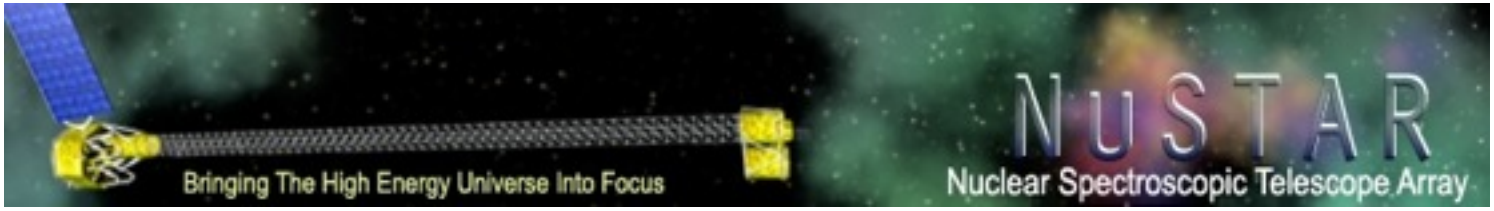


NuSTAR

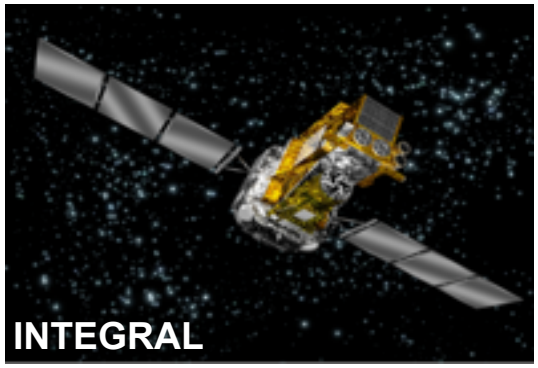
Didier Barret

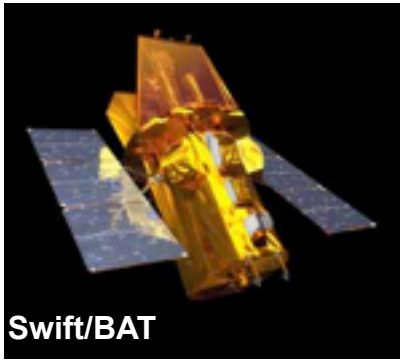
&

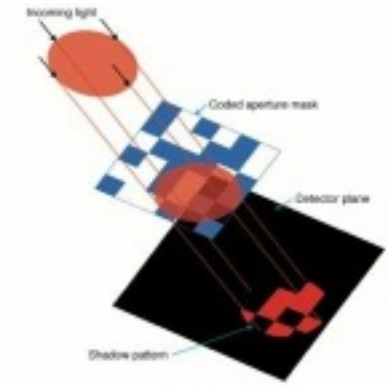
Peter von Ballmoos

Institut de Recherche en Astrophysique et Planétologie (IRAP)

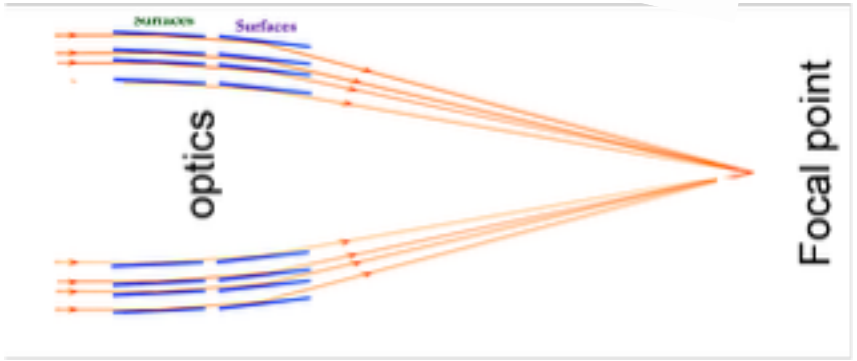
NuSTAR: the first focusing hard X-ray satellite





