Next Generation X-ray Telescopes

G. Fabbiano

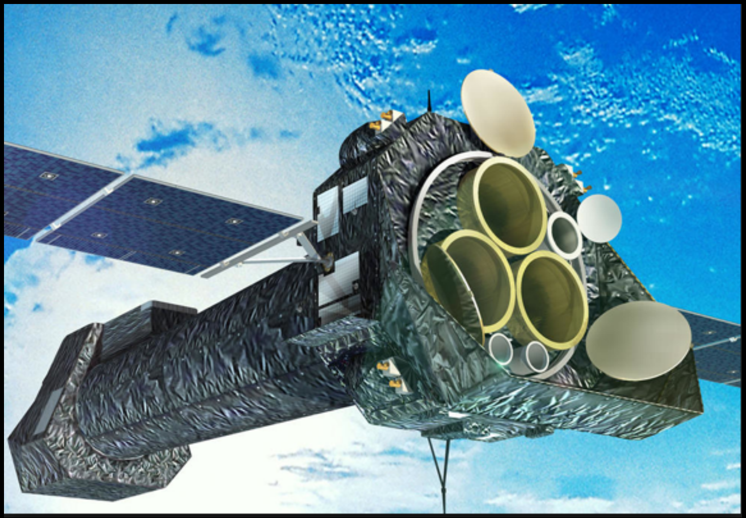
Harvard-Smithsonian CfA

The Present X-ray Landscape
Great Observatories

Chandra - NASA

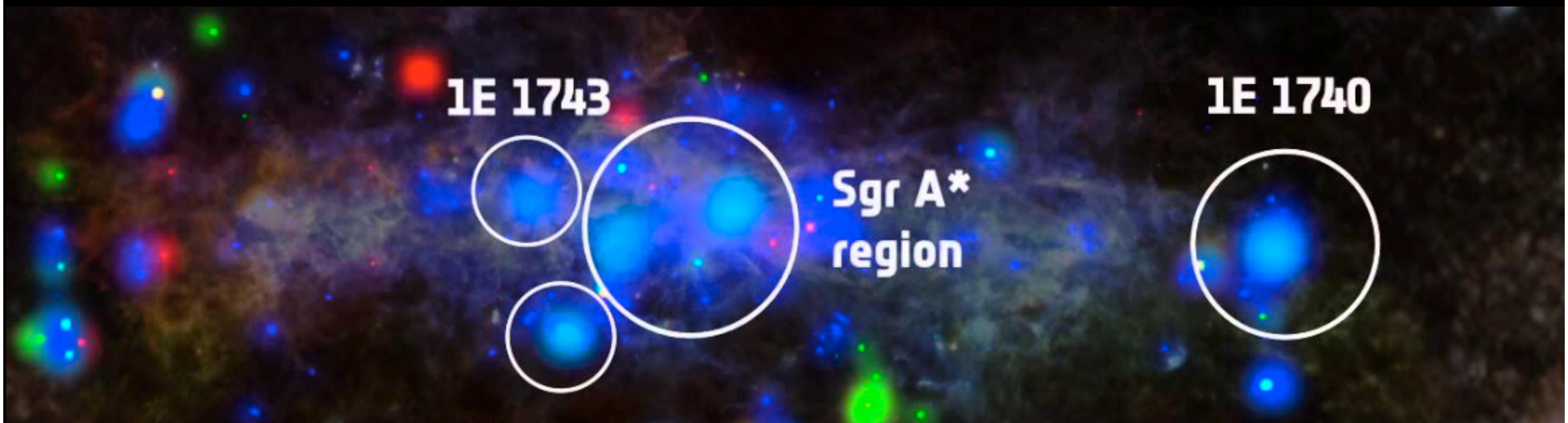
Optimizes Angular Resolution
and Sensitivity –PSF ~ 1/3 “

XMM-Newton - ESA

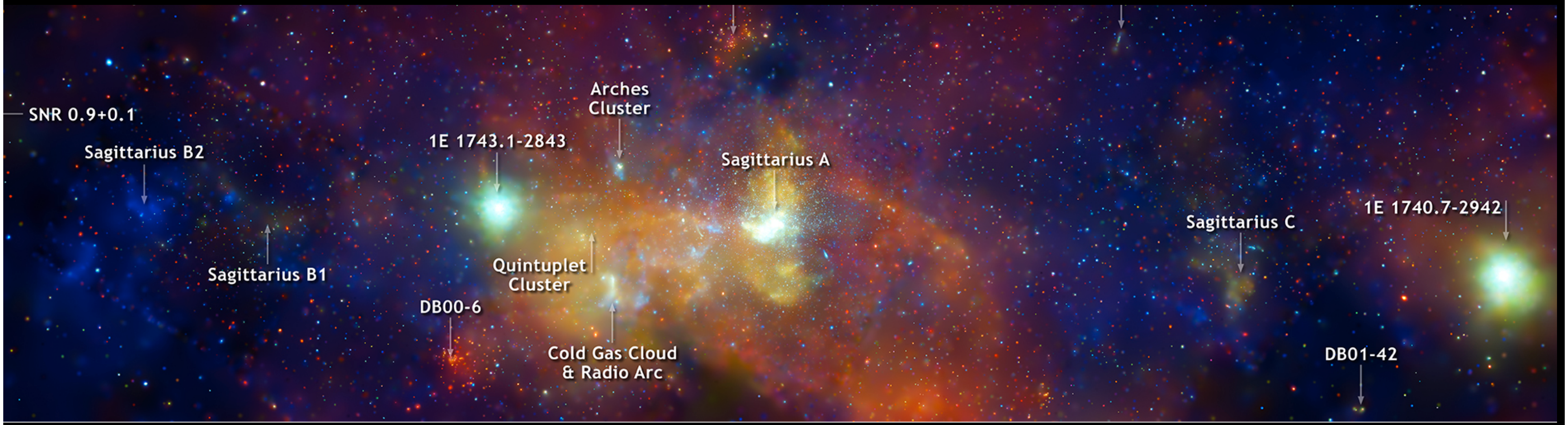


Optimizes Collecting Area 3x Chandra
PSF ~15”

