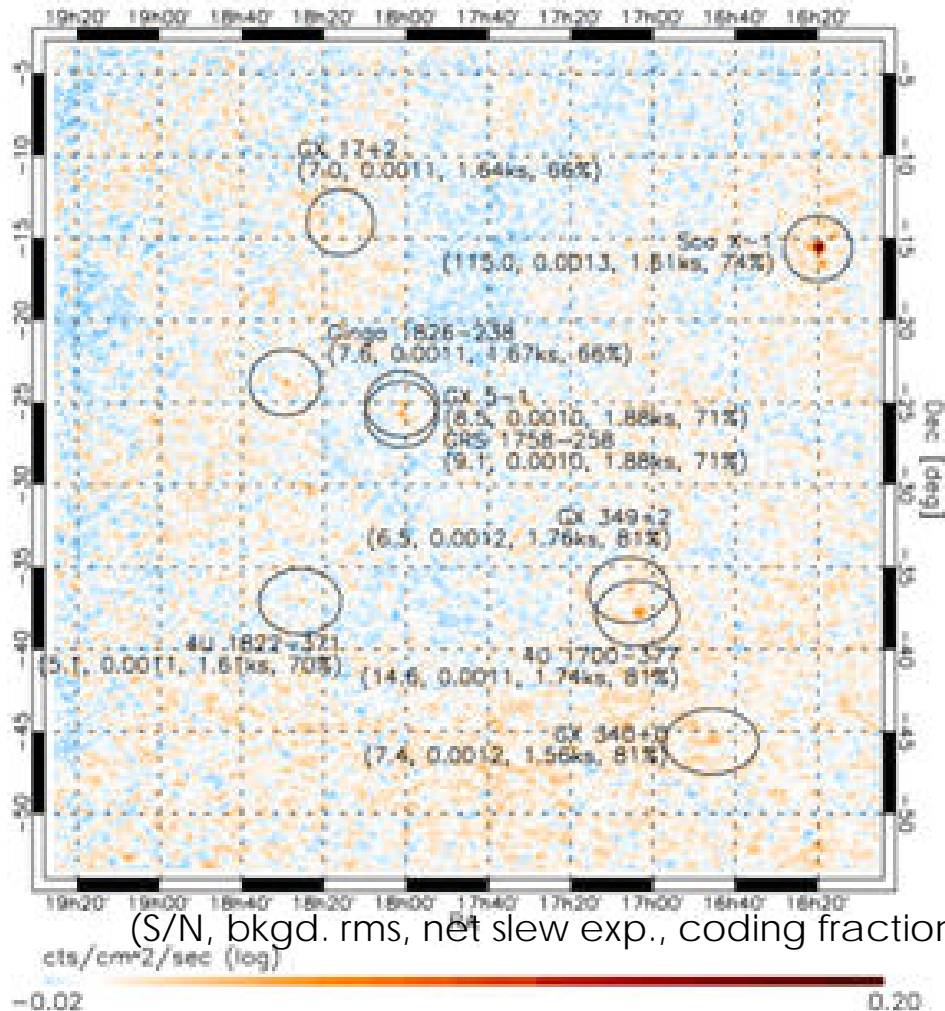
# BAT Slew Survey (BATSS)

- High time res. HX survey from ~60slews/day (between Swift targets; no data presently sent down to ground...)
- Blazar flares and short time variability of brightest AGN not covered by Swift/BAT pointings
- Higher sensitivity per unit time due to scan reducing coded aperture imaging systematics
- Prototype/test-bed for *EXIST*
- Operational software under development; Survey begins in Dec. 2006

