The Nuclear Spectroscopic Telescope Array
Extragalactic Program

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on behalf of the NuSTAR team

INTEGRAL Workshop 2013
NuSTAR  
*bringing the high energy universe into focus*

NASA Small Explorer (SMEX) mission  
Launch Date: June 13, 2012  
Phase E (science operations) Start Date: August 1, 2012  
P.I.: Fiona Harrison (Caltech)  
Project Scientist: Daniel Stern (Caltech)  
http://nustar.caltech.edu
INTEGRAL, Swift BAT

high background, large detector

NuSTAR

low background, compact detector
Pegasus launch from Kwajelein (June 13 2012): low earth orbit, 550x600 km, low inclination, 6°
Ground Station: Malindi, Kenya (thanks!)
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 (10-40 keV) in 1 Ms

*NuSTAR two-telescope total collecting area*
Imaging

- HPD: 58”
- FWHM: 18”
- Localization: 2” (1-sigma)

Field of View

- FWZI: 12.5’ x 12.5’
- FWHI: 10’ @ 10 keV
  - 8’ @ 40 keV
  - 6’ @ 68 keV

Spectral response

- Energy range: 3-79 keV
- Threshold: 2.0 keV
- ΔE @ 6 keV: 0.4 keV FWHM
- ΔE @ 60 keV: 1.0 keV FWHM

Timing

- Relative: 100 microsec
- Absolute: 3 msec

Target of Opportunity

- Response: < 24 hr (reqmt)
- Typical: 6-8 hours
- 80% sky accessibility

1 Ms Sensitivity

- 3.2 x 10^{-15} erg/cm²/s (6 – 10 keV)
- 1.4 x 10^{-14} (10 – 30 keV)
The Galactic Center

INTEGRAL (2005) (2° x 0.8°)

Galactic surveys: locate remnants of collapsed stars (white dwarfs, neutron stars, black holes) to study the endpoints of stellar evolution

NuSTAR simulation (2012)
Resolving the Core of NGC 1365 in High Energy X-Rays
The galaxy IC 342, ULX-1/2 resolved for the first time above 10 keV
NuSTAR Extragalactic Surveys: Resolving the Hard 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

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background

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

INTEGRAL/Swift

1-2 %
30 keV

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background

NuSTAR’s “first born”
• NuSTAR (in purple) serendipitous source in field of IC751

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background

- 3-tiered survey:
  - ECDFS - deep
  - COSMOS - medium
  - Swift/BAT serendipitous survey (+ all NuSTAR fields) - “shallow”

- Median redshift for Swift/BAT: $z \sim 0.03$
- Median redshift for NuSTAR: $z \sim 0.7$

Mullaney et al., in prep.
NuSTAR AGN Physics:
fundamental questions

- What are the physical properties of the so-called corona?
- What is the distribution of SMBH spins?
- What is the nature of the soft X-ray excess?
- How are jets triggered? What is their role in feedback?
- What physical processes create the absorbing structures in AGN?

Urry & Padovani (1995)
NuSTAR AGN Physics:
simultaneous XMM & Suzaku campaigns

- **Science goals**: SMBH spin, coronal properties

- **Suzaku AO-7**: 3 sources, ~310 ks, **focus on corona**
  - ✓ 3C 273*
  - ✓ NGC 4151
  - ✓ IC 4329A

- **XMM AO-11**: 6 sources, ~1.5 Ms, **focus on SMBH spin**
  - ✓ 3C 273*
  - ✓ NGC 1365
  - ✓ MCG—6-30-15
  - ✓ Ark 120
  - ✓ 3C 120 (also Swift to check for inner disk disruption)
  - ✓ SWIFT J2127.4+5654
NuSTAR AGN Physics: the importance of spectral shape

• Spin alters shape of Fe K line and Compton hump in predictable, measurable ways.

• Shape of Comptonized continuum determined by $kT$, $\tau$ of coronal plasma.

• We know that $E_{\text{cut}} \sim 3kT$, so measuring $E_{\text{cut}}$ helps break degeneracy.
NuSTAR AGN Physics:
first result on the BH spin in NGC 1365
NuSTAR AGN Physics: first result on the BH spin in NGC 1365

Risaliti et al. 2013, Nature
NuSTAR AGN Physics: a long look to MCG-6-30-15

300 ks simultaneous XMM-NuSTAR Absorption and reflection models tested in a detailed time resolved analysis

Marinucci et al., in preparation
Brenneman et al., in preparation
Kara et al., in preparation
NuSTAR AGN Physics: comptonization effects in Ark 120

Optxagnf (Done et al. 2012) is a disk/corona emission model which assumes a thermal disk emission outside the coronal radius, and soft and hard Comptonization inside.

Matt et al., in preparation
NuSTAR AGN Physics:
coronal properties of IC4329 A

- XIS-BI
- FPMA
- FPMB
- PIN

$\Gamma = 1.71$
$E_{\text{cut}} = 156 \pm 23$ keV
$R = 0.31$
Fe/solar = 0.92

Brenneman et al., in preparation

- 150 ks observation in August 2012

$\cdot kT = 40 \pm 5$ keV
$\tau = 1.44 \pm 0.03$ (slab)
$\tau = 3.41 \pm 0.10$ (sphere)
NuSTAR AGN Physics: coronal properties of MCG-5-23-16

Ec = 100 ± 10 keV
Baseline Science Mission

• As typical for an Explorer, all baseline observations led by the science team
• mixture of Level 1 and Priority A targets (with fair amount of margin in reserve)
• After the current initial calibration period is completed, observations will go public through HEASARC two months after a data set is completed (next data release will be Oct. 31st)
• 1.5 Ms of NuSTAR to be made available for coordinated observations with next XMM AO (factor 6 oversubscription)
• A paper a week is being submitted by now, for a complete list of accepted/published paper:

http://www.nustar.caltech.edu/for-astronomers/publications/refereed-papers

• ~140-person international science team broken into 13 science working groups:
## Baseline Science Mission

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[http://www.nustar.caltech.edu](http://www.nustar.caltech.edu) (look under ‘for astronomers’)
Thanks!