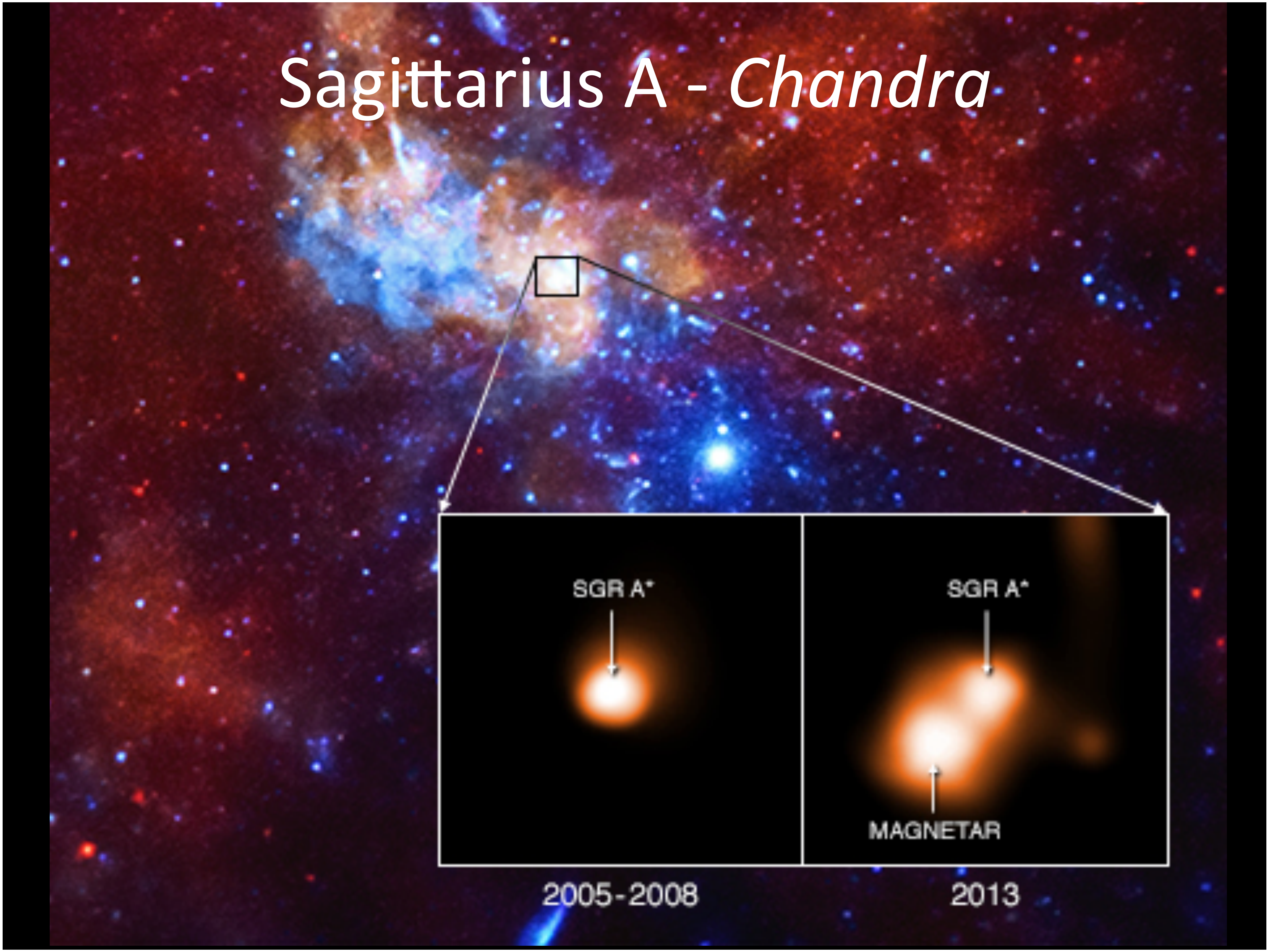
The Galactic Center - *XMM*



The Galactic Center - *Chandra*



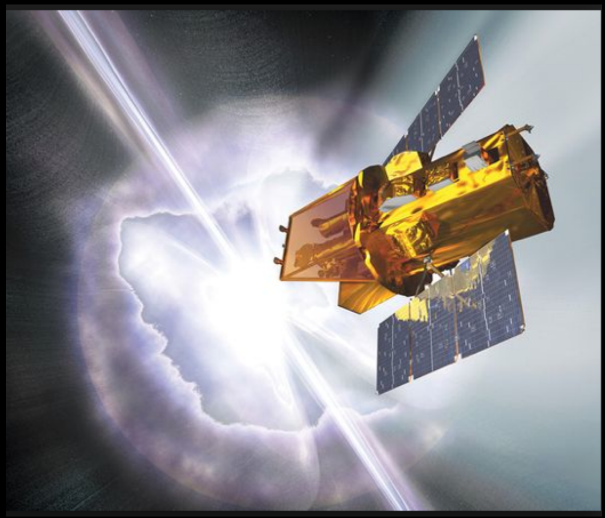
Sagittarius A - *Chandra*



The Present X-ray Landscape

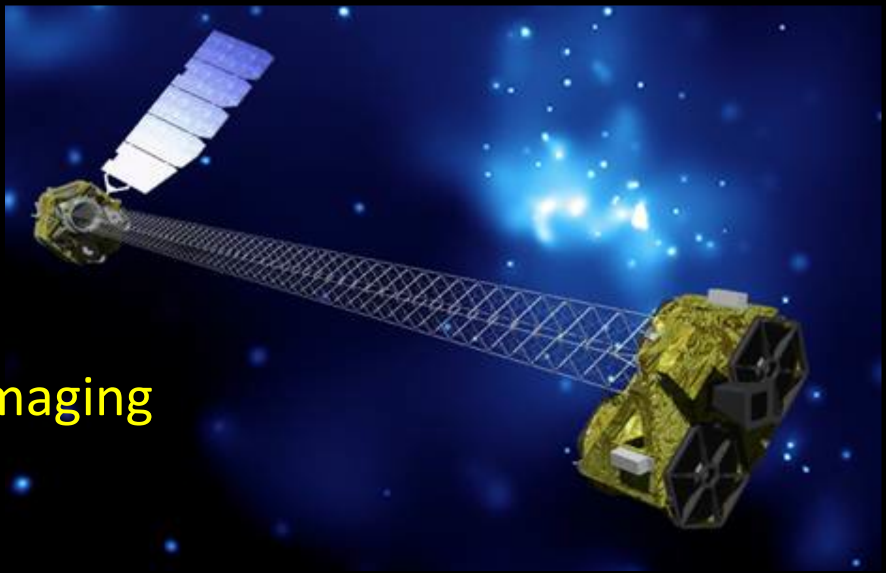
Swift - NASA

Gamma Ray Burst Mission



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 Future X-ray Landscape

Launch 2016: eROSITA ASTRO-H

Launch 2028: Athena

NASA concept study: X-ray Surveyor

+....

The Future X-ray Landscape

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Launch 2028: Athena

NASA concept study: X-ray Surveyor

Both large next generation telescopes - Area ~2-3 sqm

