Future Developments in X-ray Astronomy

XMM-Newton 10th Anniversary Meeting
2009 December 10

Mike Watson, Leicester University

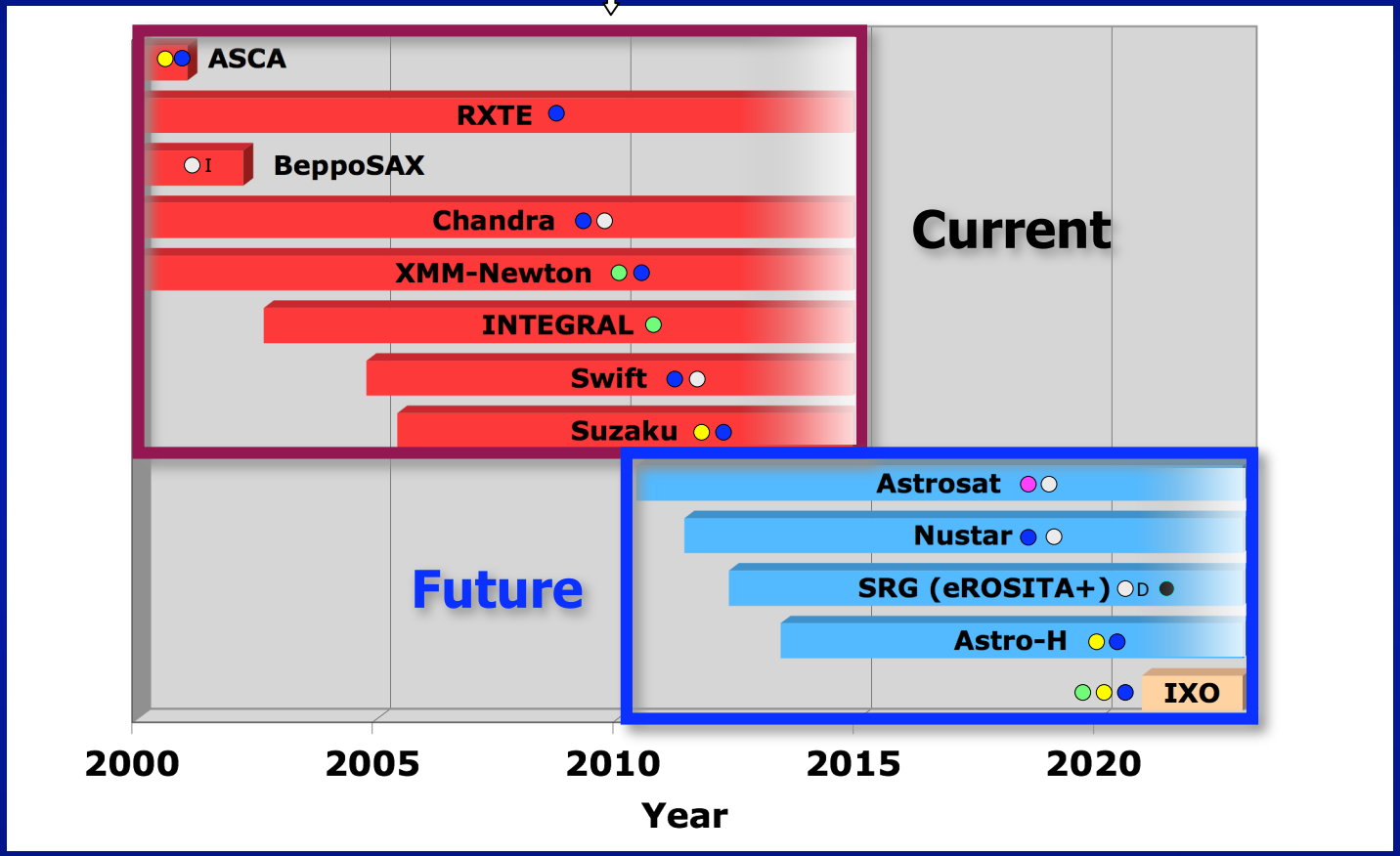
The next 15 years

- What can we look forward to?
- How will future missions complement and expand current capabilities?

- Will we still need XMM in 2015? Yes!
- Is there a case for IXO? Yes!

Credits: material liberally adapted from HEASARC, Astro-H, eRosita, Nustar and IXO websites and from presentations by Peter Predehl & Nick White

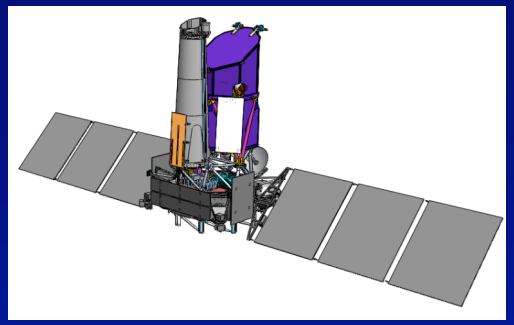
Current and future X-ray missions



other missions: Agile, Fermi, MAXI, SVOM, GEMS, NHXM …

e-Rosita

- e-Rosita:
  - 7 telescopes, 350 cm^2 each, CCD cameras
  - large field of view (61 arcmin Ø)
  - survey grasp ~4-5 × XMM-Newton (MOS+PN)
  - PSF 15" HEW on-axis, ~30" FOV-averaged
  - 4y sky survey

