High Energy Astrophysics Programs in KIPAC:

NuSTAR & NEXT

William Craig

Presentation to DOE HEP Review
06/03/2004

Overview

- NuSTAR and NeXT are non-DOE programs, in development now with NASA and ISAS funding.
- Natural followons to the science base built at SLAC for GLAST.
- NuSTAR will make contemporaneous observations with GLAST in 2007-10.
  - KIPAC has strong science and hardware role
- NeXT will follow in 2011/12

NuSTAR

Bringing the High-Energy Universe into Focus

A report on the Phase A Concept Study
June 18, 2004

William Craig

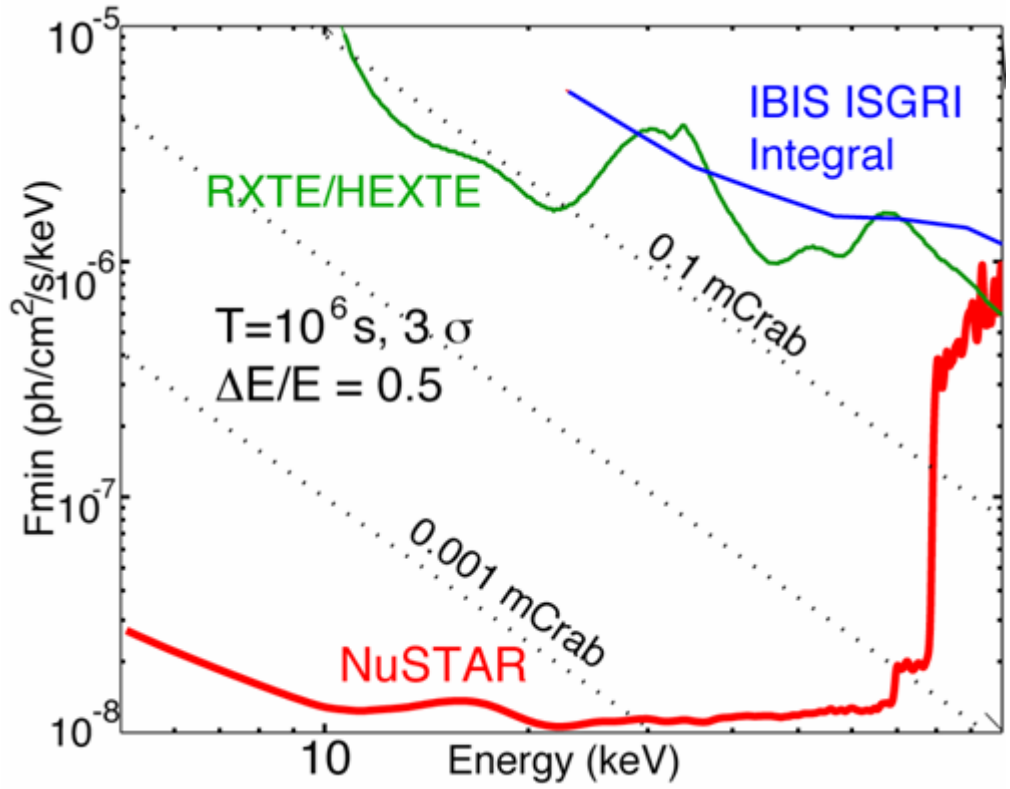
For the *NuSTAR* team

NuSTAR
the first focusing mission above 10 keV

brings unparalleled

- sensitivity,
- angular resolution, and
- spectral resolution

to the hard X-ray band



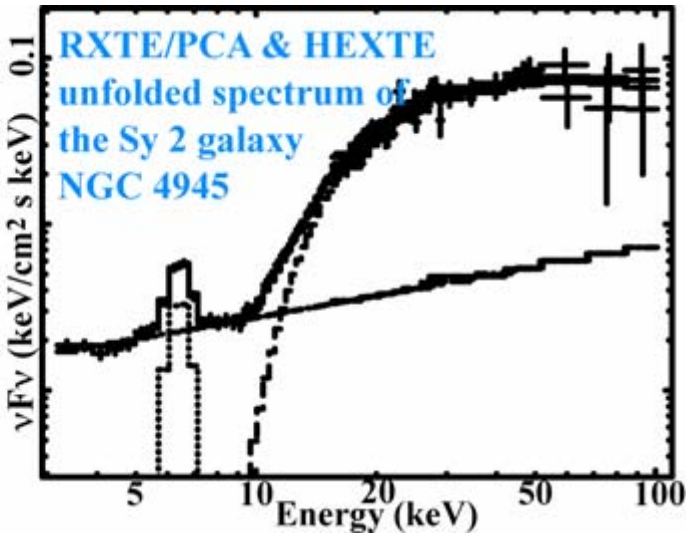
and opens an entirely new region of the electromagnetic spectrum for sensitive study. Will bring to hard X-ray astrophysics what *Einstein* brought to X-ray astronomy

Three primary science goals

1) NuSTAR will discover collapsed stars and black holes on all scales as a pathfinder for the Beyond Einstein missions

Census of massive black holes in the nuclei of galaxies

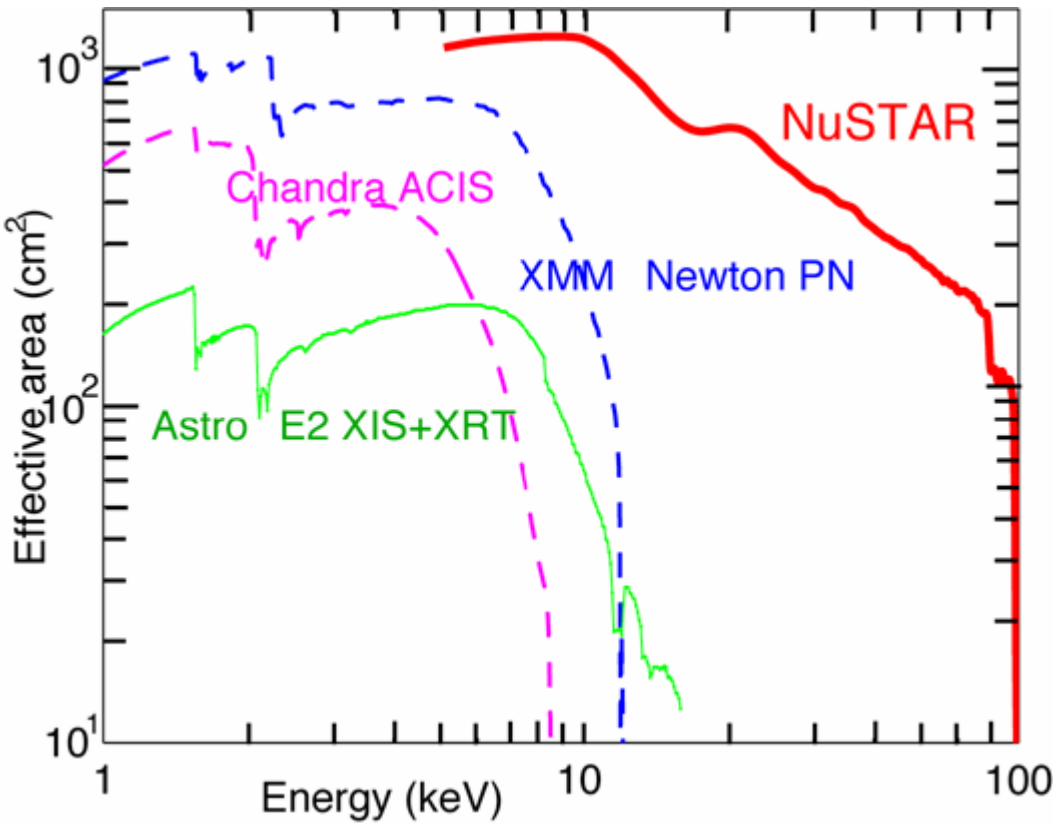
The penetrating power of high-energy X-rays means they provide a probe of dust-enshrouded sources.