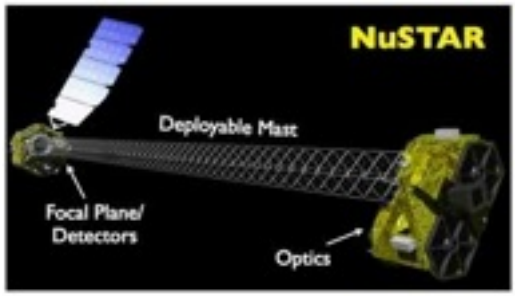


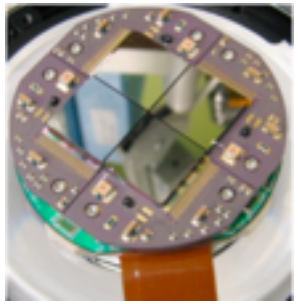
Coded Aperture Optics:
- large detector
- high background limiting sensitivity



Focusing Optics:
- compact detector
- low background, high sensitivity

NuSTAR Facts



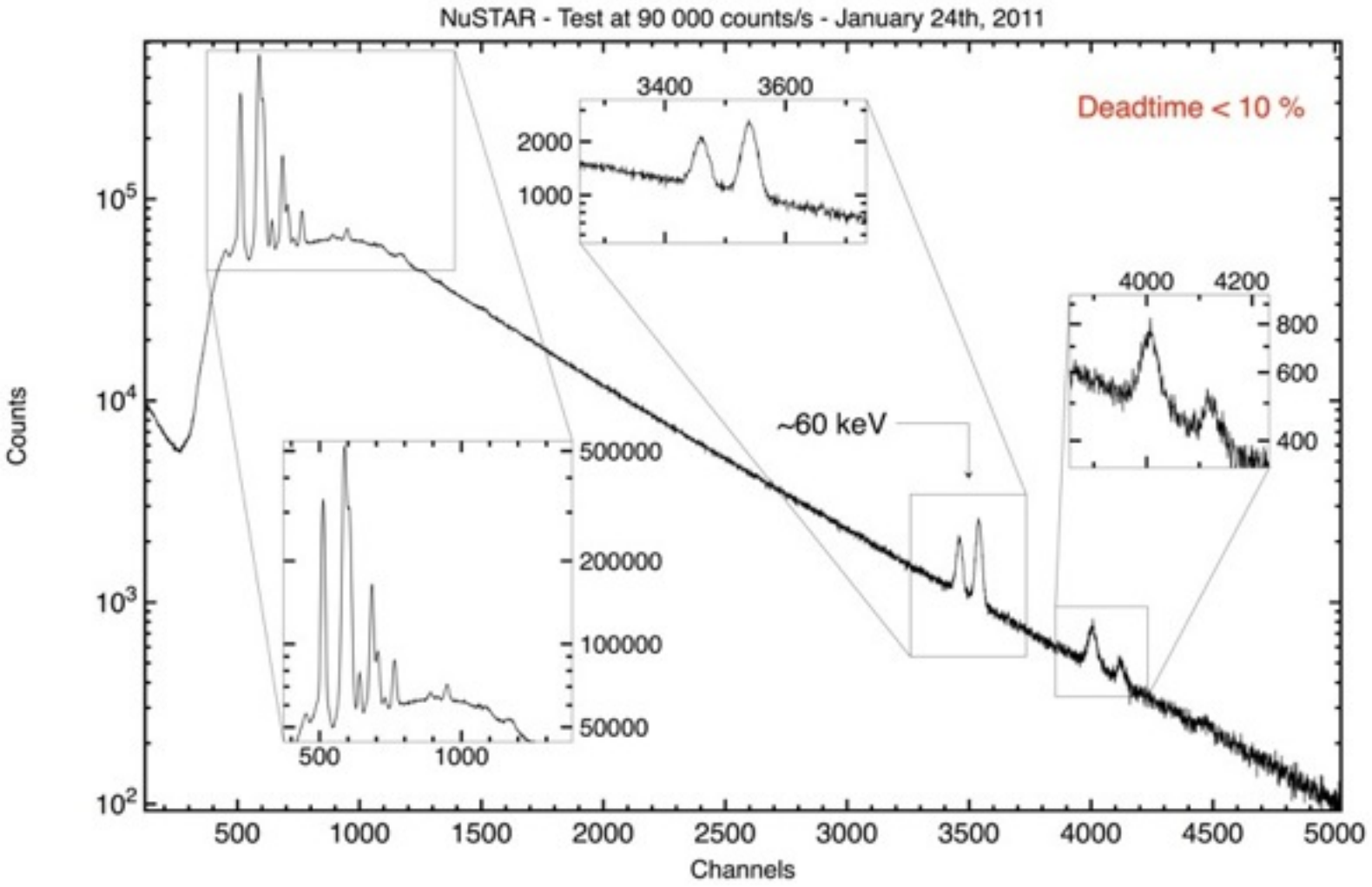


- PI: Fiona Harrison (Caltech)
- Project Scientist: Daniel Stern
- Hard X-ray Optics
  - glass slumping (GSFC)
  - multi-layer coatings (Denmark Technical University)
  - **assembly and calibration (Columbia)**
- Deployable Mast (10 m)
  - ATK (Alliant Techsystems Inc.)
- Detectors