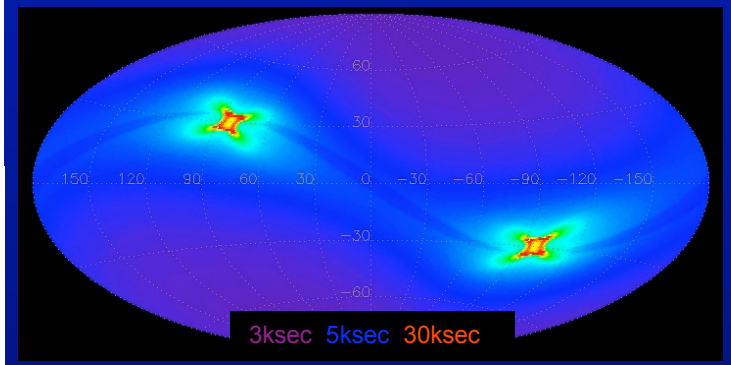


Spectrum R-G mission

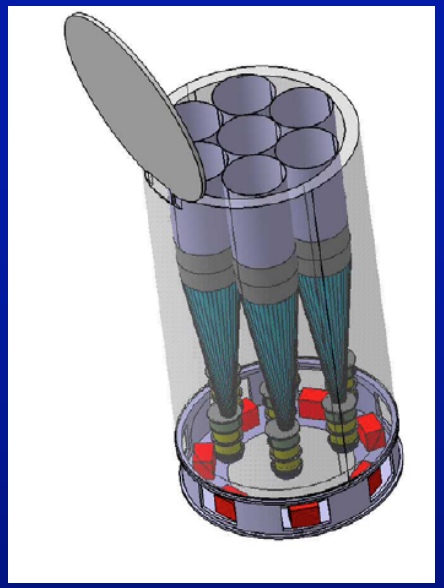
Russian / German collaboration

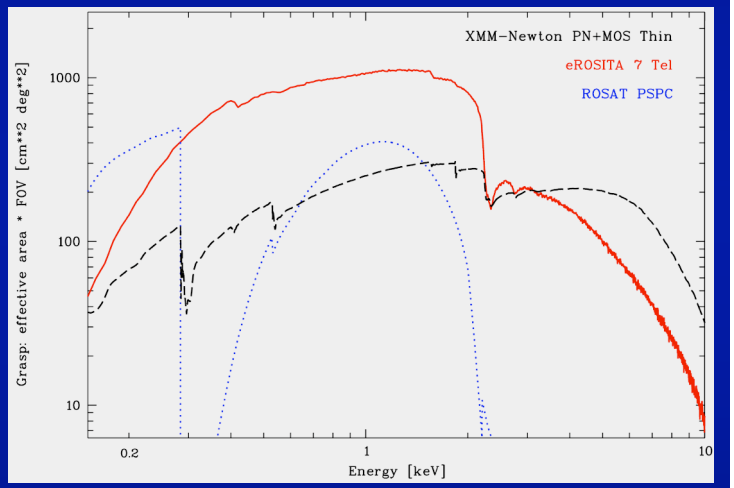
launch 2012, L2 orbit

e-Rosita: ~0.2-10 keV + ART



e-Rosita survey sky exposure (4y)

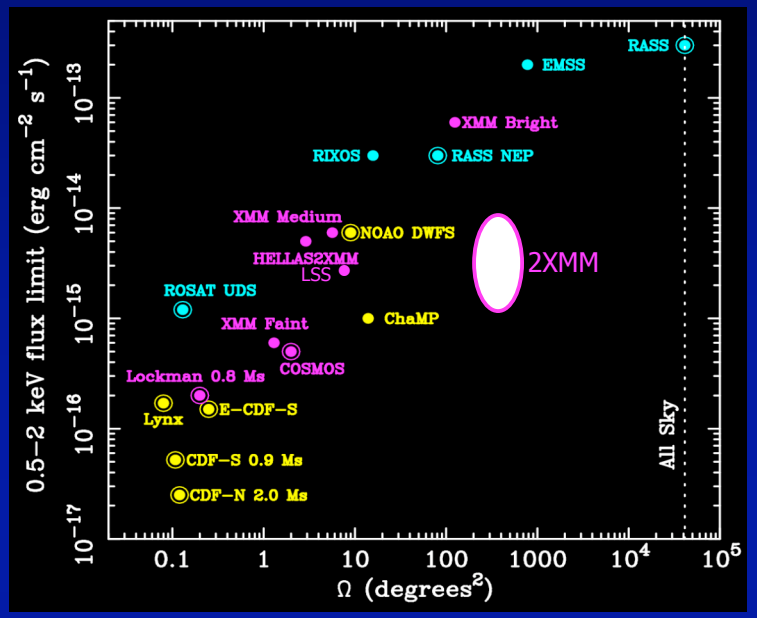




e-Rosita survey grasp A.Ω

X-ray sky surveys

- Last all-sky X-ray survey (RASS) was 18 years ago … and last all-sky hard X-ray survey (HEAO-1) was 30 years ago
- XMM-Newton surveys:
  - serendipitous survey catalogues: ~500 sq.deg
  - contiguous surveys: LSS etc. ≤10 sq.deg.



- e-Rosita sky survey
  - factor >10 fainter than previous sky surveys
  - enormous object catalogues
  - good imaging and spectral resolution (CCDs)
- Science: large scale structure and cosmology with cluster sample + AGN population studies

- e-Rosita sky survey predictions
  - 100,000 clusters
    ~100 clusters @ z>1.5
  - 3 million AGN
    [450,120, 36, 10]
    @ z >[6, 7, 8, 9]