NuSTAR observes faint objects at 30 keV - the peak in the Diffuse Hard X-Ray Background

Combined with optical and *Spitzer* IR data, *NuSTAR* will measure the luminosity density in obscured accretion and its evolution over cosmic time.

Deep extragalactic surveys



NuSTAR will spend 6 months on two extragalactic survey fields:

NDWFS (wide - 9 deg^2)

VLA, *Spitzer*, optical

Chandra (5 ks)

F(2-10) = 3×10^{-14} erg/cm^2/s with α = 1 detected 20 – 40 keV

>150 AGN detected 10 – 40 keV

GOODS (deep-500'^{2})

HST, *Chandra*, *Spitzer*

F(2-10) = 2×10^{-15} erg/cm^2/s

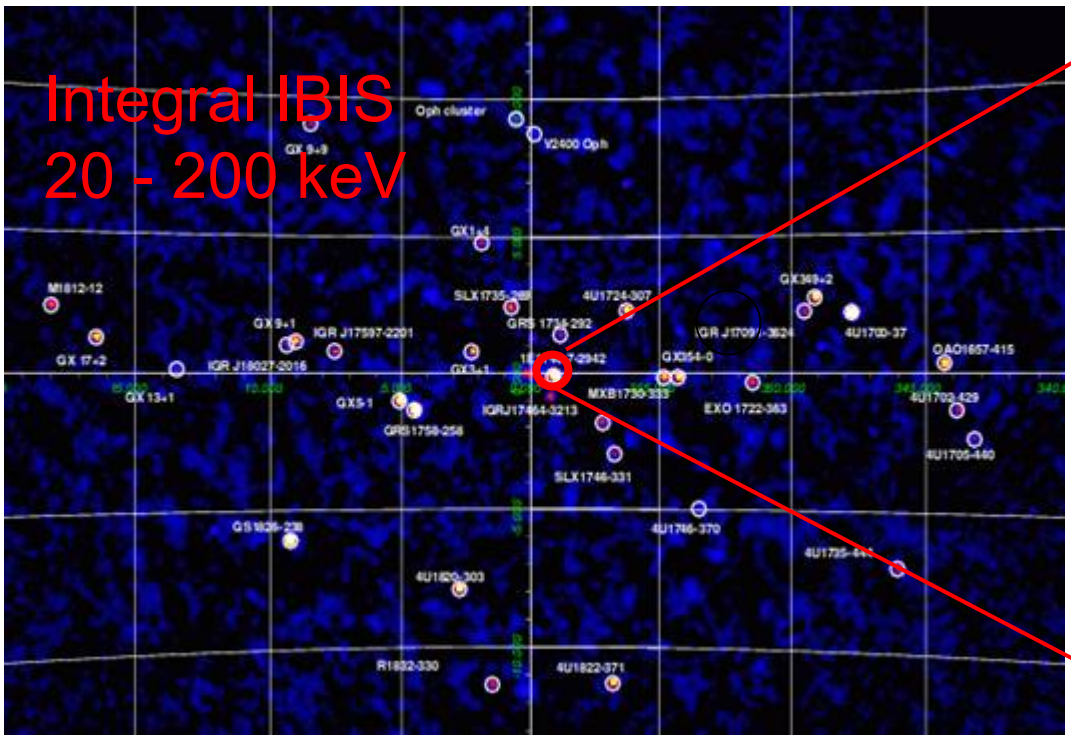
Detected 20–40 keV

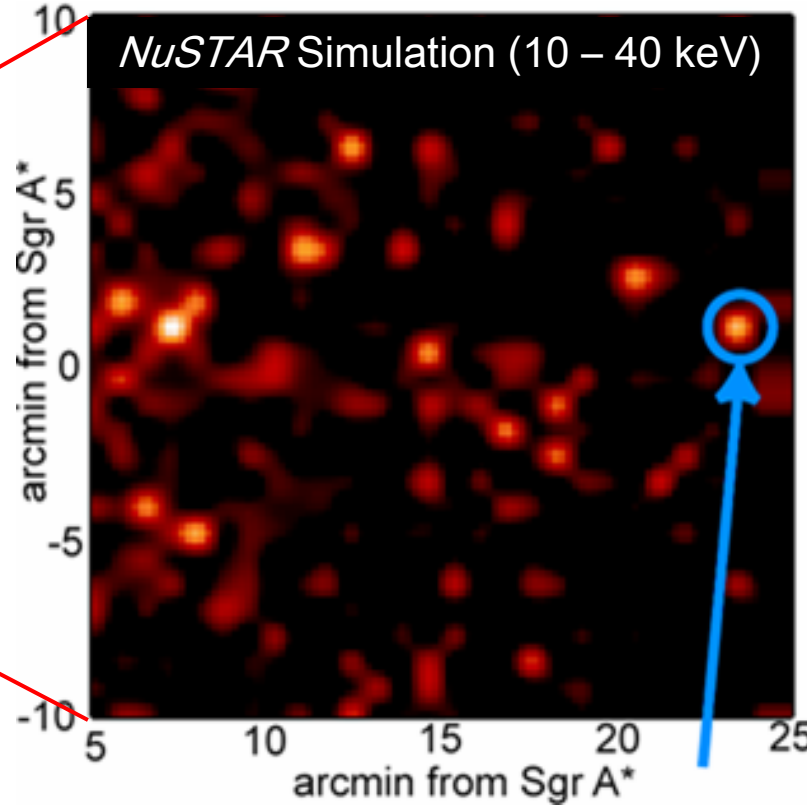
>170 AGN detected 10 – 40 keV

Obscured galactic sources

Discover the nature of the mysterious obscured Galactic sources

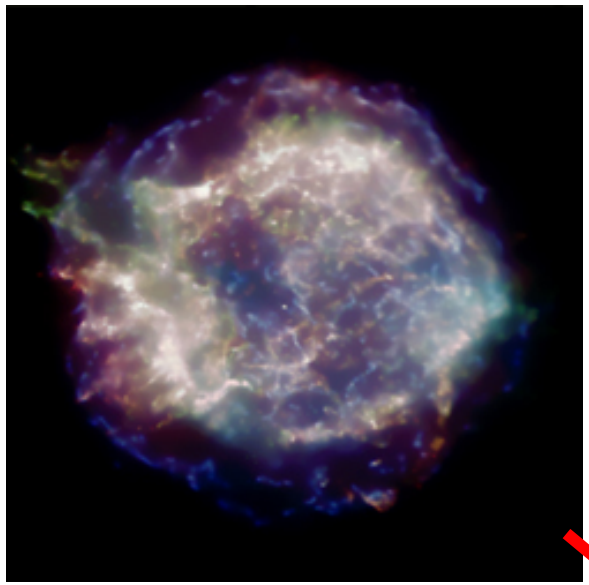
Chandra (near the GC) and *Integral* IBIS are discovering populations of hard and highly-obscured sources in the Galactic plane. *NuSTAR* will perform Galactic surveys to obtain localizations, spectra and help discover the nature of these new objects.