  - CdZnTe with 0.6 mm pixels (Caltech)
- Significant contributions from Italy

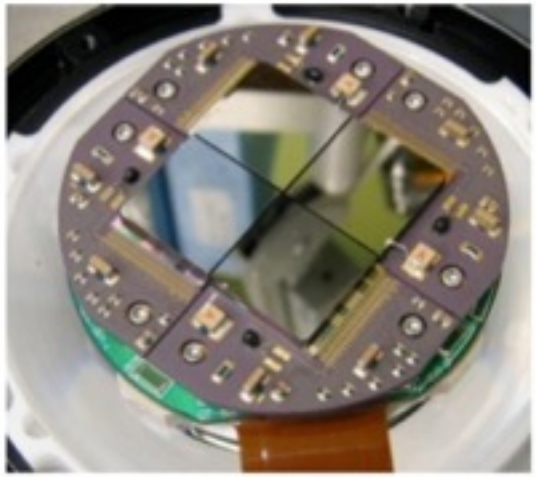
Energy Range:	~3-78 keV
Angular Resolution:	58 arcsec (HPD) 18 arcsec (FWHM)
Field of View:	10 arcmin @ 10 keV 6 arcmin @ 68 keV
Spectral Resolution:	400 eV at 6 keV 900 eV at 68 keV
Timing Resolution:	0.1 msec (absolute) 2 microsecond (relative)
Sensitivity (3σ, 1 Ms):	2 x 10 1 x 10
ToO Response:	<24 hr
Launch Date:	13 June 2012 on a Pegasus from Kajelein
Orbit:	6 degree inclination 650 km x 610 km
Mission Lifetime: **Orbit Lifetime:**	2 years baseline >7 years orbit lifetime

