

NuSTAR: Nuclear Spectroscopic Telescope Array

8th Patras Workshop on Axions, WIMPs and WISPs

22 July 2012, Chicago, IL, USA



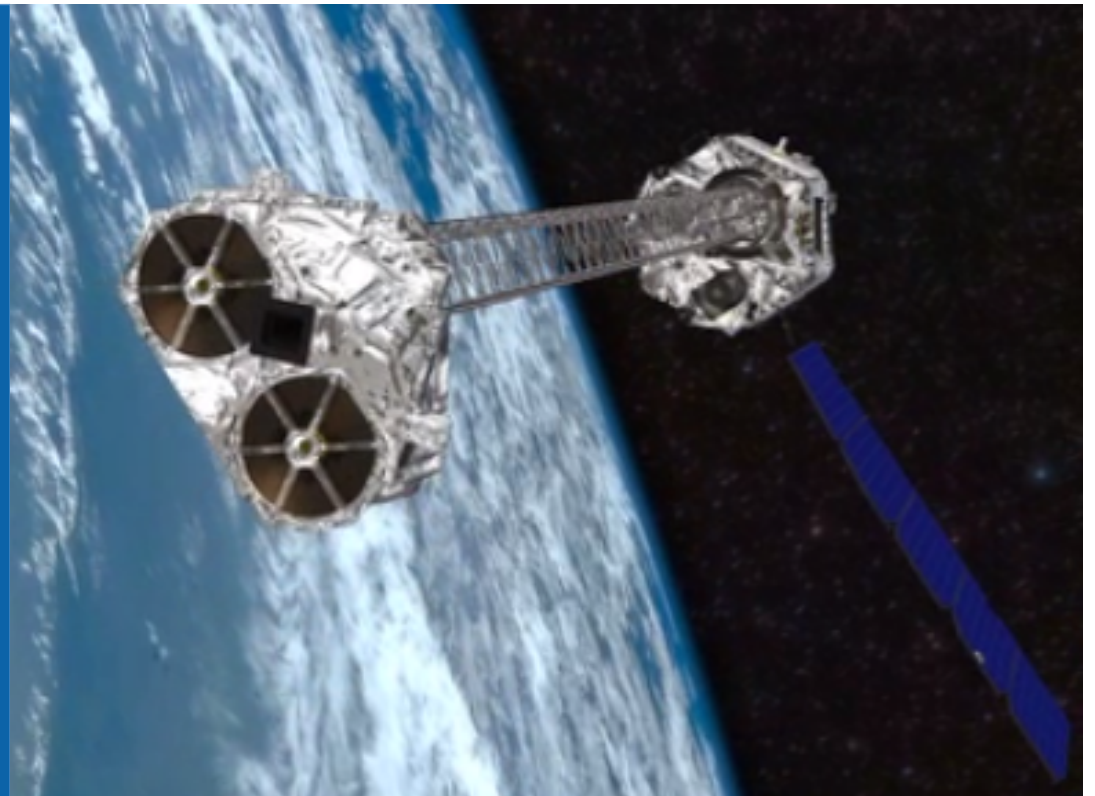
Julia K. Vogel

Lawrence Livermore National Laboratory

On behalf of the NuSTAR instrument team

LLNL-PRES-566156

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U.S. Department of Energy by Lawrence Livermore
National Laboratory under contract DE-AC52-07NA27344.
Lawrence Livermore National Security, LLC



Overview

- Why NuSTAR?
- NuSTAR Performance
- Instrument
 - Optics
 - Focal Plane
 - Mast
- NuSTAR Science
- Launch/Status

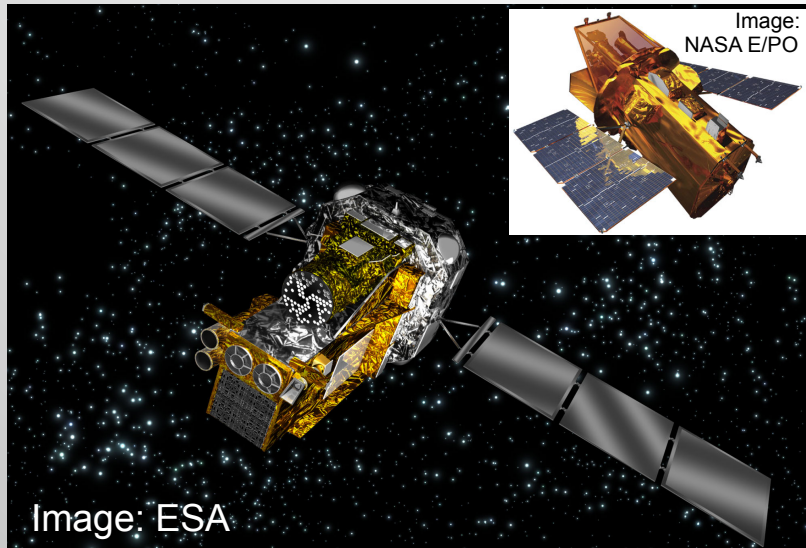
NASA Small Explorer (SMEX) mission
Launched on 13 June 2012
Pegasus XL rocket out of Kwajalein Atoll
PI: Fiona Harrison (Caltech)
Program management: Jet Propulsion Lab

additional information:

