IXO Science with Planned Future Missions

Colleen A. Wilson-Hodge

(NASA/MSFC) on behalf of the X-ray Community science team

Many thanks to Rob Petre & the Science Support Team

December 14, 2011

Approved for public release, distribution unlimited

IXO Science Objectives (1)

Table 1: Primary IXO Science Objectives

	Science Question	Measurement	Key IXO performance requirements
Strong field GR	What happens close to a black hole?	Time resolved high resolution spectroscopy of the relativistically-broadened features in the X-ray spectra of stellar mass and supermassive black holes	Spectral resolution of 2.5 eV at 6 keV; effective area > 0.65 m^2 at 6 keV and 150 cm^2 at 30 keV.
SMBH Growth	When and how did super-massive black holes grow?	Measure the spin in supermassive black holes; distribution of spins determines whether black holes grow primarily via accretion or mergers.	Spectral resolution of 150 eV at 6 keV and 1 keV at 30 keV; effective area of 3m^2 at 1.25 keV, 0.65 m^2 at 6 keV, and 150 cm^2 at 30 keV; 5 arcsec angular resolution and 18 arcmin field of view at 2 keV.

- This talk describes IXO science objectives addressed by missions that are currently being built or missions that are currently under funded study.
- This is intended as background information.

Approved for public release, distribution unlimited

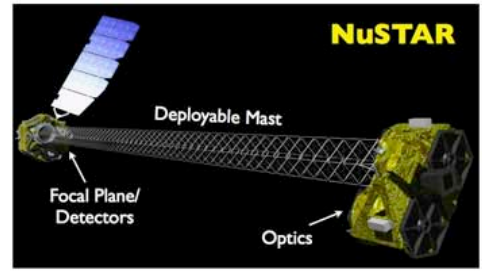
IXO Science Objectives (2)

Large Scale Structure	How does large scale structure evolve?	(i.) Find and characterize the missing baryons by performing high resolution absorption line spectroscopy of the WHIM over many lines of sight using AGN as illumination sources. (ii.) Measure the growth of cosmic structure and the evolution of the elements by measuring the mass and composition of clusters of galaxies at redshift < 2	(i.) Spectral resolving power of >3000; effective area > 1000 cm^2 in 0.3-1.0 keV band. (ii.) Imaging spectroscopy with spectral resolution of 10 eV at 6 keV; 10 arcsec angular resolution and 5 arcmin field of view across 0.3-7.0 keV band; effective area of 1 m^2 at 1.25 keV and 0.1 m^2 at 6 keV.
Cosmic Feedback	What is the connection between supermassive black hole formation and evolution of large scale structure (i.e., cosmic feedback)?	Measure the metallicity and velocity structure of hot gas in galaxies and clusters.	Imaging spectroscopy with spectral resolution of 2.5 eV at 6 keV; 5 arcsec angular resolution and 2 arcmin field of view across 0.3-7.0 keV band; effective area of 3 m^2 at 1.25 keV and 0.65m^2 at 6 keV; total bandpass of 0.3-10 keV.
NS Eq. of State	How does matter behave at very high density?	Measure the equation of state of neutron stars through (i.) spectroscopy and (ii.) timing	(i.) Spectral resolving power >3000; effective area >1000 cm^2 in 0.3-1.0 keV band. (ii.) Maximum count rate of 10^6 s^{-1} with relative timing accuracy of 10 μs and <10 percent deadtime over 0.3-10 keV band; spectral resolution of 150 eV and effective area of 0.6m^2 at 6 keV.

Approved for public release, distribution unlimited

NuSTAR

Hard Imager: 6 – 80 keV
ΔE = 0.5 keV, 0.06 m^2@20 keV
50'' HPD, 13' FOV



Launch: 2012

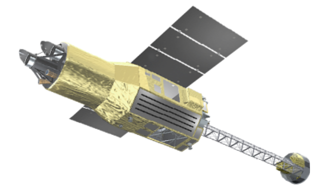
Science	Measurement	Method
Strong-field GR	Strong gravity predicts effects on X-ray spectra	Detection of Compton reflection above 10 keV in AGN and BHC
Growing SMBH	Survey of obscured AGN	Detection of ~ 100 obscured AGN in planned and serendipitous source surveys
Large Scale Structure	Get more accurate cluster masses by taking non-thermal emission into account	Will help constrain cosmic rays and magnetic fields in several clusters which would improve mass calibration
Cosmic Feedback	———	———
NS Eq. of State	Neutron star Equation of State can be mapped by measuring R, M for a range of NS	Detect cyclotron lines in accreting pulsars; absorption edges from thermonuclear NS LMXB bursts

Astro-H

Launch: 2014

uCalorimeter: 0.3 – 12 keV
ΔE = 7 eV, 0.02 m^2@1-6 keV
100'' HPD, 2.8' FOV

Hard Imager: 5-80 keV
300 cm^2 @ 30 keV
90" HPD



Science	Measurement	Method
Strong-field GR	Strong gravity predicts effects on X-ray spectra	Measure broad Fe K line with high spectral resolution integrated over orbit; shape of broad band continuum
Growing SMBH	BH spin distribution over range of redshifts	Measure Fe K line width for brightest AGN
Large Scale Structure	———	———
Cosmic Feedback	First measurements of cluster turbulence; Warm absorbers may transport AGN energy to galaxy/cluster	Measure velocity broadening in clusters; Measure density and velocity of warm absorbers, therefore determining kinetic energy outflow
NS Eq. of State	———	———