Harrison+13

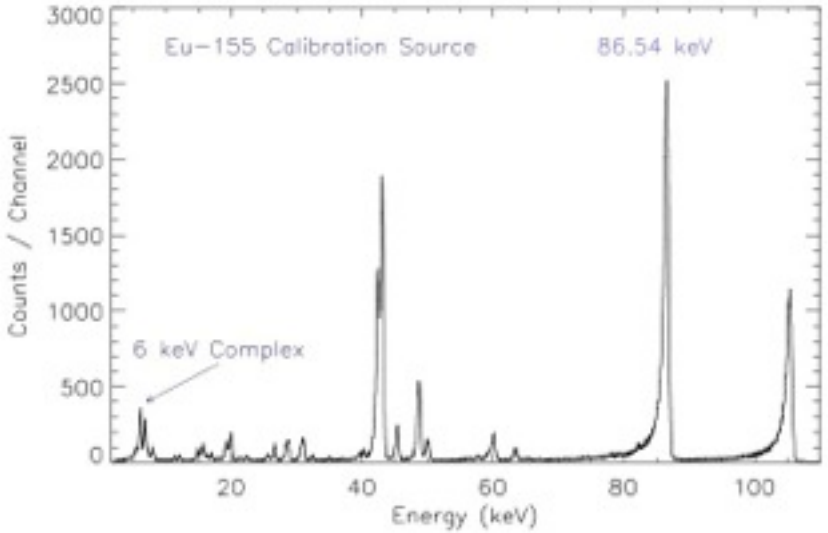
Outstanding performance

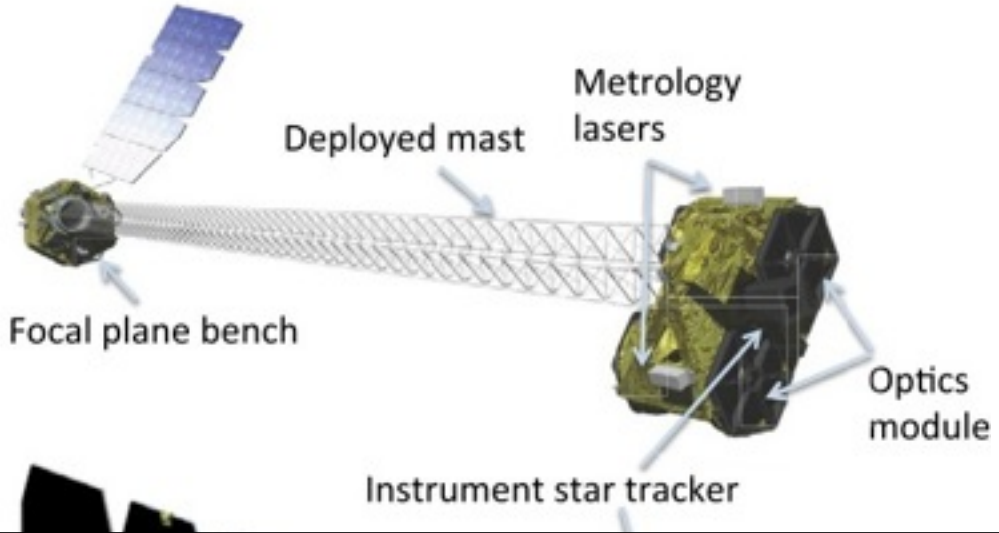


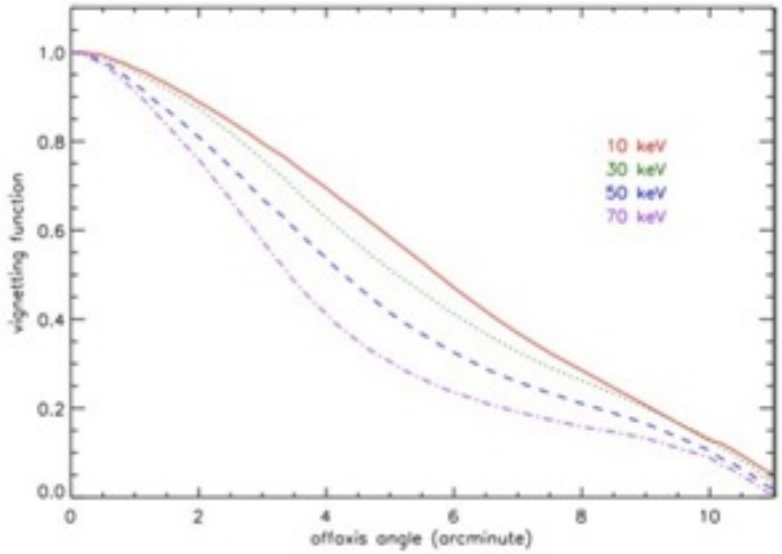
NuSTAR vs. other missions



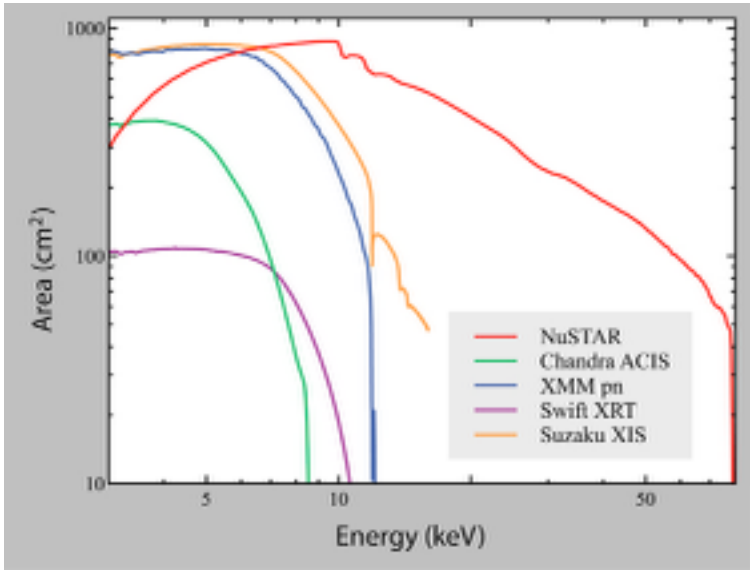
Harrison+2013



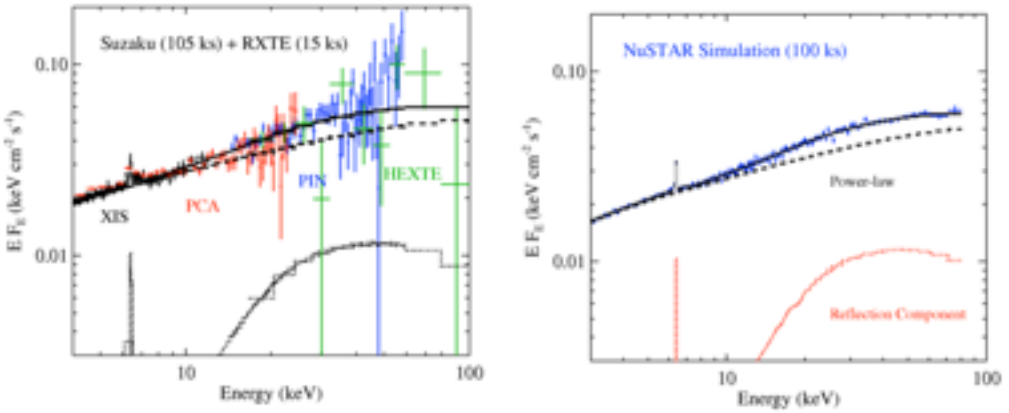




NuSTAR vs. other missions



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	~0.7 μCrab (10-30 keV) in 1 Ms



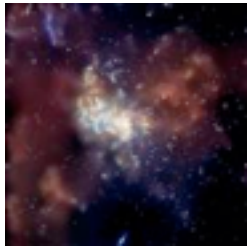
Courtesy John Tomsick

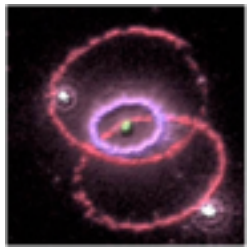
Figure and table: RXTE and Suzaku rates are those measured for the accreting BH GX 339-4 in the hard state at 5.3×10^{-11} erg/cm^2/s (2-10 keV) and L/L_{Edd} = 0.14%.

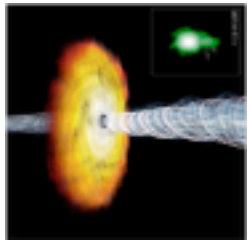
Satellite	Source rate	Background rate
RXTE (PCA)	17 c/s (5-50 keV, 3 PCUs)	56 c/s (5-50 keV, 3 PCUs)
Suzaku (HXD/PIN)	0.21 c/s (15-60 keV)	0.35 c/s (15-60 keV)
NuSTAR	2.6 c/s (5-80 keV)	0.008 c/s (5-80 keV)

Courtesy John Tomsick

NuSTAR Baseline Science Plan (first 2 years)







- *The observing plan for the 2 year baseline mission is being designed by the Science Team to address the following questions:*

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

Question #2: How are stellar remnants distributed within the Galaxy and near the Galactic center?