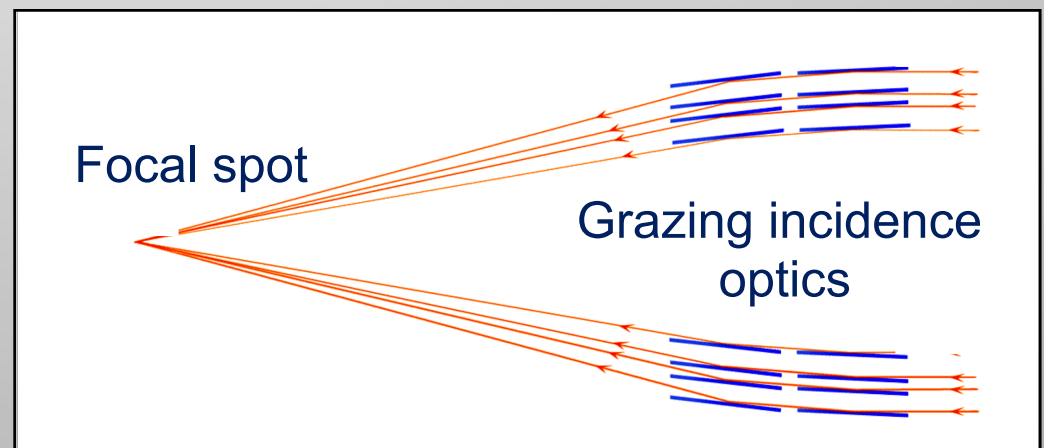
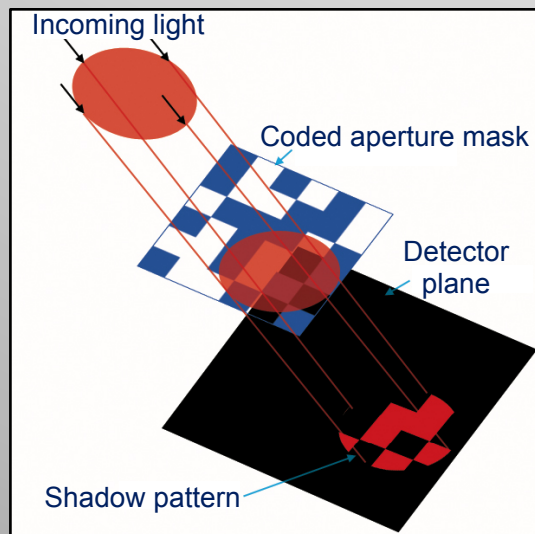
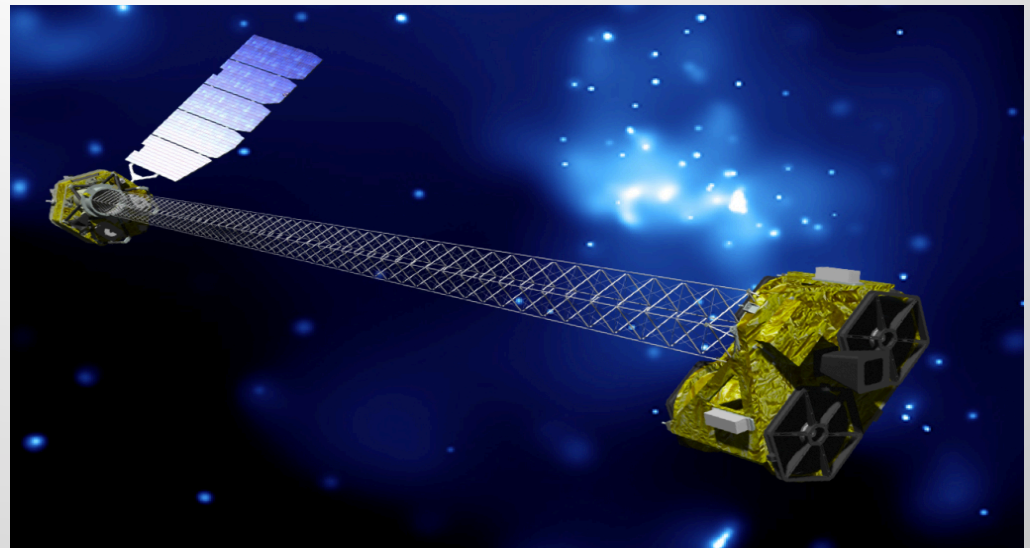
<http://www.nustar.caltech.edu/>



Integral/Swift-BAT



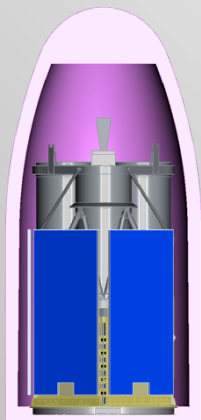
NuSTAR



Mission profile

Pegasus XL launch

13 June 2012



- 375 kg weight
- 725 watts from solar panels
- 6° inclination, 638 km x 621 km, 97 minute period
 - low background
 - 55% observing efficiency

