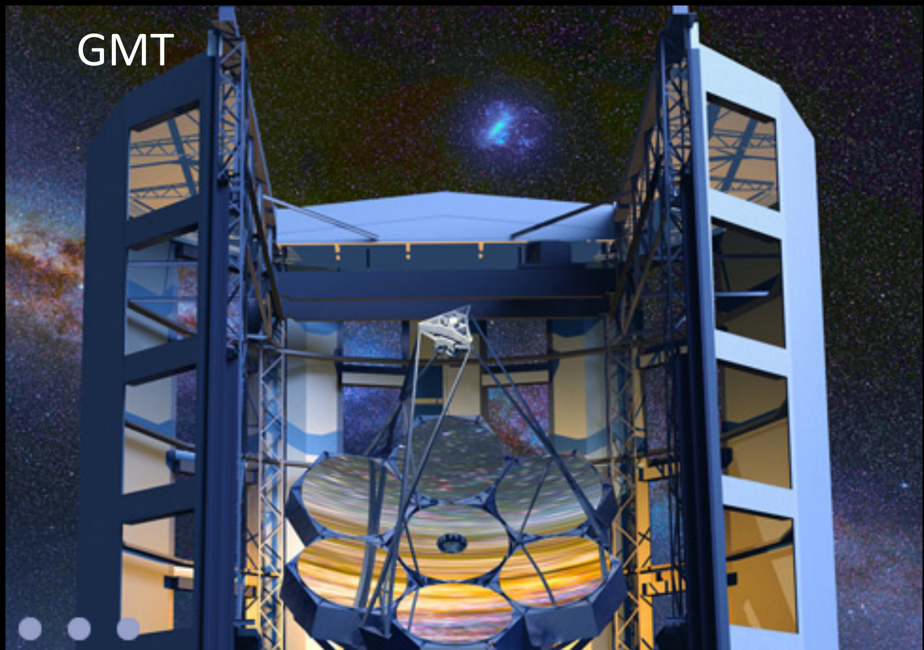
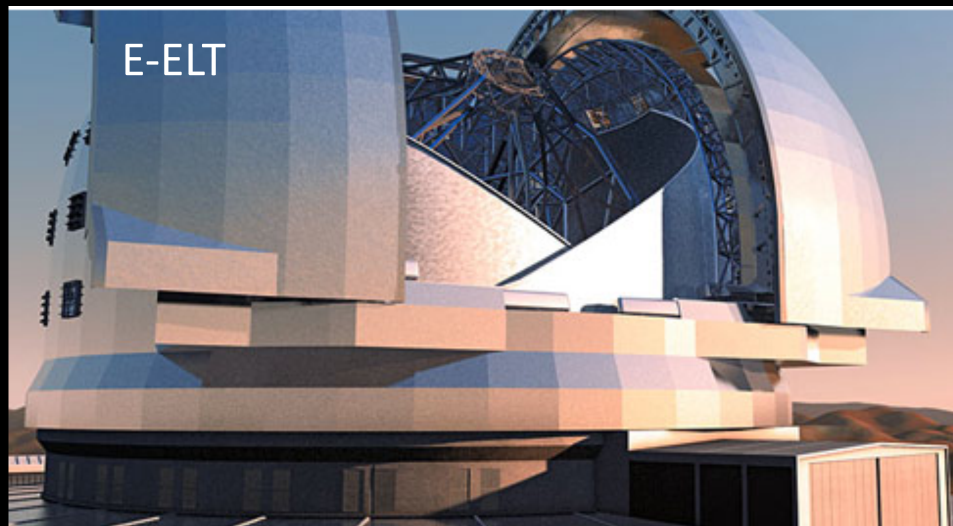
X-ray Telescopes
&
The Next Generation Large Ground Based Telescopes

G. Fabbiano
Harvard-Smithsonian CfA

Next Generation Large Ground Based Telescopes





X-ray observations provide unique synergy in the study of the high Z universe

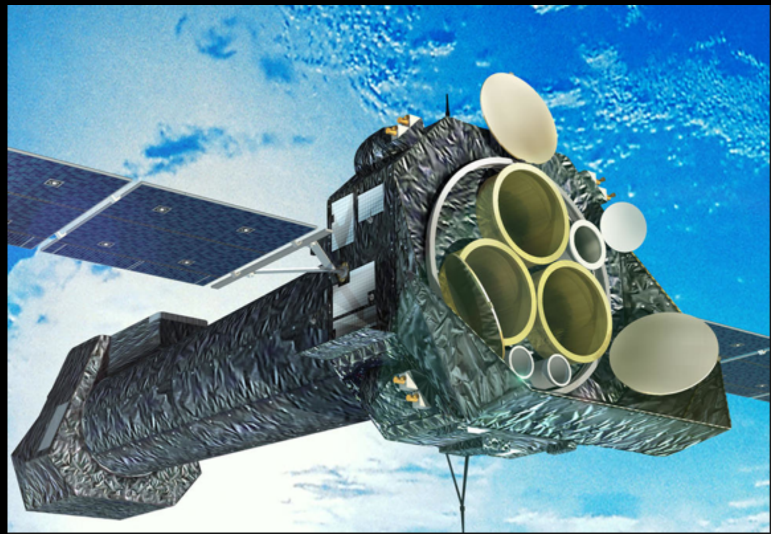
- Formation and evolution of large scale structures
  - Galaxy clusters
  - Galaxy groups
  - The cosmic web
- Formation and evolution of galaxies
  - Evolved stellar component
  - Hot ISM
- Formation and growth of BH
- Feedback