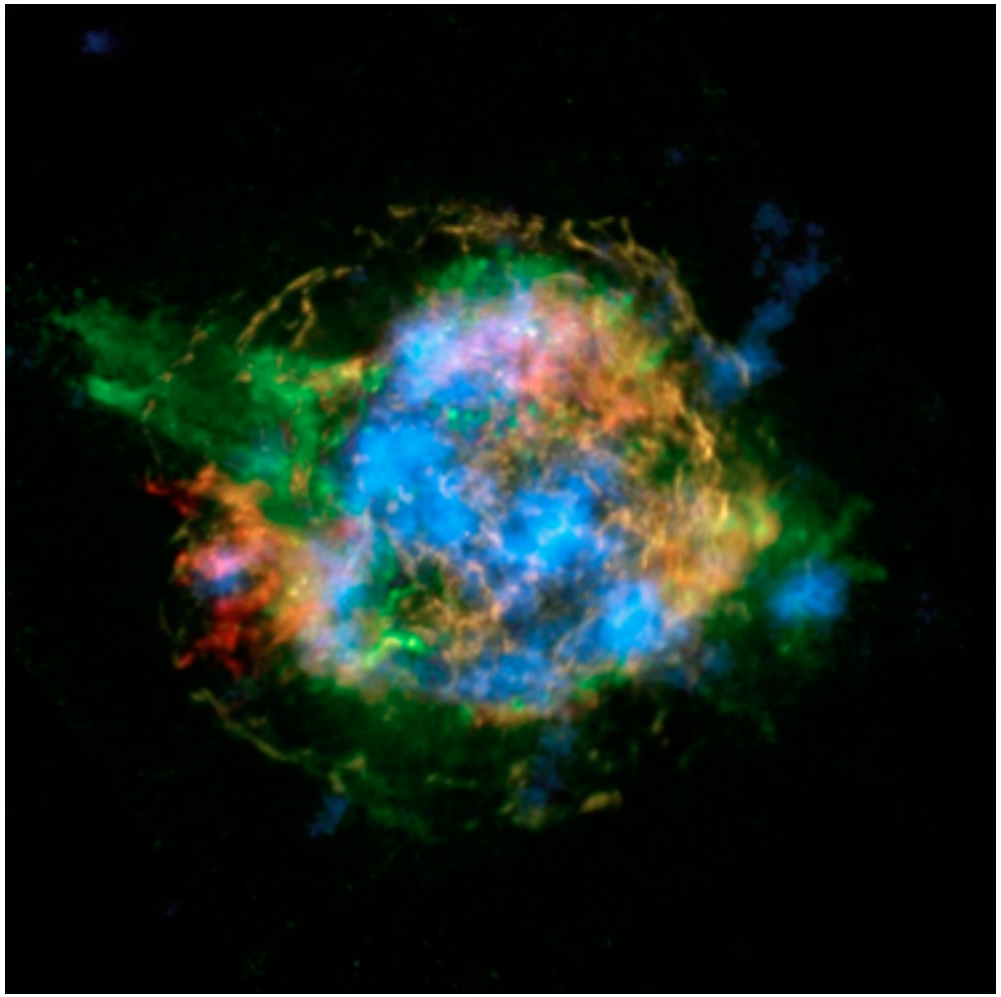
Question #3: How do stars explode and forge the elements that compose the Earth?

Question #4: What powers the most extreme active galactic nuclei?