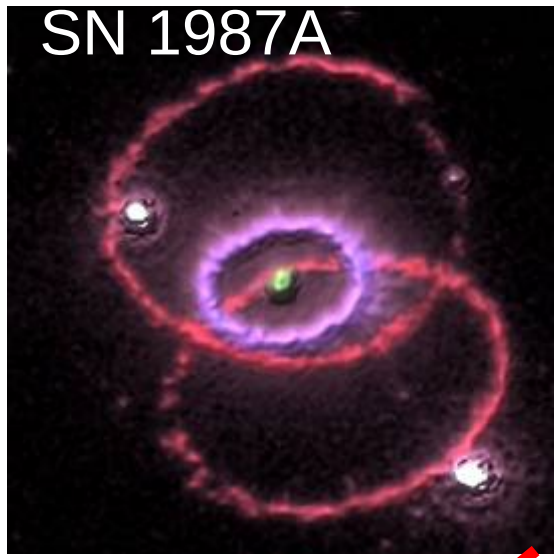


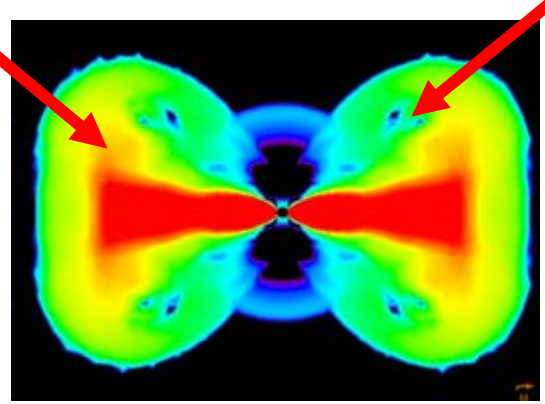


Supernova remnant science

2) NuSTAR will map the remnants of recent supernova explosions, testing theories of how stars explode, and of where the elements are born







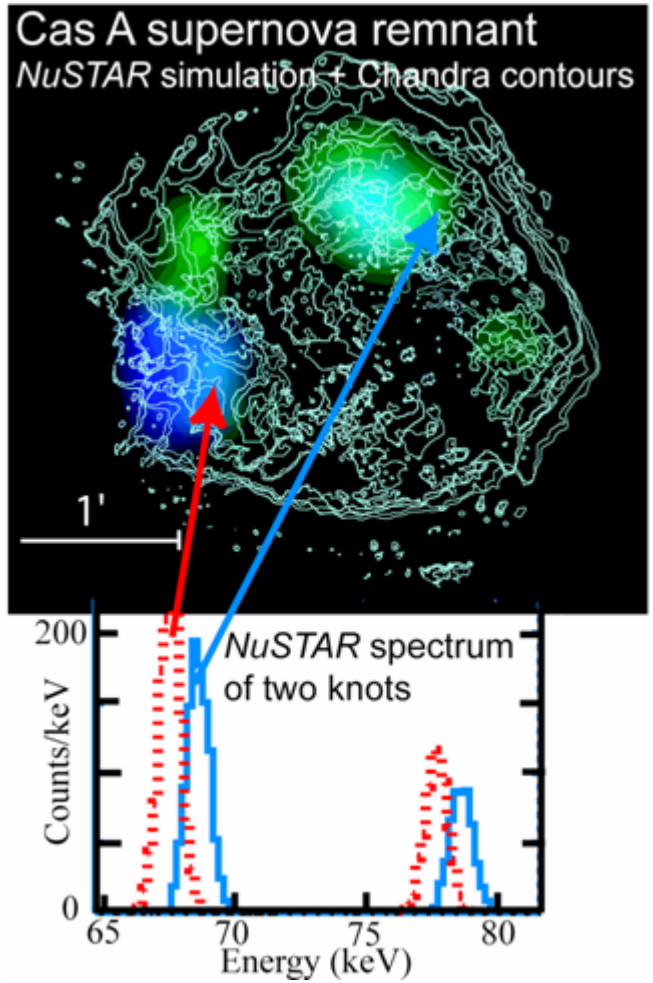
Supernovae remnants are the likely site of particle acceleration and source for the highest energy cosmic rays.

Sensitive ^{44}Ti surveys

Line flux sensitivity: ~2×10^{-7} ph/cm^2/s (10^6 s)

Map 3 young remnants
Measure asymmetry, velocity distribution
Clumpyness

Measure flux from SN1987a



Remnant	Age (yr)	Dist (kpc)	Size (')	67.9 keV flux (× 10^{-6} ph/cm^2/s)
SN 1987a	20	50	0	2.5
Cas A	327	3.4	3.6	15
Kepler	403	2.9	3.5	8.4 (?)
Tycho	435	2.3	8x5	9.2

Type Ia supernovae studies

- SNe Ia widely believed to result from thermonuclear incineration of an accreting C/O white dwarf. We don't know:

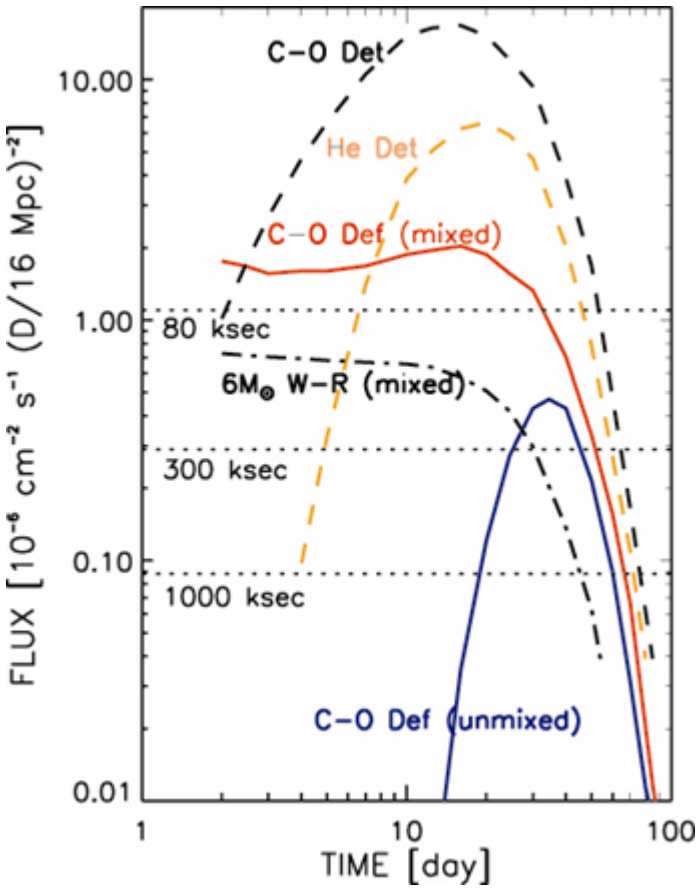
- Nature and evolution of the progenitor system
  - mass of dwarf at ignition
  - physics of subsequent nuclear burning
  - reason for the (empirical) width-optical luminosity relation