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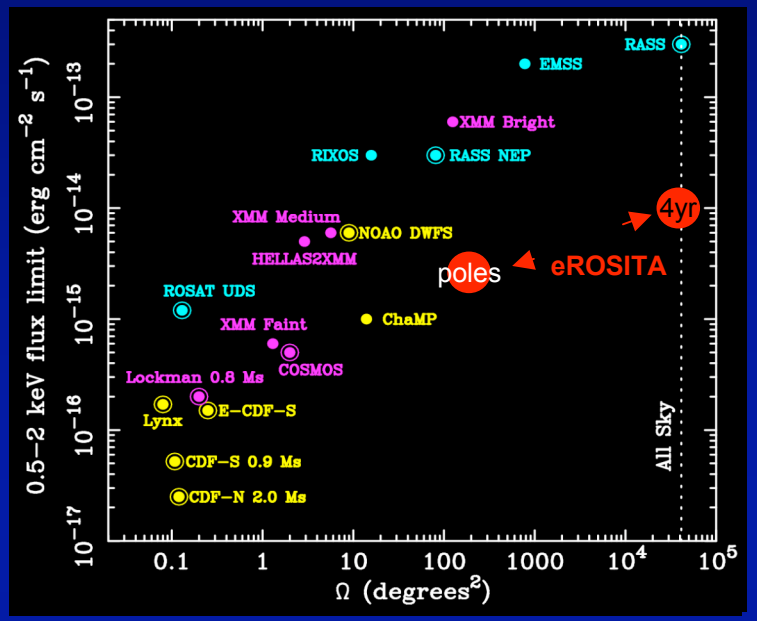

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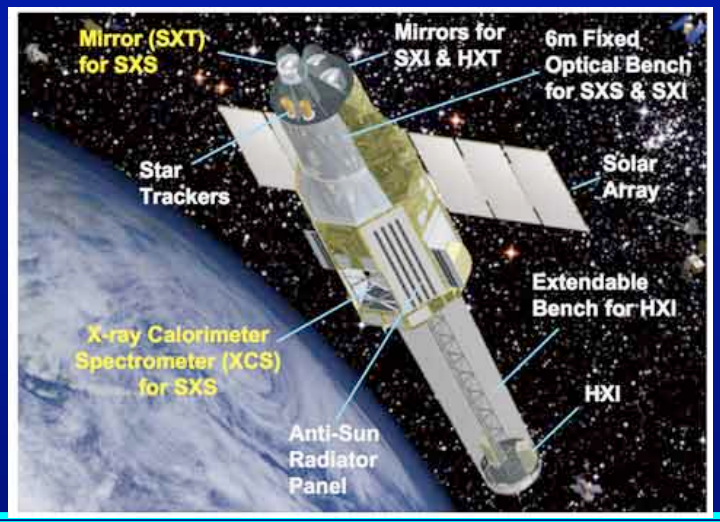
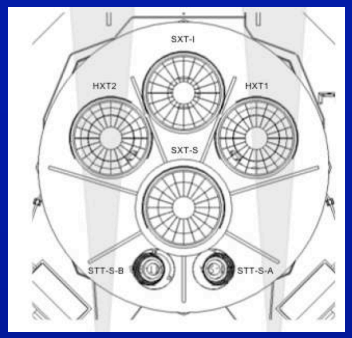
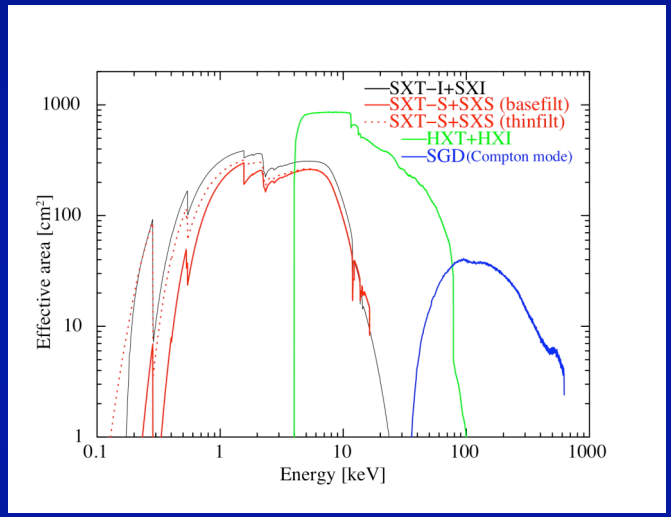
Astro-H

Japanese mission with NASA participation
launch 2013, LEO
6/12m focal length grazing incidence telescopes (SXT/HXT)
SXT/SXI & SXS: ~0.3-12 keV
HXT/HXI: 5-80 keV + SGD

- 2 soft X-ray telescopes (SXT), 2 hard X-ray telescopes (HXT)
- SXI: CCD detectors ~ 35'x35' FOV;
  SXS: calorimeter ~3'x3' FOV (6 x 6 pix);
  HXI: silicon strip and CdTe detectors ~9'x9' FOV
- Telescope PSF: 60-90"





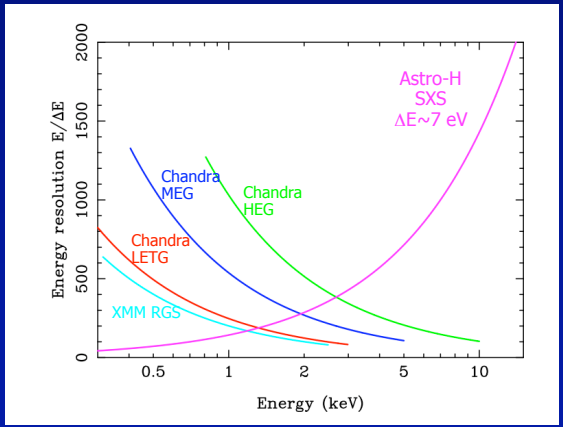


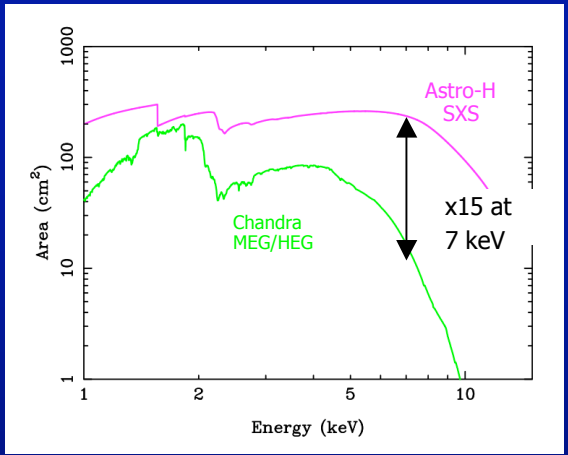
- Coverage of whole band from ~0.3 to 80 keV
- Imaging spectrometer SXS: 7eV resolution ⇒ $\Delta v \sim 300$ km s^{-1}

