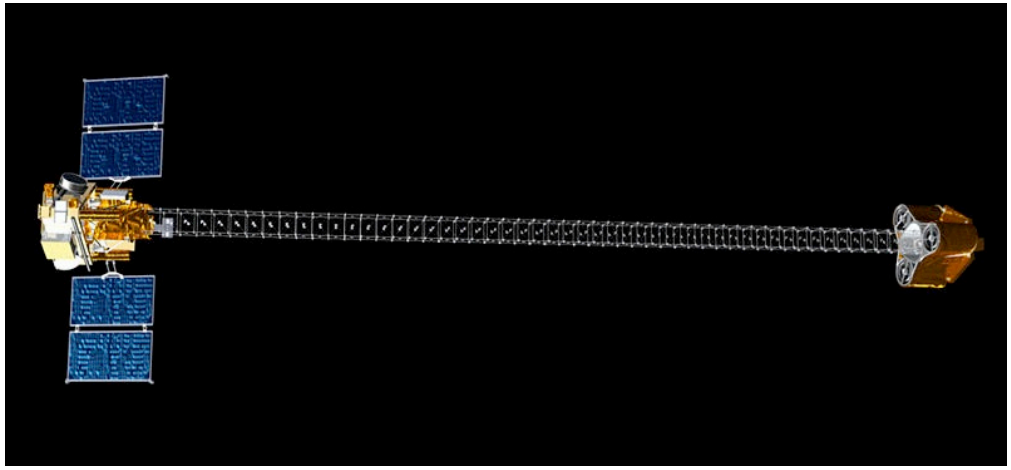
NuSTAR

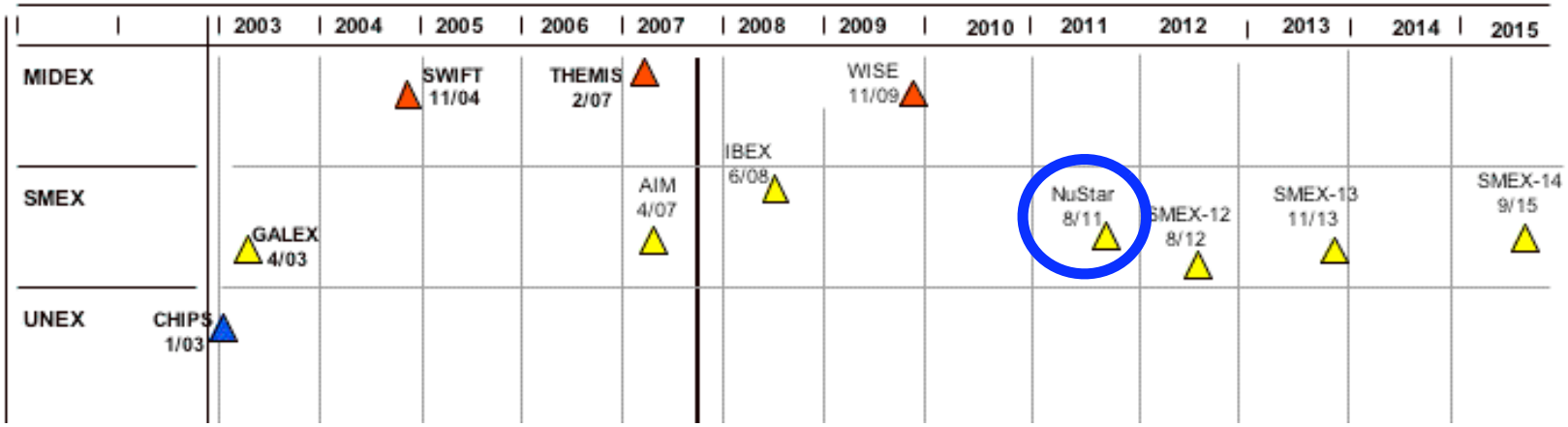
Nuclear Spectroscopic Telescope Array

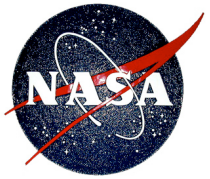
Daniel Stern, Project Scientist
(JPL/Caltech)



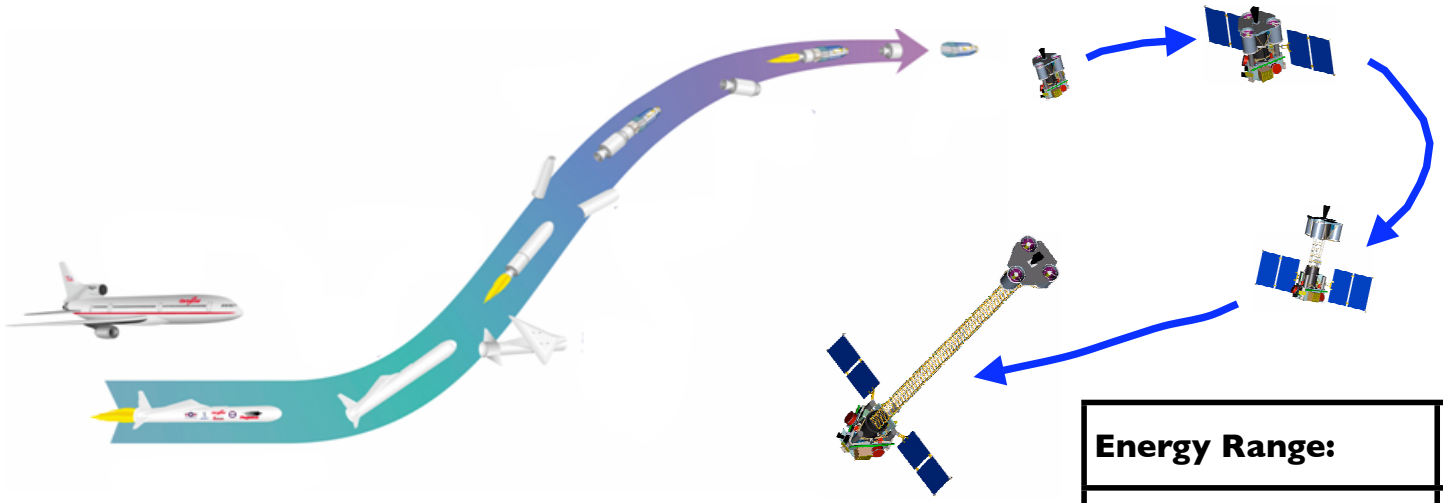
Cosmic Cartography
Chicago, 2007 December