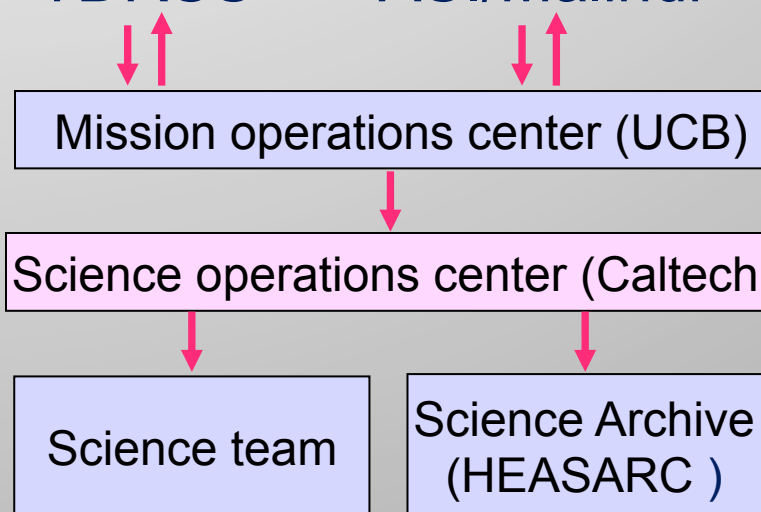
10-m mast deployment

21 June 2012



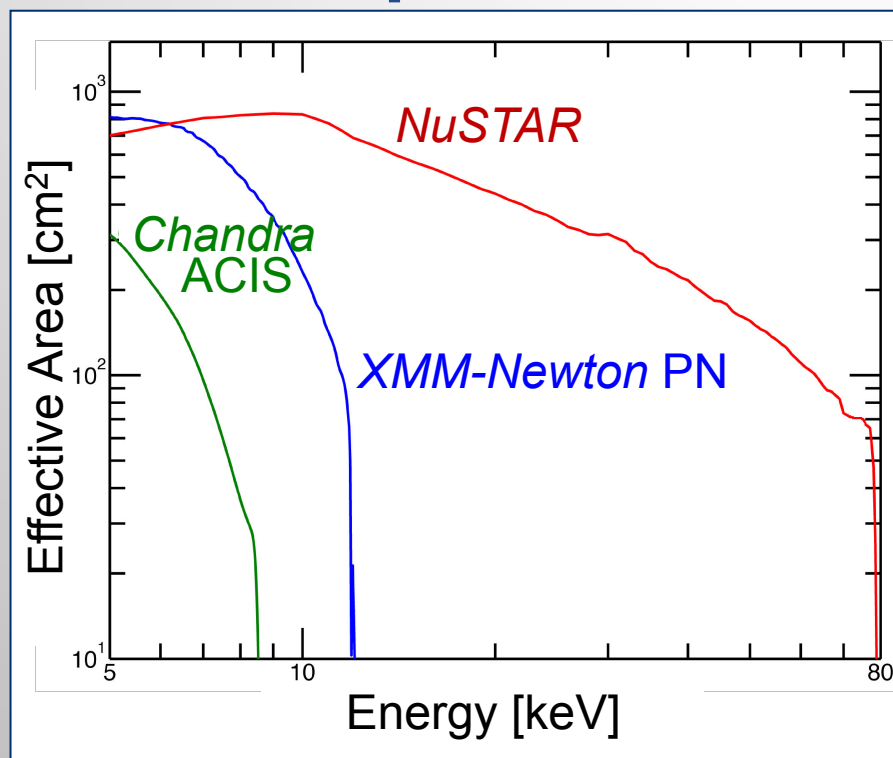
TDRSS

ASI/Malindi



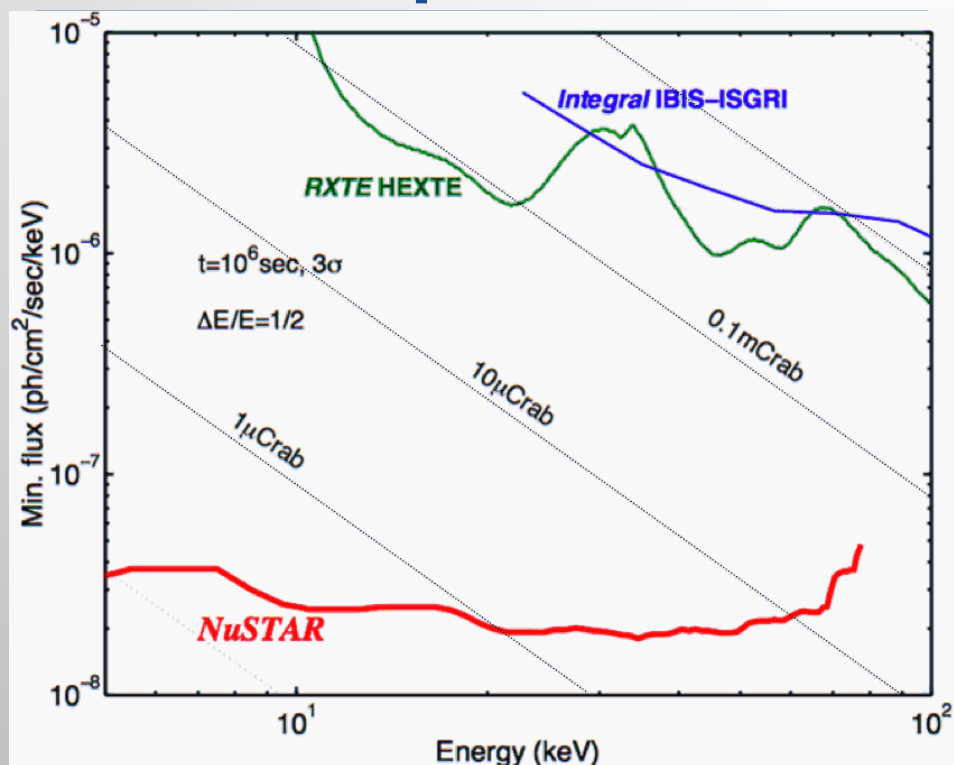
2-year baseline science mission

NuSTAR performance



Energy Range:	5-80 keV
Angular Resolution:	<60 arcsec (HPD, req ^{nt}) ~10 arcsec (FWHM)
Field of View:	12.5 x 12.5 arcmin two 4x(32x32) CdZnTe arrays
Spectral Resolution:	1.0 keV at 60 keV 0.6 keV at 6 keV
Sensitivity (3 σ, 1 Ms):	3.0×10^{-15} erg/cm²/s (6-10 keV) 1.2×10^{-14} erg/cm²/s (10-30 keV)
Timing Resolution:	100 μ sec relative 30 msec absolute
ToO Response:	<24 hr req't (6-8 hr typical) 85% sky accessible at all times
Launch:	June 13, 2012
Orbit:	6 degree inclination 638 km x 621 km 97 min period
Mission Lifetime: Orbit Lifetime:	2 years baseline ~10 years orbit lifetime

