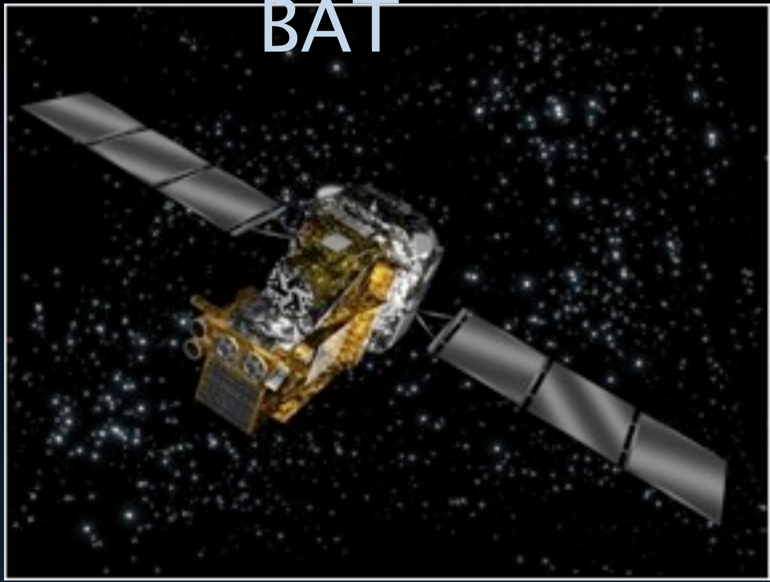
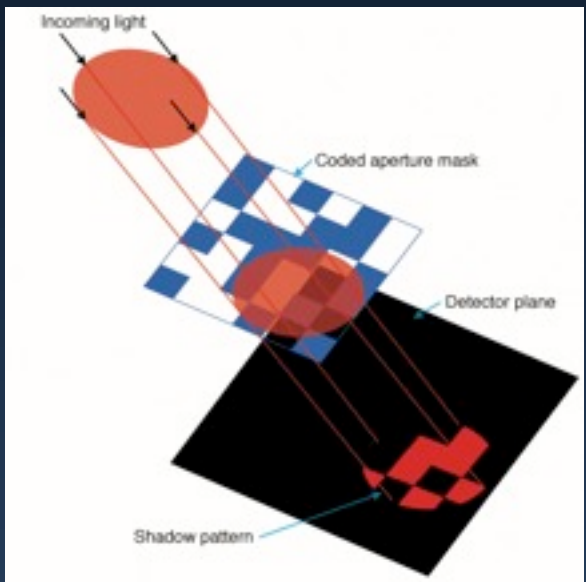
NuSTAR