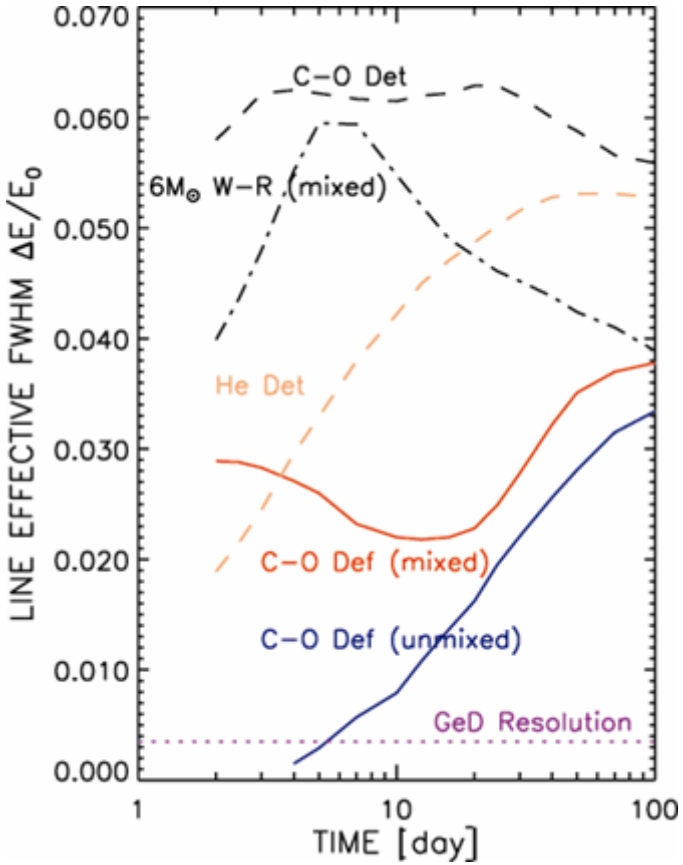
- The lightcurve is believed to be powered by the decay of ^{56}Ni
  - A SN Ia has never been seen in the X-ray/gamma-ray

- Observations of the time evolution of the ^{56}Ni line (158 keV) would provide important constraints on the explosion mechanism and dynamics

SN-Ia diagnostics

Prompt Decay of ^{56}Ni in Type Ia SNe

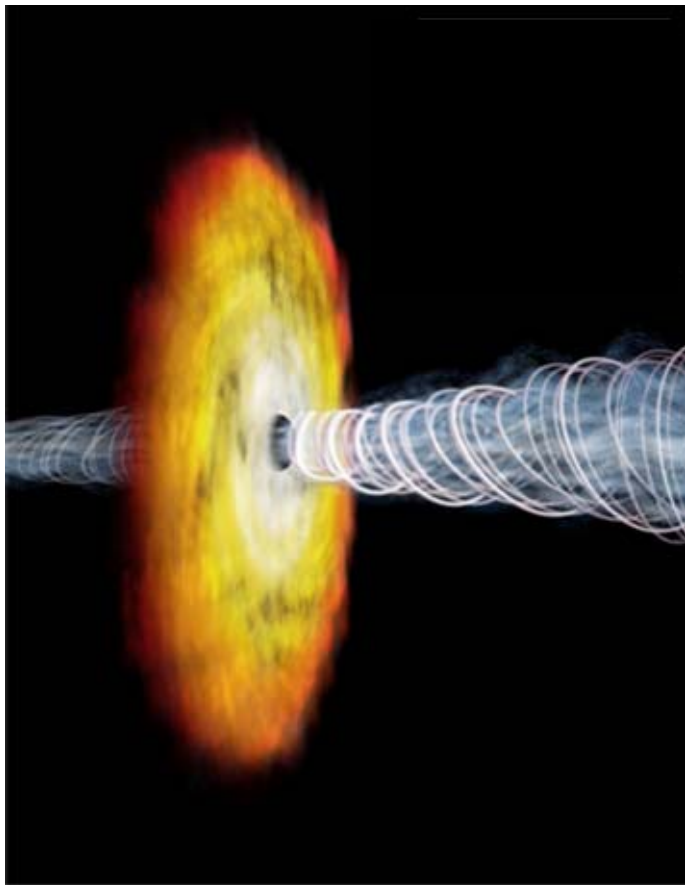




Evolution of the ^{56}Ni in Type Ia SNe is sensitive to the explosion mechanism and mixing. For example, M_{ch} and sub-M_{ch} models can be easily distinguished. *NuSTAR* can measure evolution of down-scattered HXR photons to Virgo.

Exploring the extreme Universe

3) NuSTAR will explore the most extreme physical environments in the Universe. Teaming with GLAST and TeV telescopes NuSTAR fills in an essental part of the puzzle in understanding how giant particle accelerators in massive black holes work.