High resolution X-ray spectroscopy

- Current high spectral resolution (E/ΔE>100) capability restricted to grating spectrometers:
  - *soft band*: XMM RGS, Chandra LETG/HETG
  - *hard band*: Chandra HETG
- Low effective areas ⇒ restricted to bright sources

- Astro-H SXS will provide large improvement in high resolution spectroscopy above 2 keV
  - *imaging* cryogenic detector (calorimeter) with ΔE~7 eV
- Science drivers
  - plasma dynamics
    - bulk motion, turbulence in clusters (& SNR, galaxies)
    - inflow/outflow, ionisation structure in AGN
  - detailed plasma diagnostics
  - abundances





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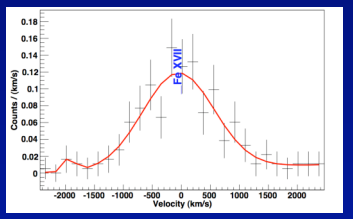
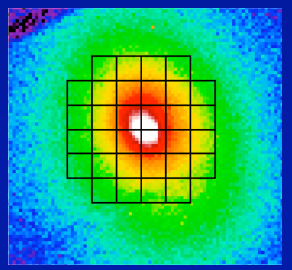
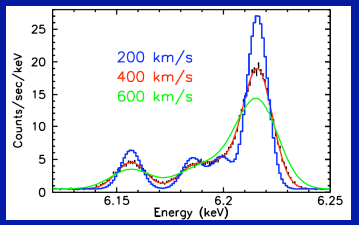
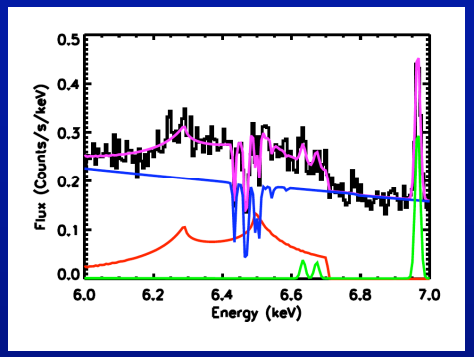


Velocity measurements of M82 superwind





Turbulence in A2029

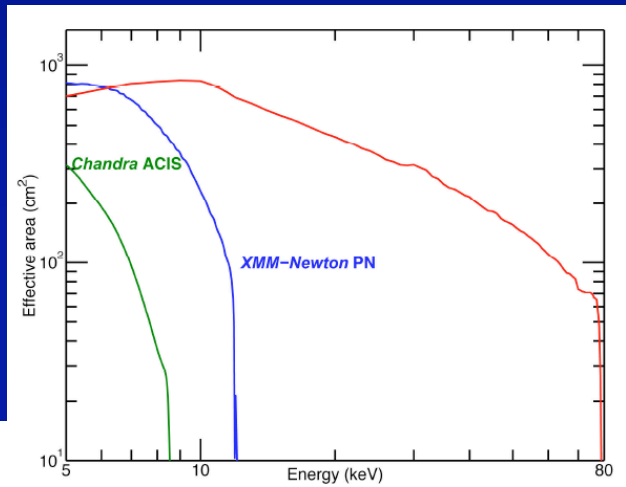


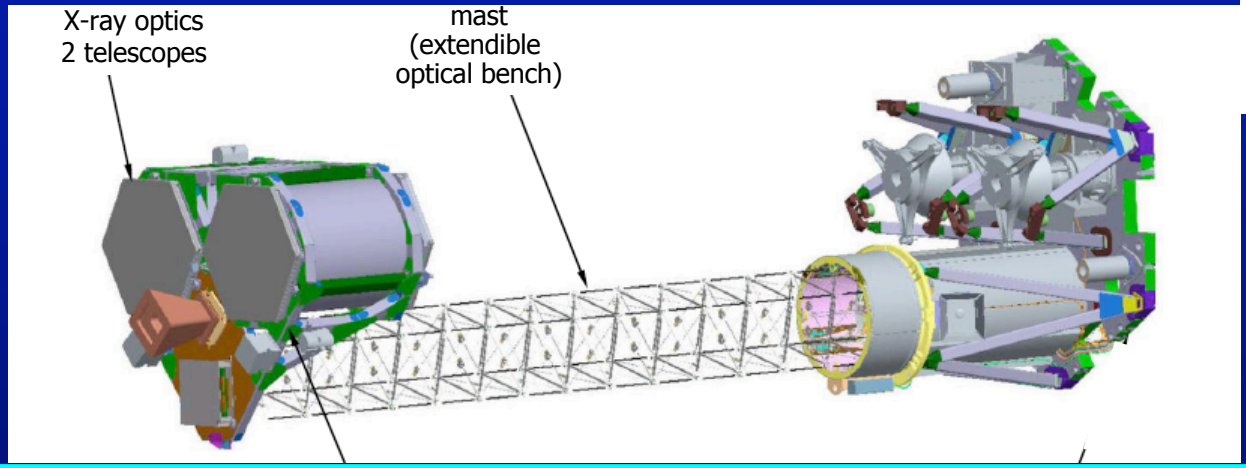
Fe K absorption lines in NGC 3783

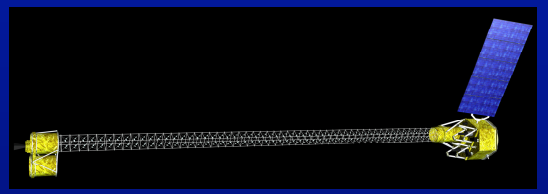
Nustar

NASA mission
led by Caltech
launch 2011, LEO
10m grazing incidence telescopes (multi-layers)
6-80 keV