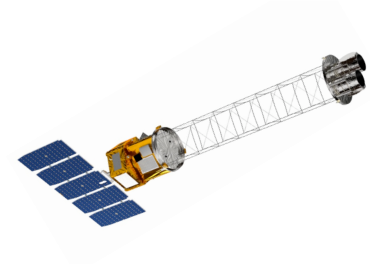
+4 Additional instruments

Approved for public release, distribution unlimited

GEMS

Launch: 2014

Polarimeter: 2 – 10 keV
1% MDP for 1 mCrab
14’ FOV; ΔE ~ 1keV



Science	Measurement	Method
Strong-field GR	Strong gravity predicts energy dependent polarization angle	Measure polarization intensity and angle in four bands
Growing SMBH		
Large Scale Structure		
Cosmic Feedback		
NS Eq. of State		

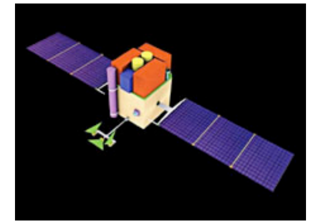
Approved for public release, distribution unlimited

Astrosat

Launch: 2012

LAXPC: 3 – 80 keV
ΔE/E = 9%, 0.6 m^2@10 keV
1-5’(scan mode), 1^o FOV

Hard Imager: 10 – 150 keV
ΔE/E~5%, 0.1 m^2 @ 20 keV
8’ FWHM, 10^o FOV



Science	Measurement	Method
Strong-field GR	Observe reflection component of inner accretion disk	Measurement of the high frequency QPOs at high energies (peaking ~30 keV) in black hole binaries
Growing SMBH	———	———
Large Scale Structure	———	———
Cosmic Feedback	———	———
NS Eq. of State	Spectral evolution during the thermonuclear X-ray bursts and the flame propagation	Bolometric measurements of the thermonuclear X-ray bursts (modestly more capably than RXTE)

* 3 Additional instruments

(Thanks to Biswajit Paul for help with Astrosat goals)

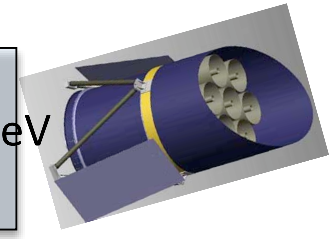
Approved for public release, distribution unlimited

Spectrum R-G

Launch: 2013

eRosita: 0.2 – 12 keV
ΔE = 130 eV, 0.23 m^2@1 keV
28'' HEW, 41' FOV

ART: 6 – 30 keV
ΔE=1.4 keV, 0.05 m^2 @6 keV
60'' HEW, 30' FOV



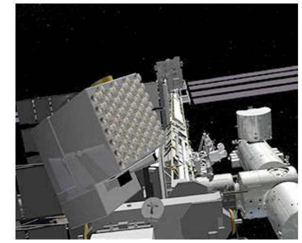
Science	Measurement	Method
Strong-field GR	Strong gravity predicts effects on X-ray spectra	Detection of Fe-K lines (eRosita) + Compton reflection (ART) in bright AGN and BHC
Growing SMBH	(i) Number counts and spectra at moderate to high z can probe growth of SMBH (ii) spin measurements	(i) Detect ~ 10^4 AGN in all-sky survey (ii) Detect broad Fe-K and Compton reflection from eRosita and ART data.
Large Scale Structure	Detect the growth of cosmic structure and the evolution of the elements	Detect up to 10^5 clusters, many with enough counts for spectral analysis, mass determination
Cosmic Feedback	———	———
NS Eq. of State	———	———

Approved for public release, distribution unlimited

NICER

Launch: 20xx

Detector: 0.4 – 10.0 keV
ΔE=300 eV, 0.06 m^2 @6 keV
Timing: 100 ns absolute; 3' HPD



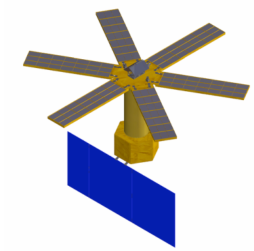
Science	Measurement	Method
Strong-field GR		
Growing SMBH		
Large Scale Structure		
Cosmic Feedback		
NS Eq. of State	Neutron star Equation of State can be mapped by measuring R, M for a range of NS	Light curve modeling of >3-4 thermally emitting rotation powered ms pulsars and 2 accreting ms pulsars; M & R to 5-10%

LOFT

Launch: 20xx

LAD: 2-50 keV
ΔE=200 eV, 10 m^2 @6 keV
Timing: 10 μs; 1° fov

WFM: 2-50 keV
ΔE=<300 eV, >80 cm^2 @6 keV
Timing: 10 μs ; 5' FWHM



Science	Measurement	Method
Strong-field GR	(i) Strong gravity predicts effects on X-ray spectra. (ii) Strong gravity effects via high frequency QPO modeling	(i) Low resolution Fe-K line fitting and continuum fitting (ii) Timing studies, harmonic content, at high count rates with high throughput
Growing SMBH	—	—
Large Scale Structure	—	—
Cosmic Feedback	—	—
NS Eq. of State	Neutron star Equation of State can be mapped by measuring R & M for a range of NS	Measure M to 4% and R to 2-3% for > 5 NS Constrain spin distribution maximum for LMXB NS; Seismic oscillations in SGRs

Approved for public release, distribution unlimited

Summary

- 5 missions in progress (NuSTAR, Astro-H, GEMS, Spectrum R-G, Astrosat)
- 2 missions under funded study (NICER, LOFT)
- All address at least one IXO objective at some level

Approved for public release, distribution unlimited