The Future X-ray Landscape

Launch 2016: eROSITA ASTRO-H

Launch 2028: Athena

NASA concept study: X-ray Surveyor

Both large next generation telescopes - Area ~2-3 sqm

Athena : XMM = X-ray Surveyor : Chandra

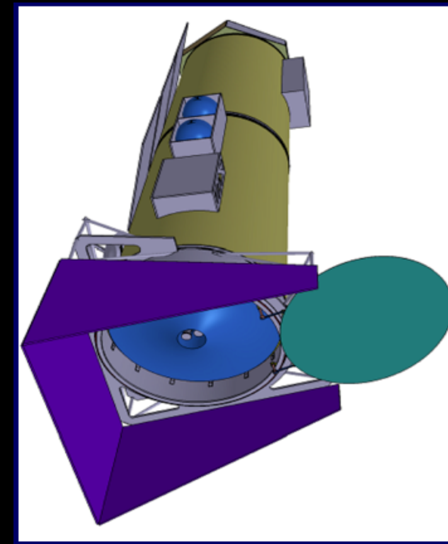
Athena – ESA – L2 –l. 2028

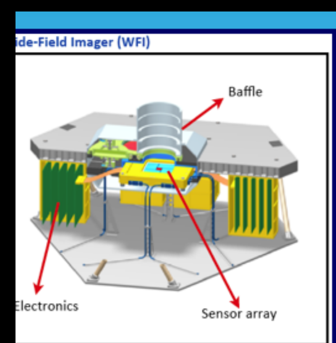
Parameter	Requirements
Effective Area	2 m² @ 1 keV (goal 2.5 m²) 0.25 m² @ 6 keV (goal 0.3 m²)
Angular Resolution	5" (goal 3") on-axis 10" at 25' radius
Energy Range	0.3-12 keV
Instrument Field of View	*Wide-Field Imager:* (WFI): 40' (goal 50')
	X-ray Integral Field Unit: (X-IFU): 5' (goal 7')
Spectral 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