The X-ray Landscape (present) Great Observatories

Chandra - NASA

Optimizes Angular Resolution and Sensitivity

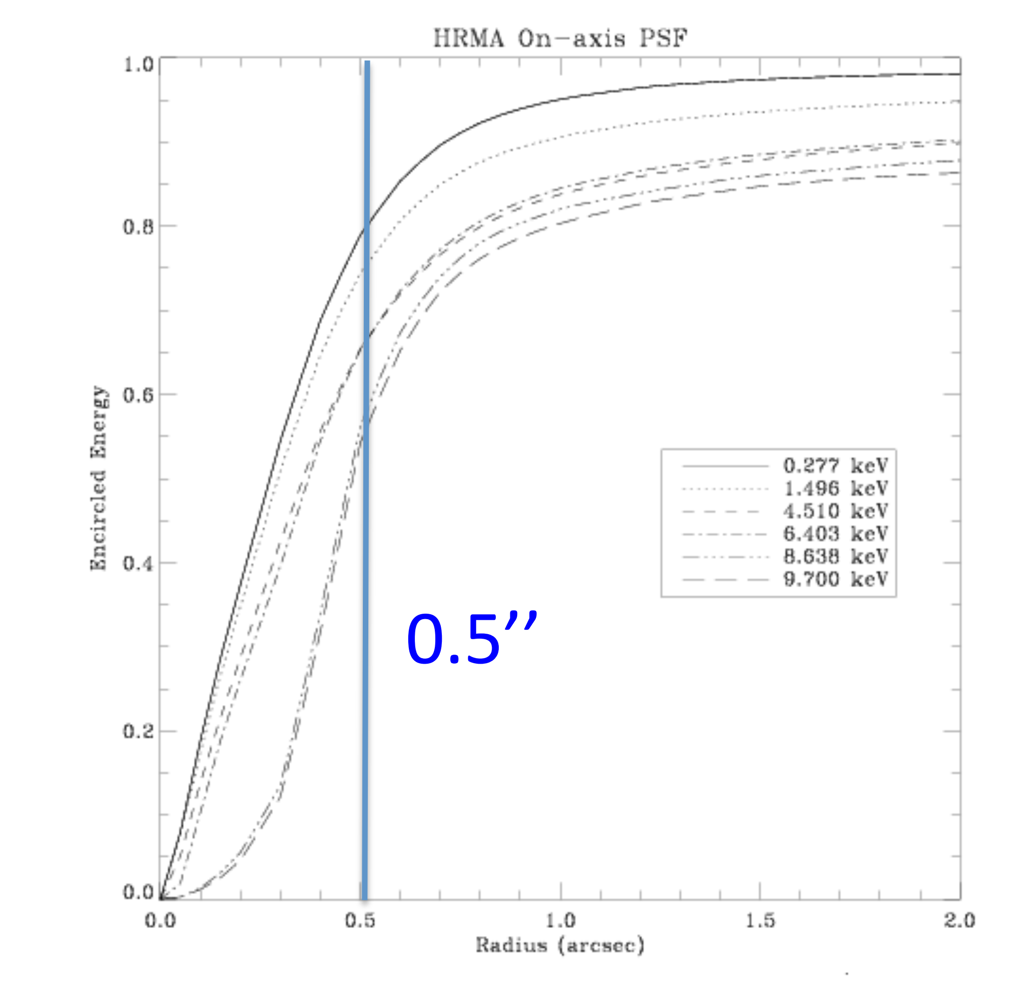
XMM-Newton - ESA

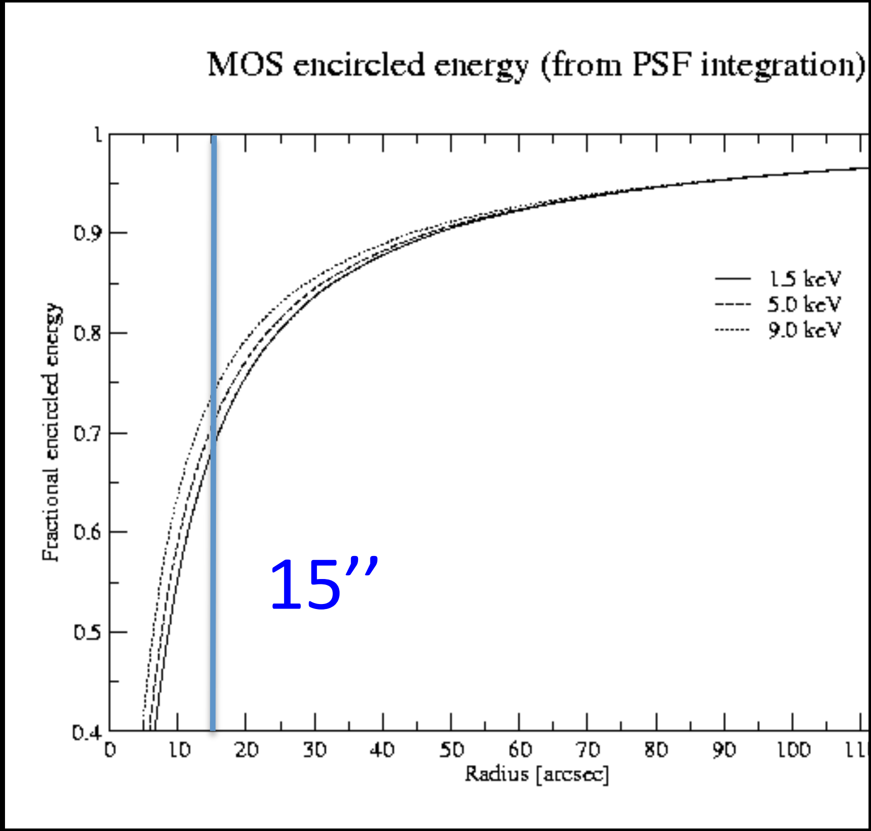


Optimizes Collecting Area

Chandra *XMM-Newton*

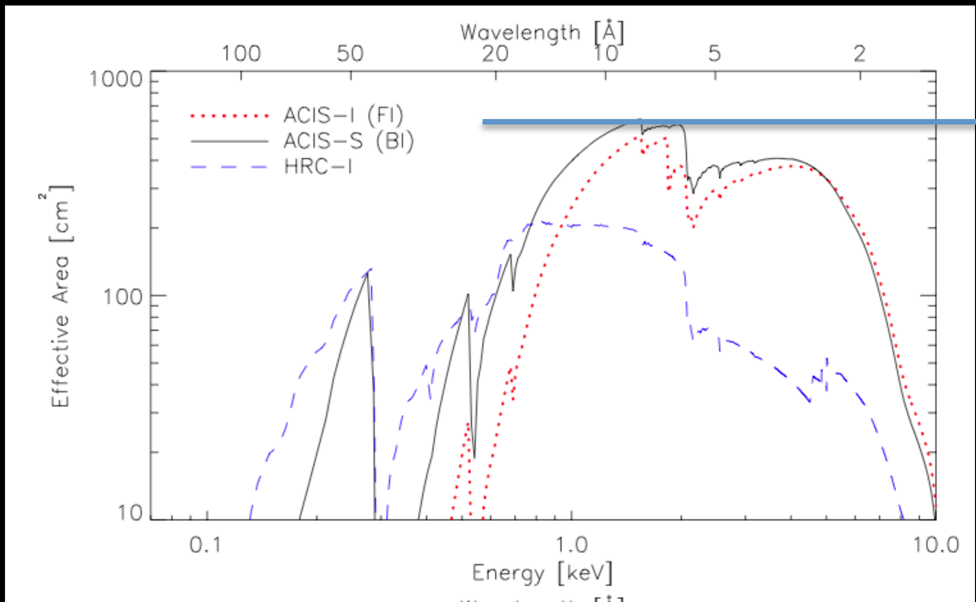
Angular Resolution

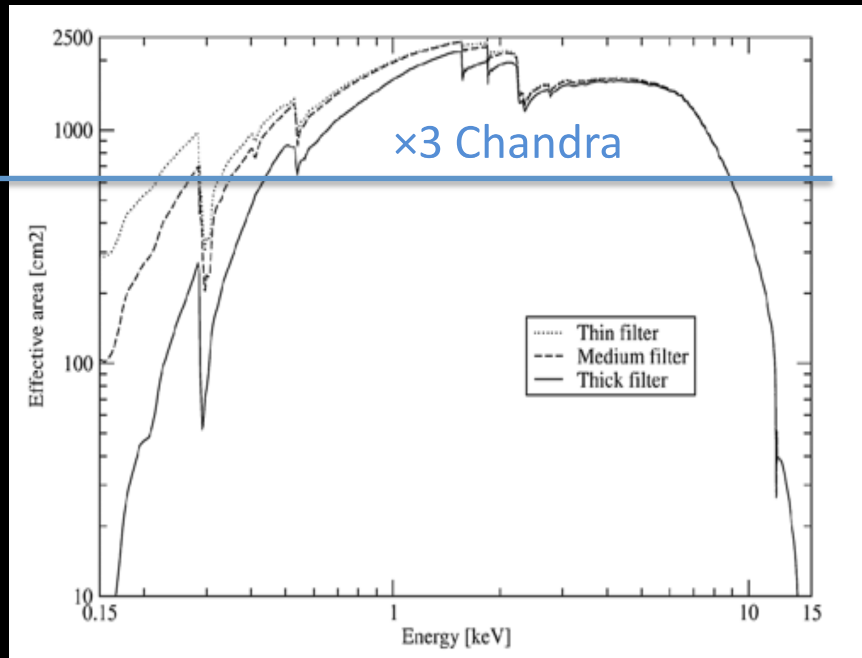




Chandra *XMM-Newton*

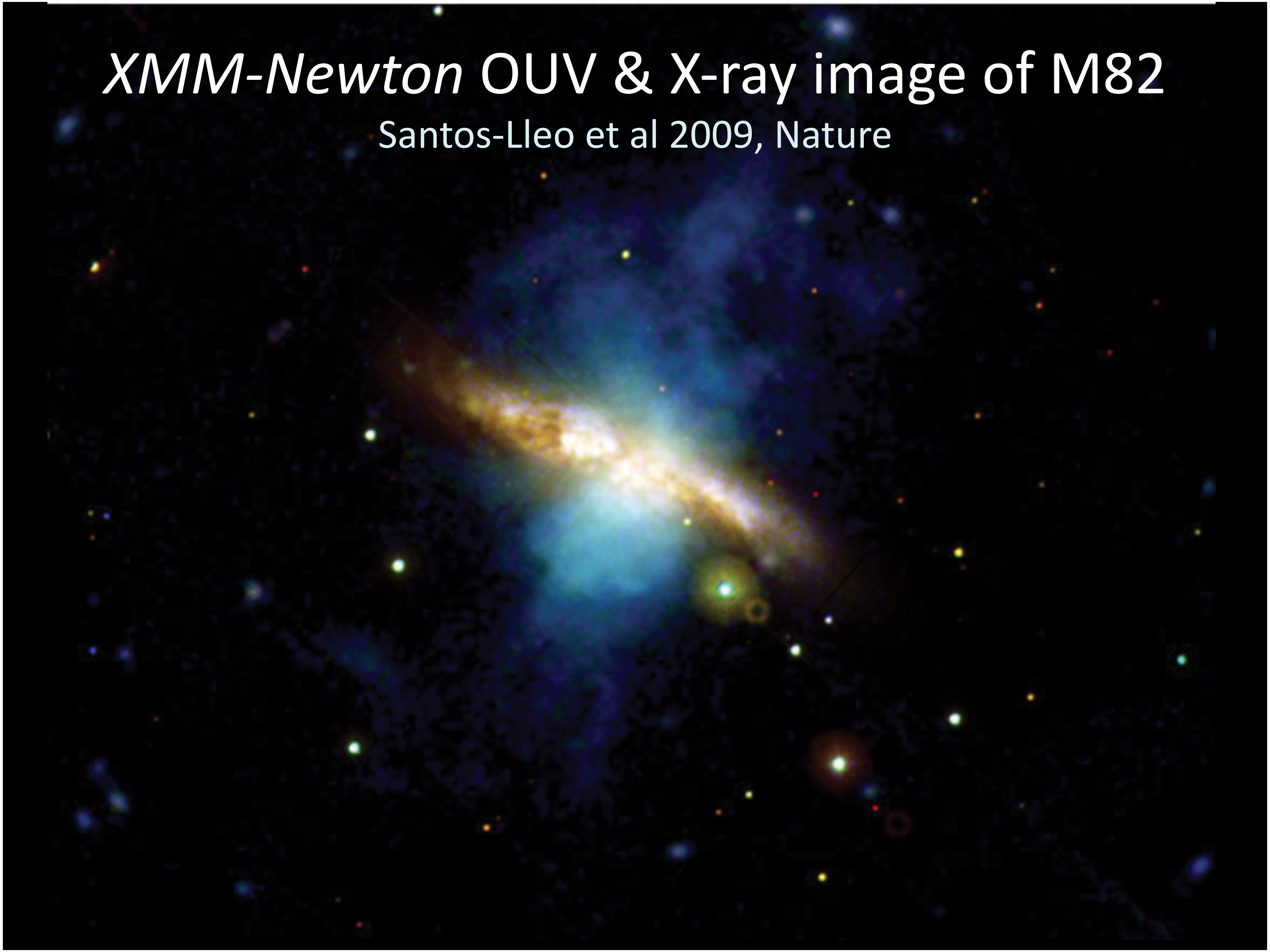
Imagers Effective Area

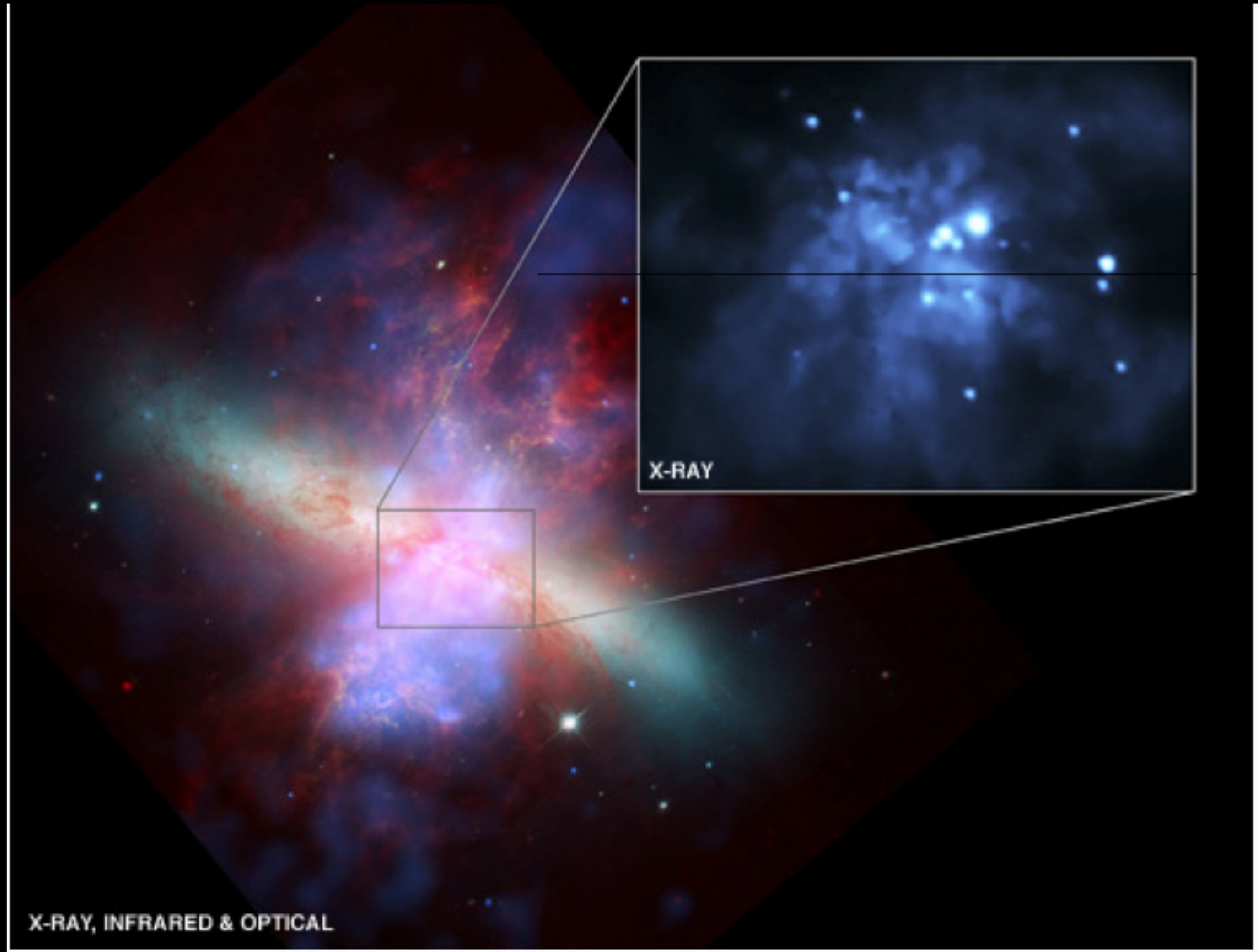




XMM-Newton OUV & X-ray image of M82

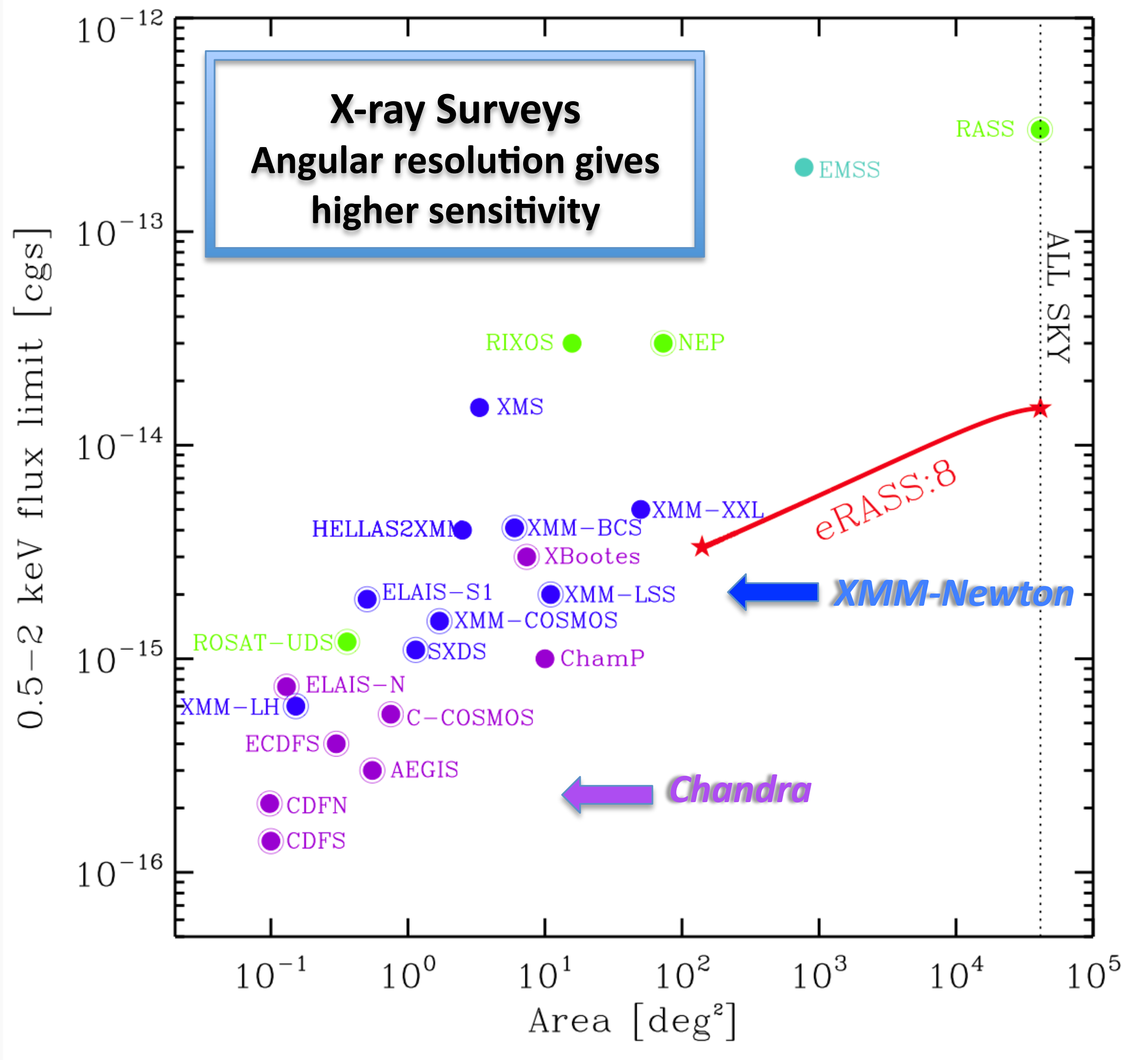
Santos-Lleo et al 2009, Nature