NuSTAR performance



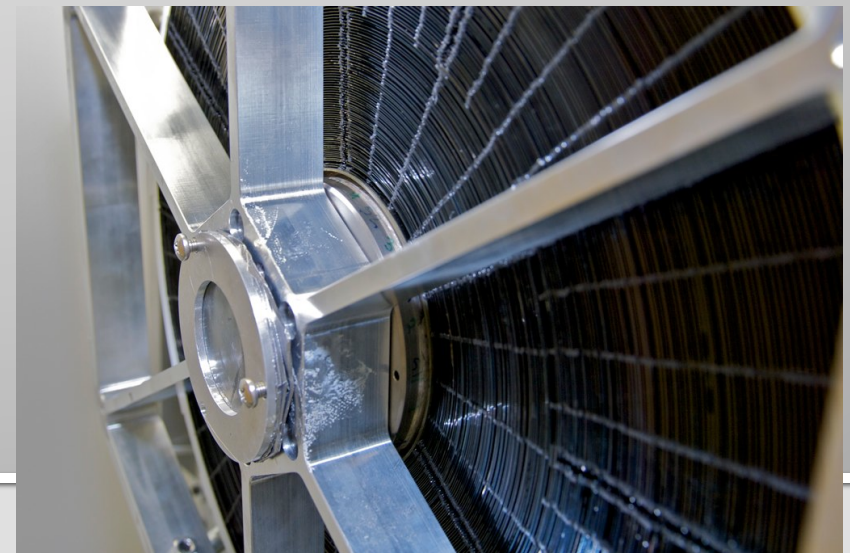
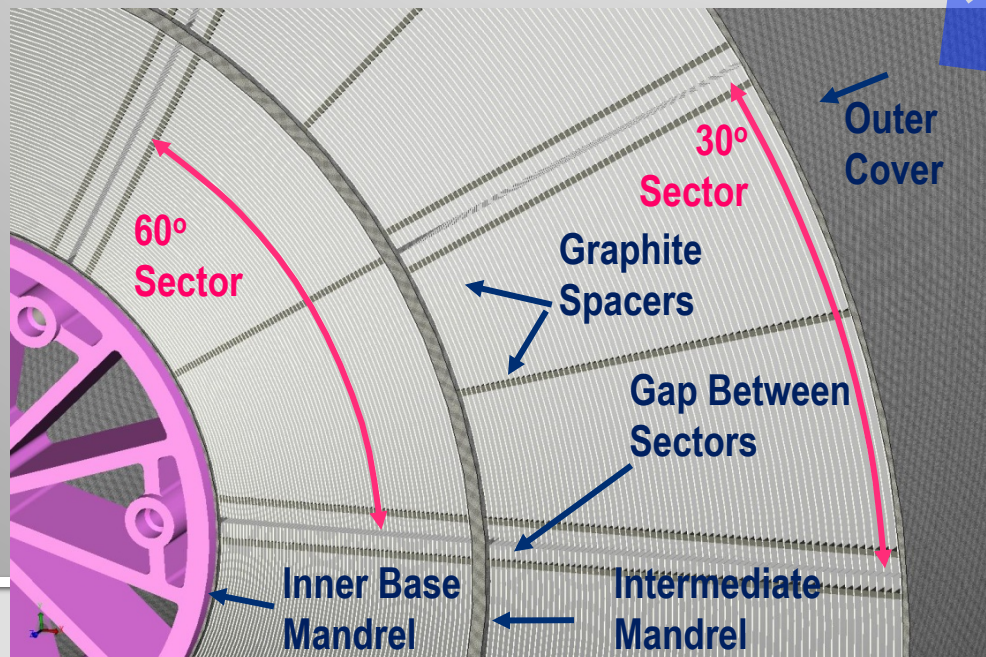
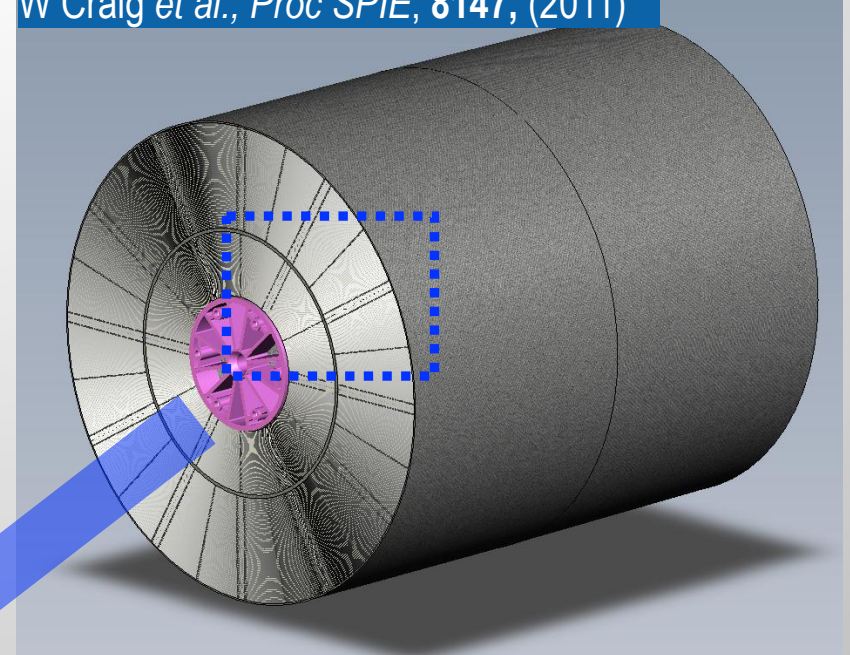
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Satellite/Instr.	Sensitivity
INTEGRAL-ISGRI	~0.5 mCrab (20-100 keV) with >Ms exposures
Swift-BAT	~0.8 mCrab (15-150 keV) with >Ms exposures
NuSTAR	~0.8 μ Crab (10-40 keV) in 1 Ms

NuSTAR Optics

C Hailey et al. *Proc SPIE*, 7732, (2010)
 J Koglin et al., *Proc SPIE*, 8147, (2011)
 W Craig et al., *Proc SPIE*, 8147, (2011)

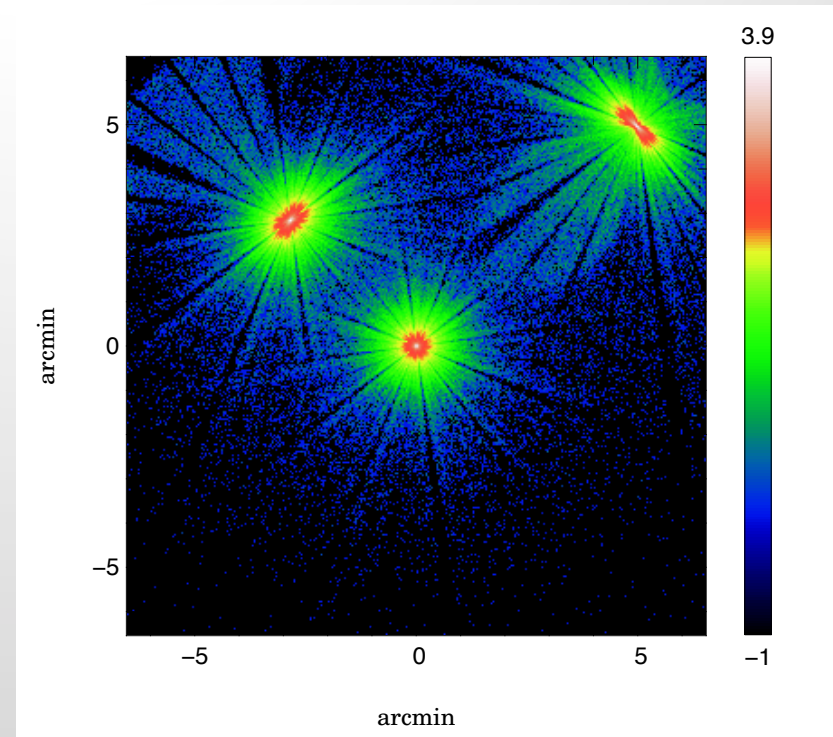
Number of telescopes	2
Focal Length	10.15 m
Shell Radii	51–191 mm
Graze Angles	$0.074\text{--}0.224^\circ$
Shell Length	225 mm
Mirror Thickness	0.22 mm
Shells Per Module	133
Mirror Segments Per Module	2376