The Nuclear Spectroscopic Telescope Array

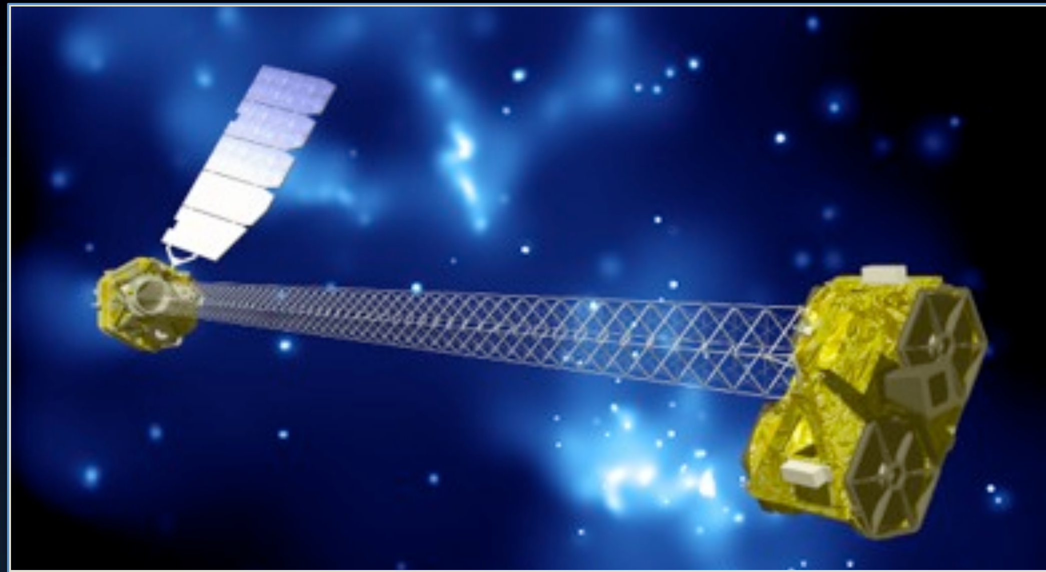
Fiona Harrison

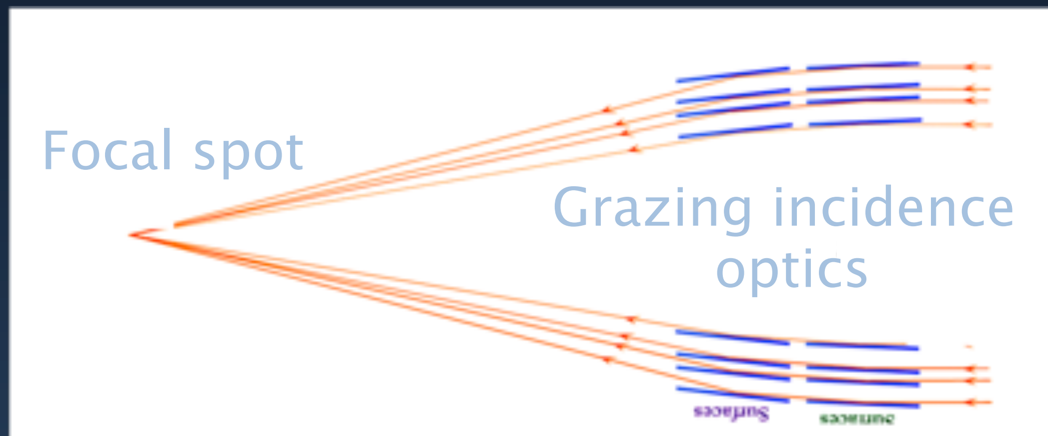
INTEGRAL, Swift BAT

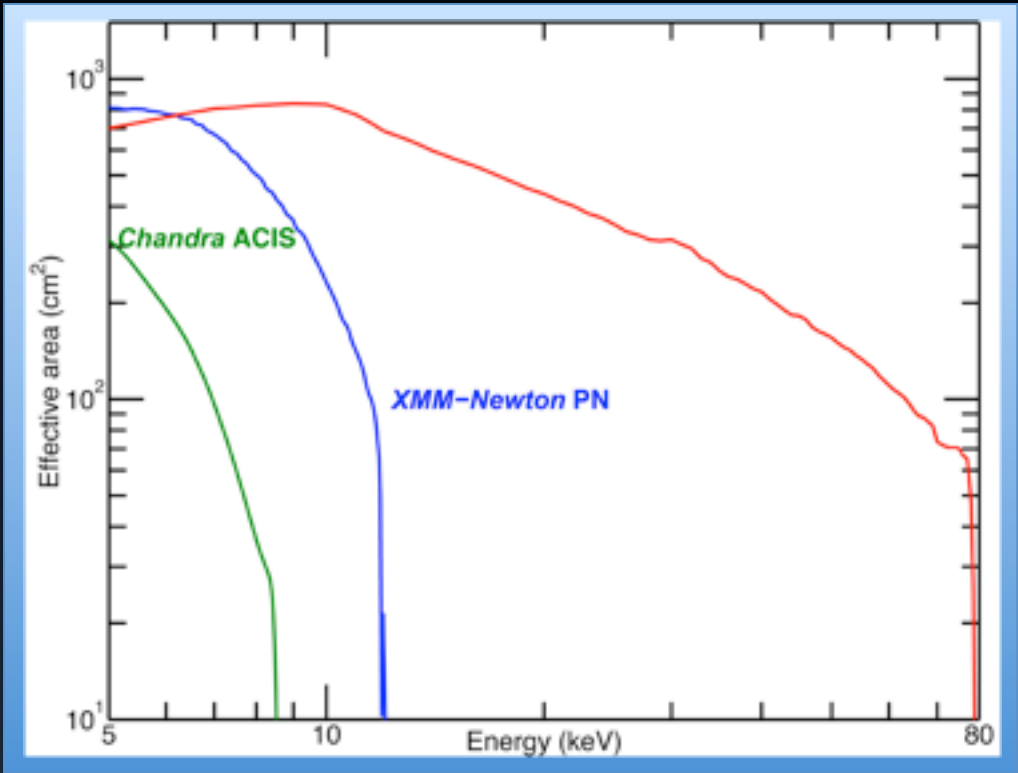




NuSTAR







NuSTAR two-telescope total collecting area

Satellite (instrument)	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 μCrab (10–50 keV) in 1 Ms

Sensitivity comparison

1 Ms Sensitivity

3.0×10^{-15} erg/cm^2/s (6 – 10 keV)

1.2×10^{-14} (10 – 30 keV)

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Imaging

HPD ~50”

FWHM 10”

Localization 2” (1-sigma)

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1.2×10^{-14} (10 – 30 keV)

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HPD ~50”

FWHM 10”

Localization 2” (1-sigma)

Field of View

FWZI 12.5’ x 12.5’

FWHI 10’ @ 10 keV

8’ @ 40 keV

6’ @ 68 keV

1 Ms Sensitivity

3.0×10^{-15} erg/cm^2/s (6 – 10 keV)

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Timing

relative 100 microsec

absolute 30 msec

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relative 100 microsec

absolute 30 msec

Spectral response

threshold 2.5 keV

ΔE @ 6 keV 0.6 keV FWHM

ΔE @ 60 keV 1.0 keV FWHM

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3.0×10^{-15} erg/cm^2/s (6 – 10 keV)

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HPD ~50”

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ΔE @ 60 keV 1.0 keV FWHM

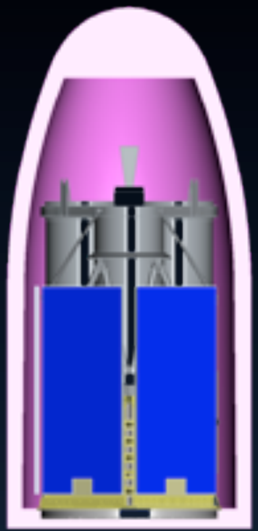
Target of Opportunity

response <24 hr (reqmt)