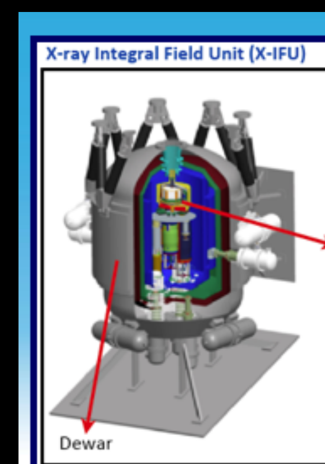
10 × XMM

1/3 XMM

Key parameters and requirements of the Athena mission. Th







Athena – ESA – L2 –l. 2028

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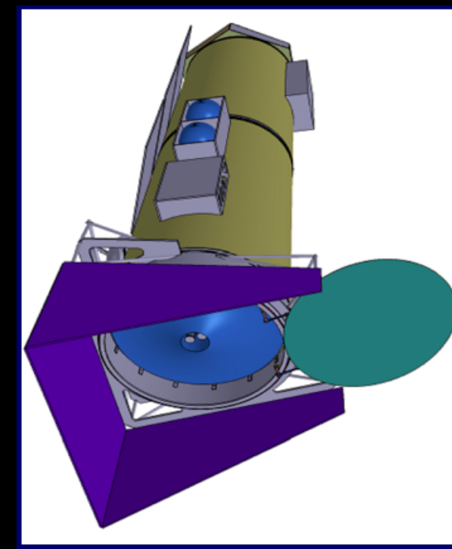
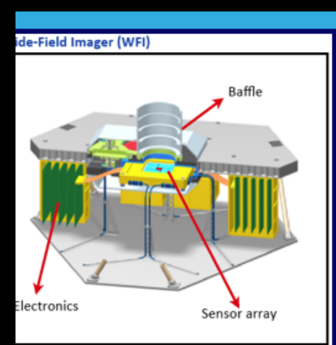
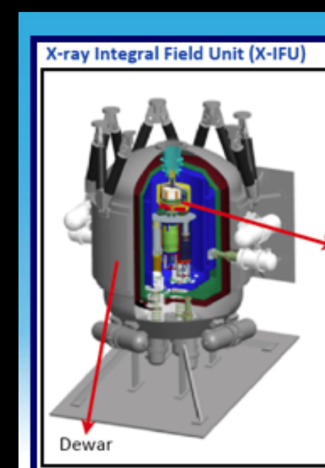
Key parameters and requirements of the Athena mission. Th

> 10 times worse than Chandra







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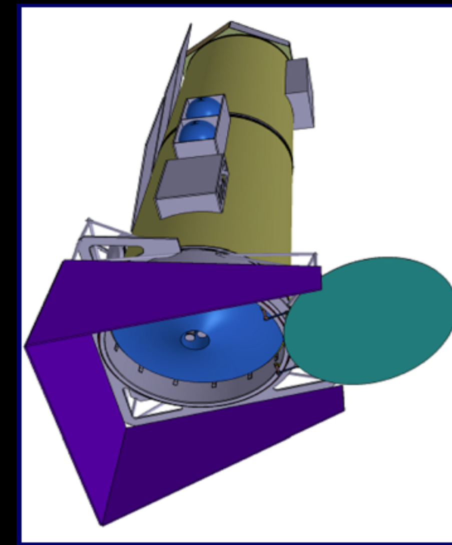
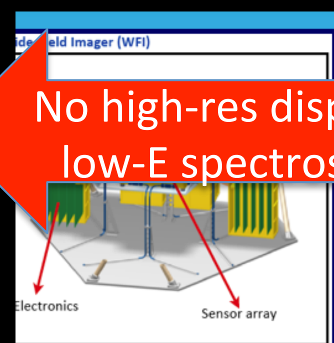
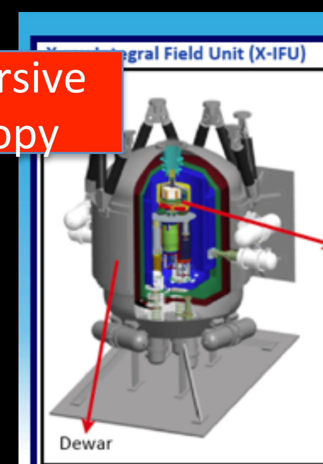
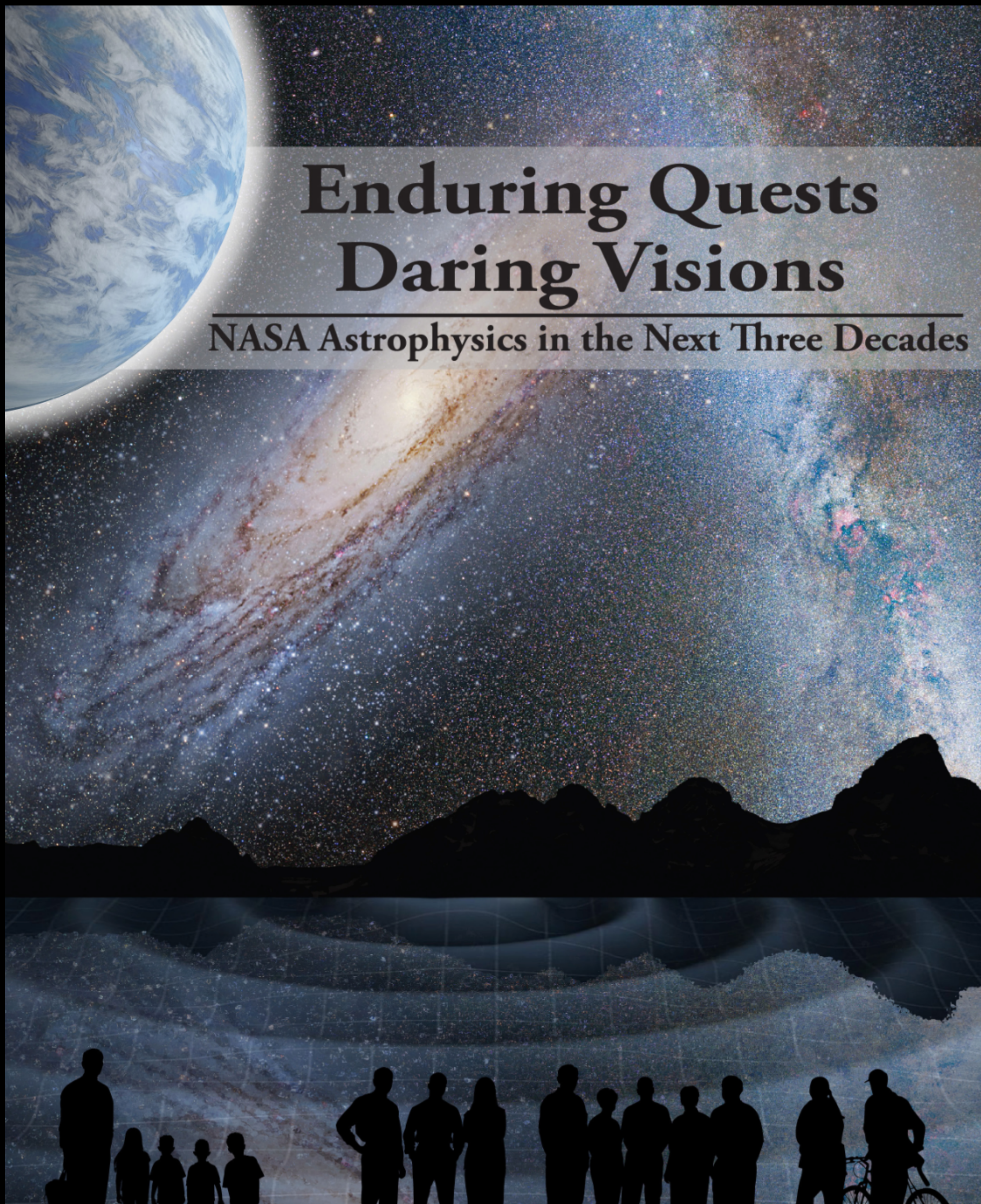