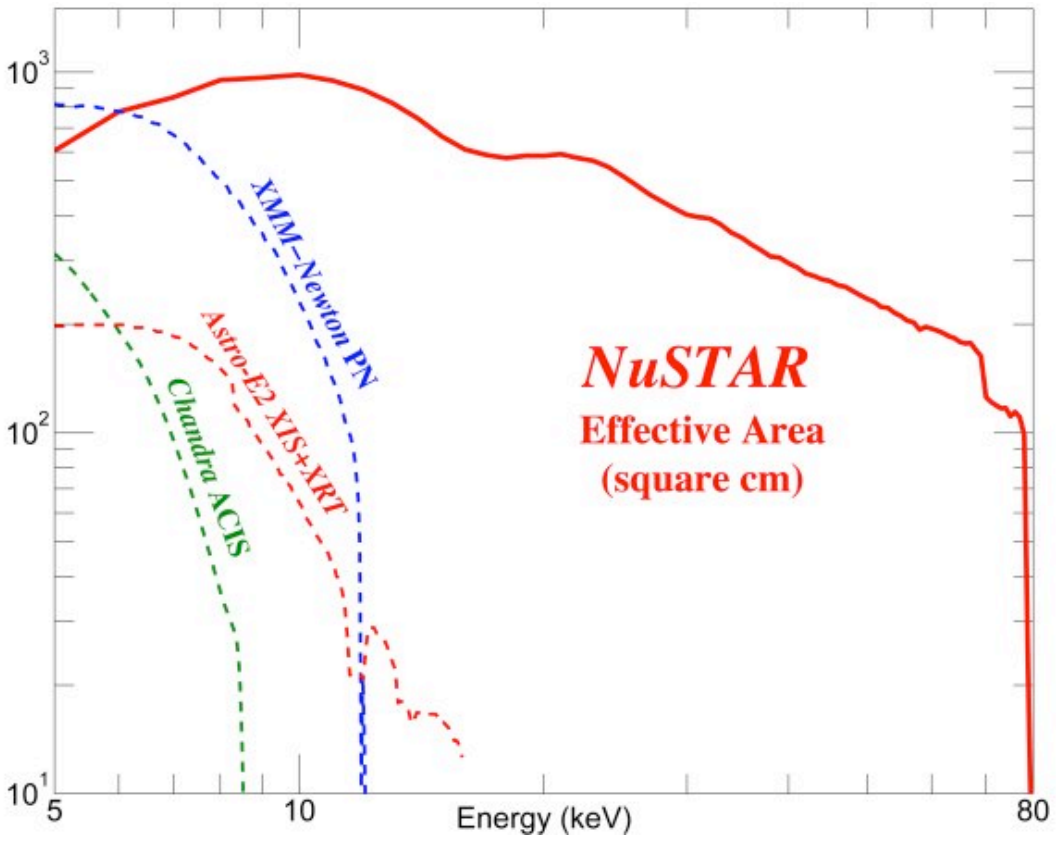
Launch Schedule





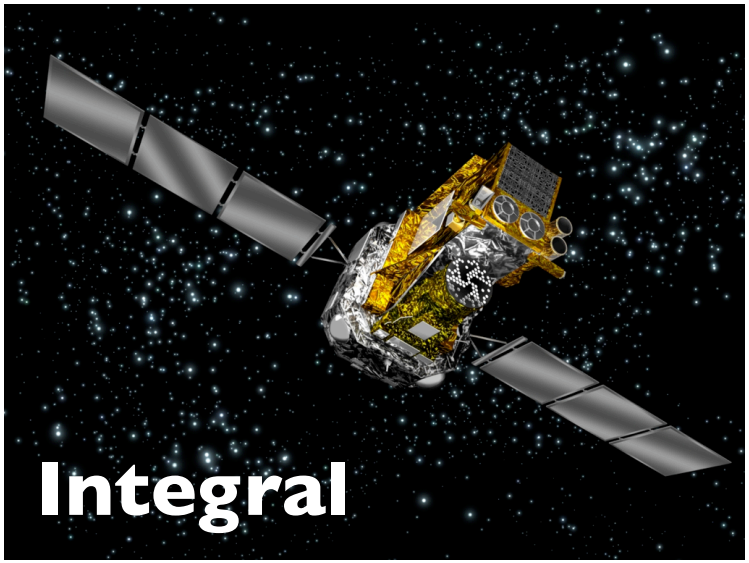
Fiona Harrison (P.I., Caltech)
Steve Boggs (UC-Berkeley)
Finn Christensen (DSRI)
Lynn Cominsky (EPO, Sonoma State)
Walter Cook (Caltech)
William Craig (Inst. Manager, Livermore)
Charles Hailey (Columbia)
Greg Madejski (Stanford)
David Meier (JPL/Caltech)
Daniel Stern (Proj. Sci., JPL/Caltech)
Stephen Thorsett (UC-Santa Cruz)
Stan Woosley (UC-Santa Cruz)
Yunjin Kim (Proj. Manager, JPL/Caltech)
Will Zhang (GSFC)
Andrea Razzaghi (GSFC)