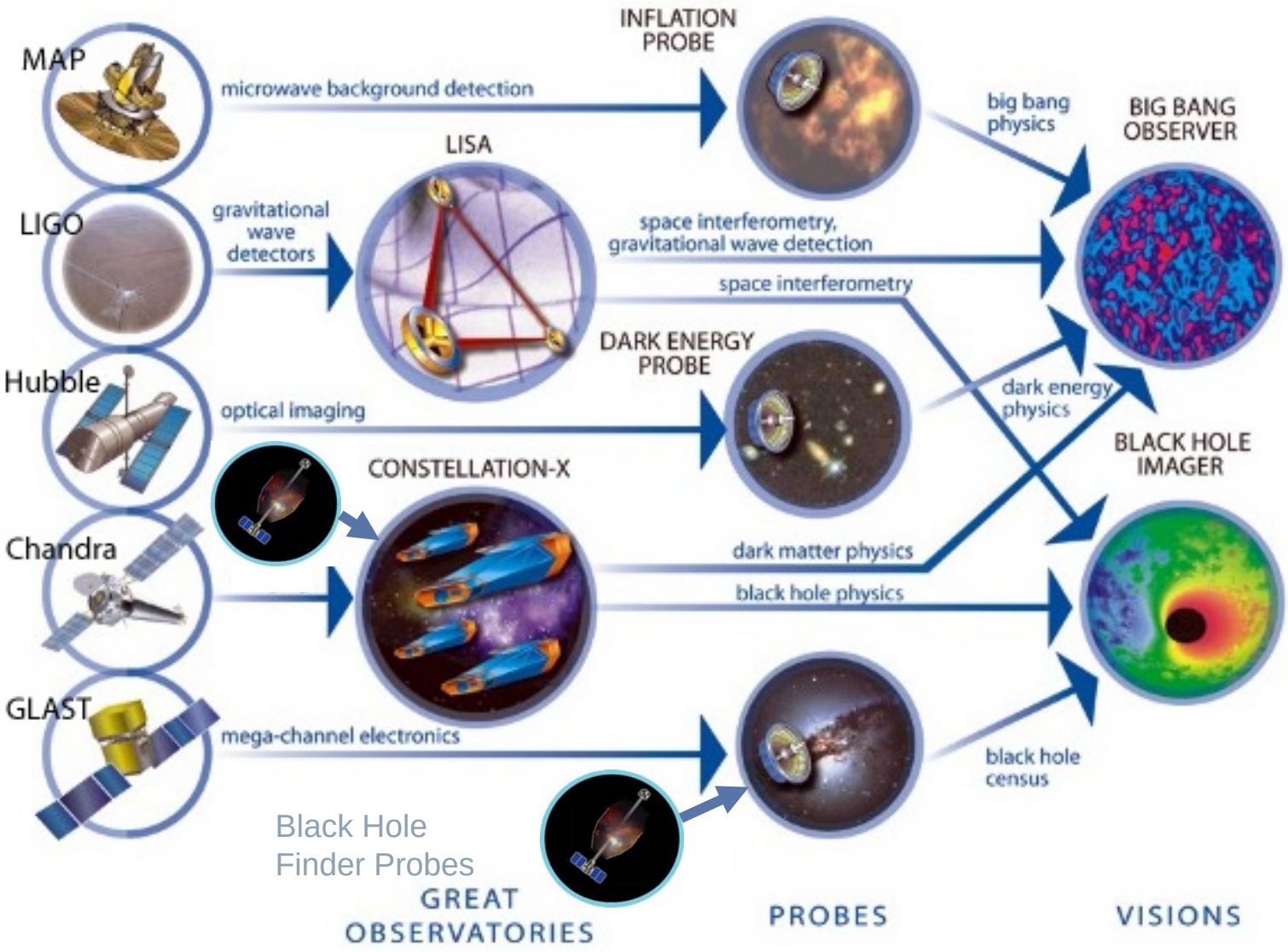
Simultaneous observations with

GLAST

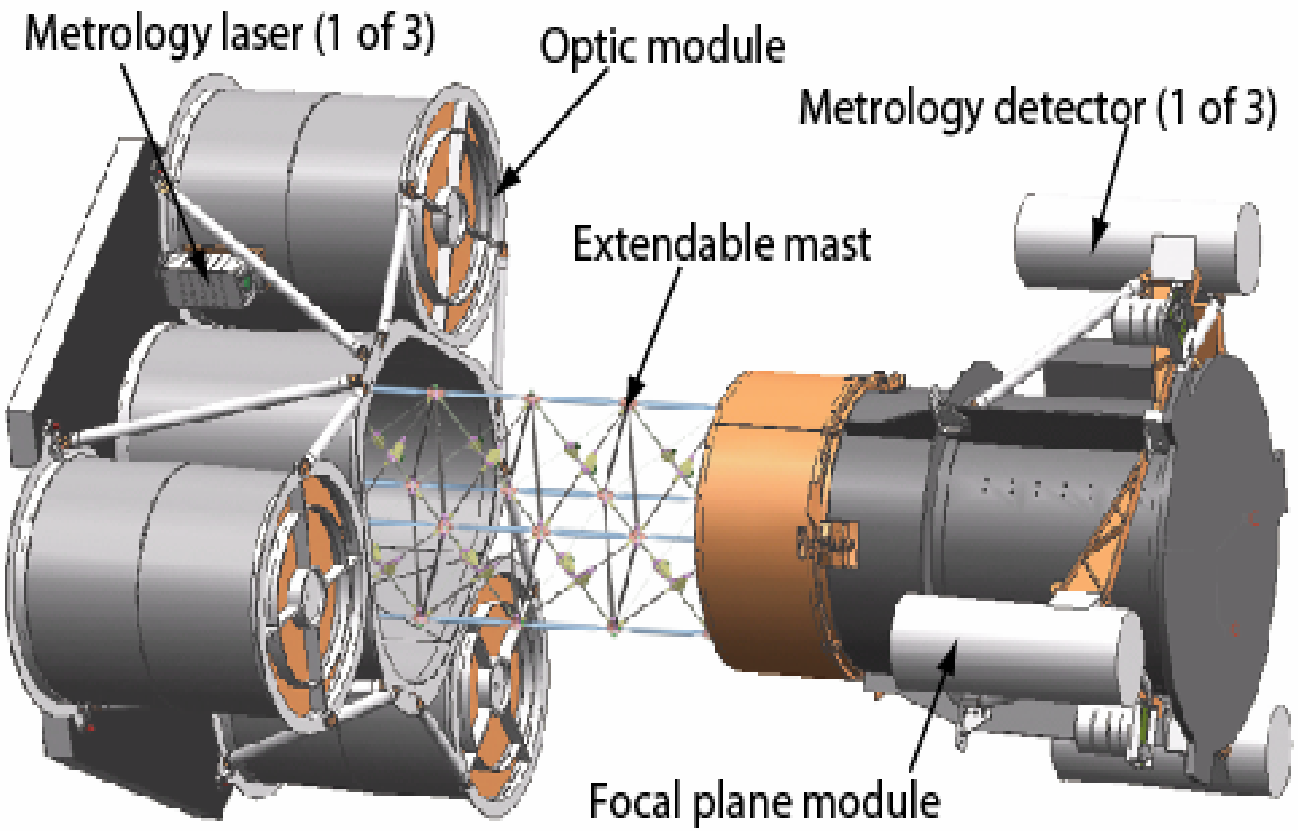
NuSTAR

TeV telescopes

The Beyond Einstein roadmap



Instrument concept



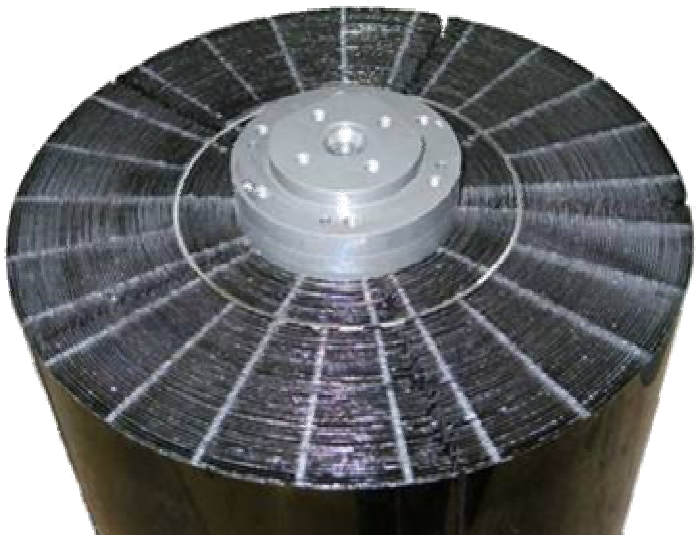
NuSTAR instrument (shown partially deployed)

NuSTAR employs a 10-meter extendable mast to separate hard X-ray optics from CZT detector modules

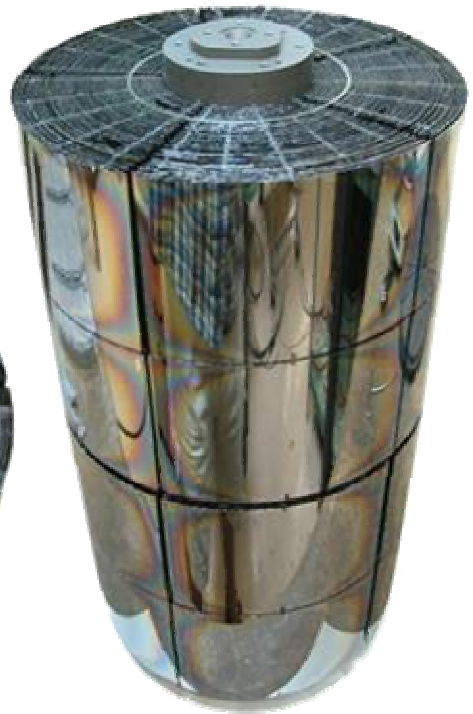
NuSTAR *HEFT* program provides heritage

- *HEFT* Flight Units (HF-1, -2, -3)
- *Constellation-X* Prototypes (ConX-0, -1, -2)