Chandra (blue), *HST* (orange & green), *Spitzer* (red)

Chandra Press Release - April 29, 2010



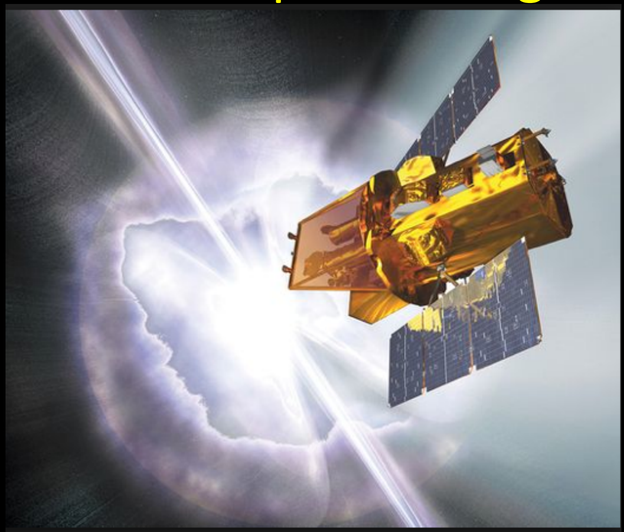
eRosita planned survey area versus flux in comparison to existing AGN surveys

The X-ray Landscape (present)

Swift - NASA

Gamma Ray Burst Mission

~1'' burst positioning



Suzaku – JAXA-NASA

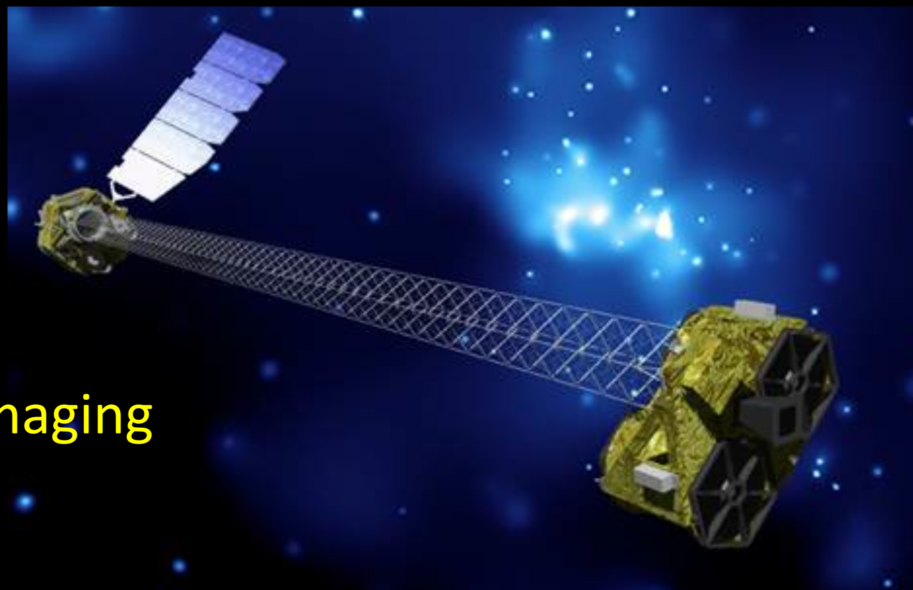
Originally to perform ~6 keV high resolution spectroscopy

NuSTAR - NASA

6 – 79 keV

First High Energy X-ray Imaging telescope

PSF ~ 40"

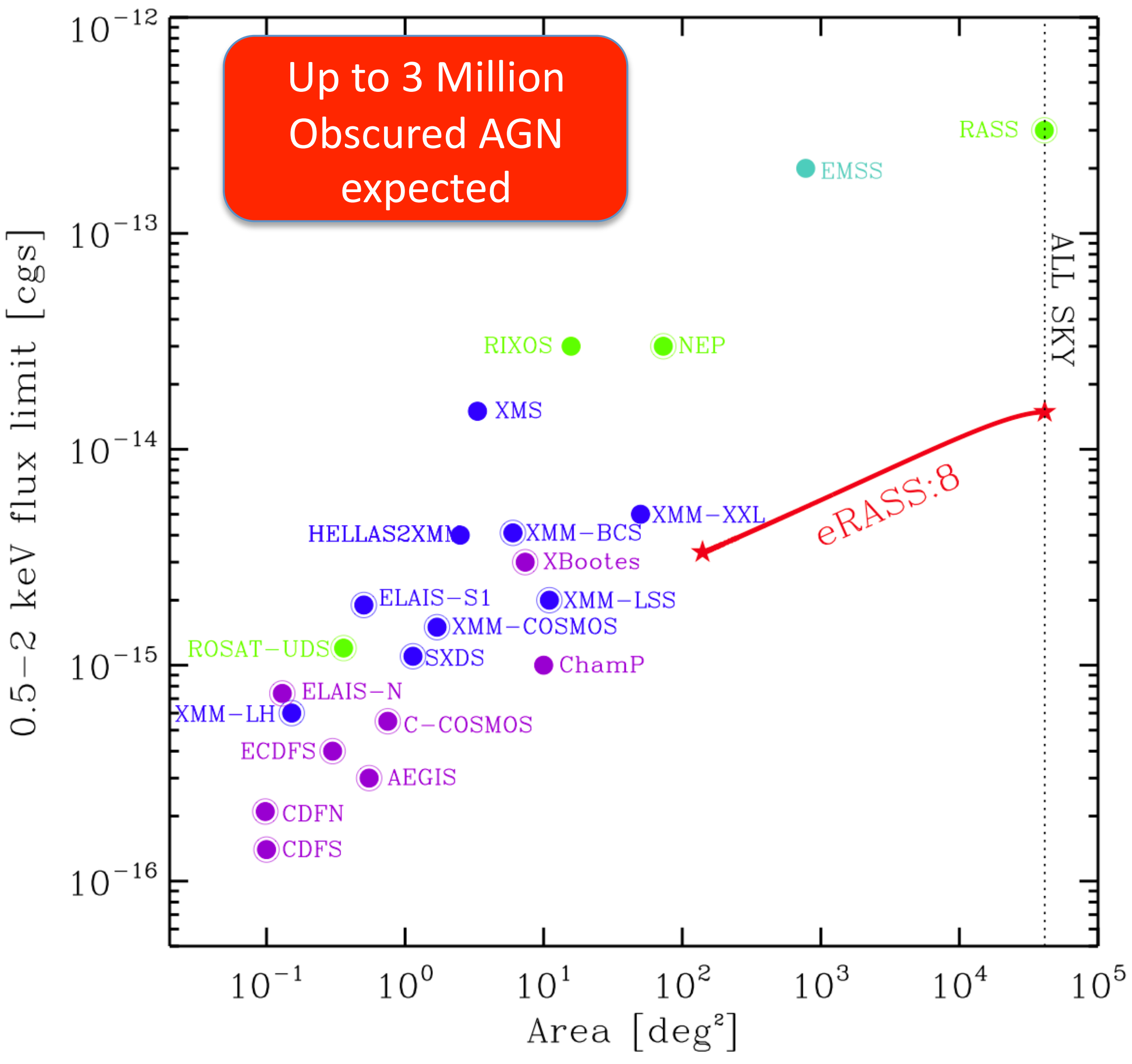


The X-ray Landscape (approved)