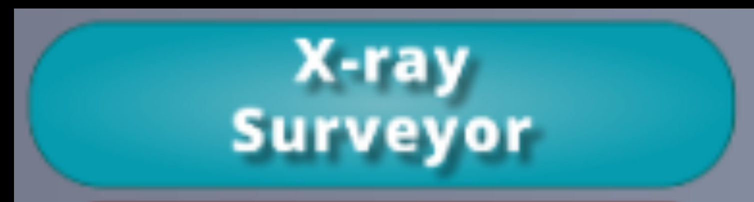
No high-res dispersive low-E spectroscopy







The Telescope to follow *Chandra*

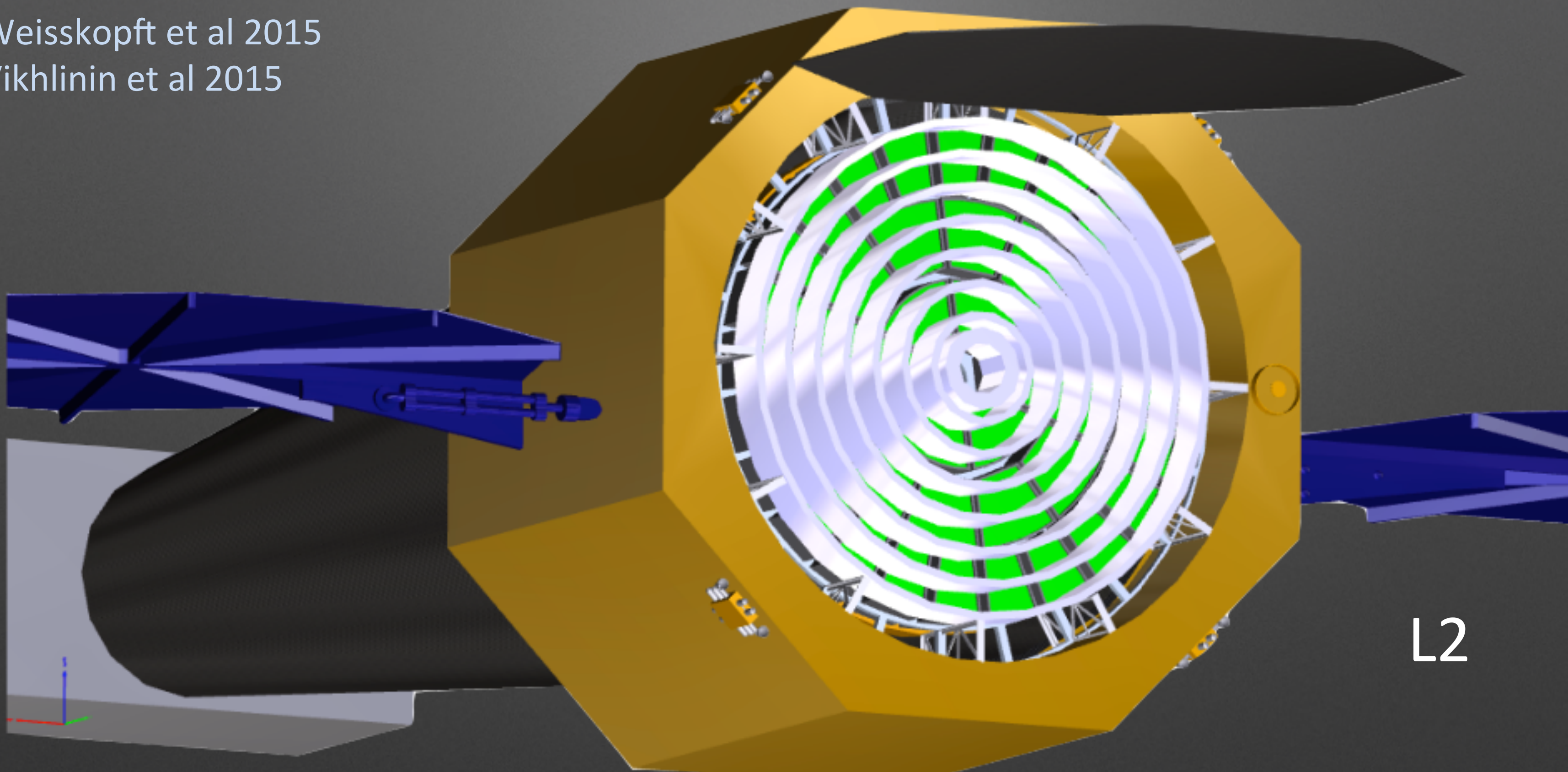


- Chandra's subarcsecond angular resolution
- Much larger (~3 sqm) collecting area