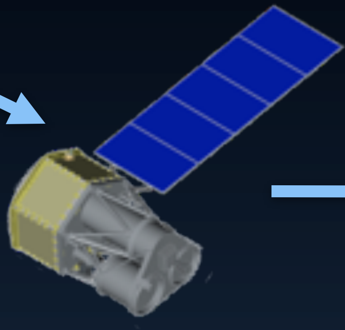
typical 6-8 hours

85% sky accessibility

Mission Profile

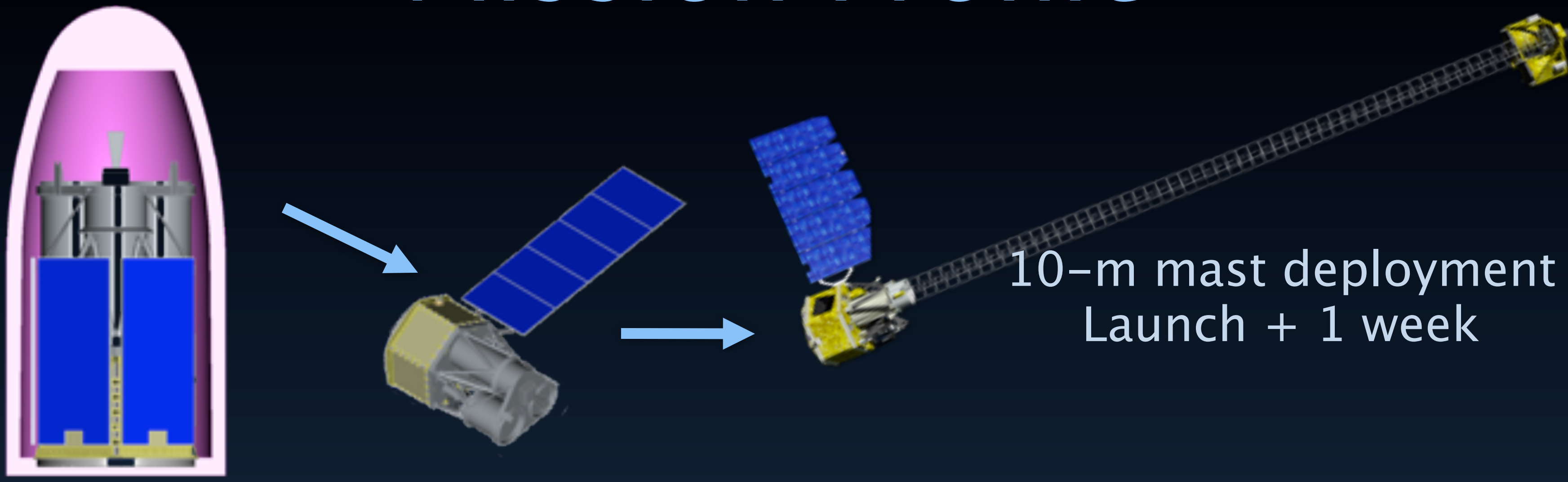


Pegasus XL
Mar 3 2012



10-m mast deployment
Launch + 1 week

Mission Profile



Pegasus XL
Mar 3 2012

6° inclination 550 x 600 km
Low background
55% observing efficiency

TDRSS ⇅ ASI/Malindi ⇅

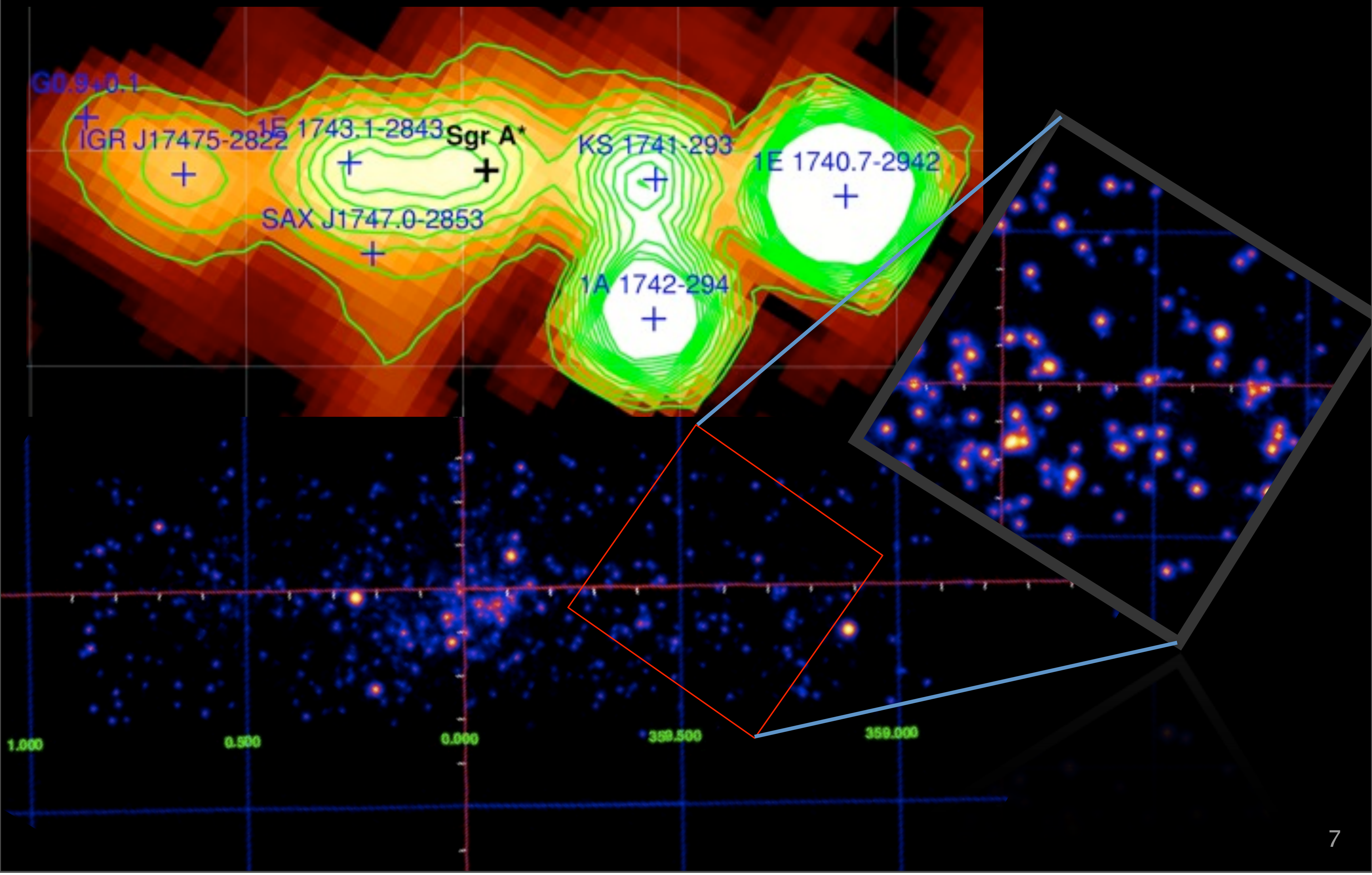
Mission operations center (UCB)
↓
Science operations center (Caltech)
↓ Science team
↓ Science Archive (HEASARC)

2-year baseline science mission

Baseline Science Mission

Key science goal	Observations	Time (weeks)
Locate massive black holes	Deep and wide-field extragalactic surveys (GOODS S, COSMOS, BAT-shallow)	23
Study the population of compact objects in our Galaxy	Survey Galactic Center and other fields of varied ages (spiral arms, bulge)	20
Explosion dynamics and nucleosynthesis in core collapse and 1a SNe	Pointed observations of young ($\tau < 500$ yr) remnants – Cas A, SN1987A, GX1+9 ToO observations of nearby SN1a	22
Understanding relativistic jets in supermassive black holes	Contemporaneous multiwavelength observations of GeV/TeV blazars	6
Other Objectives	**Observations**	**Time**
Varied	In final planning stage	33

Galactic Surveys



Population Studies

Understand compact object properties in regions of different ages

Hard X-rays can: distinguish NS vs BH HMXBs, distinguish intermediate polars

Galactic chronology/understanding evolution/end states of binaries – HMXBs (~10 MYr) CVs (Gyr)

Field	Size (deg)	Field center	Depth/pointing
Galactic center/ inner bulge	0.8 x 2	l = 337.5°, b = 0°	12 ksec
Norma	0.8 x 2	l = 0°, b = 0°	12 ksec
Latitude survey	0.13 x 0.13	L=+/-2.5,5 deg, b=0	100 ksec

Extragalactic Surveys

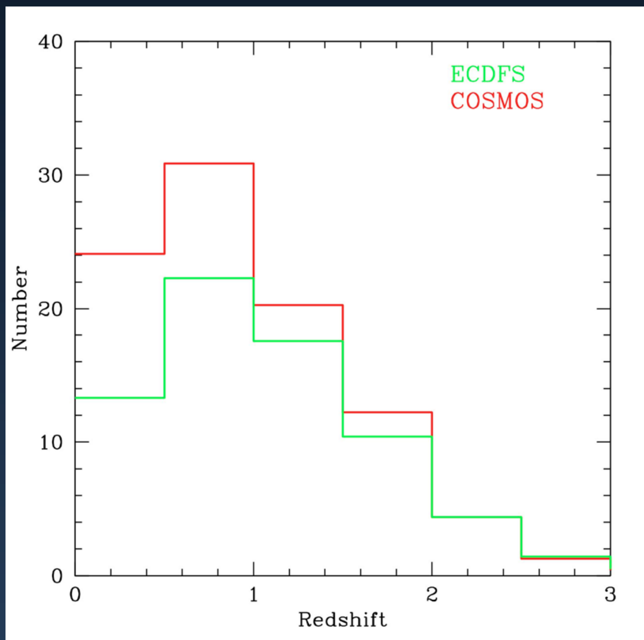
First sensitive surveys 10 - 30 keV

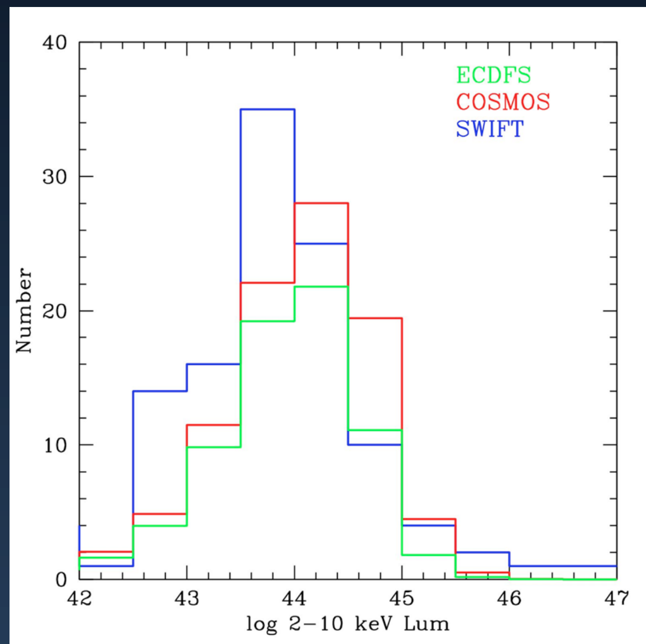
- What AGN populations dominate the background at 30 keV?
- How were black holes growing as a function of redshift, independently of absorption?
- Does the obscured AGN fraction increase with redshift?
- Do the most heavily obscured AGNs reside in specific host-galaxy environments?