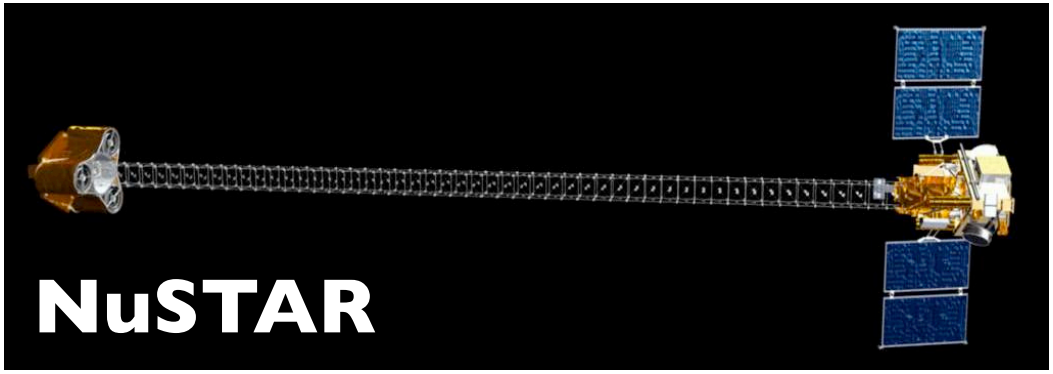


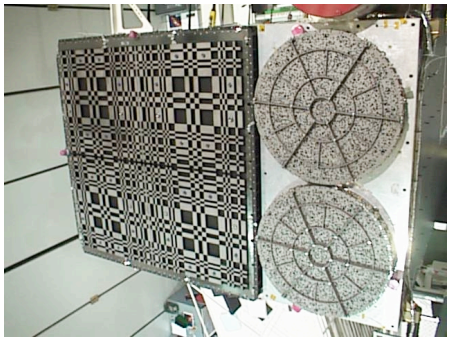


Energy Range:	6-80 keV
Angular Resolution:	40 arcsec (HPD)
Field of View:	13.4 x 13.4 arcmin
Spectral Resolution:	1 keV at 68 keV
Sensitivity (3σ, 1 Ms):	1 μCrab (20 keV) 10 μCrab (60 keV)
Timing Resolution:	1 msec
ToO Response:	<24 hr
Launch Date:	August 2011
Orbit:	27 degrees 525 km
Orbit Lifetime:	84 months (nominal)

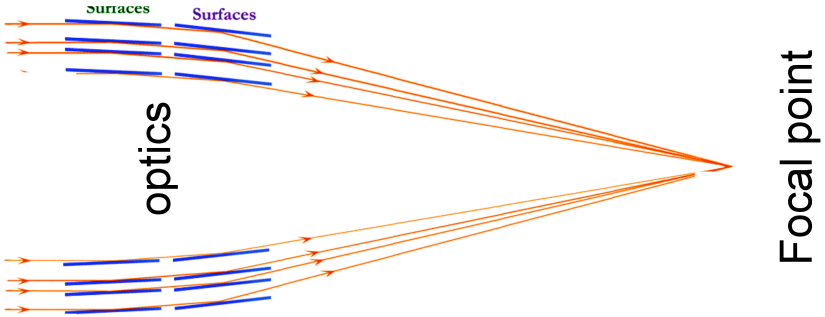
NuSTAR's **breakthrough** is the first use of focusing optics in the hard X-ray band





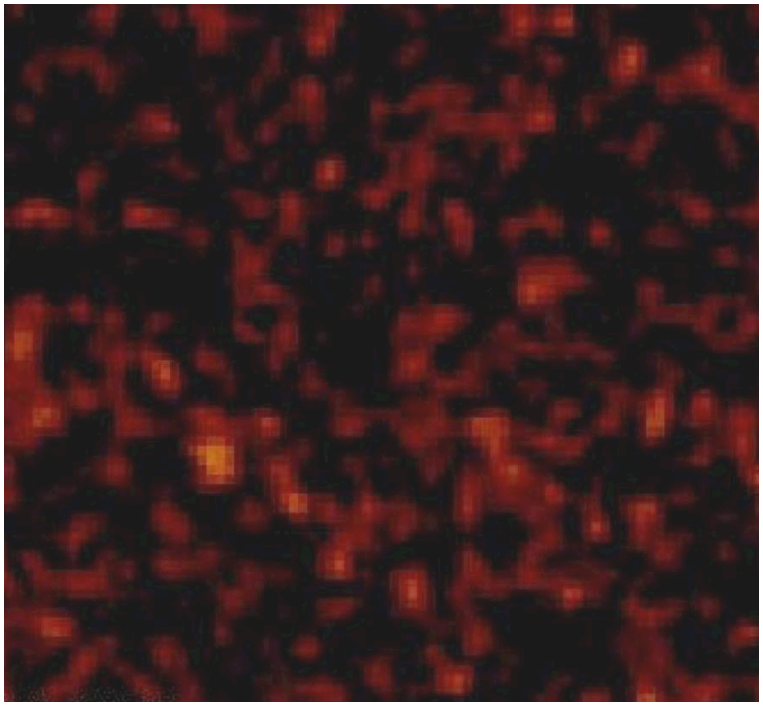


Pinhole Camera:
high background, large detector



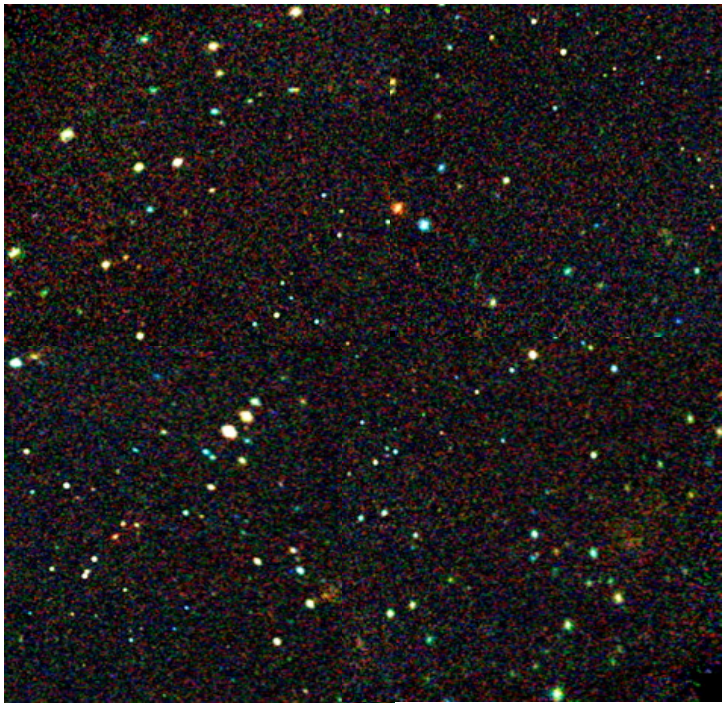
Focusing Telescope:
low background, compact detector