- Grazing incidence hard X-ray telescope (with multilayers)
  - PSF ~45" HEW
  - FOV ~12x12'
- CZT detector; $\Delta E \approx 1$ keV @ 60 keV
- First high energy X-ray imaging (above 10 keV)







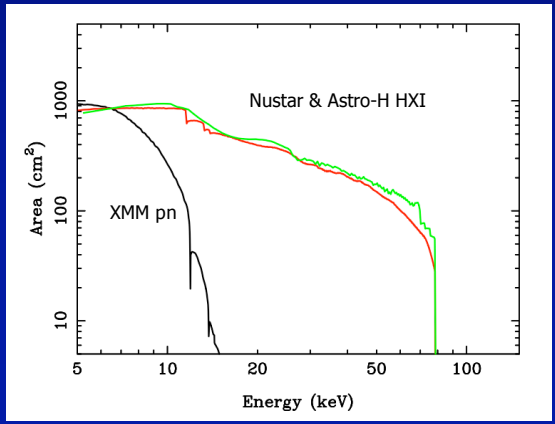
X-ray imaging above 10 keV

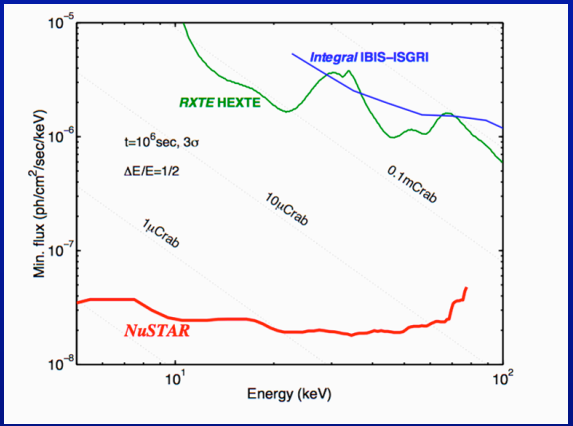
- Observations above ~10 keV currently limited to non-imaging instruments (eg. Suzaku HXD, Swift BAT, Integral IBIS)

⇒ Limited to bright sources

- Nustar and Astro-H HXT/HXI will bring first imaging to the hard X-ray band
  - sensitivity increase by factor ~100
- Science drivers
  - obscured AGN
  - particle accelerators/non-thermal spectra: GC, SNR, PWN, AGN-jets

  ...





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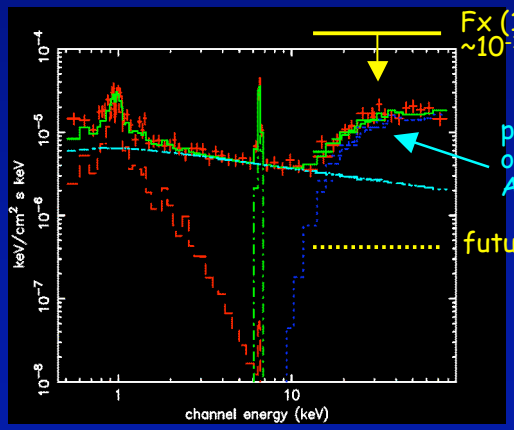
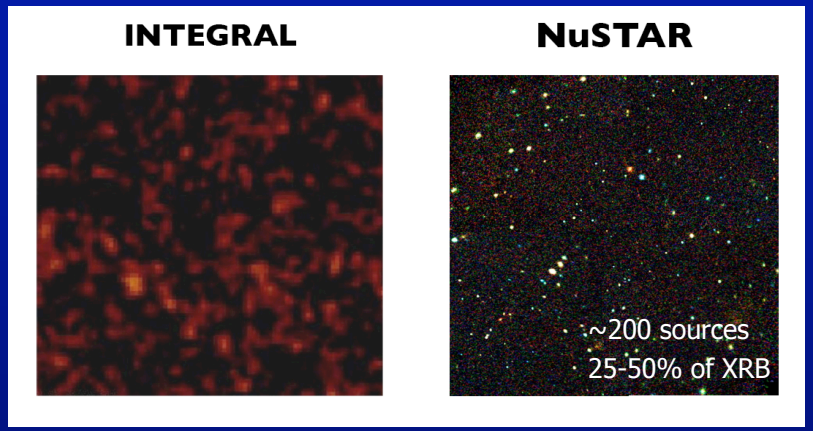