…we had the first community workshop in October

Leap in sensitivity:
High throughput with sub-arcsec resolution

Weisskopft et al 2015
Vikhlinin et al 2015



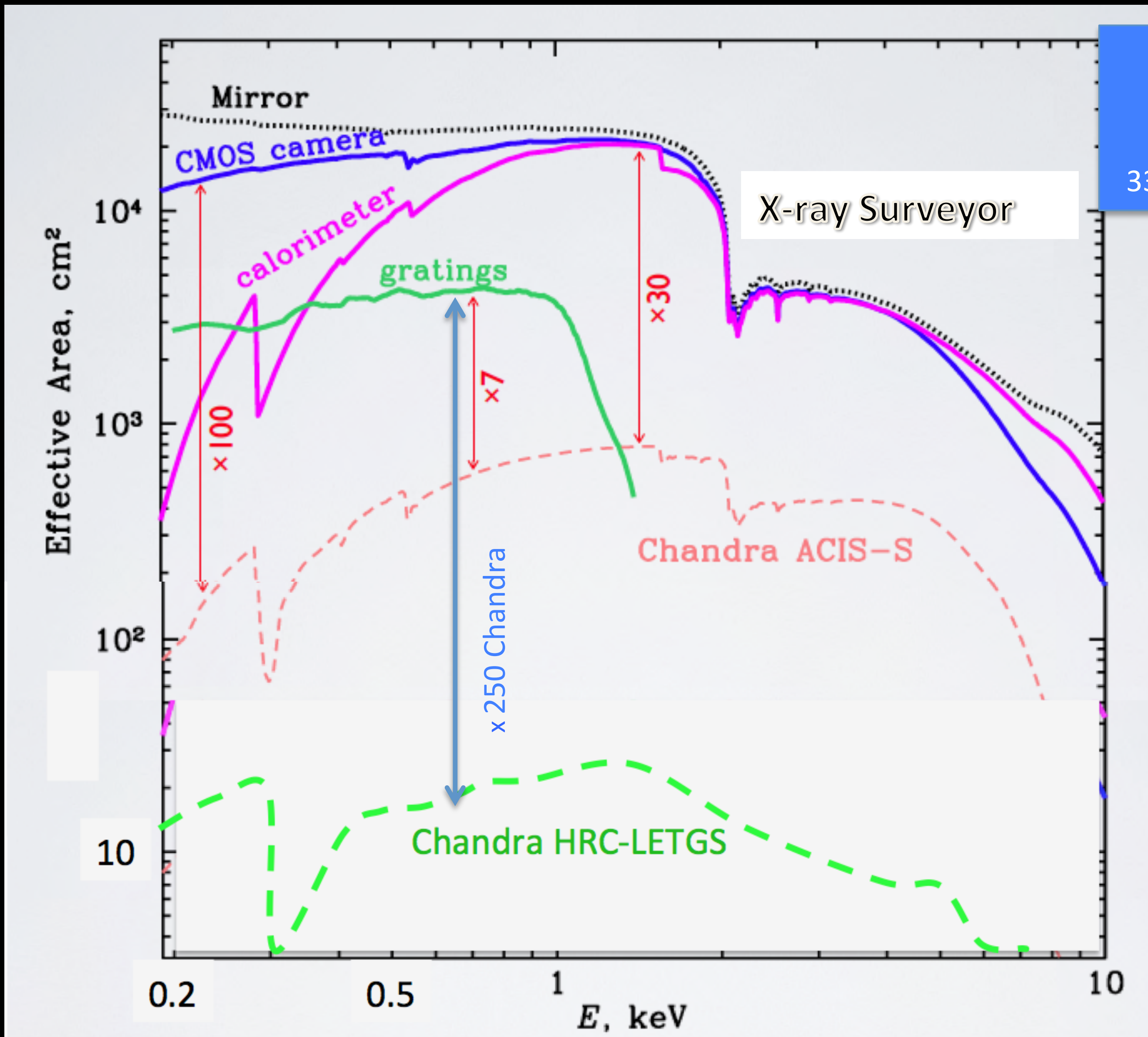
- ×50 more effective area than *Chandra*. 4 Msec *Chandra* Deep Field done in 80 ksec. Threshold for blind detections in a 4Msec survey is ~ $3{\times}10^{-19}$ erg/s/cm^2 (0.5–2 keV band)
- ×16 larger solid angle for sub-arcsec imaging — out to 10 arcmin radius
- **×800 higher survey speed at the *Chandra* Deep Field limit**

Towards the X-ray Surveyor

High-resolution, light-weight, large X-ray optics

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

The Way Forward – X-Ray Surveyor ‘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. R<500