See Ballantyne et al. 2011 ApJ

Extragalactic Surveys

Field	Area	Exposure	Depth (10 – 30 keV) $erg/cm^2/s$
E-CDFS	0.3 deg^2	200 ksec	2×10^{-14}
COSMOS	1 deg^2	50 ksec	4×10^{-14}
BAT shallow	3 deg^2	7 ksec	$1 - 1 \times 10^{-13}$





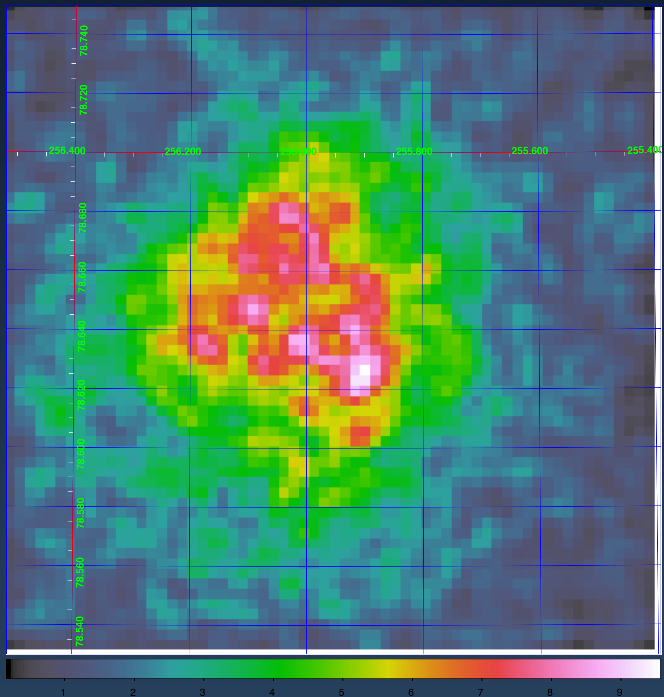
Galaxy Clusters

First true imaging observations E> 10 keV

- Detect/characterize (controversial non-thermal components)

  Halos and relics. Constrain magnetic fields

- Characterize hot thermal emission in vicinity of shock fronts



50 ksec simulation of NuSTAR A2256 (15-40 keV) - cluster with several steep spectrum radio sources and temperature struction

Galaxy Cluster Targets

Non-thermal emission

Target	$\Delta F_x/F_x$ – Error on NT component (rel.)	Exposure (ksec)
A2163	20%	200
A2256	20%	300
NGC 1275	20%	200
Bullet	30%	500

Merger Shocks

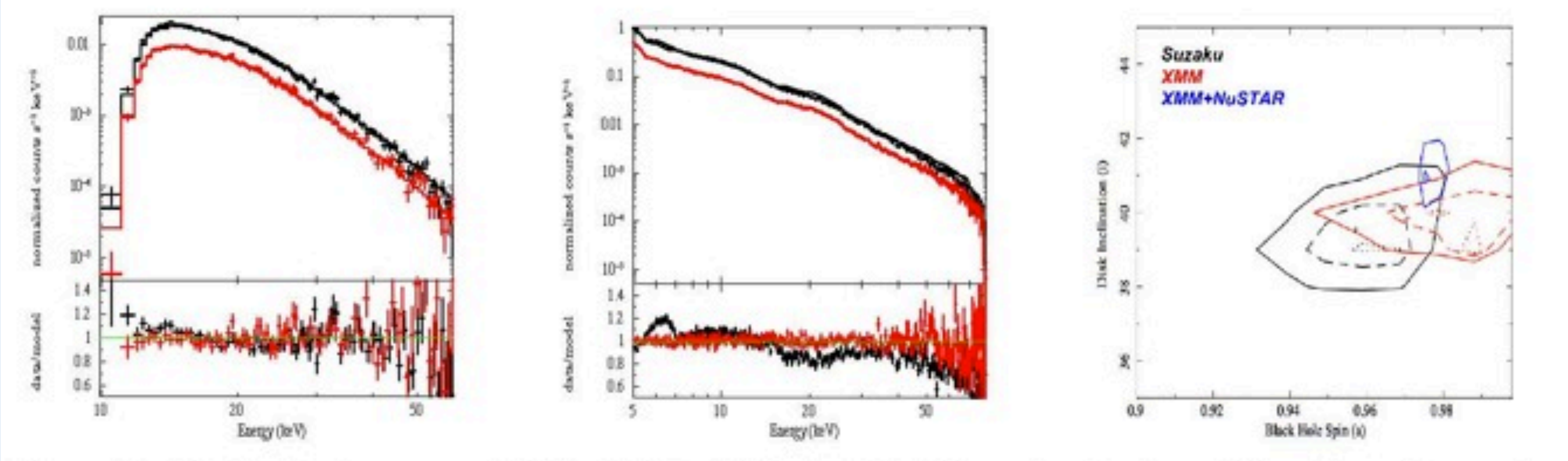
Target	$\Delta T_{dw}/T_{dw}$	$\Delta T_{up}/T_{up}$	Exposure
A754	10%	30–40%	200
Coma	20%	30–50%	900

Additional Science

- Supernova remnants
- Planetary Wind Nebulae
- Supernova Ia ToO
- Magnetars
- X-ray Binaries
- Pulsars
- Gamma-ray binaries
- Flaring protostars
- Sun
- AGN physics (corona temperature)
- Ultra-Luminous Infra-Red Galaxies (ULIRGs)
- Compton-thick AGN
- Starburst galaxies
- Galaxy clusters
- Blazars
- Radio galaxies
- Ultra-Luminous X-ray Sources