Integral

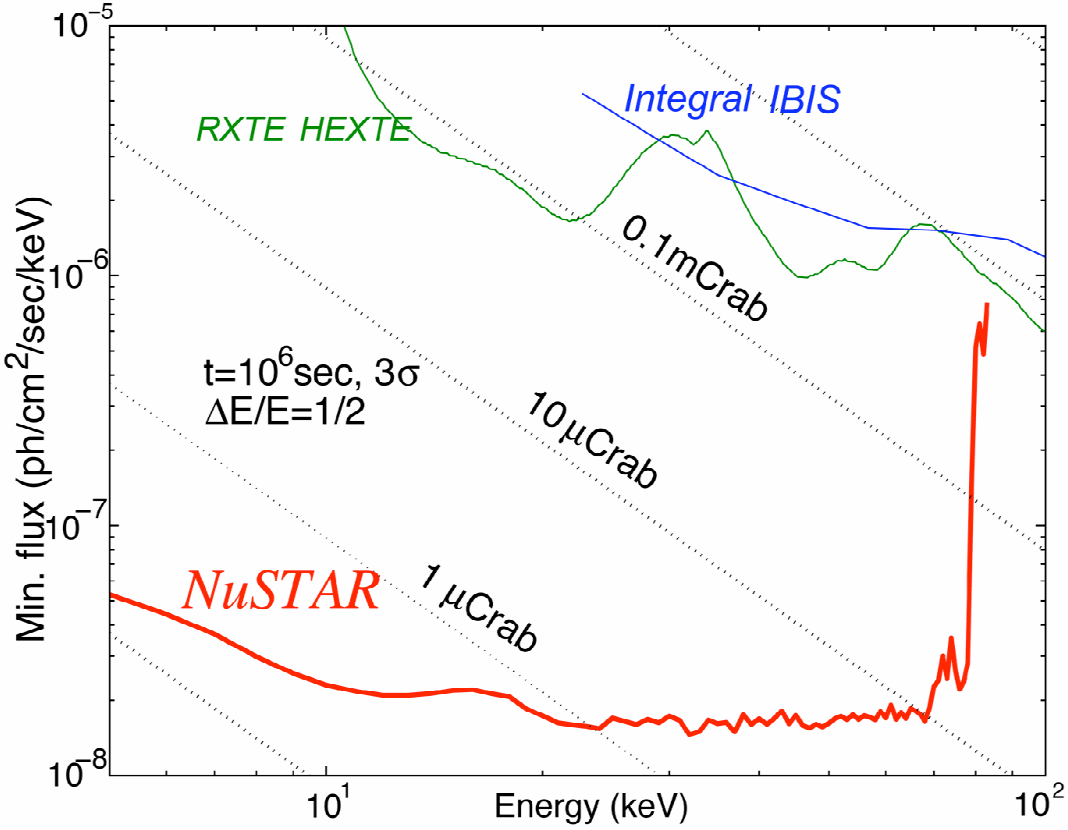


2x2 degrees, 20-40 keV
1.5 month w/ IBIS

NuSTAR



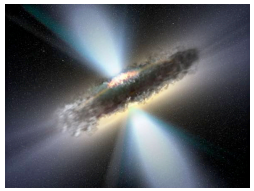
2x2 degrees
simulated NuSTAR image



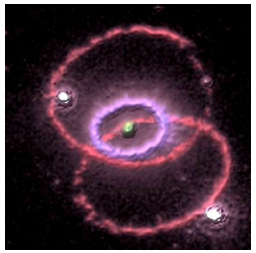
More than an order of magnitude advance in spatial and spectral resolution!

More than 2 order of magnitude advance in sensitivity!

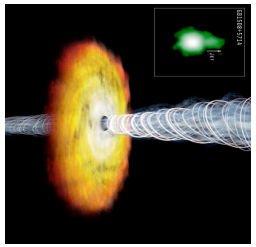
Why Open the Hard X-Ray Band?



Hard X-rays are the peak in emission from active black holes in the centers of galaxies; shining with a luminosity that rivals that of starlight

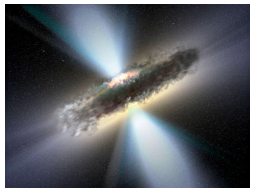


Hard X-rays escape from the deepest layers of exploding stars, revealing newborn chemical elements



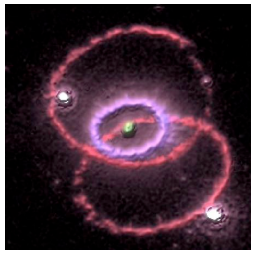
Hard X-rays are copiously emitted by the most extreme particle accelerators found anywhere in the universe

Science Objectives of NuSTAR



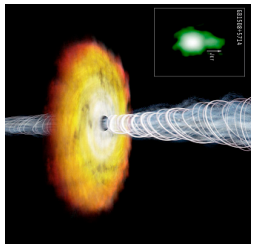
Goal #1: How are black holes distributed through the cosmos, and how do they affect the formation of galaxies like our own?

- *15 months surveying regions of the sky*



Goal #2: How do stars explode and forge the elements that compose the Earth?

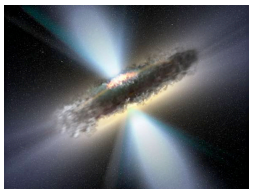
- *6 months mapping young supernova remnants*



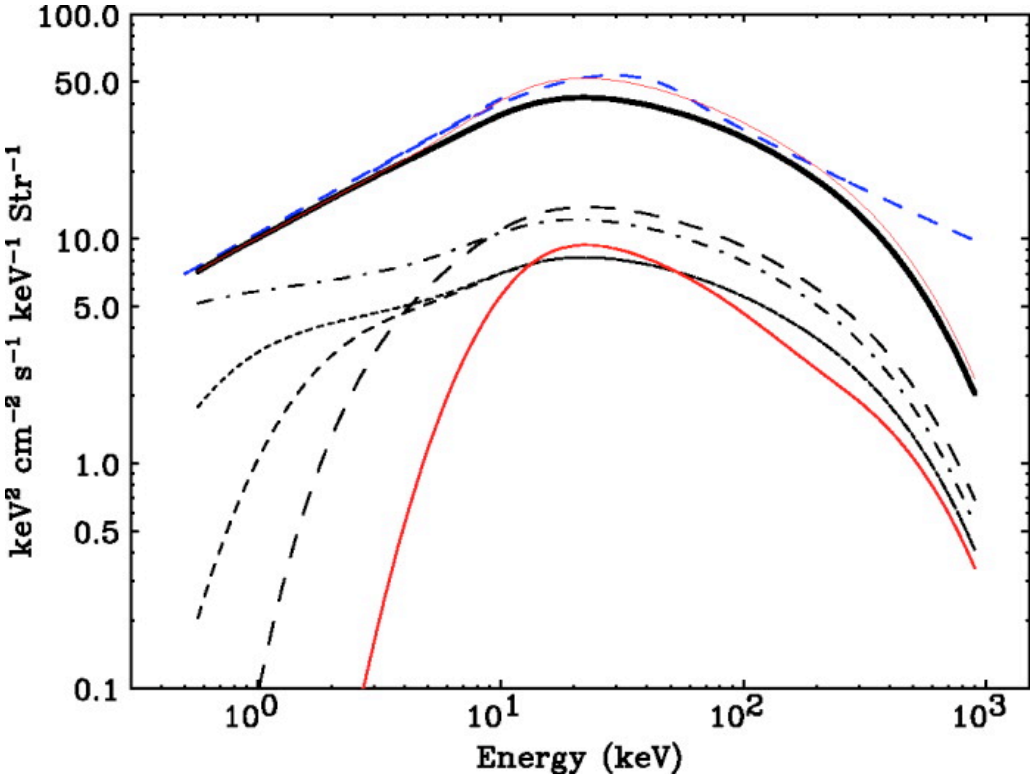
Goal #3: What powers the most extreme active galactic nuclei?