Launch 2015: eROSITA ASTRO-H

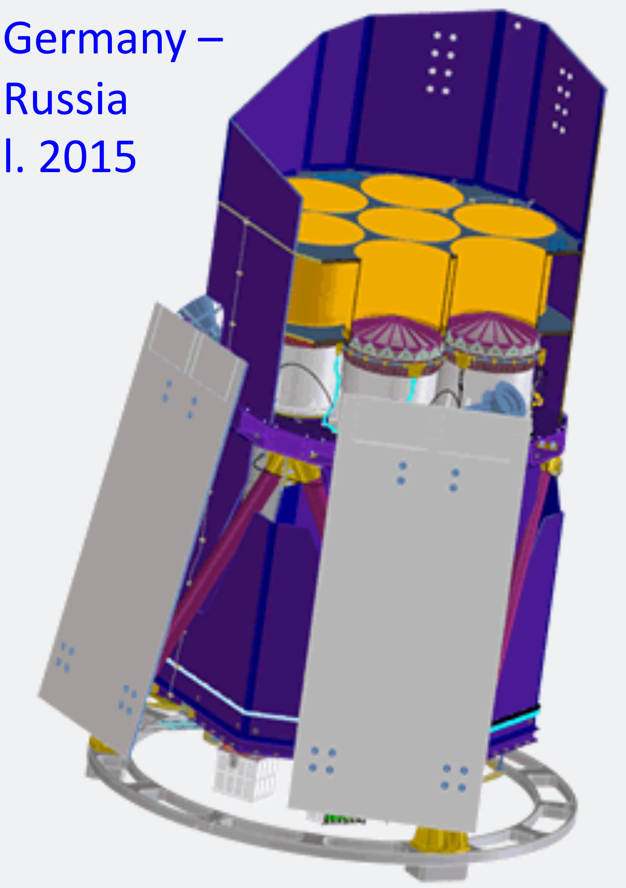
Launch 2028: Athena

eROSITA AGN Survey



eRosita planned survey area versus flux in comparison to existing AGN surveys

Germany – Russia
l. 2015

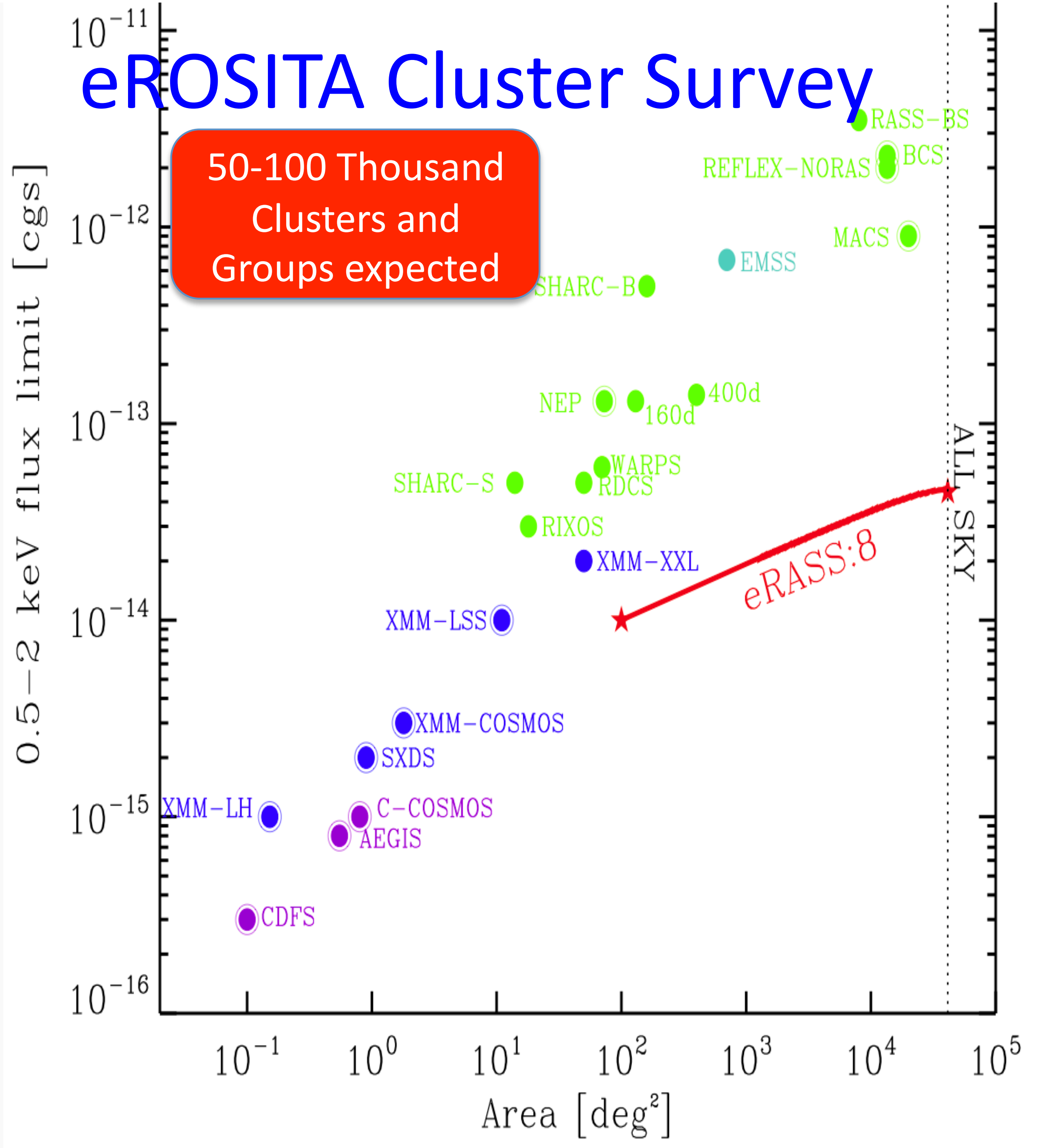


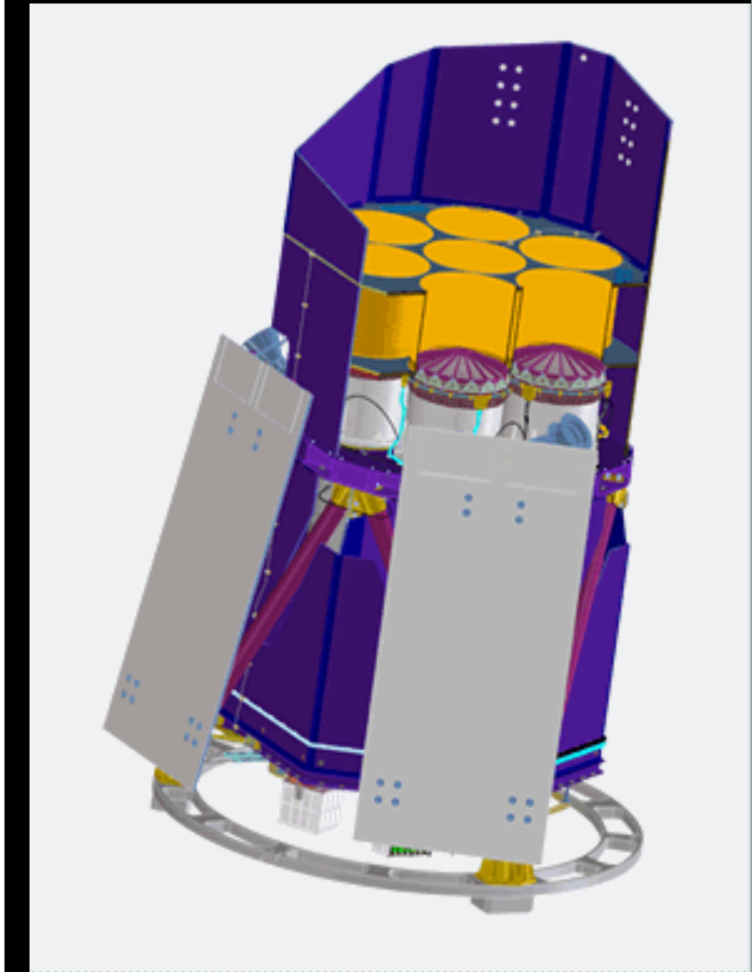
The eROSITA telescope on board SRG	
Launch	2015
End of Mission	open
Status	Phase C/D

- 0.5-10 keV
- HEW <15'' on axis
- ~28'' survey
- All-sky in ~4yr

eROSITA Cluster Survey

50-100 Thousand Clusters and Groups expected





The eROSITA telescope on board SRG	
Launch	2015
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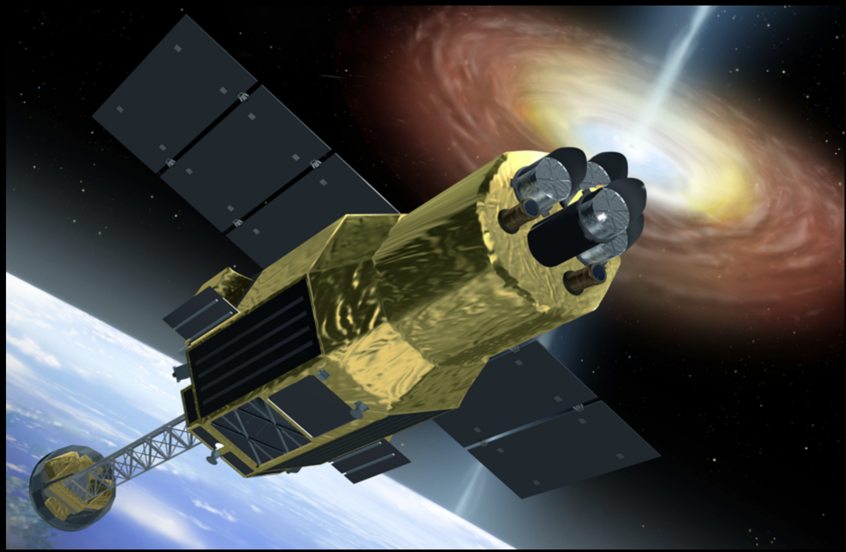
Status	Phase C/D

Astro-H JAXA/NASA – l. 2015

- Hard X-ray Imaging System
  - 5-80 keV
  - 300 cm^2 @ 30 keV
- Soft X-ray Spectrometer (Calorimeter)
  - 0.3 – 12 keV
  - 210 cm^2 @ 6 keV (Fe K lines)
  - 2'.85×2'.85 f.o.v.
- Soft Imager
  - 35'×35' f.o.v.
  - 1.7' HPD
- Non-focusing 10-600 keV detector