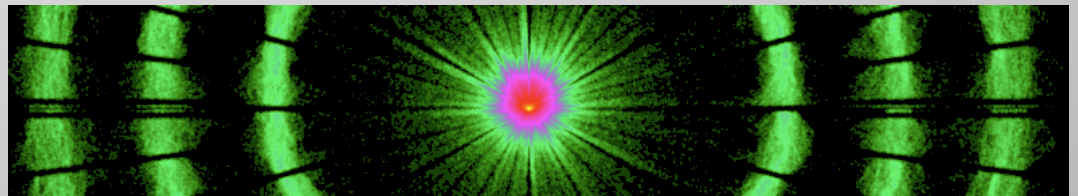
NuSTAR Optics

- Effective area and PSF calibration at RaMCaF
- X-ray tube 163m away from optics:
 - Hard x-ray continuum up to 100 kVp
- Detector at 10.82 m from telescope:
 - Best focus for finite source distance
- Data acquired for variety of illumination conditions

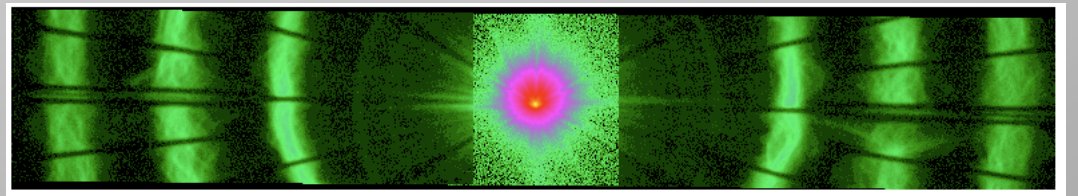
→ All requirements fulfilled