Arp 220 simulation, courtesy Valentina Braito

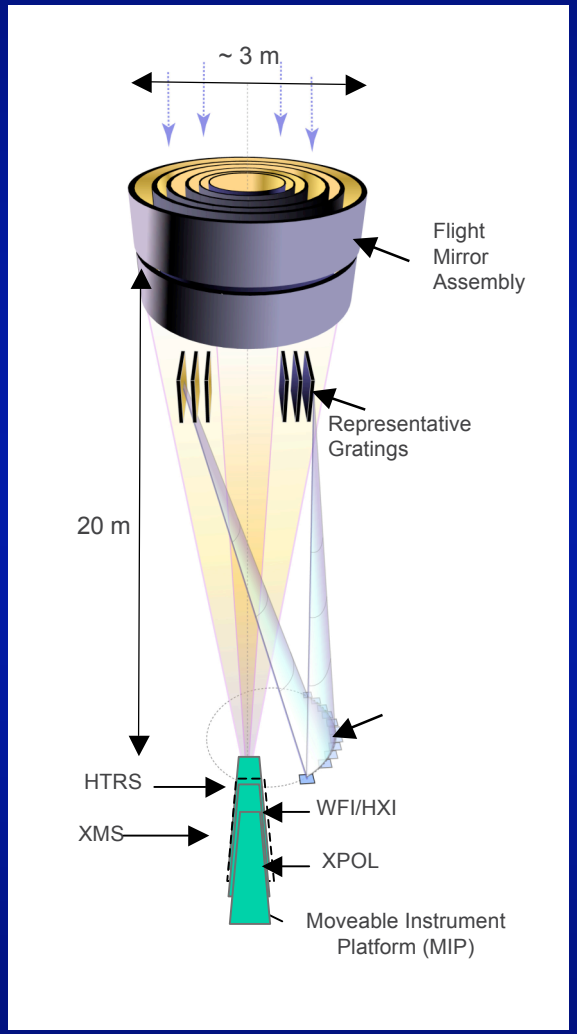


Simulation of 2x2 deg. field

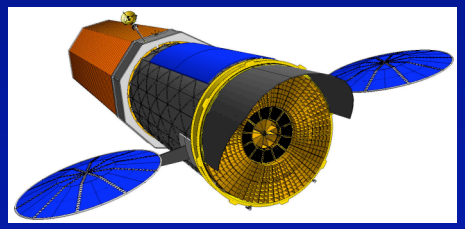
IXO

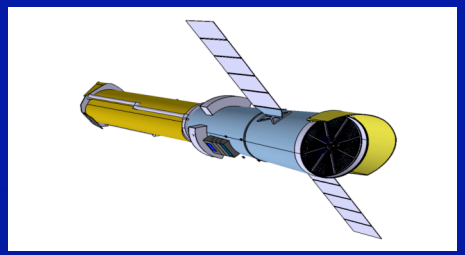
International X-ray Observatory

Joint ESA/JAXA/NASA Mission
merger of Con-X & XEUS July 2008
under review in US Decadal and ESA Cosmic Visions
launch 2021, L2 orbit
20m focal length
XMS, WFI, HTRS, XPOL, XGS, HXI



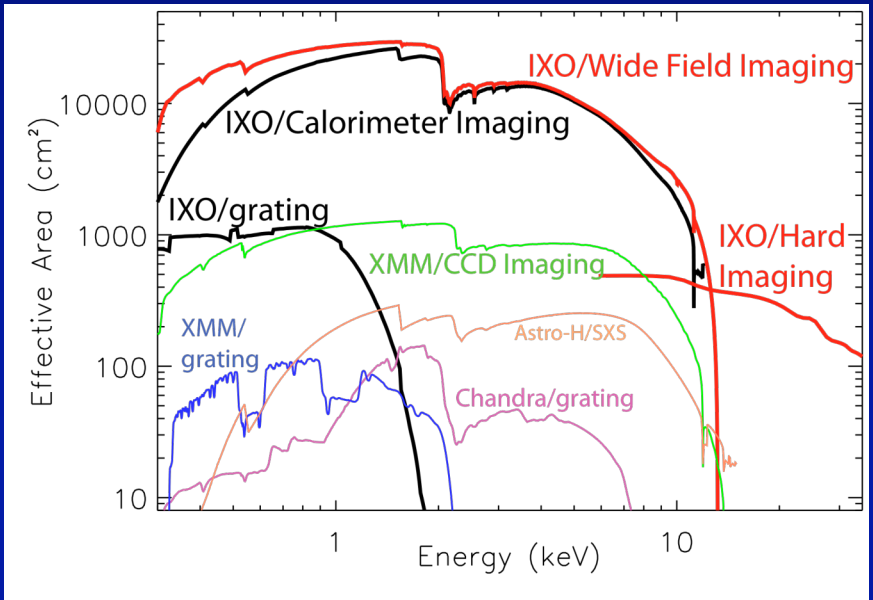
- X-ray mirrors (aka FMA)
  - highly nested grazing incidence optics
  - 3 sq m @ 1.25 keV with a 5" PSF
- Instruments
  - X-ray Micro-calorimeter Spectrometer (XMS)
  - X-ray Grating Spectrometer (XGS)
  - Wide Field Imager (WFI) and Hard X-ray Imager (HXI)
  - X-ray Polarimeter (XPOL)
  - High Time Resolution Spectrometer (HTRS)

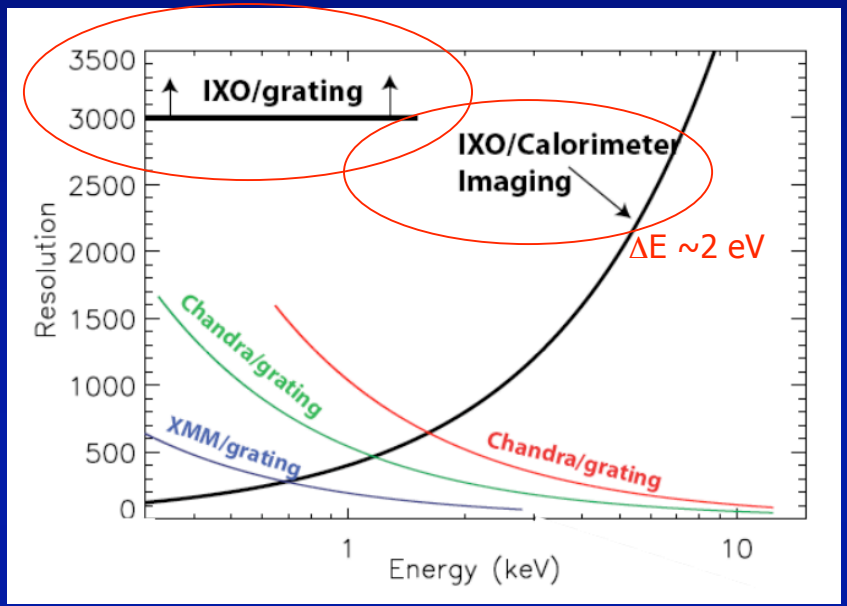




Instrument		Bandpass	PSF (HPD)	FOV	Energy Resolution	Science Driver
		keV	arcsec	arcmin	eV@keV	
XMS	Core	0.3–12	5	2 × 2	2.5@6	Galaxy Clusters
	Outer			5 × 5	10@6	
WFI/ HXI	WFI	0.1–15	5	18 diameter	150@6	SMBH survey
	HXI	10–40	30	8 × 8	1000@30	SMBH Spin
XGS		0.3–1.0	5	N/A	E/ΔE = 3000	Cosmic Web
HTRS		0.3–10	N/A	N/A	150@6	NS EoS
XPOL		2.0–10.0	6	2.5 × 2.5	1200@6	SMBH Spin