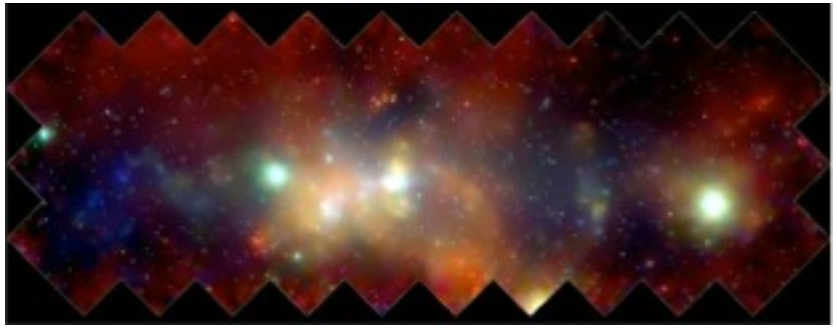
Supernova Remnants

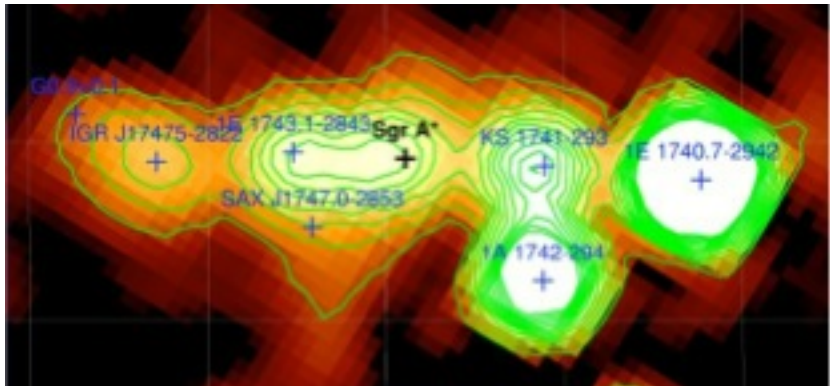
- Constraining the synchrotron spectrum
  - particle acceleration and the origin of cosmic rays
- 68 keV ^{44}Ti emission line
  - Amount and distribution of ^{44}Ti function: function of SN type (Ia or core collapse) and symmetry of the explosion
- clumps at the core —> mild asymmetries scenario

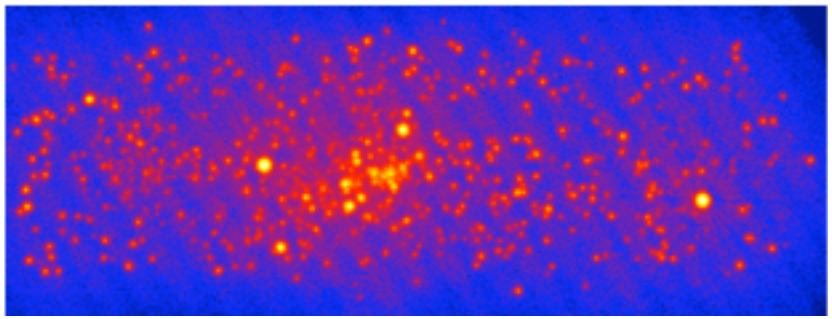
—> yelow = continuum
—> red = Fe
—> green = Si + Mg
—> blue = Ti