- *3 months monitoring extreme black holes.*

- *10 months of science reserve; discovery follow-up + community access*

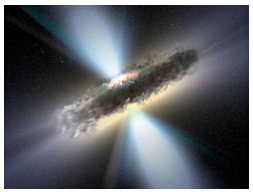


Goal #1: Census of Black Holes
Probe the Cosmic X-Ray Background



- peaks at ~30 keV
- constrains the accretion history of the universe, e.g., the formation history of supermassive black holes
- requires a population of heavily obscured AGN

Ueda et al. 2003, ApJ, 598, 886



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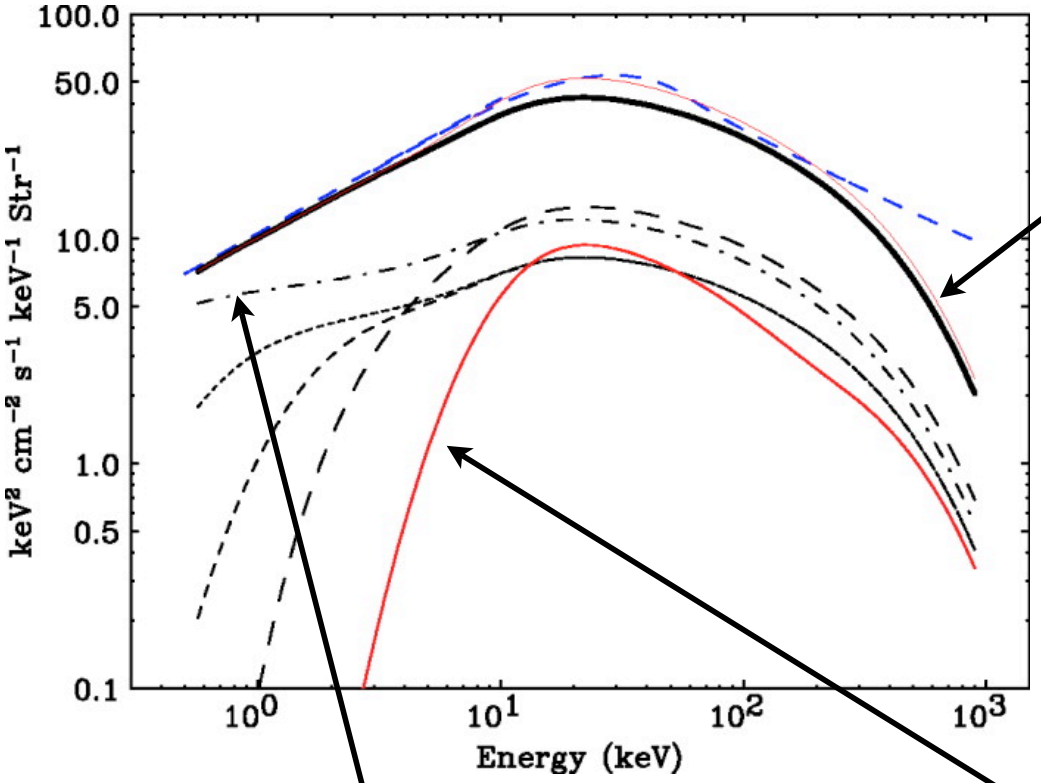
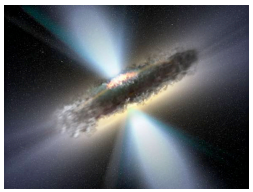


cosmic X-ray background

unobscured sources

heavily obscured sources

Ueda et al. 2003, ApJ, 598, 886



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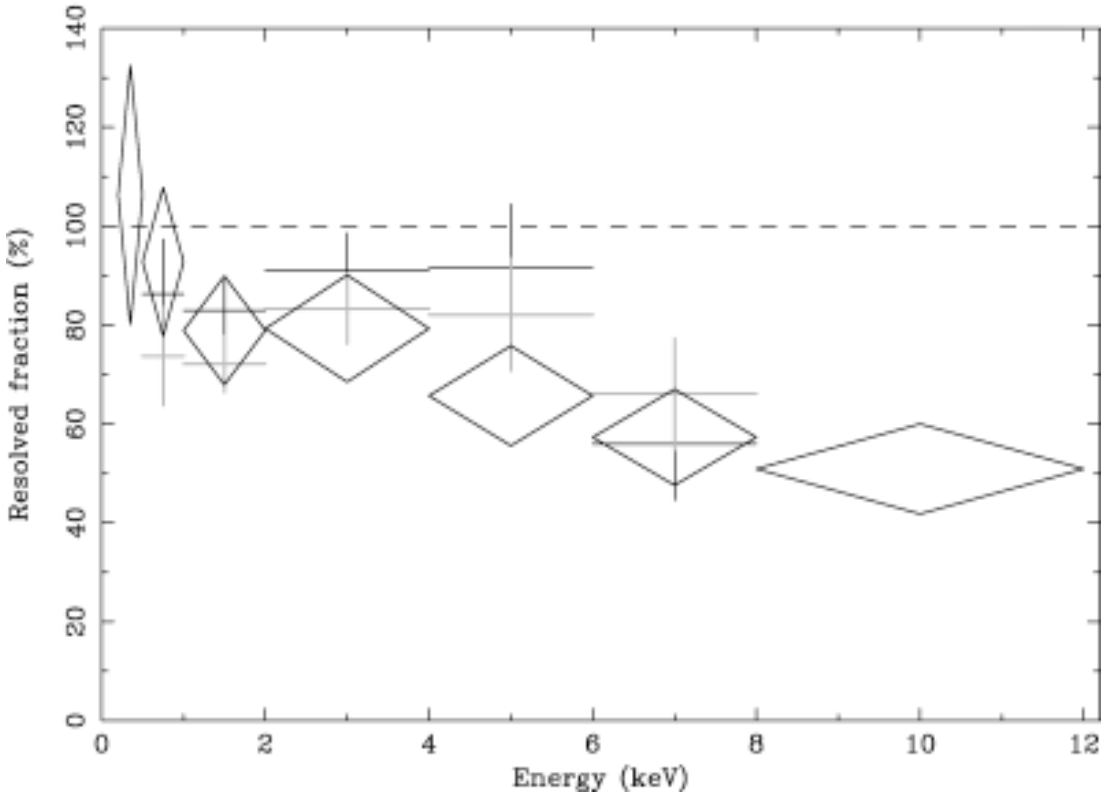
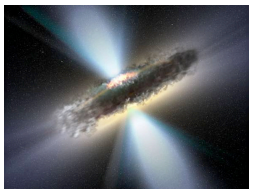
Probe the Cosmic X-Ray Background