Measuring spin in super-massive black holes

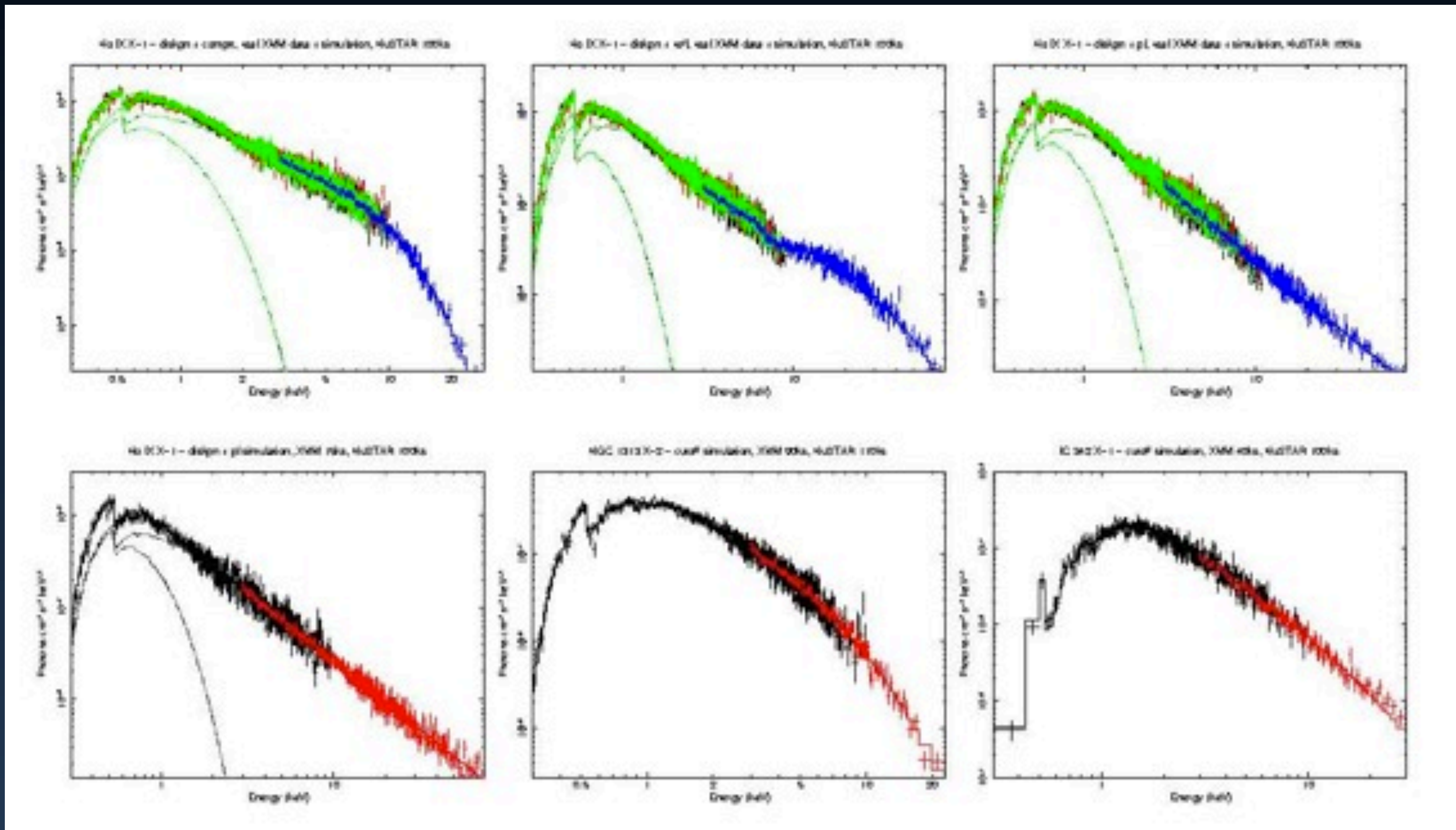
Suzaku XMM+NuSTAR



MCG 6-30-15 simulation (NuSTAR 150 ksec) - relativistic reflection + warm absorption (black) vs. absorber only (black)

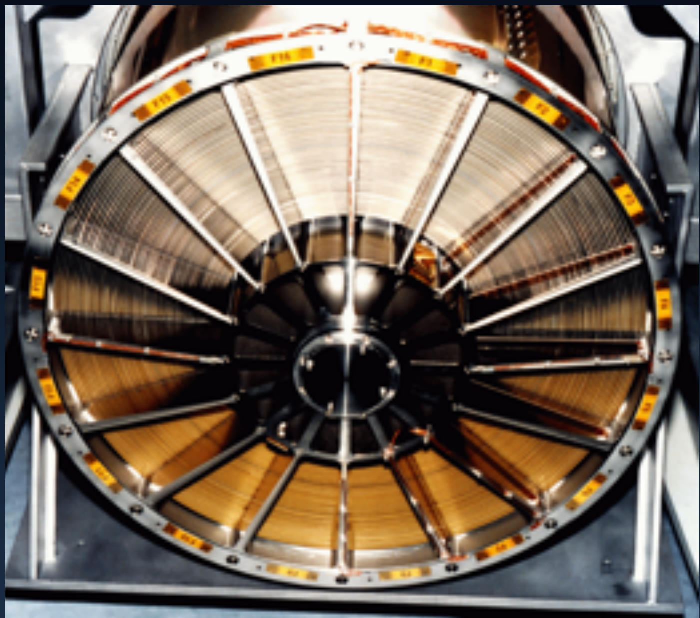
Partnering Opportunities with XMM and eROSITA