IXO performance

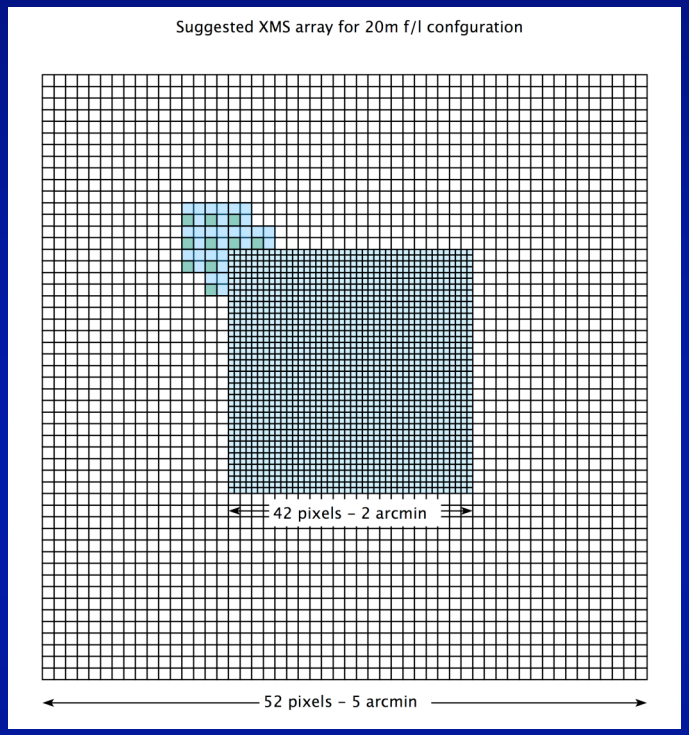


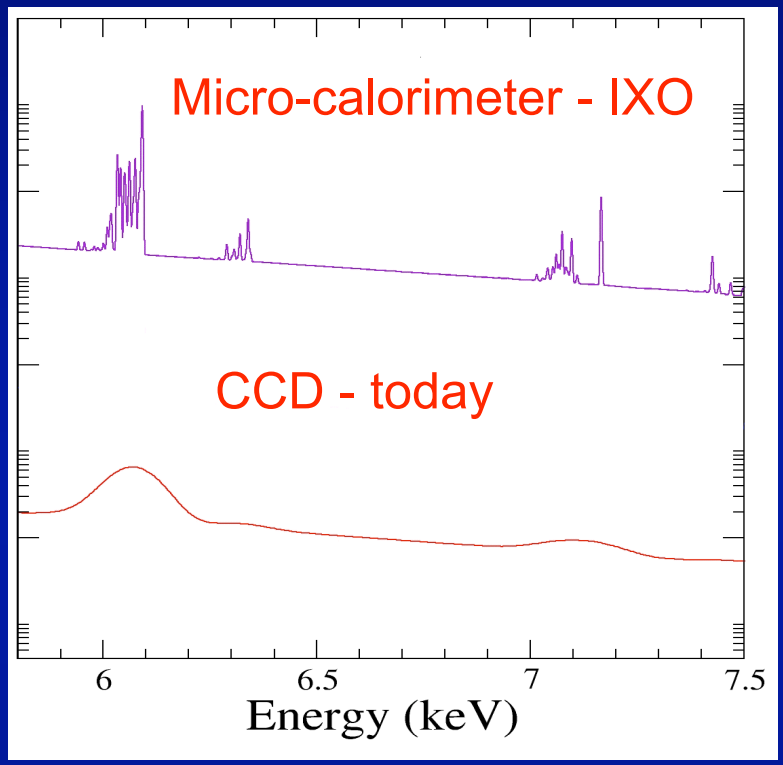


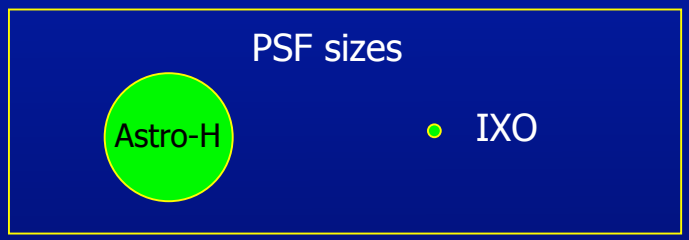
- Imaging/CCD spectroscopy: effective area a factor of >10x of current missions
- Imaging high resolution spectroscopy: capabilities >100x of current missions

The improvement of IXO relative to current X-ray missions is equivalent to a transition from a 4m telescope to a 20m telescope, while at the same time shifting from multi-band imaging to an integral-field spectrograph.