fraction of the cosmic X-ray background which is resolved as a function of energy



pluses = Chandra Deep Fields/GOODS
diamond = XMM Lockman Hole

Worsley et al. 2005, MNRAS, 357, 1281



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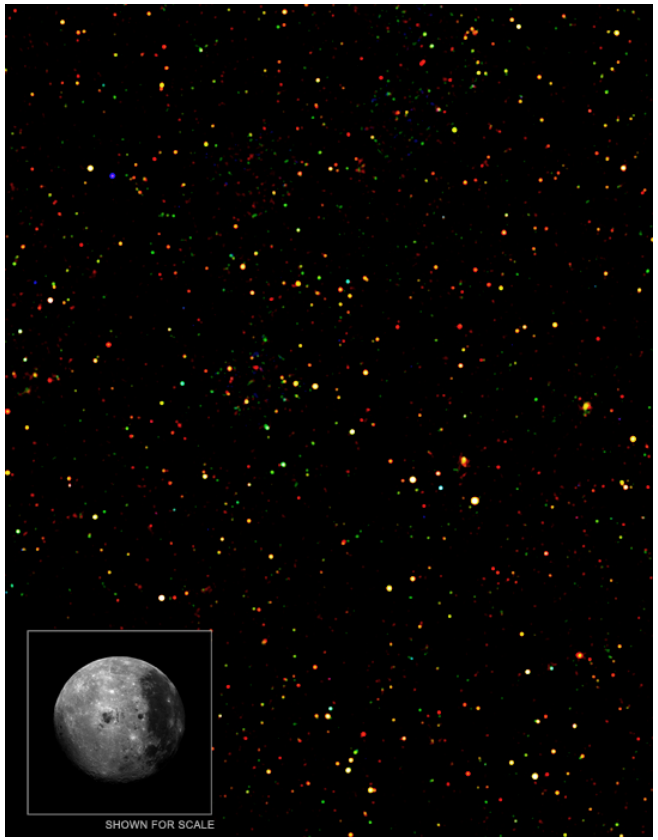
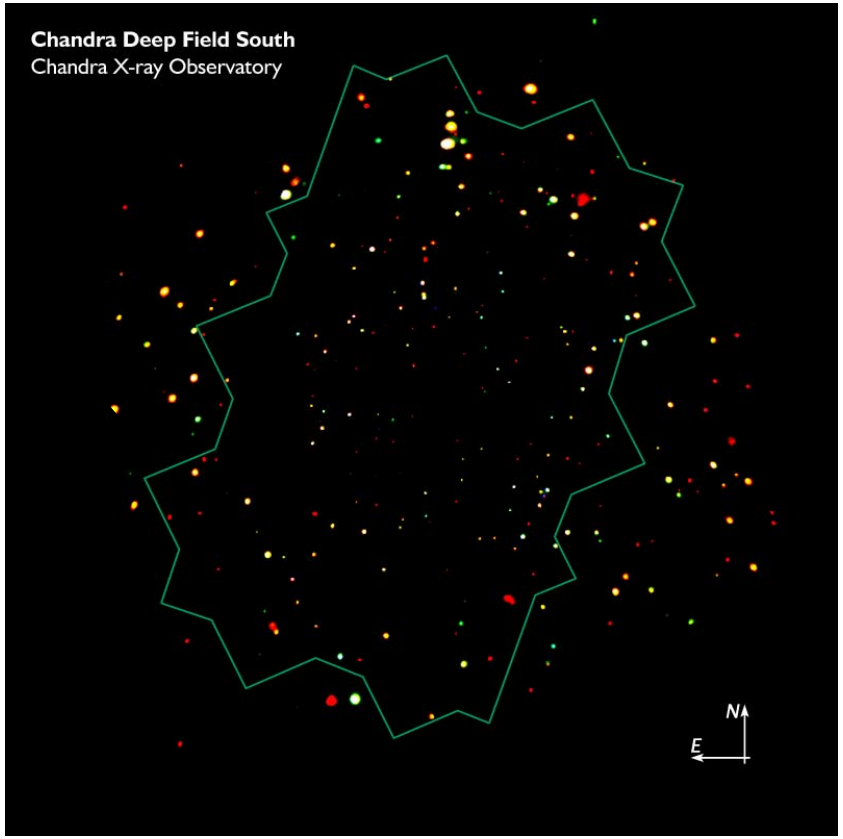
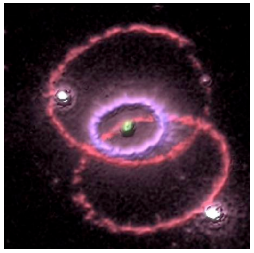


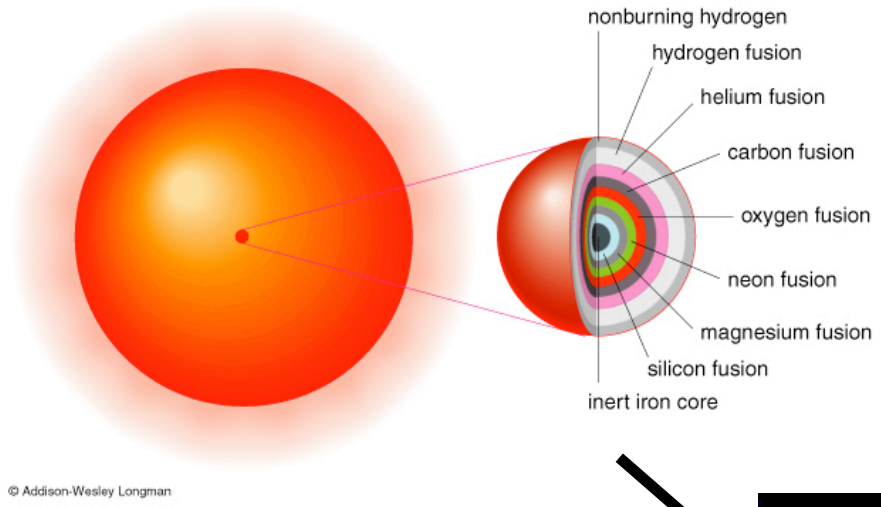
NDWFS Boötes Field
9 deg^2
8 month survey