Understanding the nature of ultra-luminous X-ray sources



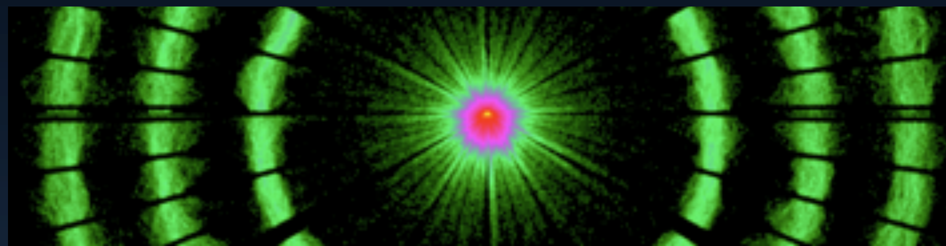
Also - magnetars, X-ray binaries

Optics

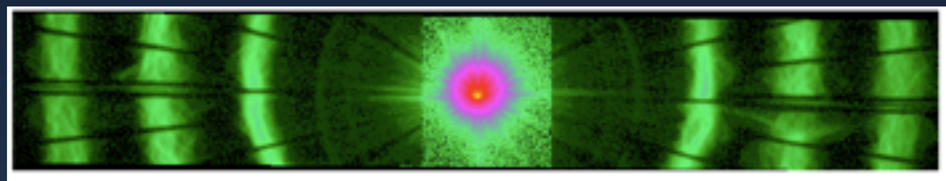


Depth-graded multilayer coated optics – 133 shells

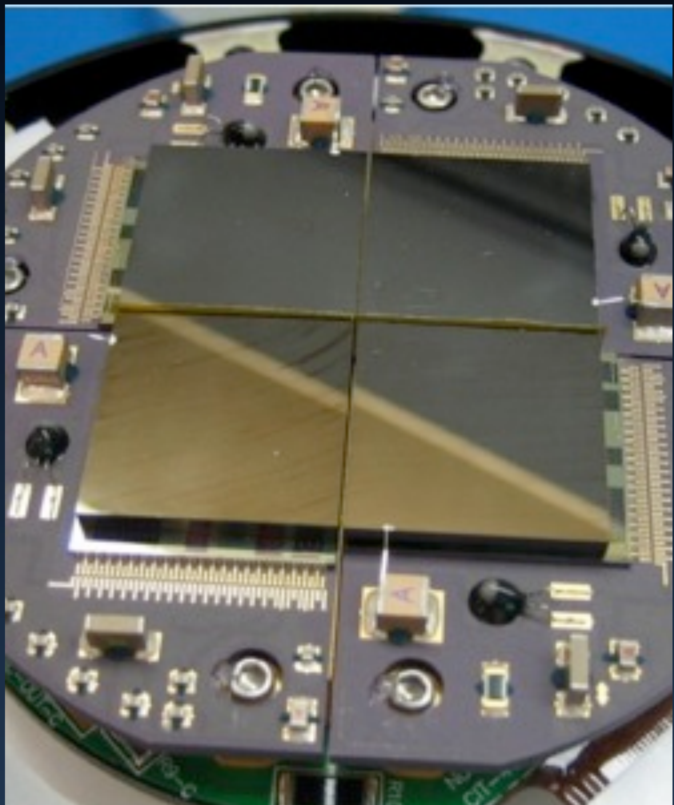
Simulated

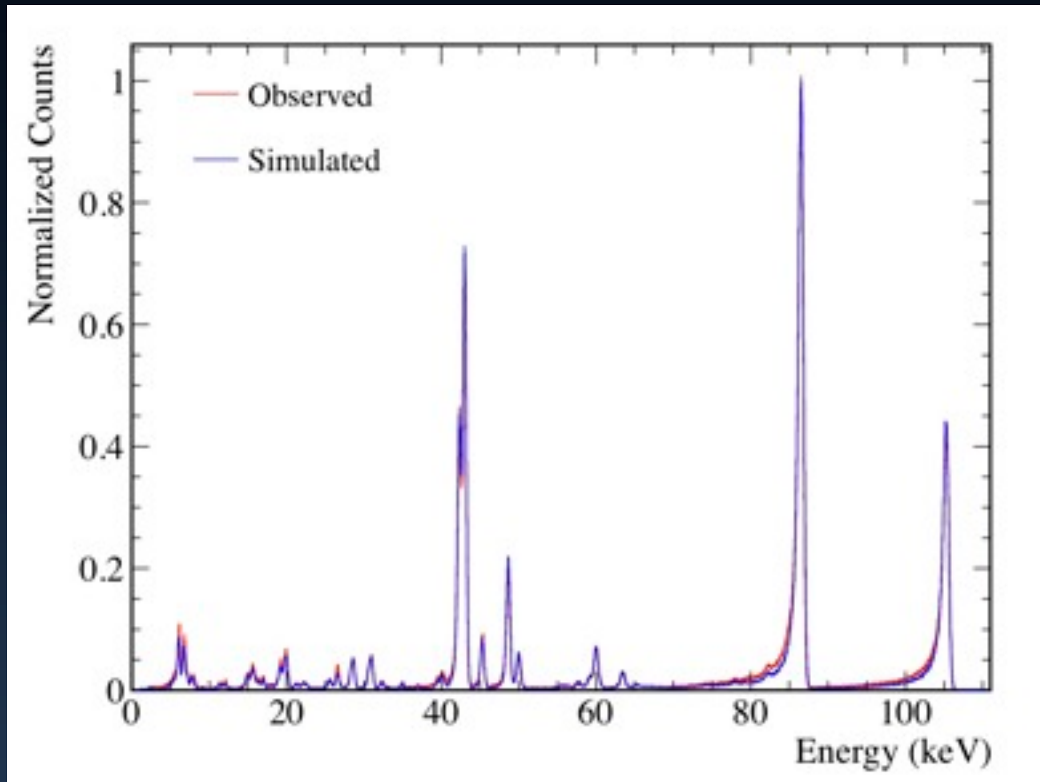


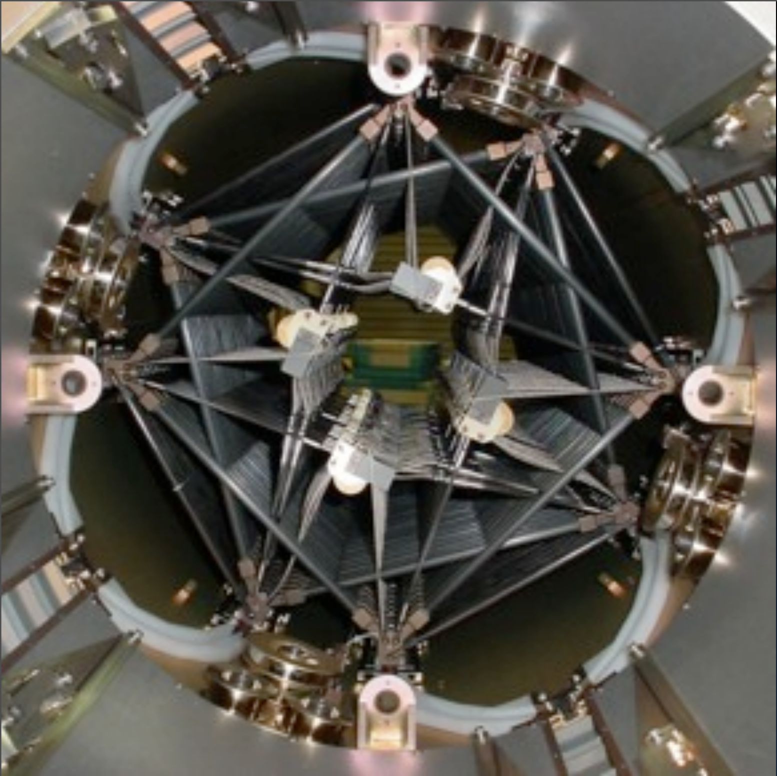
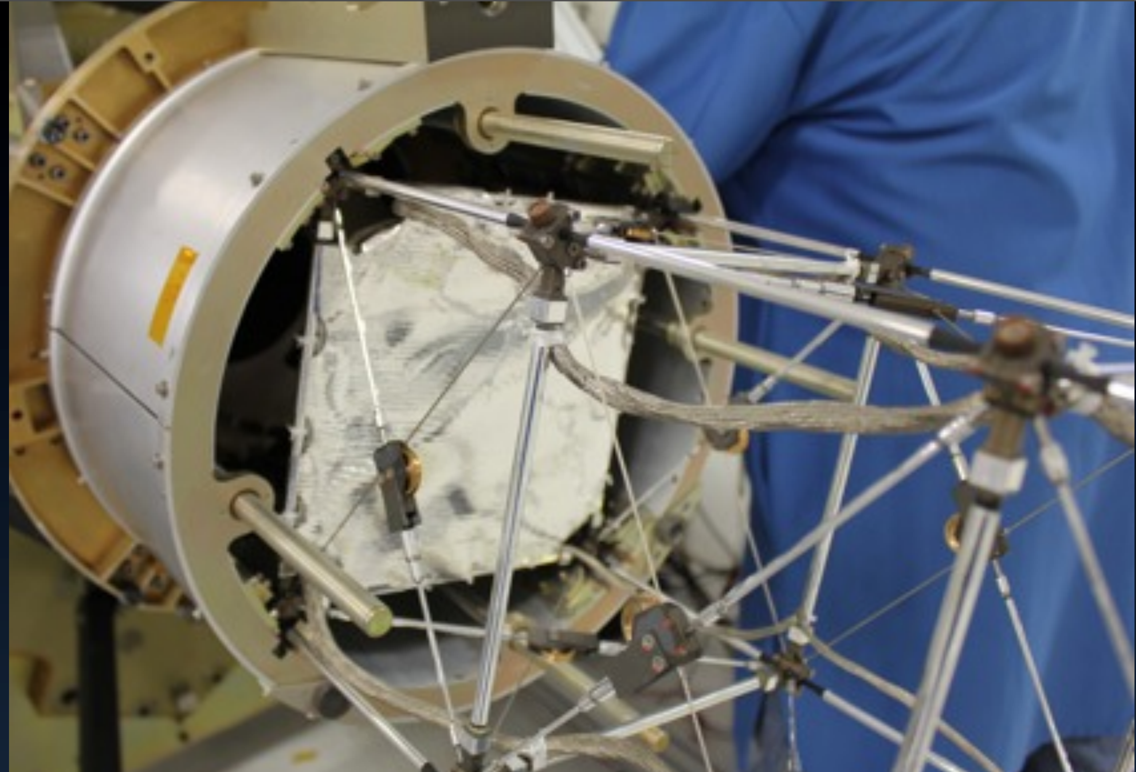
Calibration data