Galactic center with NuSTAR





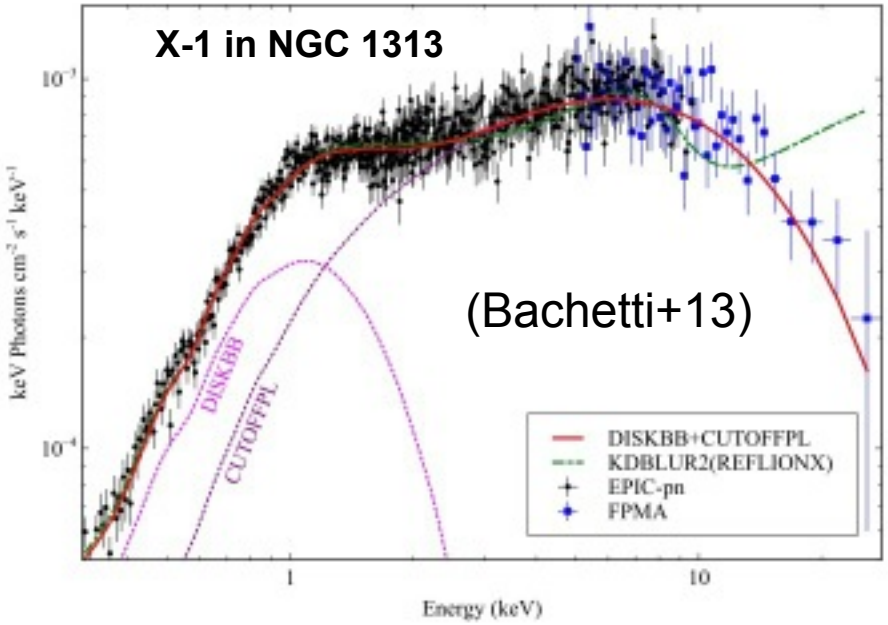


- Chandra
  - 0.5-8 keV
  - Wang et al. (2002); Muno et al. (2004, 2006, 2009)
- INTEGRAL
  - 20-60 keV
  - Belanger et al. (2005)
- NuSTAR simulation
  - 5-80 keV
  - Detection limit ~2x10^{33} erg/s at 8 kpc

Courtesy John Tomsick

Ultraluminous X-ray sources

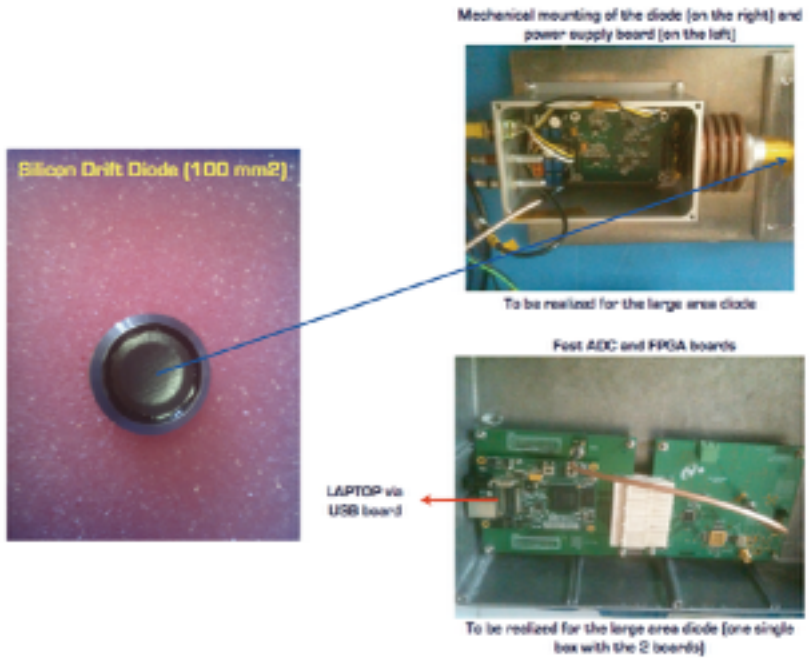
- What powers ULXs? What feeds them? Which emission processes dominate (e.g. origin of the power law, comptonization, reflection, ..)? Is beaming important? How do they compare to galactic X-ray binaries (e.g. ULX QPOs)?



- clear cutoff above 10 keV
- ULXs harbor small, stellar-mass black holes (70-100 Msol)
- Accreting at Eddington rate

IRAP contribution

- A high count rate detector for optics calibration - 100s kcts/s
  - Large area Silicon Drift Detector (heritage from IXO-HTRS)
  - Digital shaper - Digitization of the signal at the output of the charge amplifier by a fast ADC and energy recovery through FPGA (fast and slow triggers)



- R&T funding by CNES (IXO-HTRS contract)
- IRAP team: D. Barret., P. Von Balmoos, D. Rambaud, G. Ortner, W. Marty, K. Lacombe

Summary and Conclusions

- NuSTAR is an extremely powerful hard X-ray observatory
  - Black Holes
  - Supernovae explosions
  - galactic sources populations
  - Neutron Stars
  - Relativistic Jets
  - Sun
- NuSTAR provides:
  - ~3 orders of magnitude in hard X-ray sensitivity for studies
  - imaging of extended objects like SNRs and reflection nebulae
- Mission of opportunity. French contribution via IRAP.
  - DB is a NuSTAR science team member