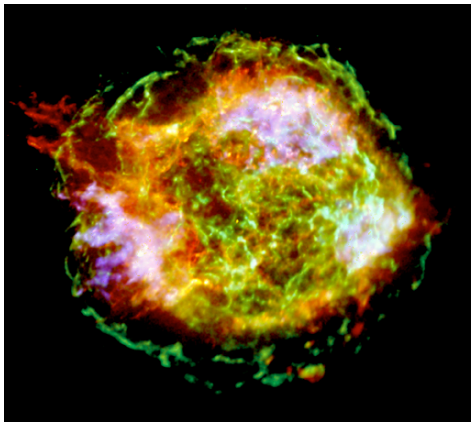


GOODS Fields
300 arcmin^2
3 month survey



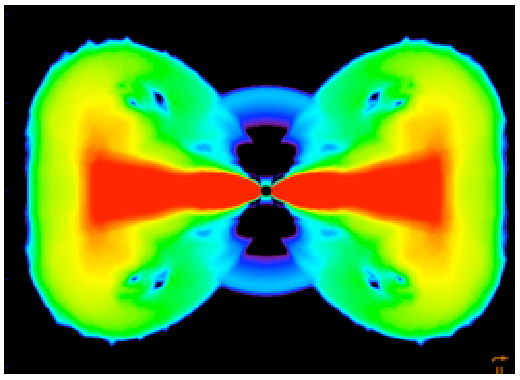
Goal #2: Understand the Physics of Supernovae and Supernova Remnants



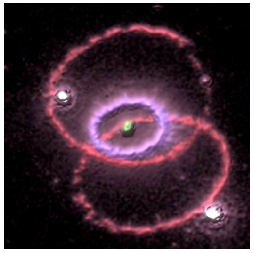


SN Remnant
(Cassiopeia A)

NuSTAR will provide a new, powerful tool for studying the physics of supernove explosions, probing down to the very core



Supernova Explosion
(theory)



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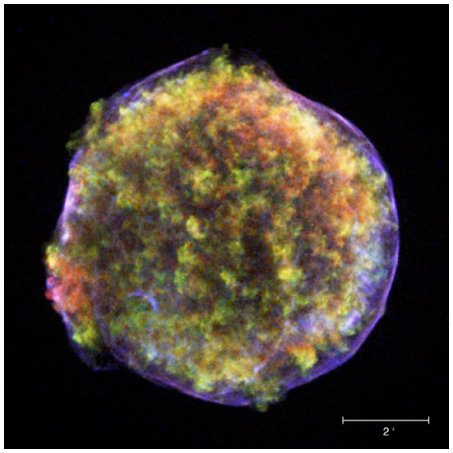
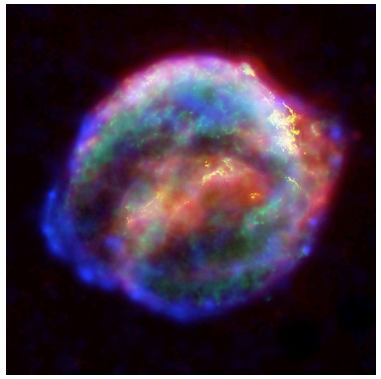
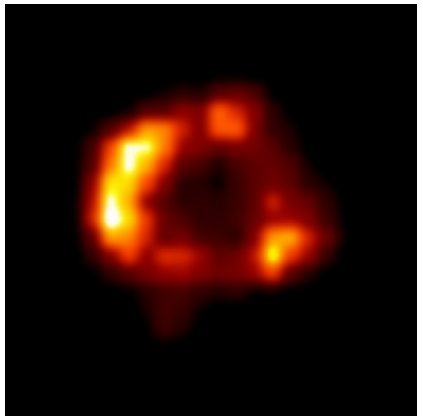


Tycho



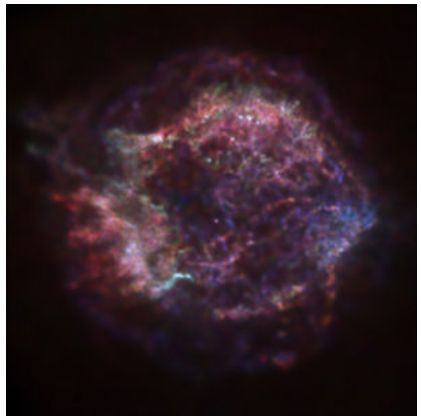
Kepler



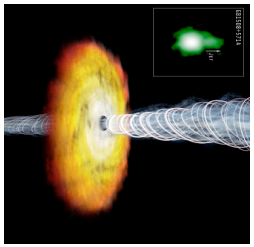
SN 1987A

NuSTAR will spend *6 months* mapping historic supernova

the ^{44}Ti lines at 68 and 78 keV provides important, new diagnostics



Cassiopeia A

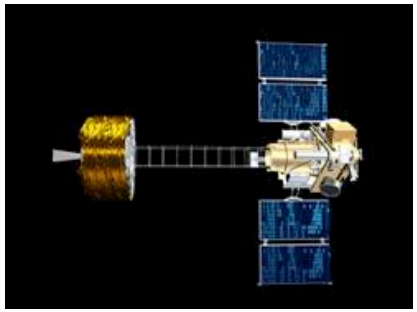


Goal #3: Study Extreme Environments Nature's Powerful Particle Accelerator

NuSTAR will conduct coordinated surveys with NASA's Gamma-ray Large Area Space Telescope (GLAST) and ground-based TeV telescopes to provide "temporal tomography" of nature's most powerful particle accelerators

3 months of observations:

- high-quality, continuous 10-day lightcurves for five TeV blazars
- high-quality 30-day lightcurves for five GLAST blazars
- positioning for other GLAST sources



NuSTAR
X-ray (keV)