# Swift/BAT slew imaging for AGN variability

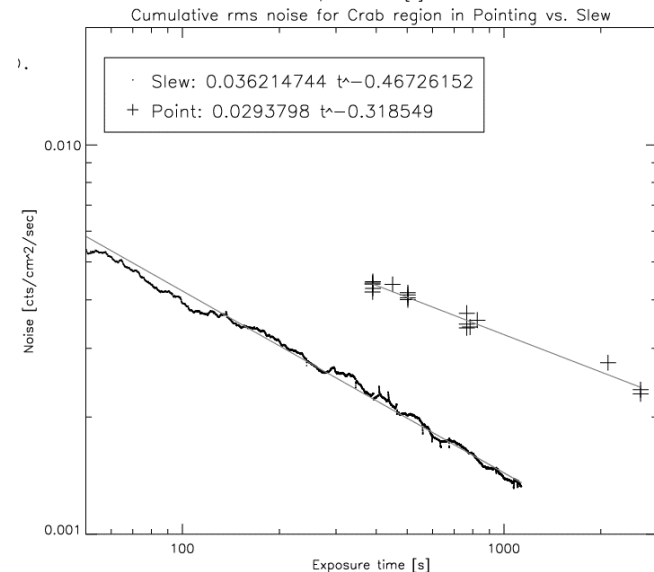
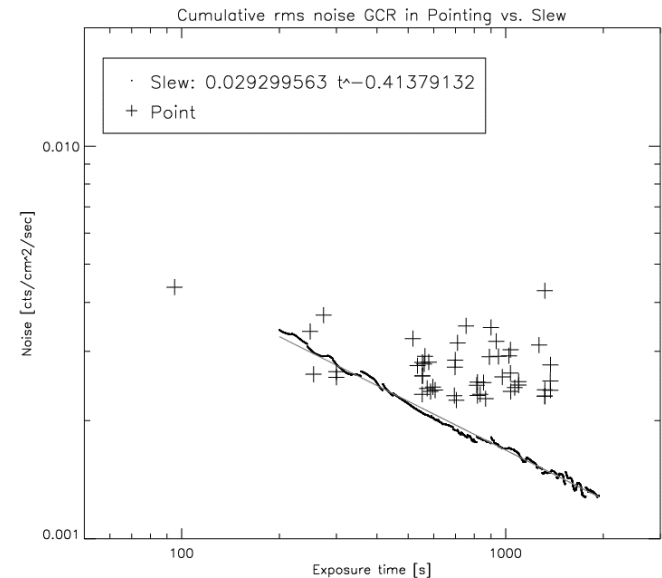
## And higher sens./unit time HX imaging...