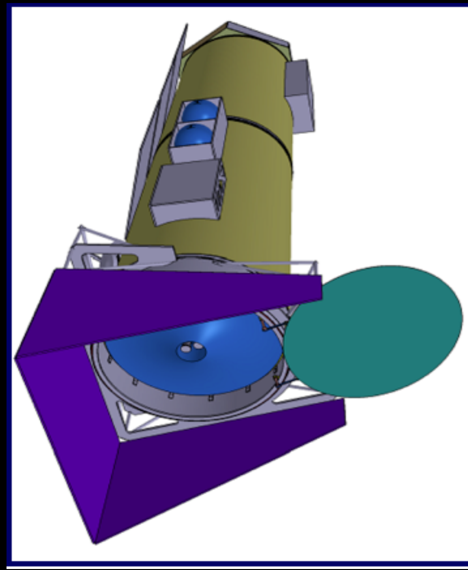
Athena – ESA – L2 –l. 2028

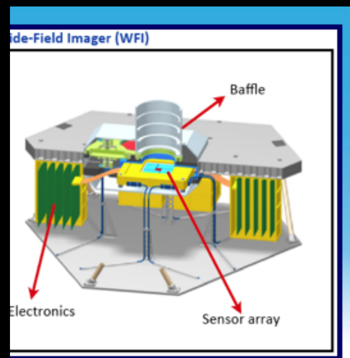
Parameter	Requirements
Effective Area	2 m^2 @ 1 keV (goal 2.5 m^2) 0.25 m^2 @ 6 keV (goal 0.3 m^2)
Angular Resolution	5" (goal 3") on-axis 10" at 25' radius
Energy Range	0.3-12 keV
Instrument Field of View	*Wide-Field Imager:* (WFI): 40' (goal 50')
	X-ray Integral Field Unit: (X-IFU): 5' (goal 7')
Spectral Resolution	WFI: <150 eV @ 6 keV
	X-IFU: 2.5 eV @ 6 keV (goal 1.5 eV @ 1 keV)
Count Rate Capability	> 1 Crab[3] (WFI)
	10 mCrab, point source (X-IFU) 1 Crab (30% throughput)
TOO Response	4 hours (goal 2 hours) for 50% of time

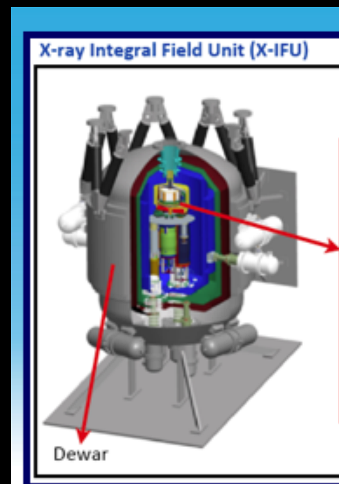
10 × XMM

1/3 XMM

Key parameters and requirements of the Athena mission. Th







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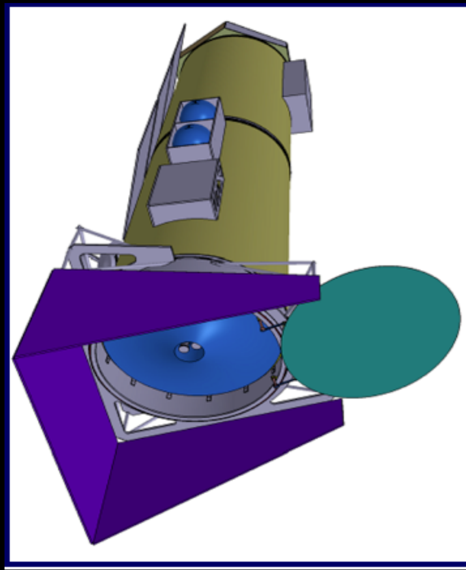
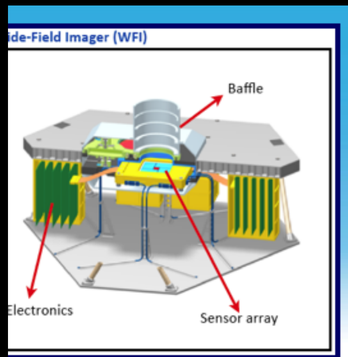
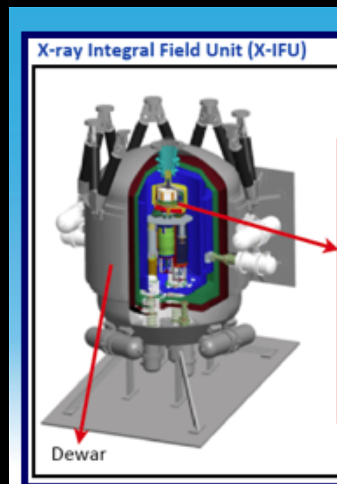
Key parameters and requirements of the Athena mission. Th