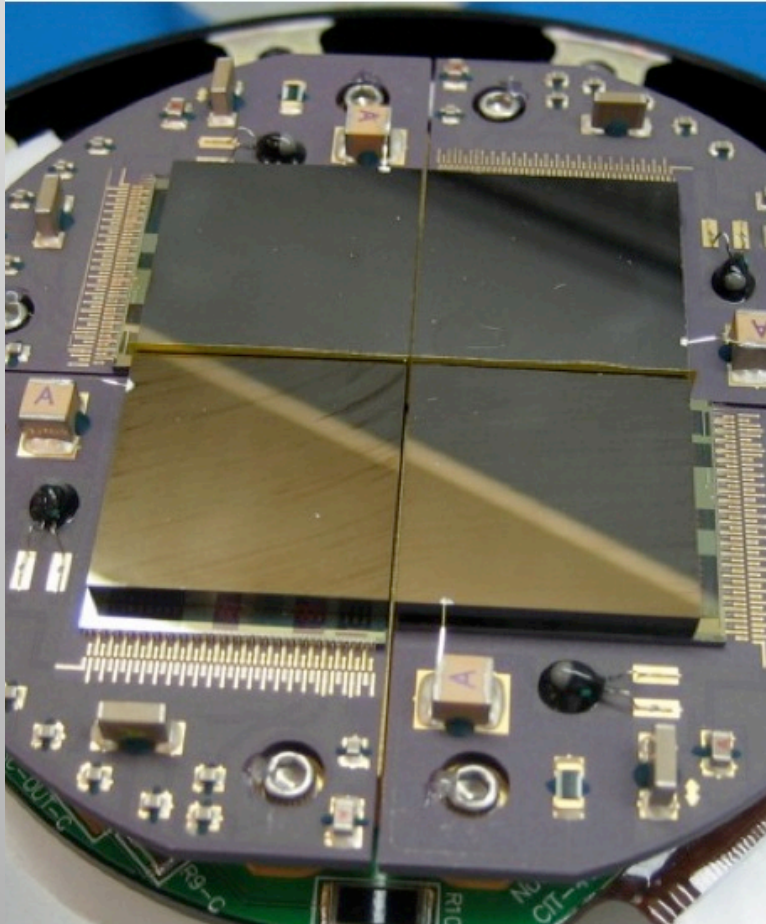
Simulation



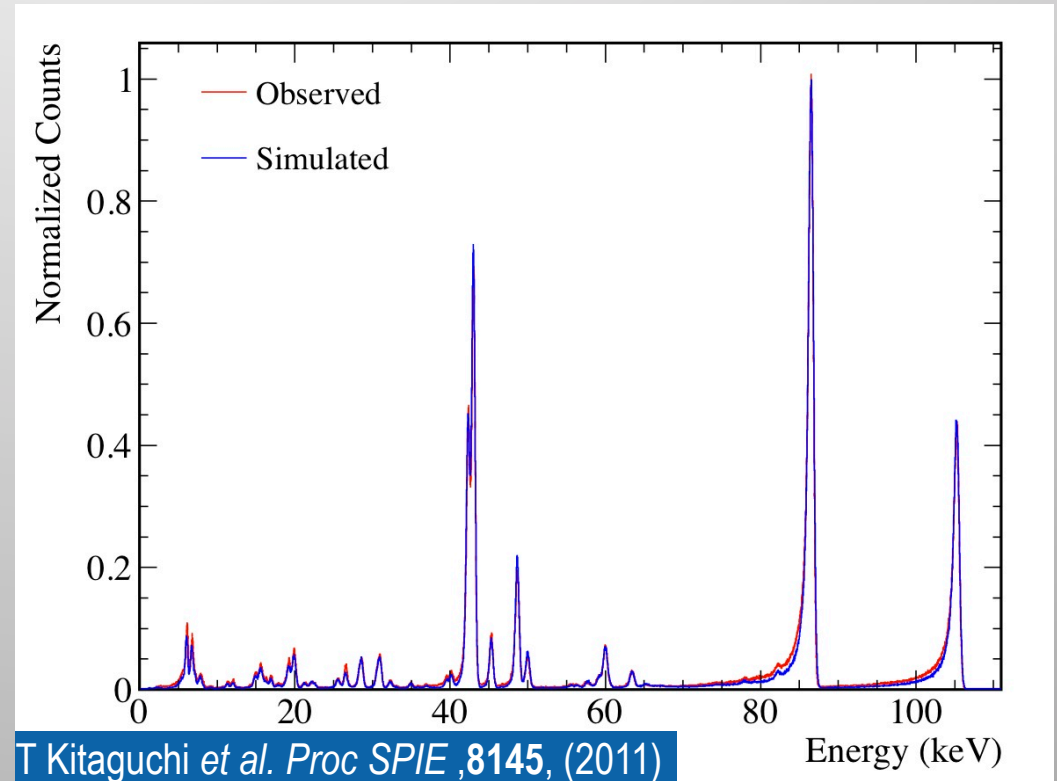
Calibration data



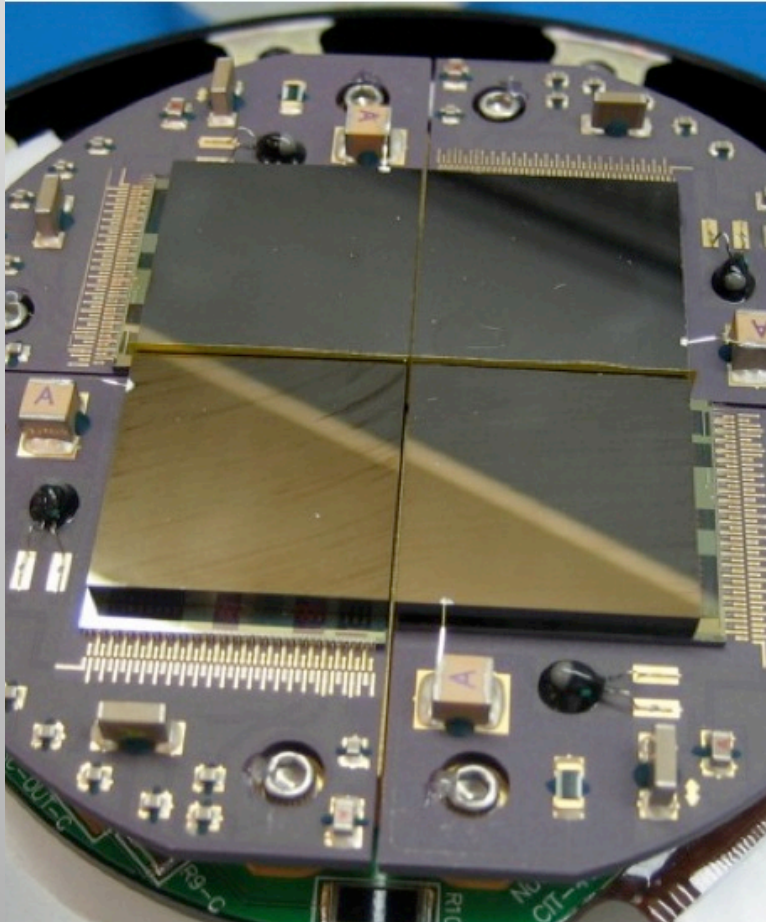
CZT Focal Plane



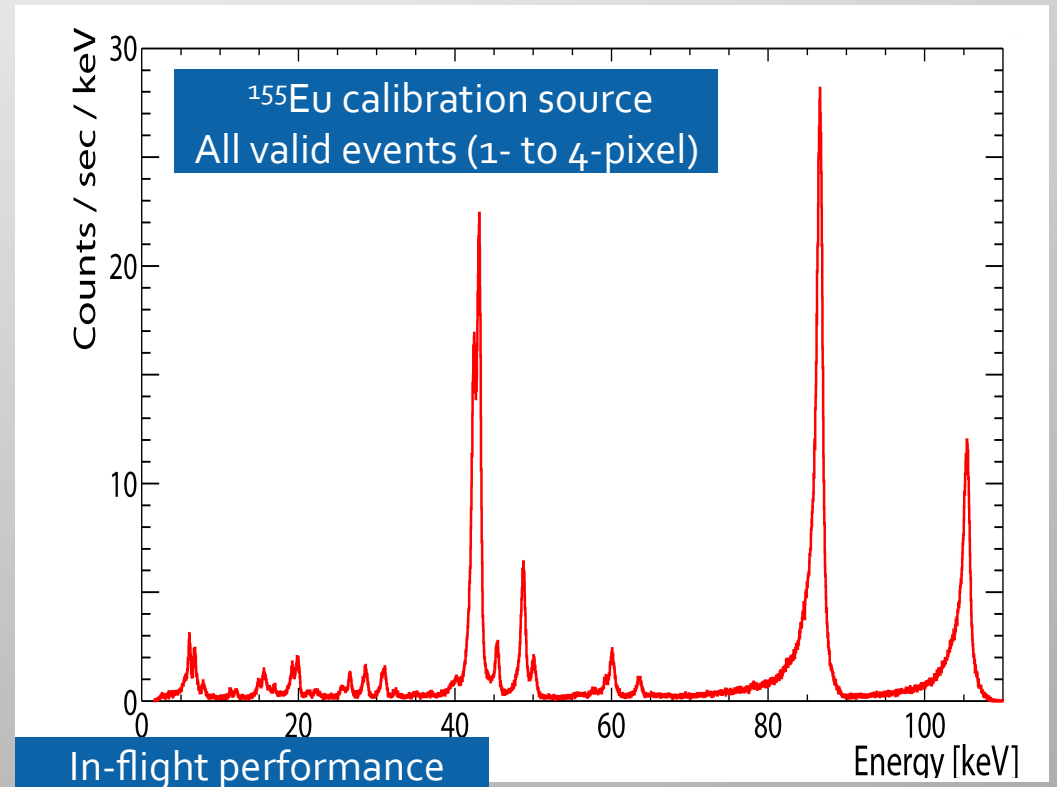
Number of focal planes	2
Chips per focal plane	4 = (2 × 2 array)
Pixels per chip	32 × 32
Pixel pitch	605 μm × 605 μm 12 arcsec × 12 arcsec
Total chip array area	2 cm × 2 cm
CdZnTe thickness	2 mm