NEAR GAL. CENT



15 slews (60sec ea.) on Gal. Ctr. region

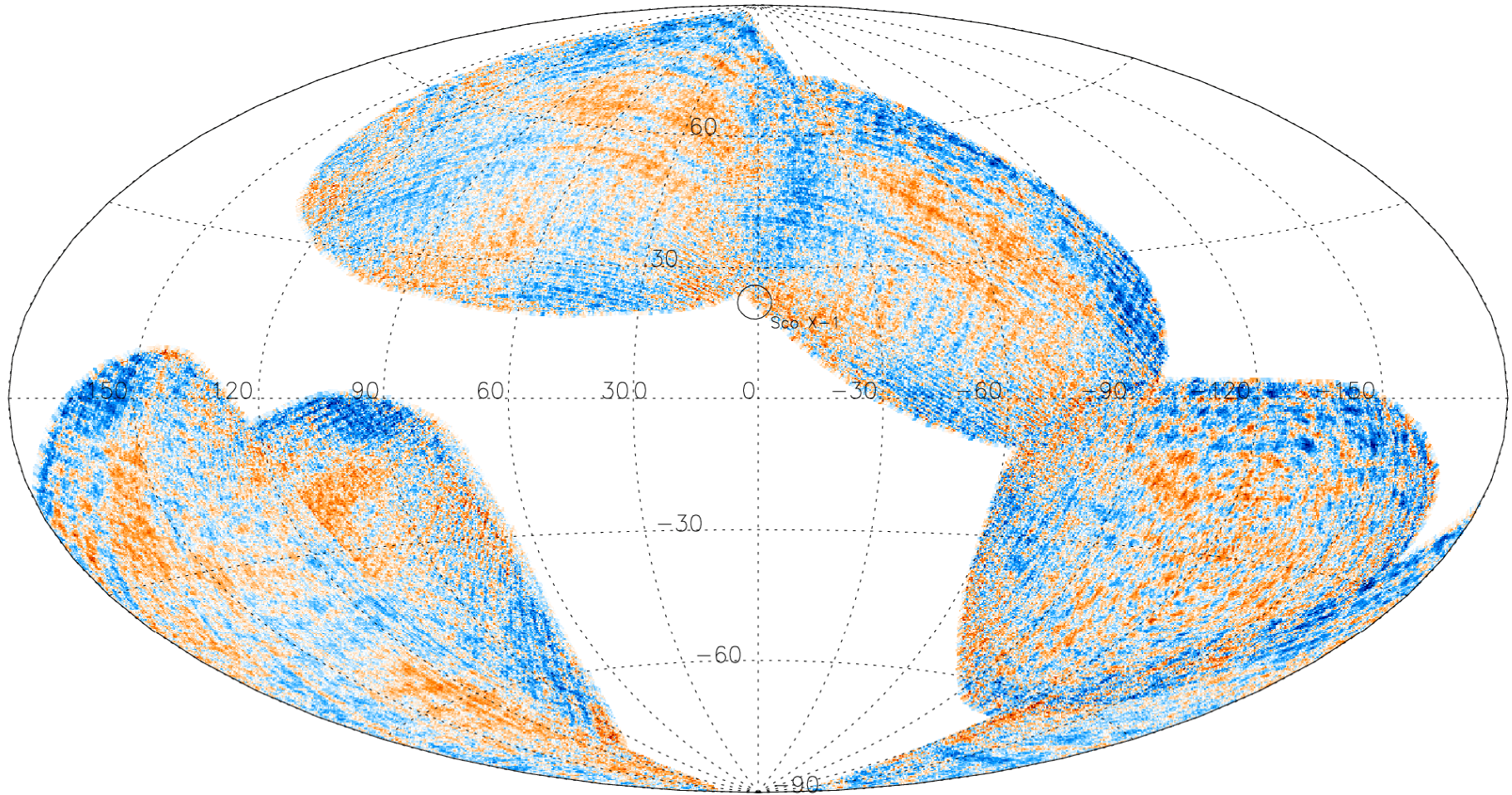
Noise reduced vs. equiv. time pointing due to averaging effects of scan





# 3 orbits of BAT slews vs. pointing

(Sept. 14, 2006)



Plot color scale:  
cts/cm<sup>2</sup>/sec (log)

-37.81 0.00 33.44

Arcmins per databin: 4

IMAGE noise reduced >3 by scanning...