Focal Plane

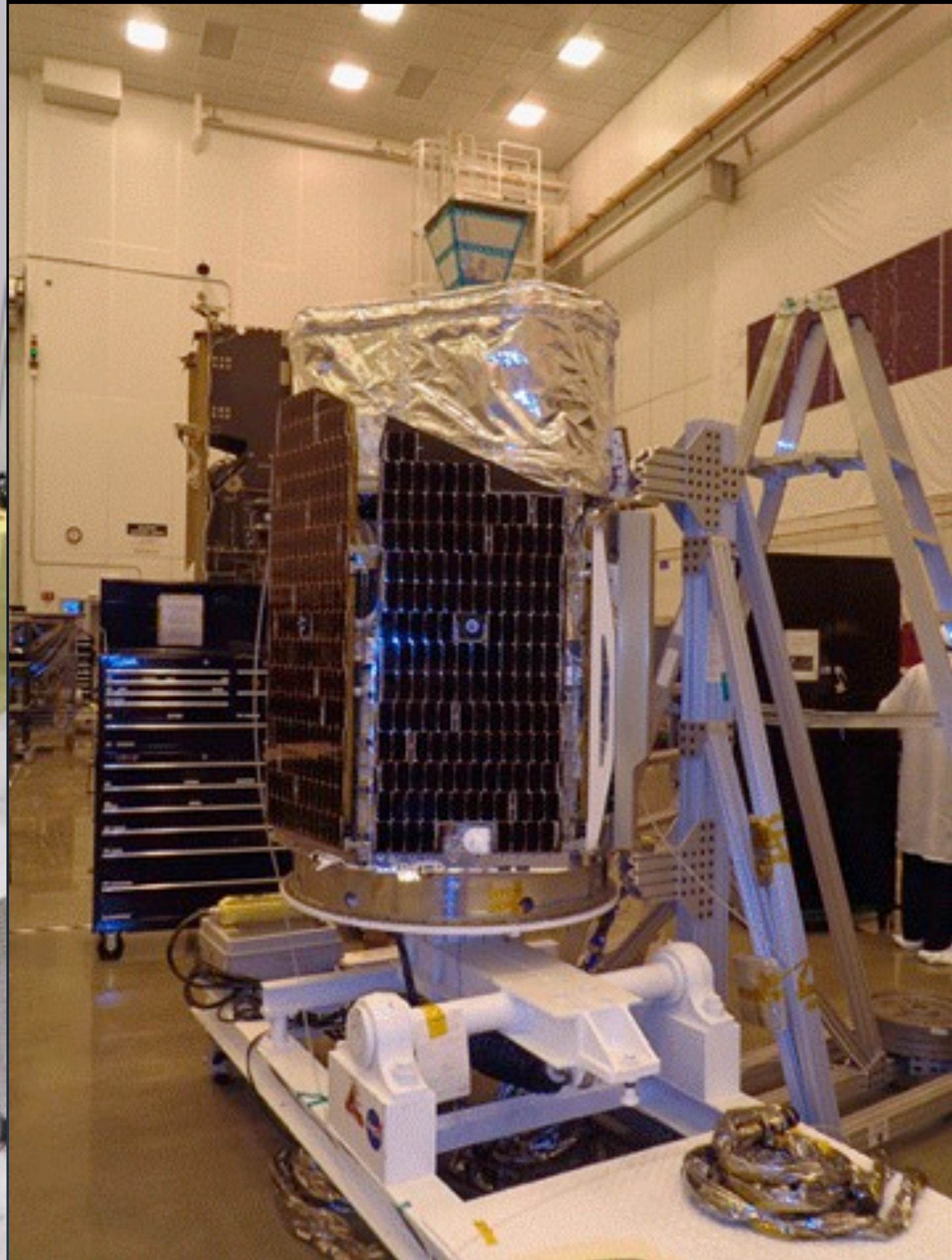


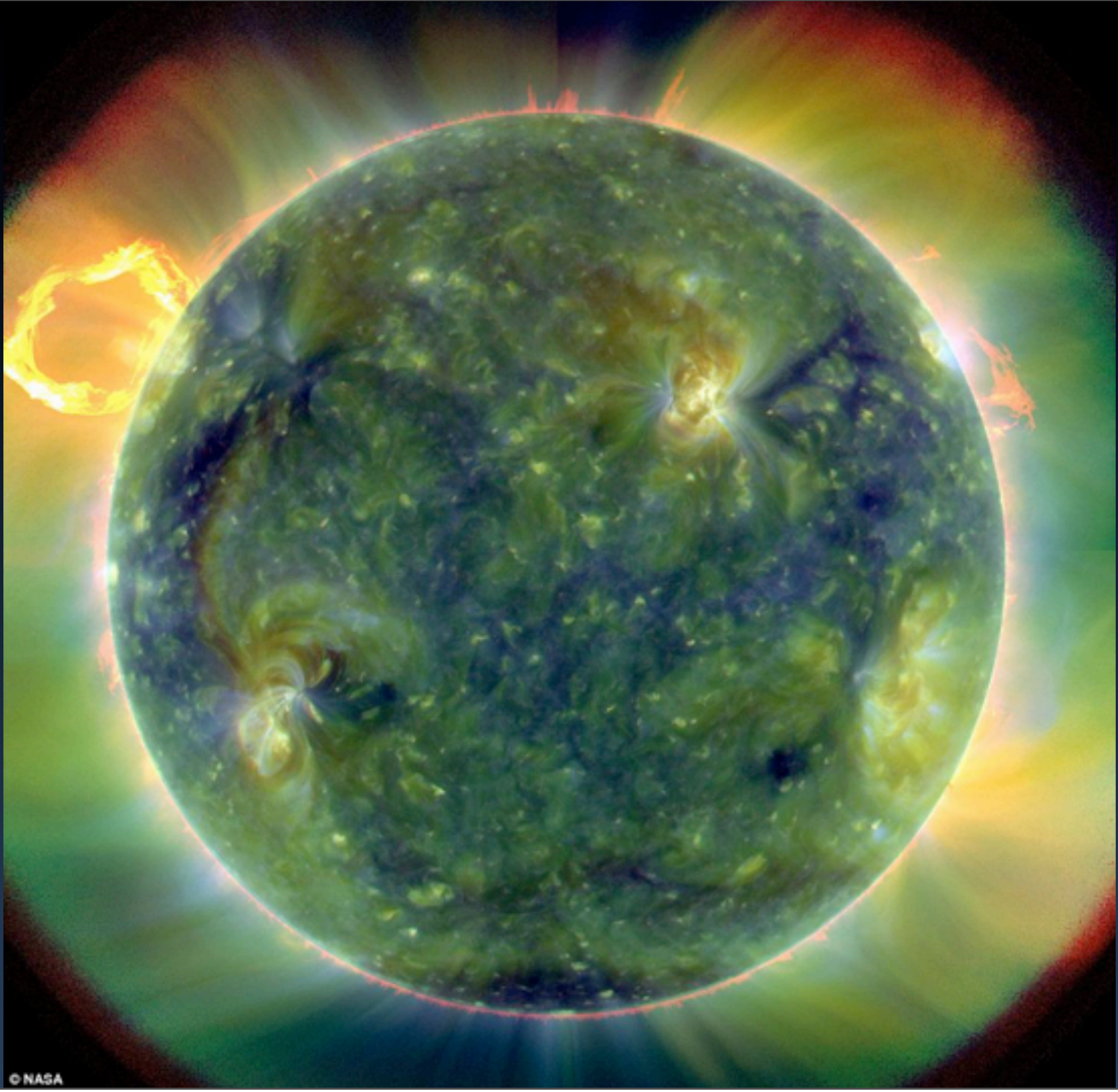

Normalized Counts
Observed
Simulated
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
Energy (keV)