CZT Focal Plane

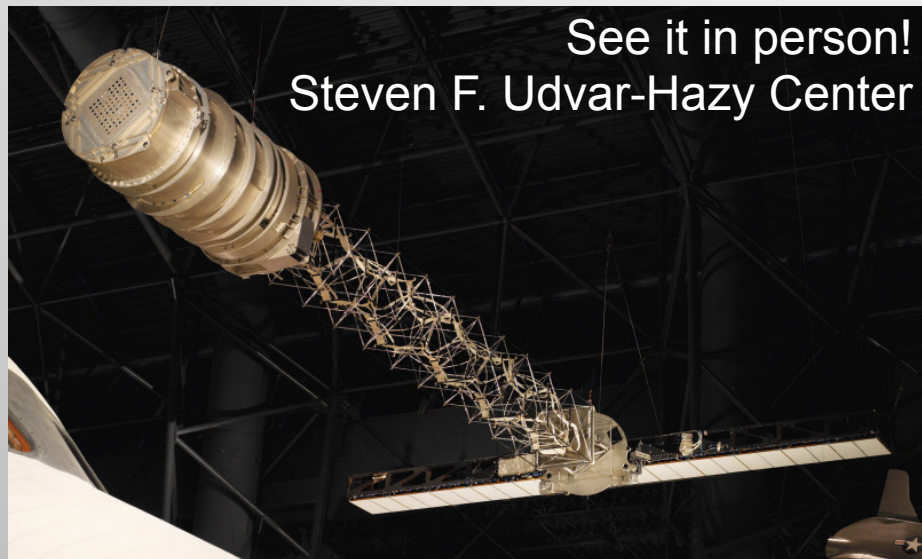


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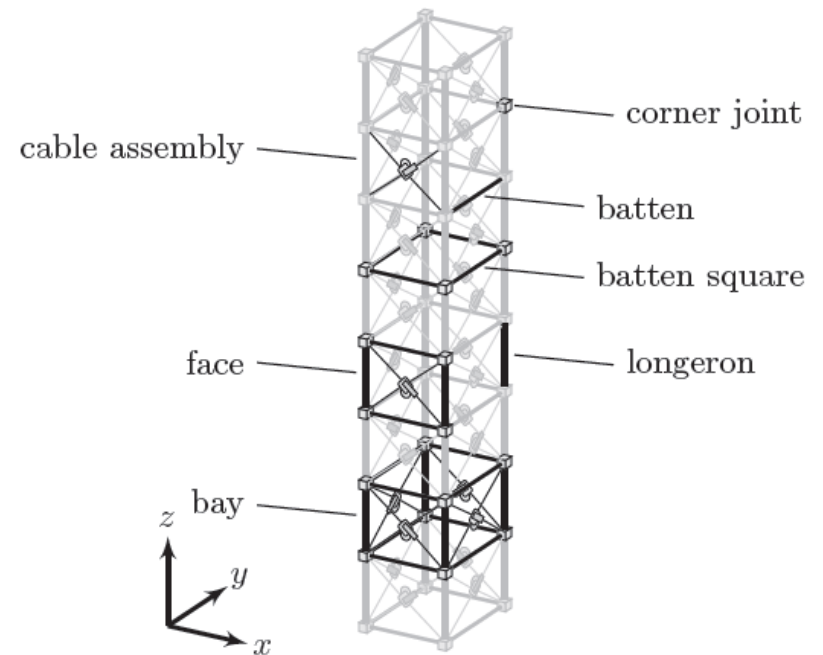


Mast and Metrology

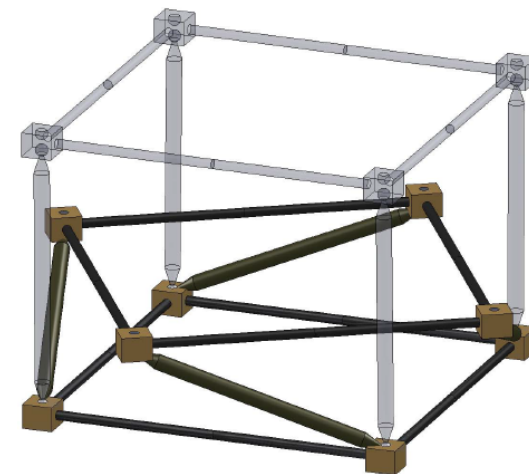
- ABLE Deployed Articulated Mast (ADAM)
 - Built by ATK Space Systems Goleta, CA



- “ADAM design can be understood as a deformable box-shaped structure of stiff members, shaped and rigidized by cables and integrated latching system”



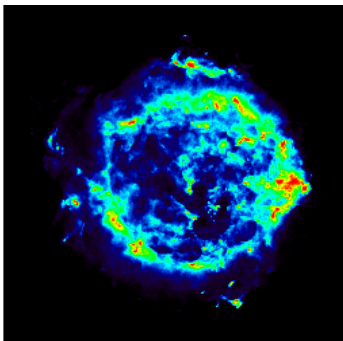
Olive Stohlman, “Repeatability of joint-dominated deployable masts,” PhD Thesis (2011)



NuSTAR Science

2-year baseline science mission

1. Locate massive black holes
2. Study the population of compact objects (e.g. neutron stars) in the Galaxy
3. Understand explosion dynamics and nucleosynthesis in core collaps/Type 1a SN
4. Constrain particle acceleration in relativistic jets
5. Observe the Sun (Nanoflares, axions...)



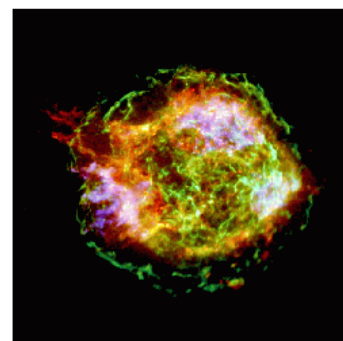
Radio wave (VLBI)



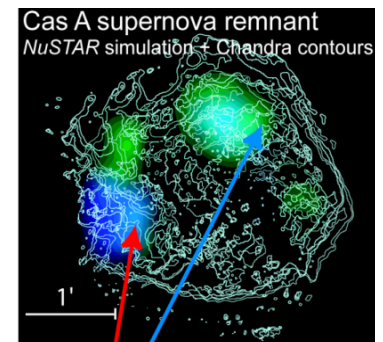
Infrared radiation (Spitzer)



Visible light (Hubble)