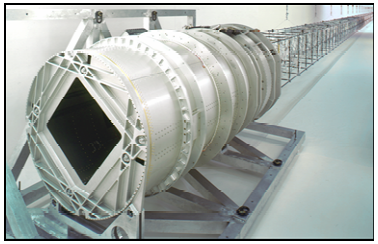
GLAST
γ-ray (MeV-GeV)

Hess, Veritas
γ-ray (TeV)

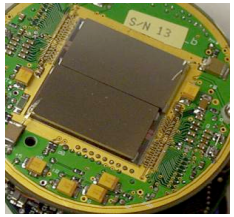
Three Key Technologies

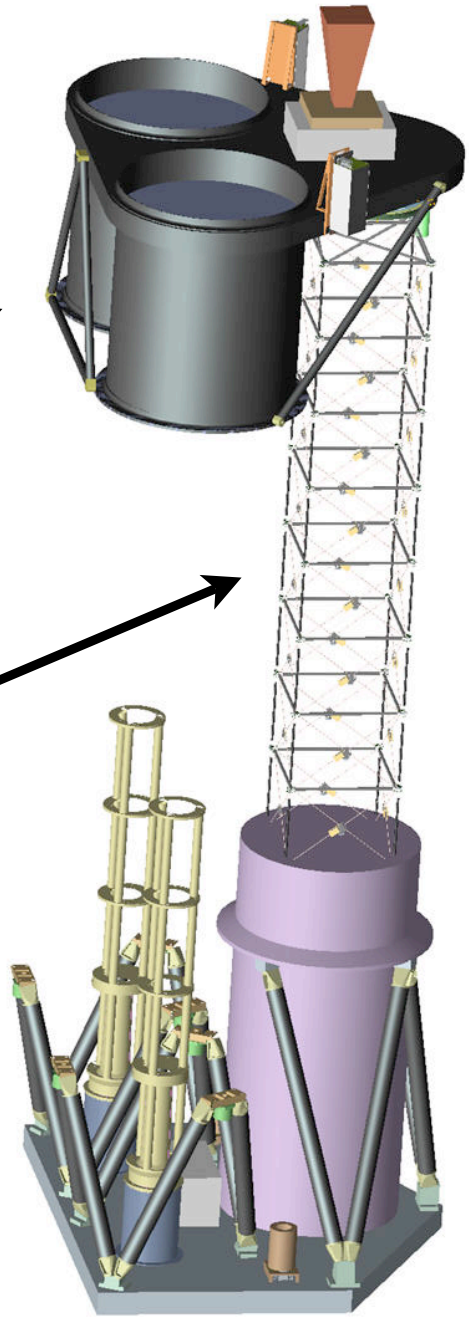
hard X-ray optics
(HEFT balloon)

deployable mast
(SRTM: Shuttle Radar
Topography Mission)

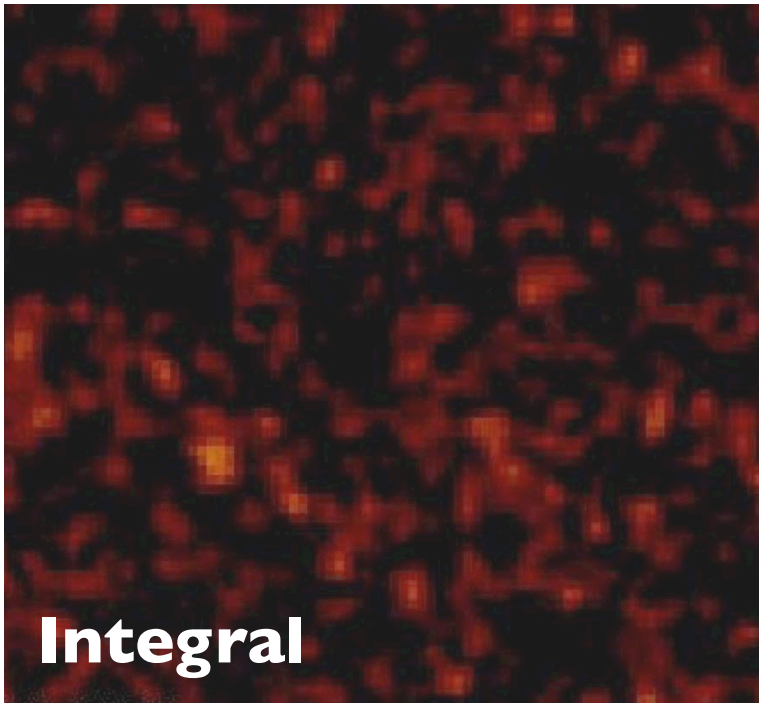


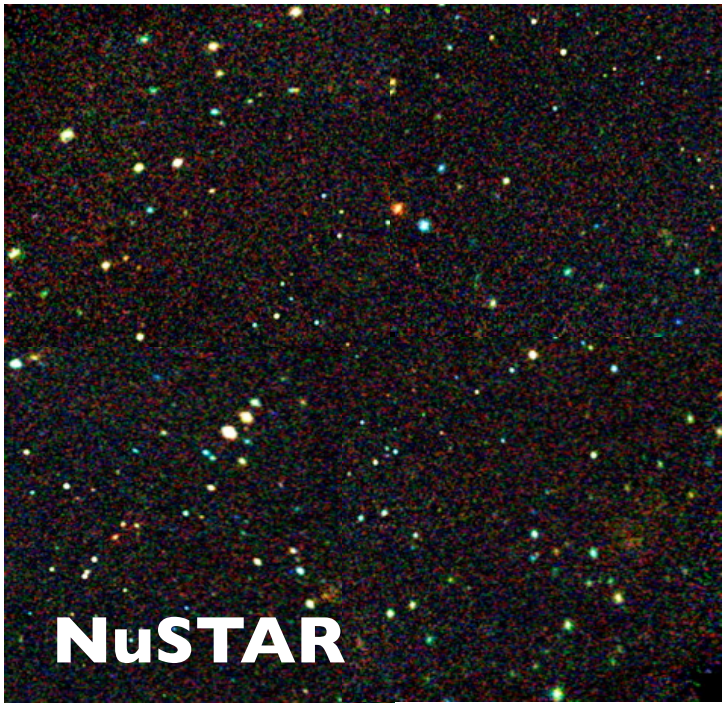
solid state
hard X-ray detector
(HEFT balloon)





Summary





Two orders of magnitude improvement in
sensitivity over any previous hard X-ray mission

NuSTAR will open a new observational frontier by bringing the high energy universe into focus