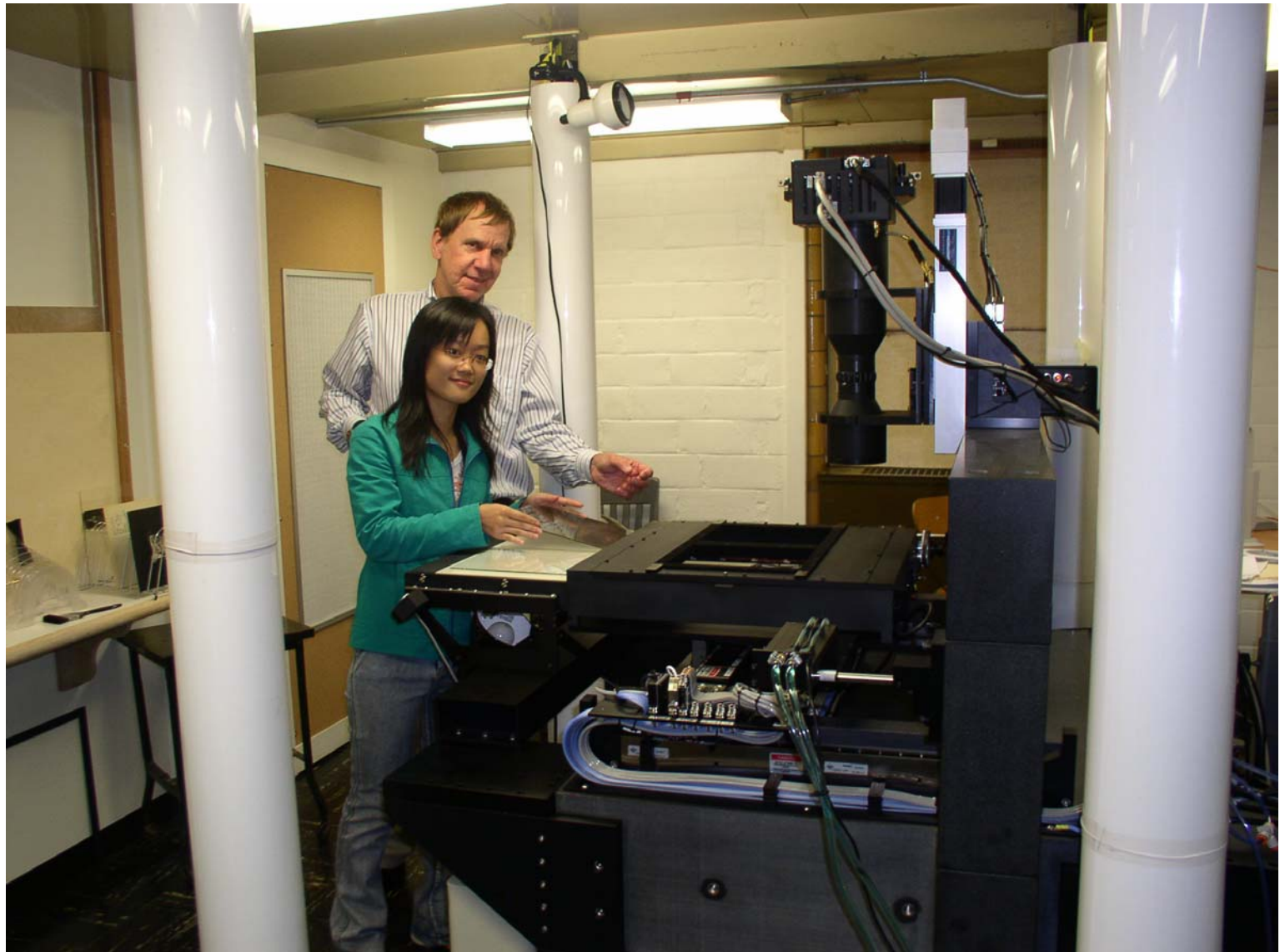
# AGN Optical variability from *DASCH* (*Digital Access to a Sky Century from Harvard*)

- Have designed/built world's fastest plate scanner (12bit, 1micron pos. acc.: digitizes TWO 8 x 10in plates in 70sec!) to (ultimately...) digitize the ~500,000 Harvard plates (see Simcoe, Grindlay et al [astro-ph/0610351](https://arxiv.org/abs/astro-ph/0610351))
- Will extend AGN lightcurves ( $V < 15-18$ ) ~100y into past
- BH masses from PDS breaks; tidal disruption events
- Complement LSST/PanSTARRS/BATSS/EXIST...