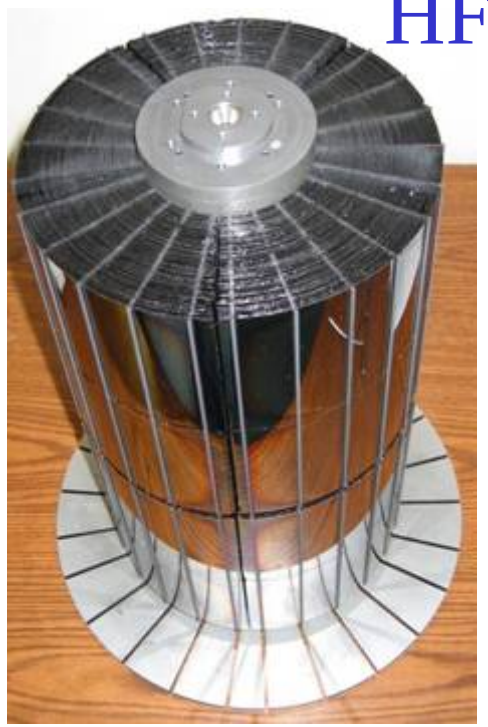
HF1



HF2

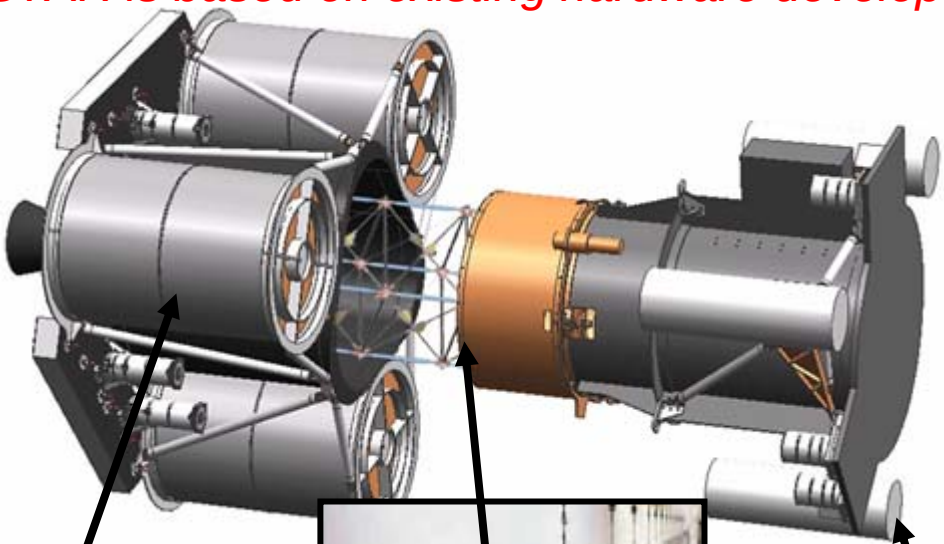


HF3



Mission concept

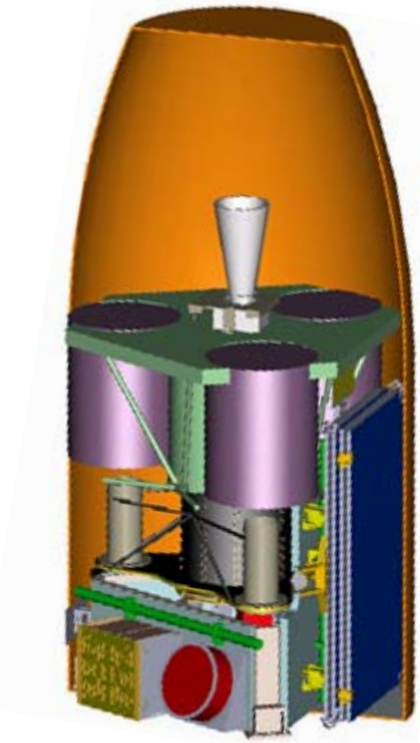
NuSTAR is based on existing hardware developed in the 9 year HEFT program



The three *NuSTAR* telescopes have direct heritage to the completed *HEFT* flight optics.

The 10-m *NuSTAR* mast is a direct adaptation of the 60-m mast successfully flown on *SRTM*.

***NuSTAR* detector modules are the *HEFT* flight units.**



Based on the Spectrum Astro SA200-S bus, the *NuSTAR* spacecraft has extensive heritage. *NuSTAR* will be launched into an equatorial orbit from Kwajalein.

Orbit	525 km 0° inclination
Launch vehicle	Pegasus XL
Launch date	late 2007
Mission lifetime	3 years
Coverage	Full sky

NuSTAR capabilities

Energy range	6 – 80 keV
Angular resolution (HPD)	40 arcseconds
FOV (20 keV)	10 arcminutes (mean)
Strong/weak src positioning	4.8 arcsec/12 arcsec
Spectral resolution	1 keV @ 60 keV
Timing resolution	1 ms UTC
Mission lifetime	3 years
Orbit	Near-Earth equatorial
ToO response	< 24 hours
Solar angle constraint	none
Observing efficiency (typical)	65%

NuSTAR status

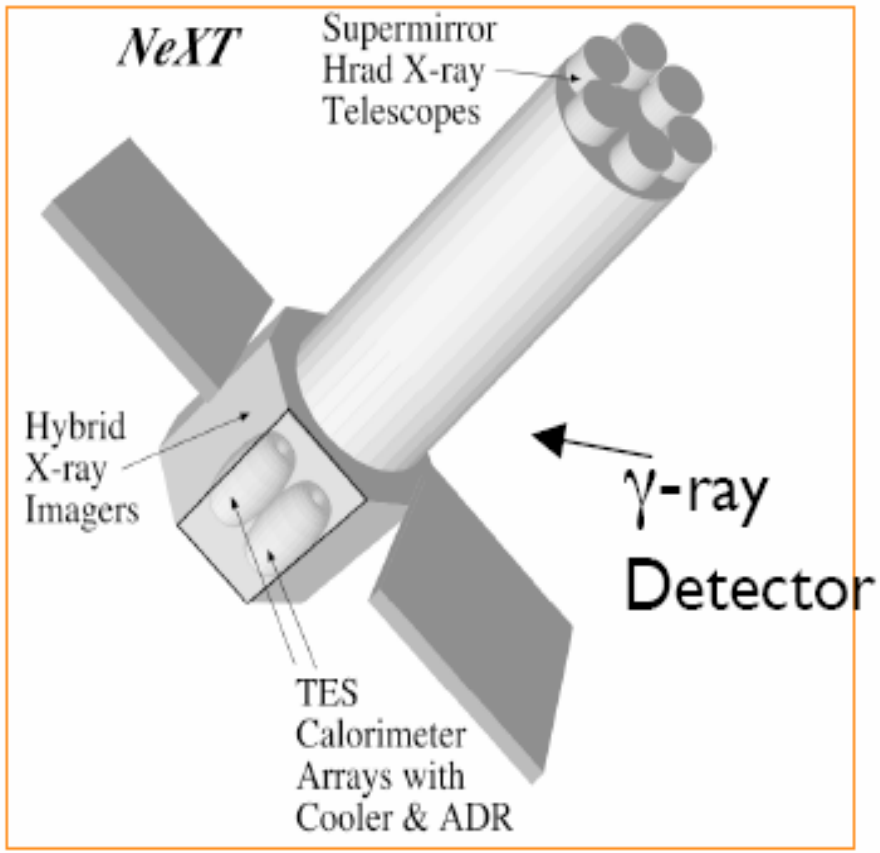
- Concept study report in preparation.
- Prototype optics in test now, 40″ – 48″ performance validated.
- Concept Study completed June 18.
- Site visit in August ’04, downselection in November ’04.
- Launch November 2007