> 10 times worse than Chandra

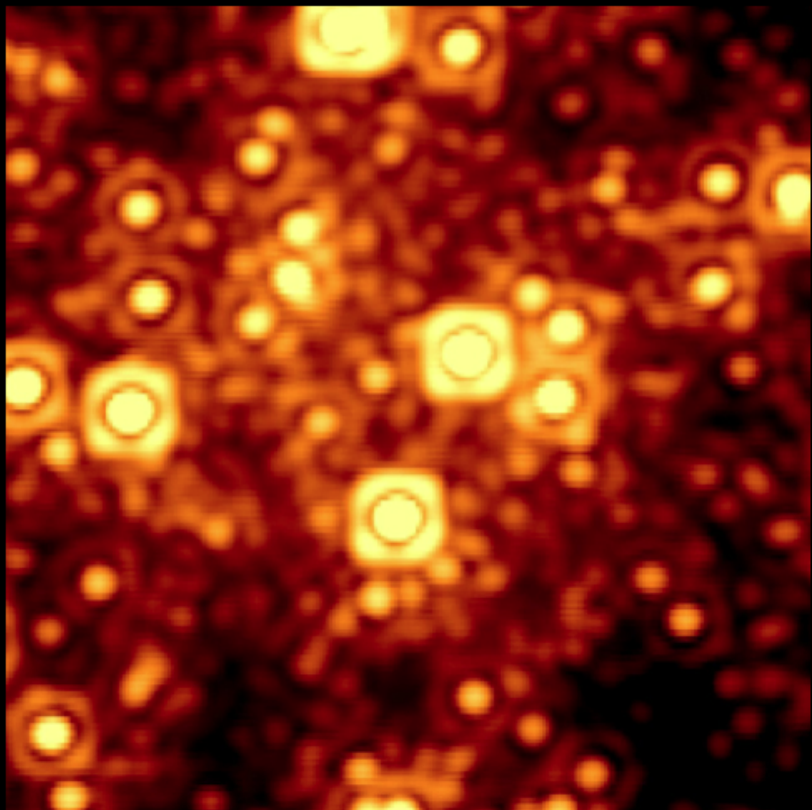


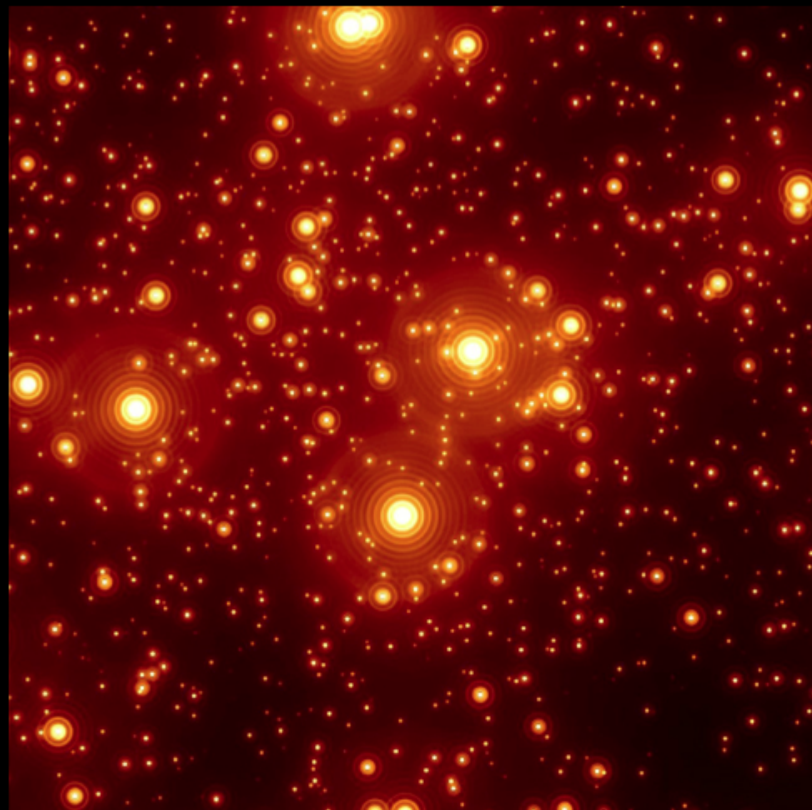




X-ray Deep Surveys
Angular Resolution is essential

- to go deep
- for matching the new class of large telescopes


Hubble


GMT

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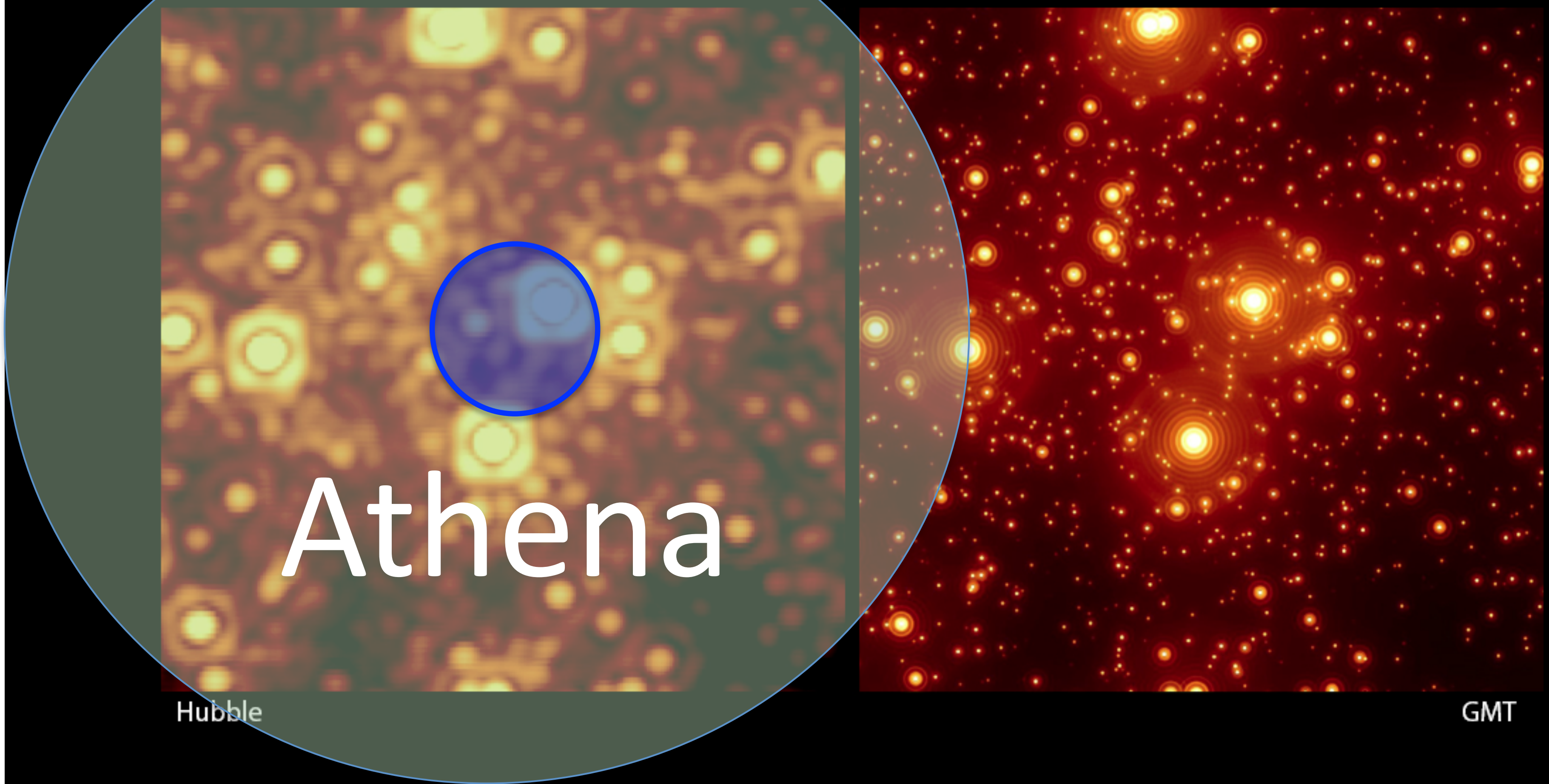


The Way Forward

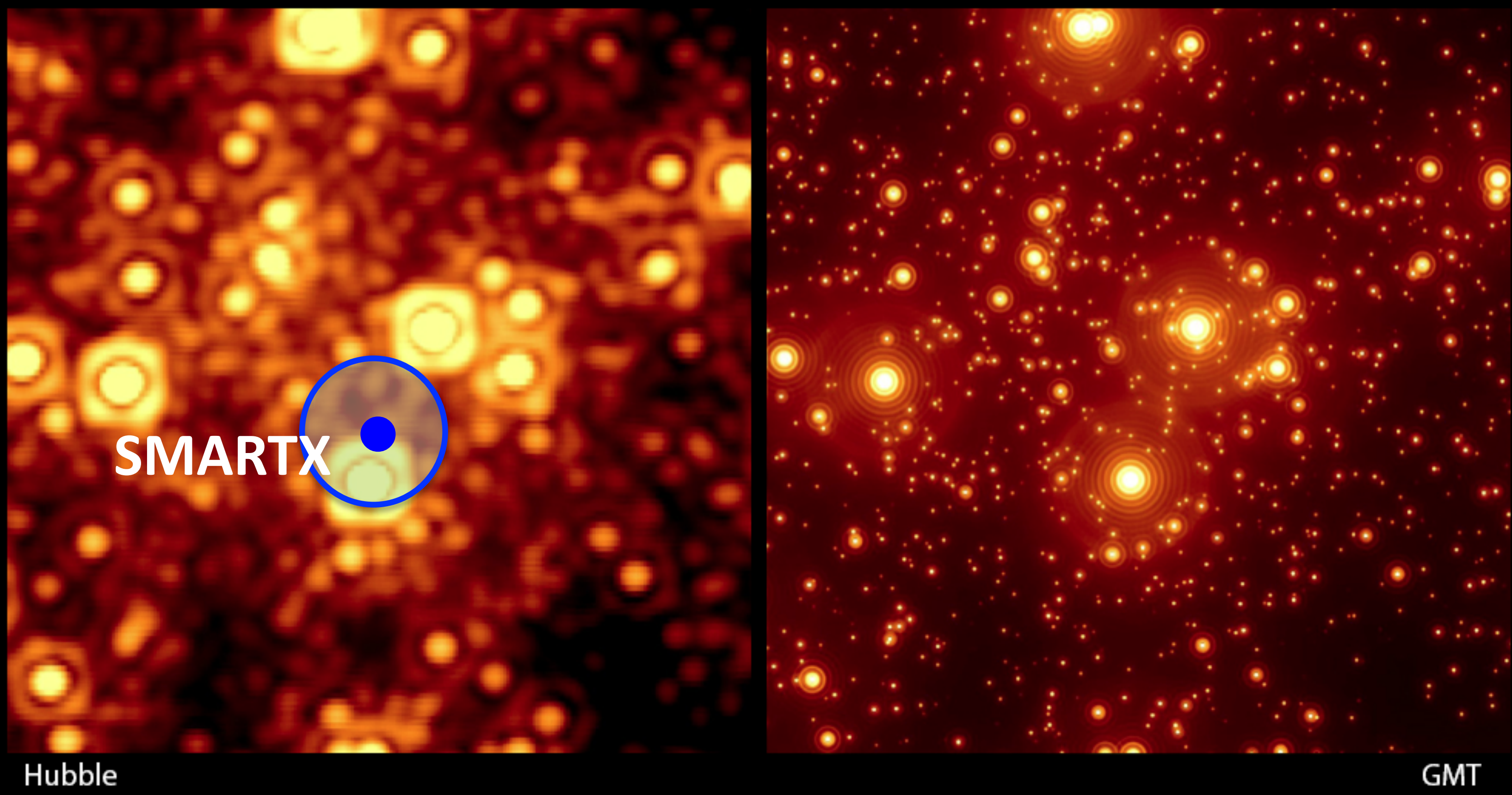
We need to preserve Chandra's resolution and band-width, while increasing effective area and spectral resolution

➔ Square Meter Arcsec Resolution Telescope

➔ http://smart-x.cfa.harvard.edu/doc.html

X-ray Deep Surveys
Angular Resolution is essential

- to go deep
- for matching the new class of large telescopes



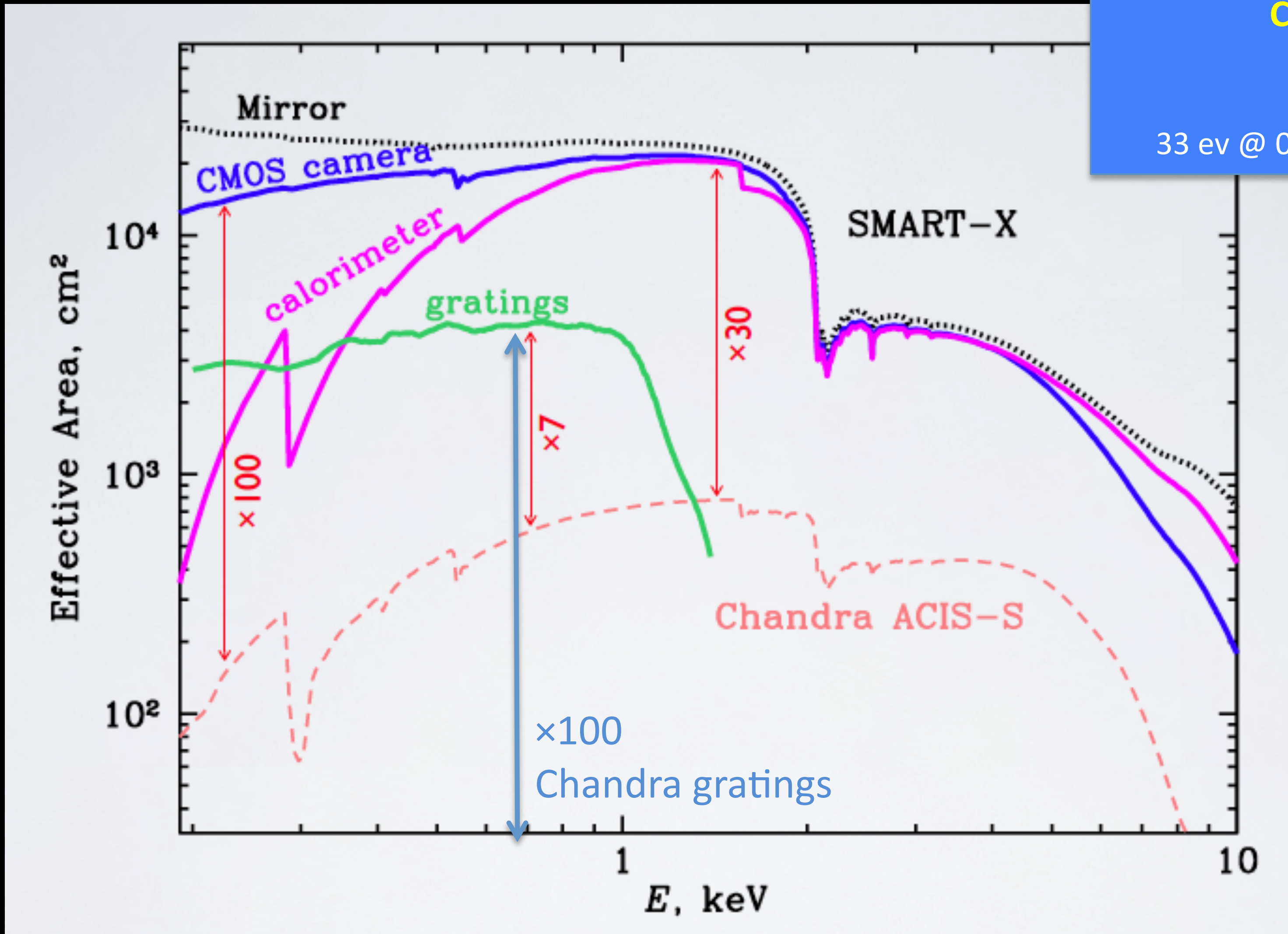
The X-Ray Telescope to Follow Chandra

- Angular resolution comparable to Chandra
  - > 10 times more resolution than Athena
- ~2.5 m^2 Mirror Effective Area
  - comparable to Athena
- 30 – 100 times the Effective Area of Chandra
- Sub-arcsec imaging over 15’×15’ f.o.v.

SMART-X

- SAO (Lead, Optics, Program Management)
- PSU (Piezo)
- MIT (Gratings)
- GSFC (Microcalorimeter)
- MSFC (Optics)
- JHU, Stanford, NIST/Boulder, U. Chicago

The Way Forward – *SMART-X* 'straw-man'



CMOS camera
0.33" pixel
22'×22' f.o.v.
33 ev @ 0.5keV – 120 eV @ 6keV

Calorimeter
1" pixel
5'×5' f.o.v.
<5 eV res.