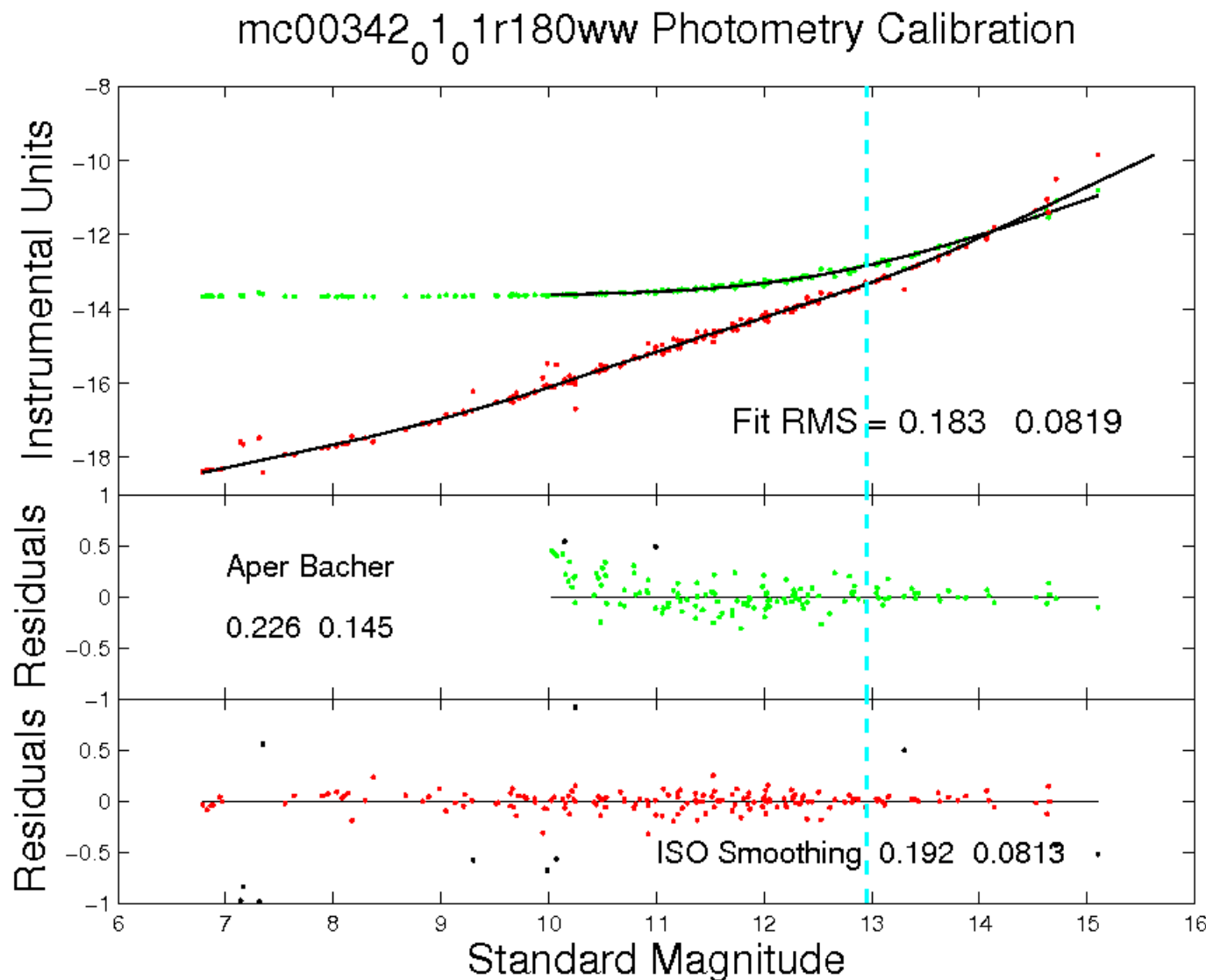
# *DASCH scanner*

(and Harvard-Tsinhua/IHEP connection!)



# DASCH Photometry to $\sim 0.08\text{mag}$

- Photometry (SExtractor and custom tools) under development
- Pilot project on M44 eclipsing binaries
- Initial AGN photometry soon with first sample of PG QSOs: constrain PDS break
- Trial galaxy subtractions for tidal disruption searches
- 3-5y to digitize all plates (**need donor!**)



# Summary

- All-sky, all-time AGN survey (all types...) possible with EXIST; competing with Con-X, LISA, JDEM for first slot in Beyond Einstein queue...
- Fast-time variability (flares) HX survey of AGN about to begin with BATSS
- Long-timescale (100y!) optical ( $V < 15-18$ ) survey of AGN now possible with DASCH; seeking support to digitize full Harvard plate collection