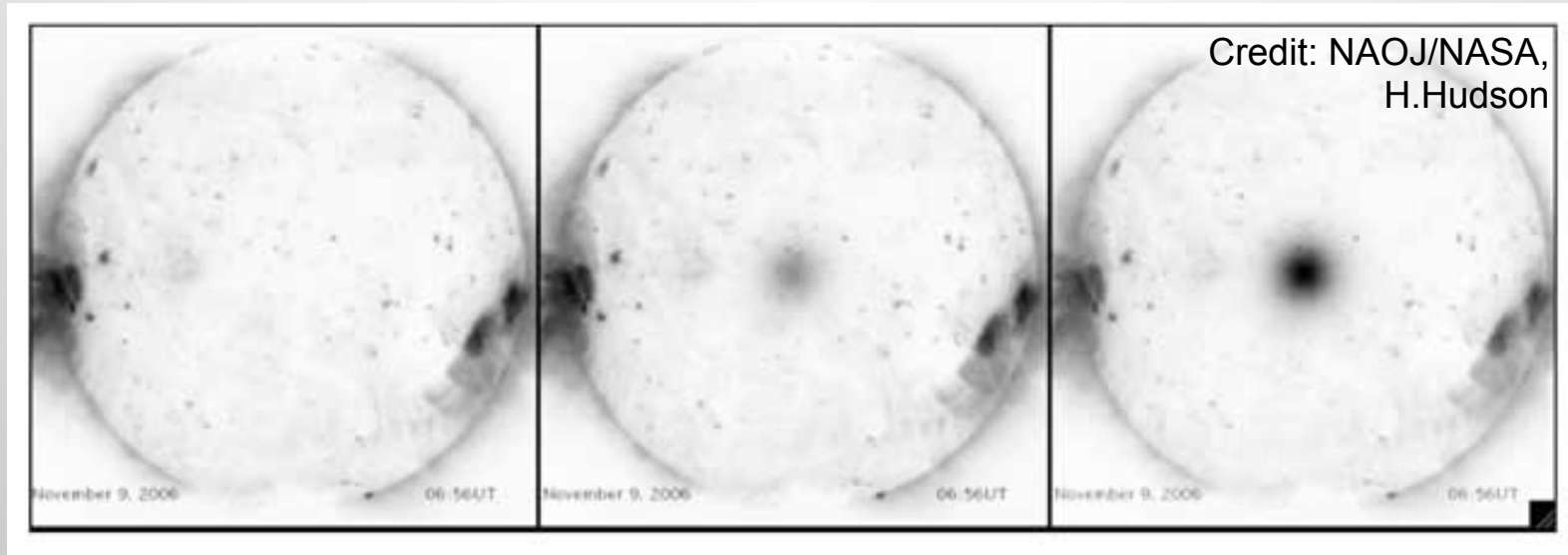


Low E x-ray (Chandra)



High x-ray
NuSTAR (68 keV)

NuSTAR Solar Axions

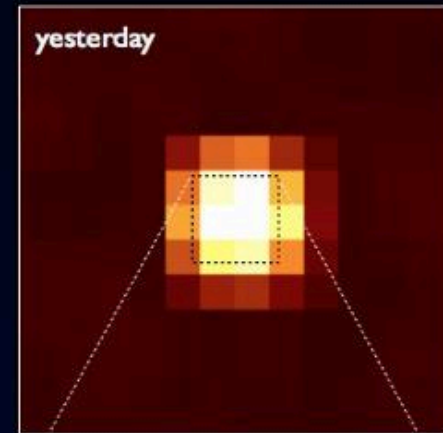
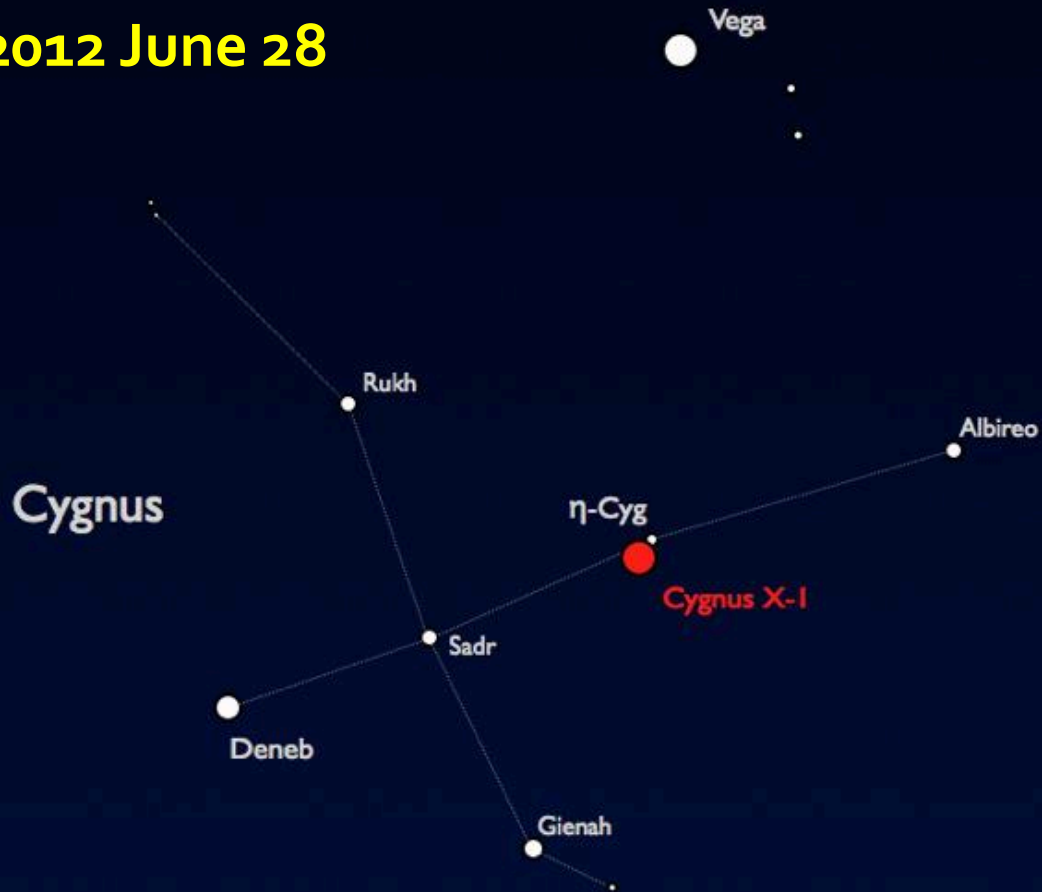


- Previously similar studies performed with e.g. Rhesi
- Primakoff production in the solar core
- Reconversion in solar magnetic field
- “For free” with heliophysics observations (e.g., looking for nanoflares)

Movie

NuSTAR first light

2012 June 28



Thank you!