Hard X-ray optics are the enabling technology… from concept to space-ready in less than 10 years.

The New X-Ray Telescope (NeXT)

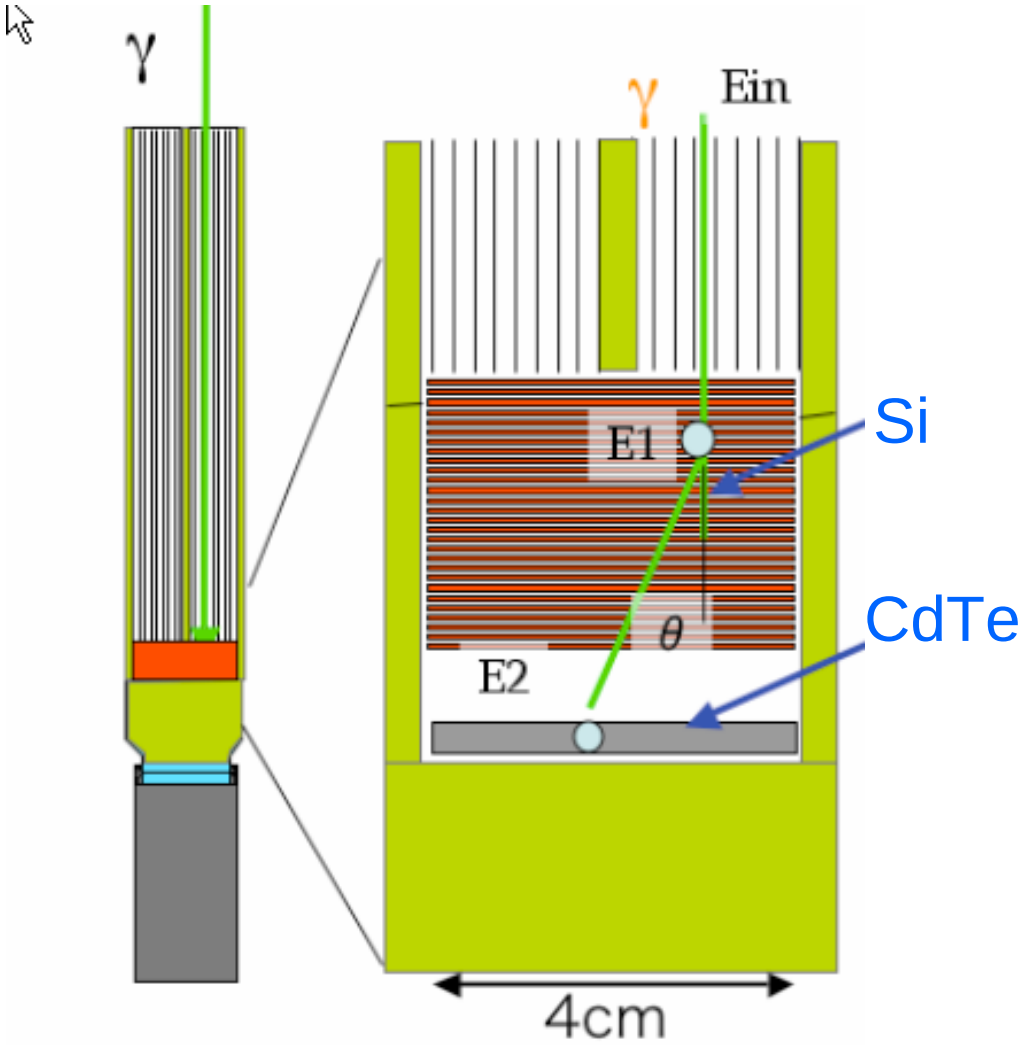
- NeXT is a Japanese X-ray satellite mission, likely to launch ~ 2011 or 2012.
- Designed to emphasize studies of the “non-thermal universe” - X-ray and gamma-ray emission from relativistic particles in XRBs, SNRs, AGNs, and clusters.
- Followup on NuSTAR and GLAST discoveries, extending to higher, and perhaps softer, energies.