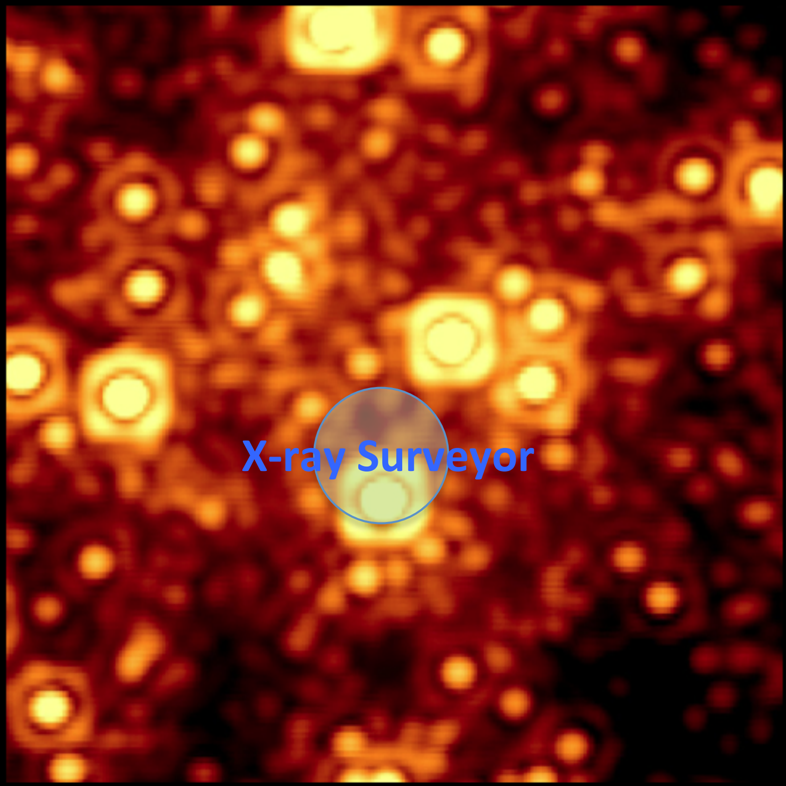
Gratings
A=4000 cm^2
Res. Power =5000

>10 × Chandra
Resolves thermal line widths

Vikhlinin et al 2015
Weisskopf et al 2015

X-ray Deep Surveys
Angular Resolution is essential

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

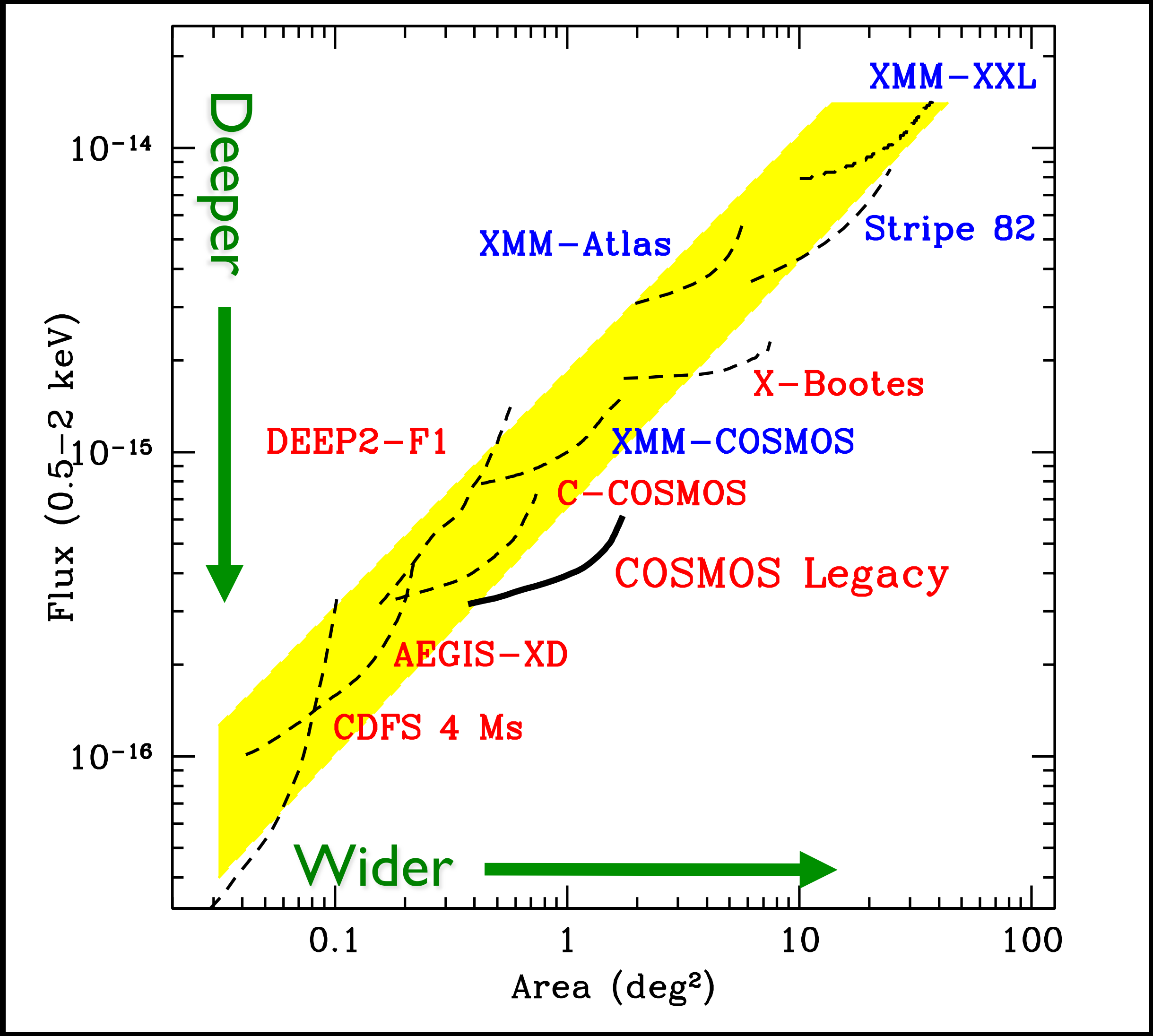