FLAMMABLE
KEEP FIRE AWAY

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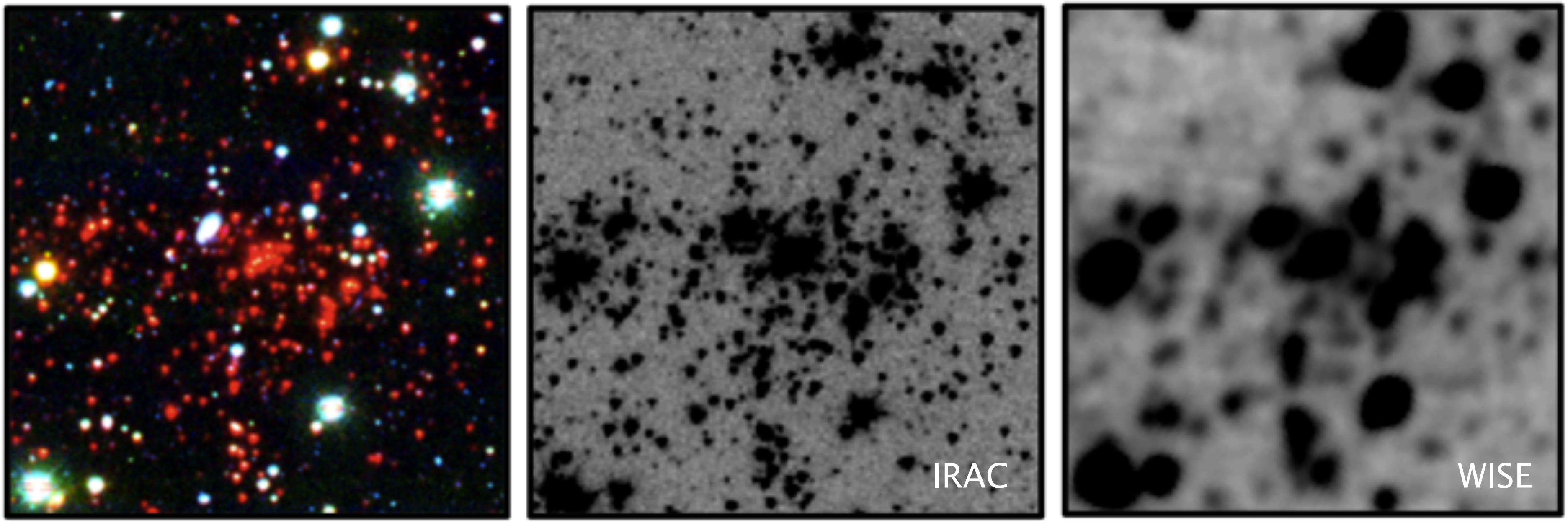
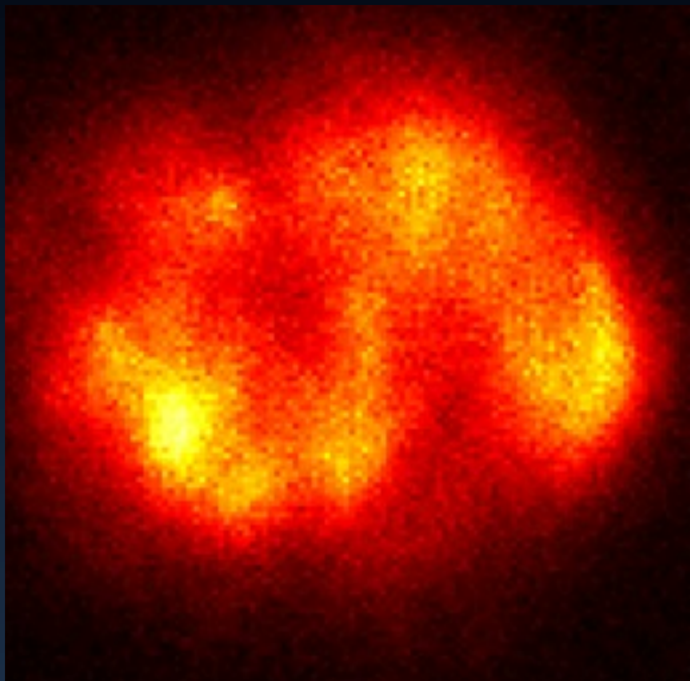


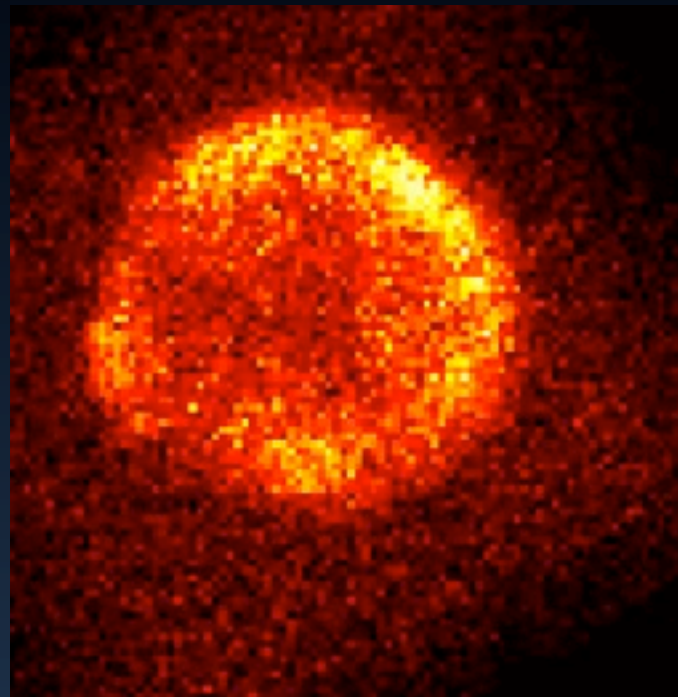
WISE-eROSITA Synergy - Clusters

- WISE is sensitive to L* galaxies out to z~1.2 all-sky
- massive clusters at z>1 (e.g., SPT clusters) clearly identifiable in WISE images
- vast majority of eROSITA clusters will be obvious in WISE data; WISE will be important for confirming eROSITA cluster candidates [currently working with Planck team on their SZ cluster sample]
- Survey of WISE-selected z>1 cluster candidates started (Subaru+SOAR+MMT imaging in the last month; first Keck/LRIS spectroscopy later this week)
- eROSITA- get X-ray masses; WISE - study galaxy populations
- WISE - help with AGN identification in high-z clusters - higher redshift clusters more likely to host an AGN (e.g., Galametz et al. 2009; Martini et al. 2009)

Supernova Remnants



Cas A (> 10 keV) 1 Msec



Tycho (> 10 keV) 200 ksec

See poster by Zoglauer et al.