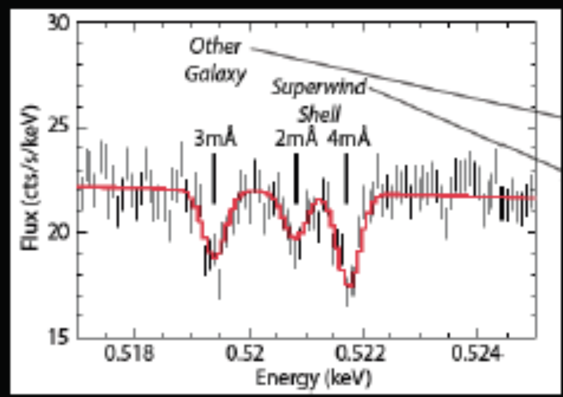
Gratings
A=4000 cm^2
Res. Power =5000

~10 × Chandra
Resolves thermal line widths

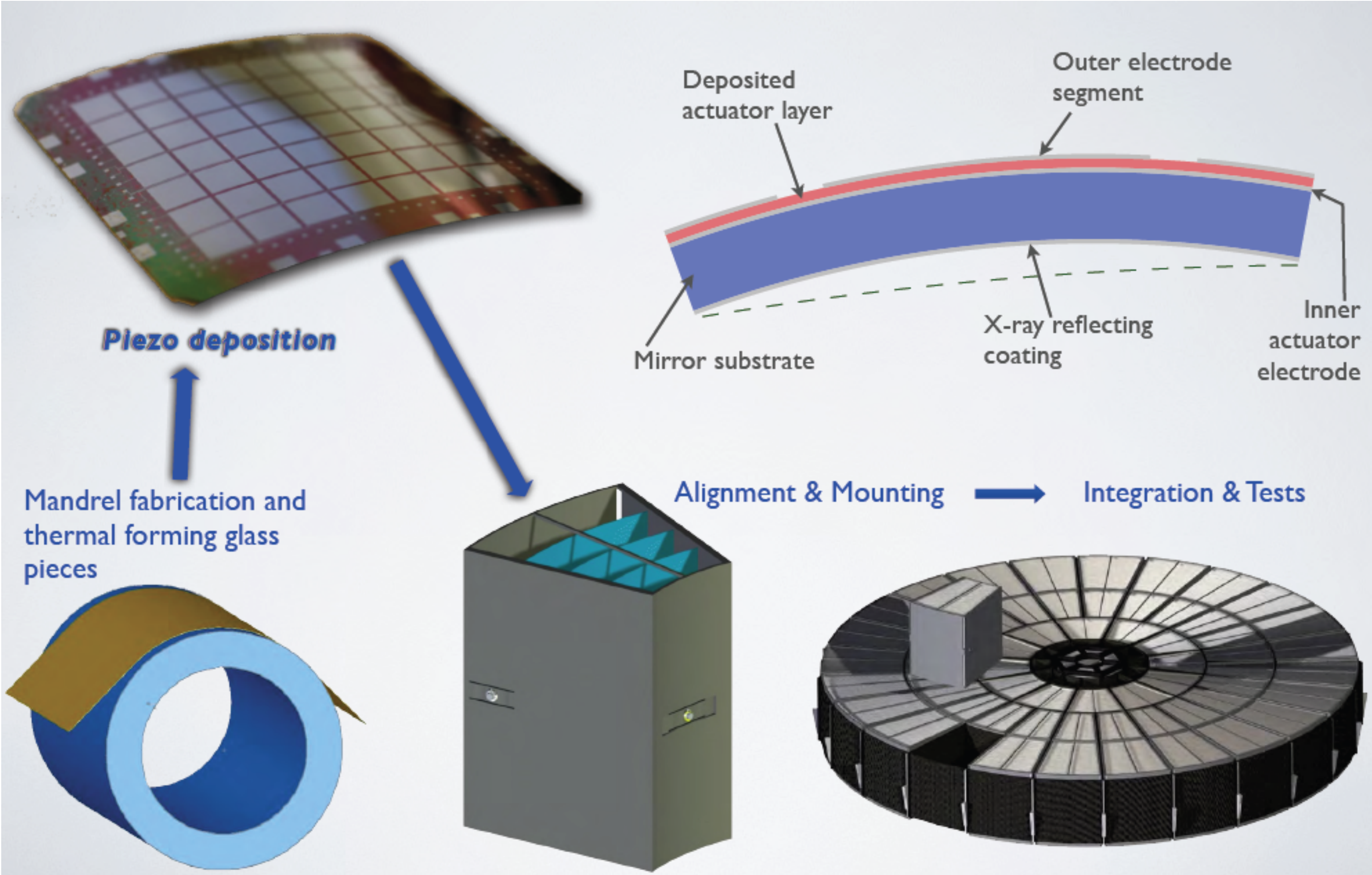
Vikhlinin et al

SMART-X Science

- Map the high z universe spatially and spectrally
  - The hot web, clusters and groups
- Study MBH formation, merging and feedback
  - Intense X-ray emission of ‘point-like’ sources will identify obscured AGNs out to z = 10
    - 10 keV /1+z = 0.9 keV for z=10
- Study group evolution out to z=6
- Study galaxy evolution out to z=3
  - Hot halo formation and physical/chemical evolution
  - AGN merging
  - Faint AGN
  - Evolved stellar population via compact binaries
- Uncharted Local Universe
  - Hot baryons in the Cosmic Web in emission and absorption