IXO XMS calorimeter: 5’ x 5’ FOV pixel size matches PSF



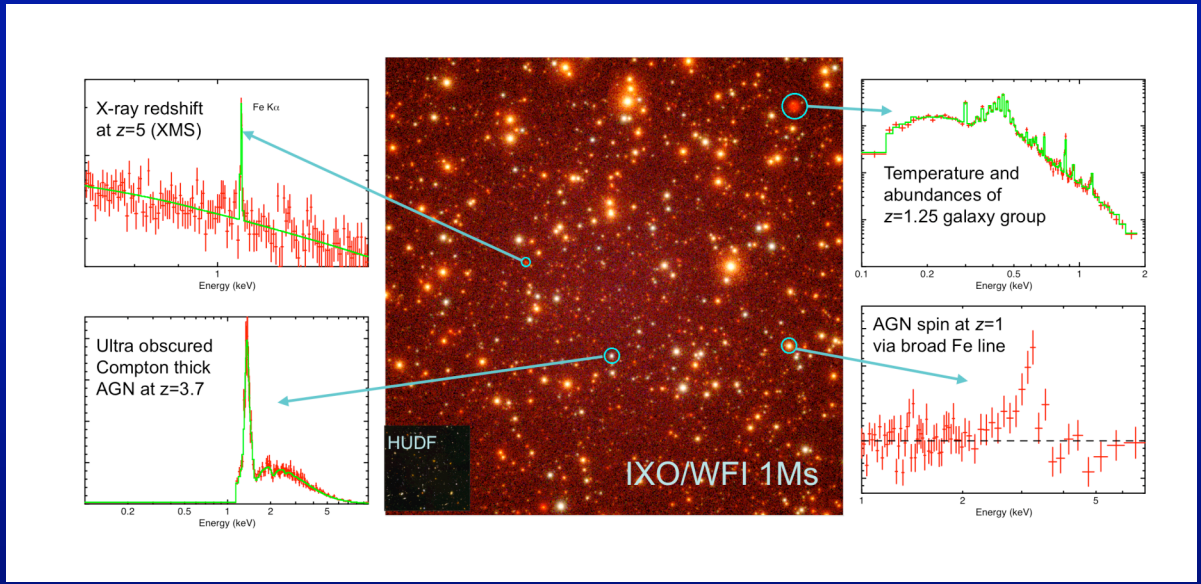




IXO science

- Interconnected science goals:
  - extreme environment and evolution of black holes
  - energetics and dynamics of the hot gas in large cosmic structures
  - constrain the equation of state of neutron stars
  - track the dynamical and compositional evolution of interstellar and intergalactic matter

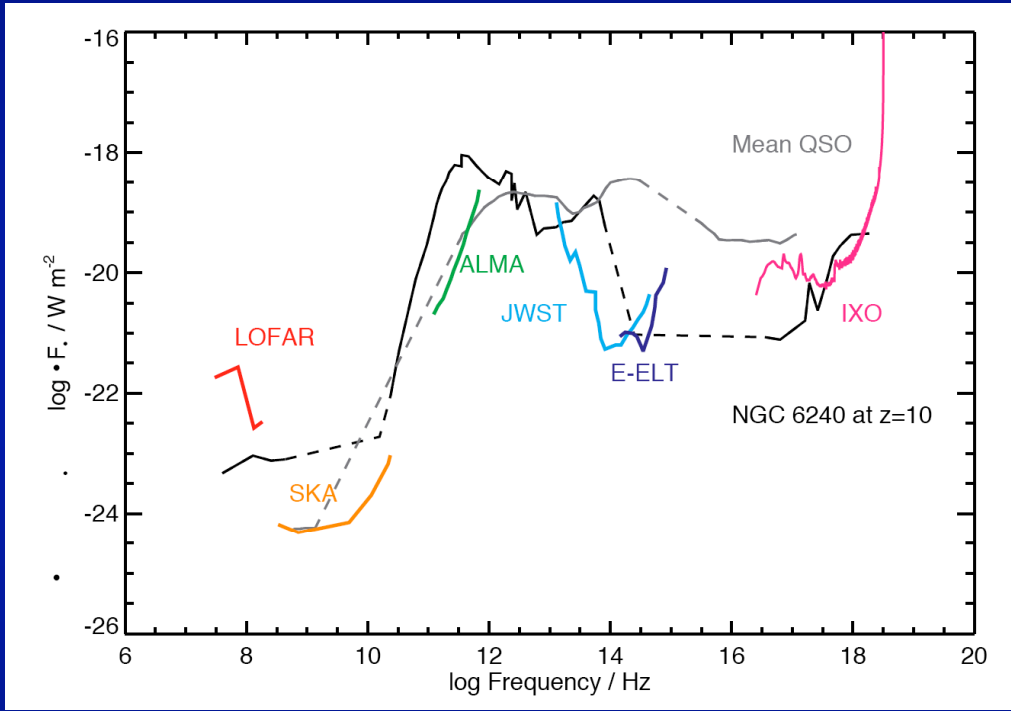
IXO studies of virtually every class of astronomical object will return rich new discoveries



The case for IXO

IXO addresses wide range fundamental astrophysics questions …

- X-ray studies provide the best way to explore the hot and extreme Universe - complementary to UV/opt/IR/radio ..
- IXO capabilities represent a significant step forward - by factors of 10 to 100
  - *not available for missions to be launched in next 5 years*
  - IXO required to extend X-ray studies beyond the local Universe
  - and to match planned capabilities at other wavelengths
- Worthy successor to XMM-Newton and Chandra



Nandra et al., 2009. Decadal White Paper

Summary

Next 5 years

- e-Rosita 2012
  - new hard X-ray sky survey, *target discovery for other missions*
- Nustar 2011
  - true hard X-ray imaging above 10 keV
- Astro-H 2013
  - high resolution spectroscopy (& imaging) up to 10 keV

  … plus broad band-pass and true hard X-ray imaging

Beyond

- IXO 2021
  - enormous area for imaging/spectroscopy/polarimetry/timing … extending to 80 keV
  - more revolution than evolution!

XMM's capabilities unique?

	2009	2019	
EPIC: highest throughput for X-ray imaging & CCD spectroscopy + best PSF (apart from Chandra!)	yes	yes	Astrosat,eRosita and Astro-H have lower areas and worse PSF
RGS: low energy grating spectroscopy (including small-scale extended objects)	yes	yes	no new grating instruments, calorimeter resn.not competitive below ~2 keV