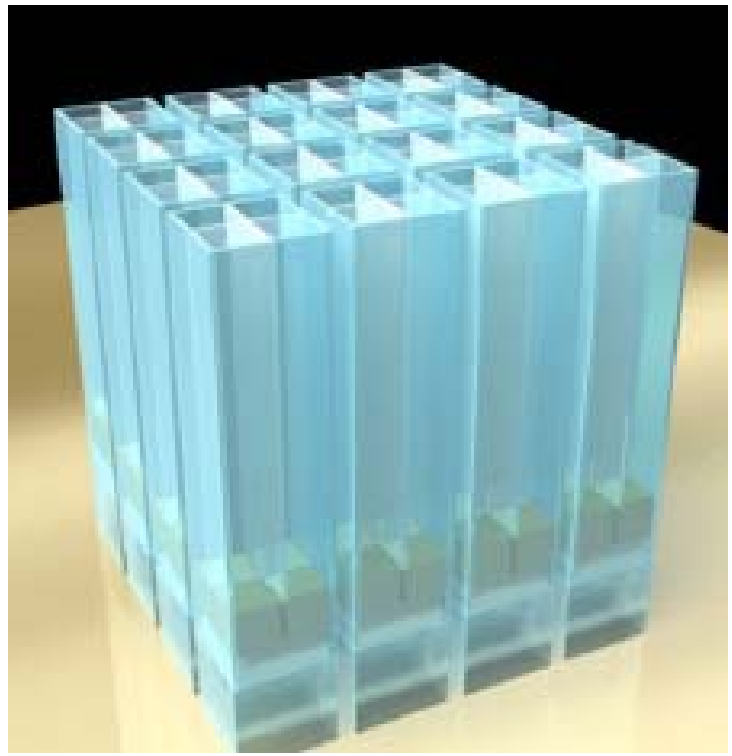
NeXT Concept



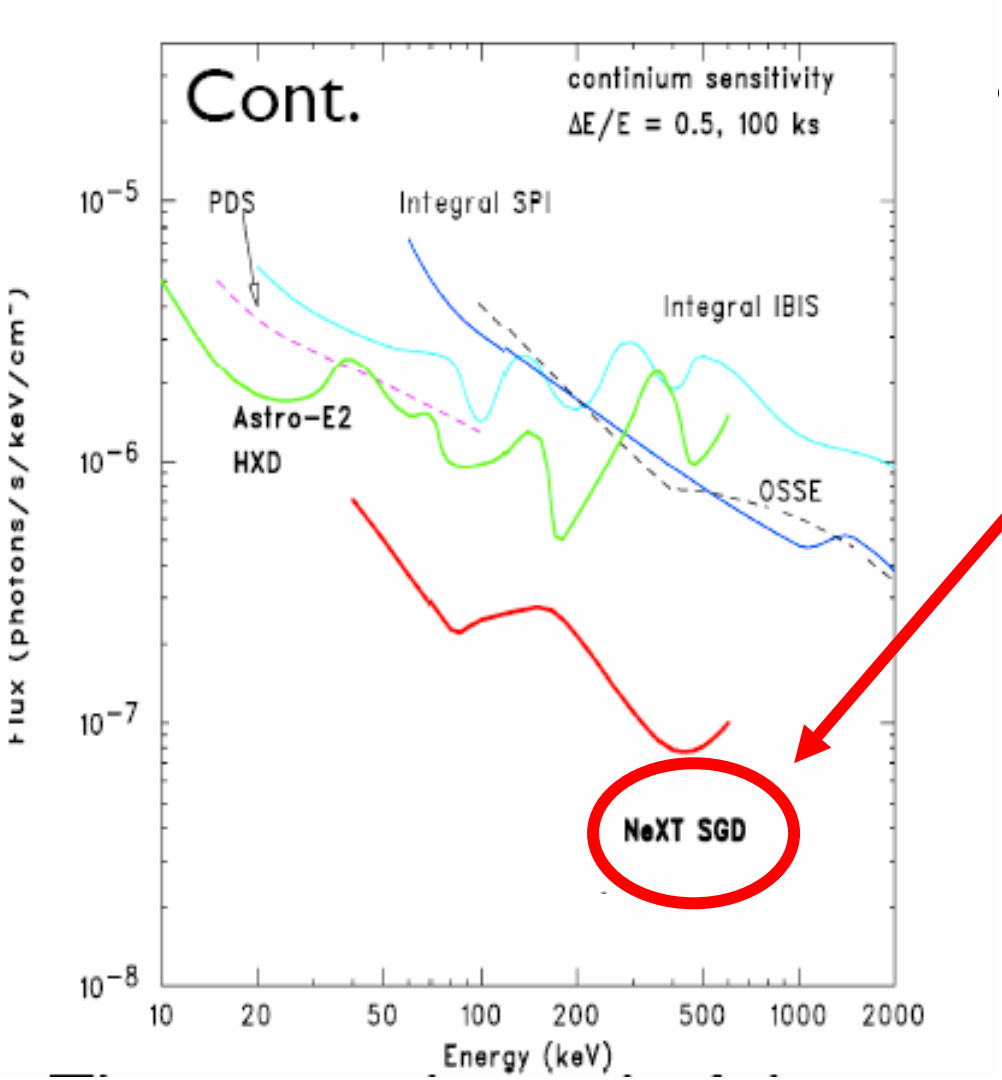
- Three major experiments:
  - SXT: An X-ray TES microcalorimeter at the focus on an XRT.
  - HXT: A CdTe detector at the focus of a NuSTAR-like telescope.
  - SGD: An actively collimated soft gamma-ray telescope.

SLAC will participate in the SGD



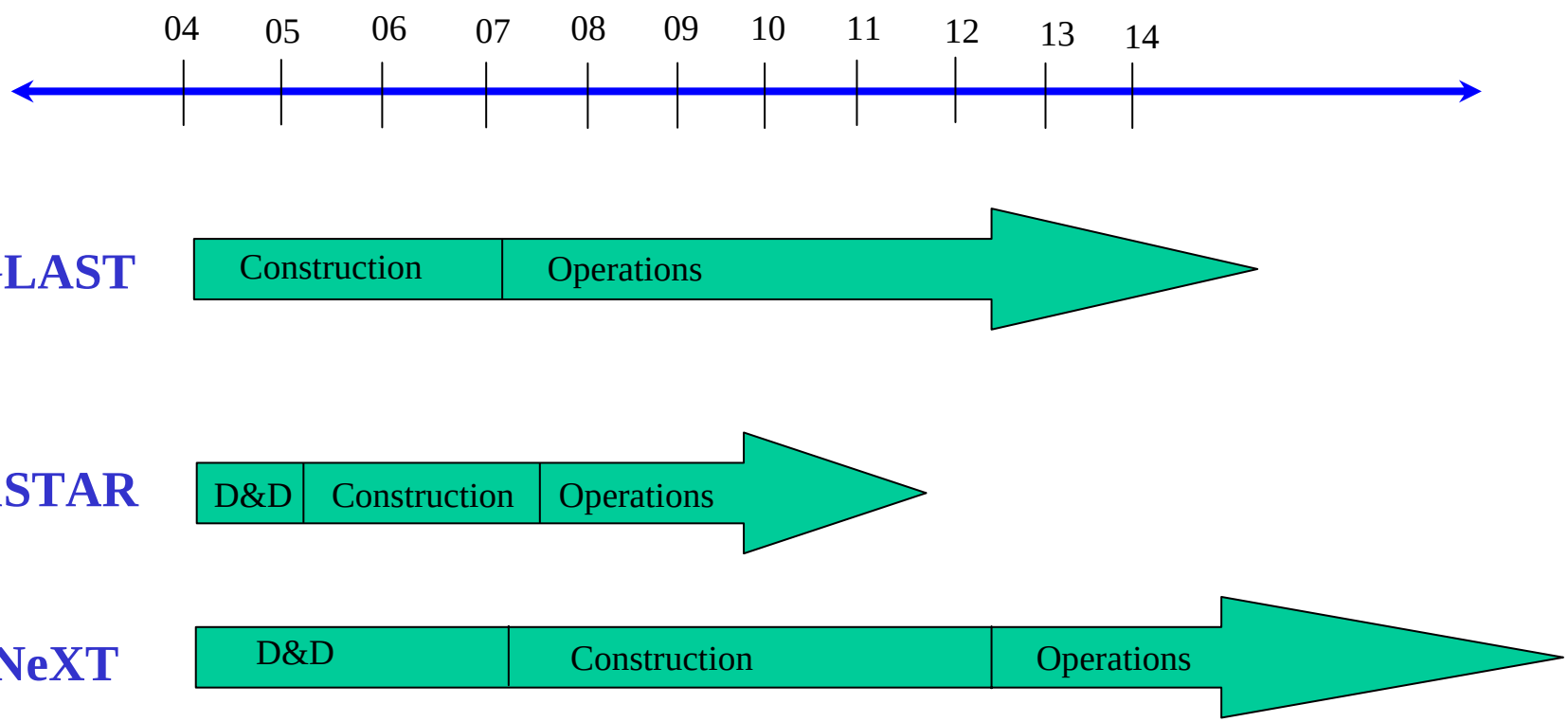


SGD Sensitivity



The SGD will achieve dramatic improvements in sensitivity over the 100 - 600 keV band.

Schedules


04
05
06
07
08
09
10
11
12
13
14
GLAST
Construction
Operations
NuSTAR
D&D
Construction
Operations
NeXT
D&D
Construction
Operations