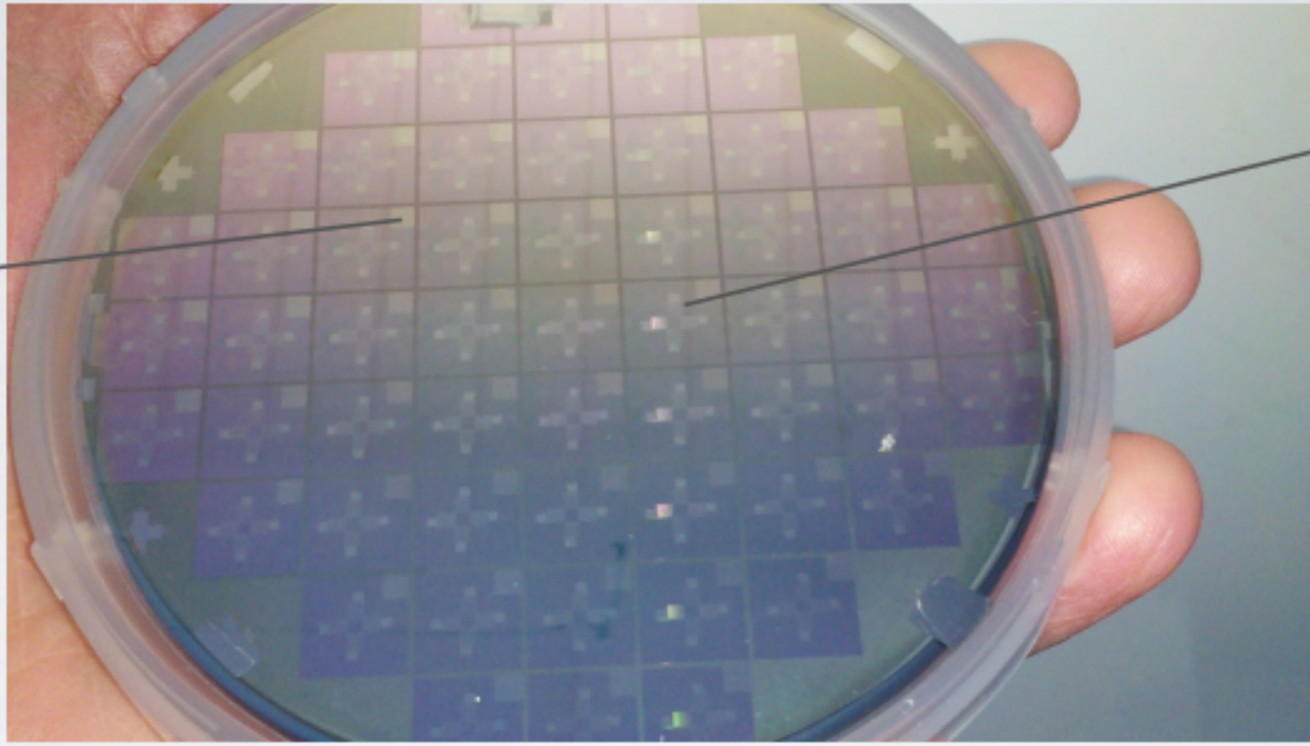
Path to large-area sub-arcsec mirrors

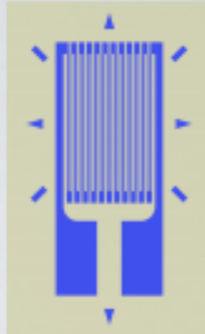


Vikhlinin et al

Current state of mirror development

ZnO transistors for row-column addressing



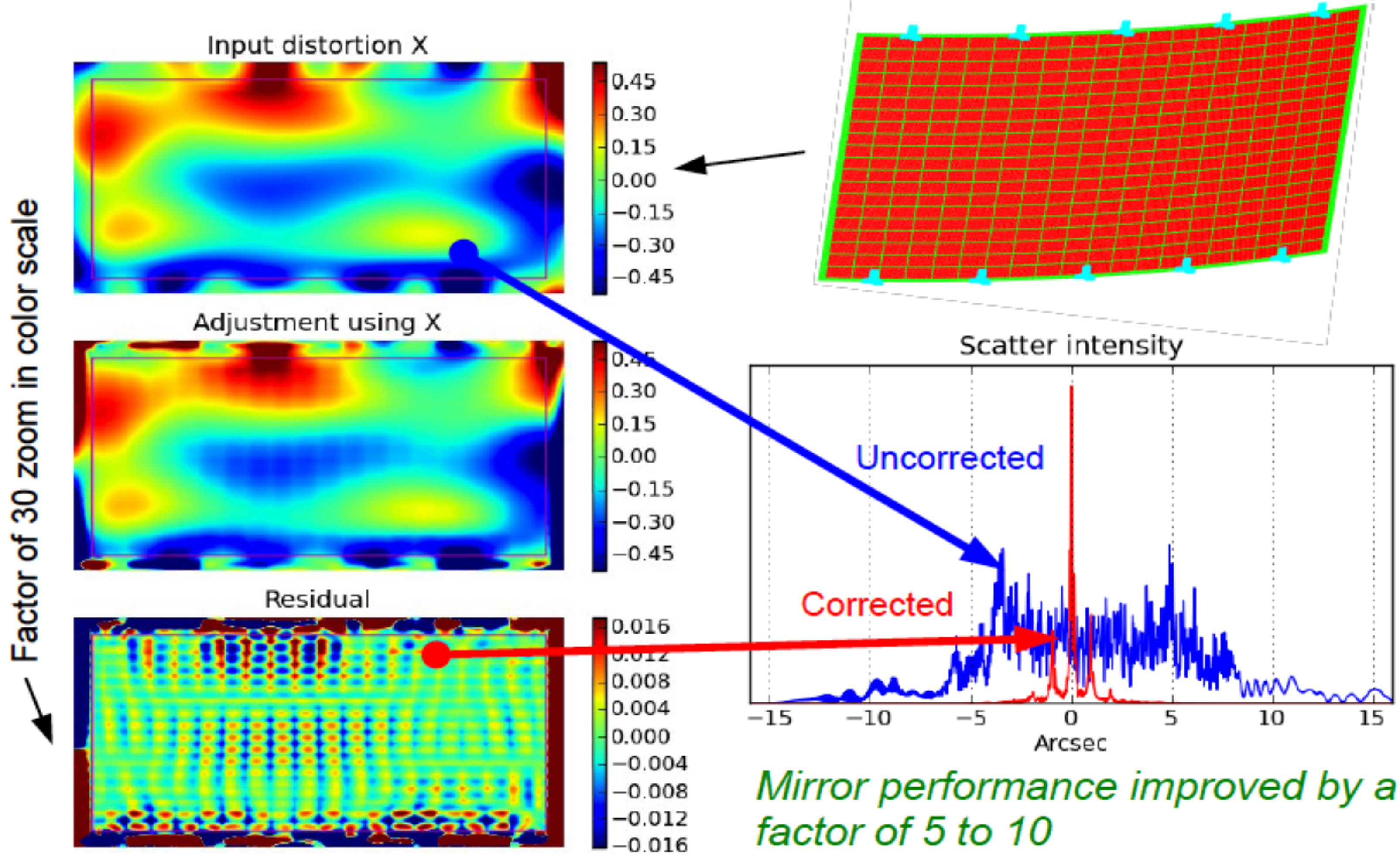


Strain gauges to control sub-arcsec imaging *in flight*

- Demonstrated the ability to coat conical mirror segments with piezo-film, and compensate for much of the coating stress.
- High-fidelity math model of the mirror developed and still being improved.
- Work gears towards an X-ray test of a mirror pair in 2015 (precision alignment, slumping of initial segments, precision calibration of the piezo-cell performance).

Piezo-controlled X-ray optics simulation

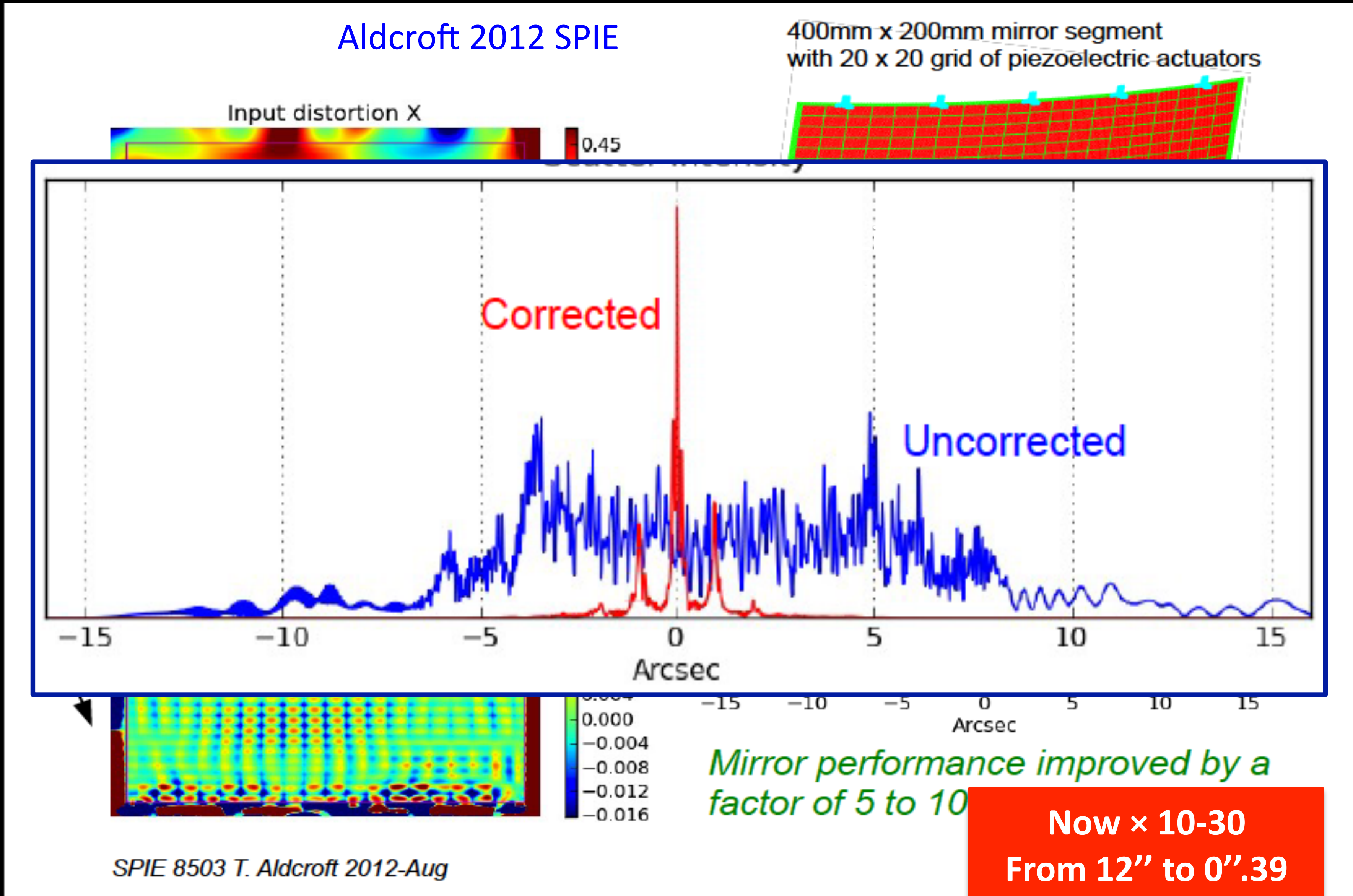
Aldcroft 2012 SPIE



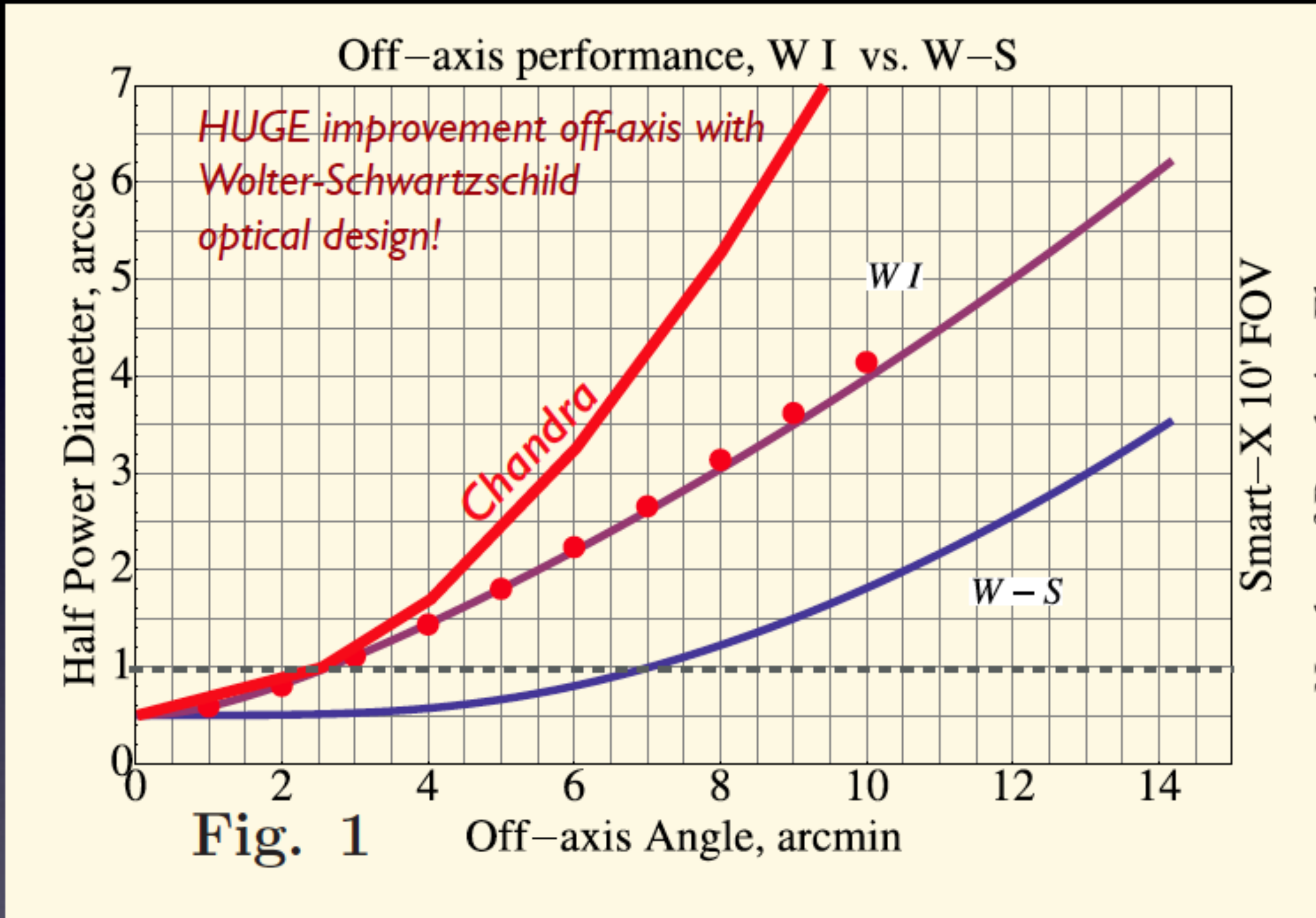
Mirror performance improved by a factor of 5 to 10

SPIE 8503 T. Aldcroft 2012-Aug

Piezo-controlled X-ray optics simulation



SMART-X mirror optical design



- ×30 higher sensitivity: 4Msec Chandra Deep field depth reached in 80 ksec
- ×10 larger solid angle for sub-arcsec imaging
- Entire 20′×20′ field of view not source-confused down to CDFS limit
- ×500 higher survey speed at the CDFS limit

SMART-X

- Capability far exceeds
  - Chandra
    - × 20-100 area
    - high-res spectroscopy for point and extended sources
    - Wider high angular resolution f.o.v.
  - Athena
    - ×~10 –20 better angular resolution, i.e. it can go 100 times fainter (less bkg)
- Same as going from Palomar to TMT
- Excellent match to JWST, ALMA, LSST, eVLA
- ~30m class OIR telescopes : TMT, GMT, E-ELT

In summary….

- Chandra's resolution best match for TMT
  - Will be around 10+ yrs
  - Propose for key project
- Other X-ray missions approved
  - E-ROSITA will provide AGN and Cluster catalogs (~30")
  - Athena good for 'bright' source spectroscopy
- SMARTX best match for TMT
  - A large area Chandra, with ~0.5" PSF – 15'×15' f.o.v.
  - 500 times increase in survey speed, 22'×22' CMOS imager
  - 100 × transmission grating spectroscopy speed, R=5000
  - IFU, 5'×5' f.o.v., R>500 (microcalorimeter)
  - **Needs your scientific support**