Hubble

X-ray Deep Surveys
Angular Resolution is essential

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

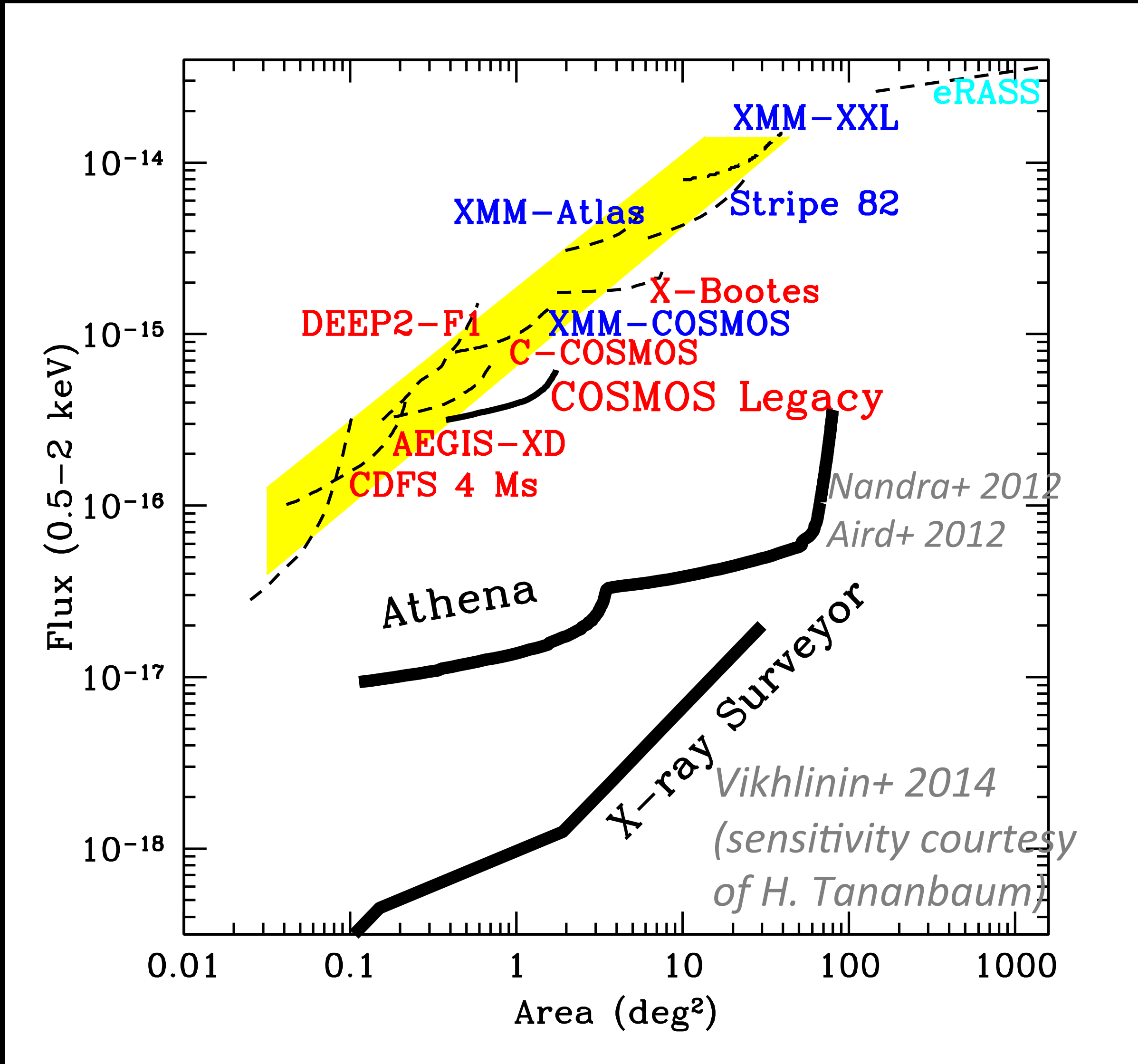
Current Surveys Sensitivity



Civano+ 2015

Future Surveys Sensitivity

Current:
>50 Ms
of total
exposure

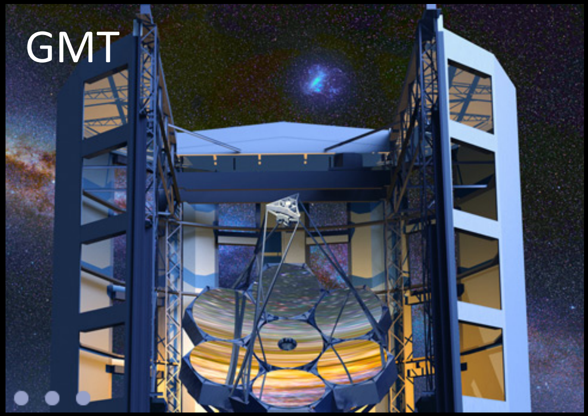


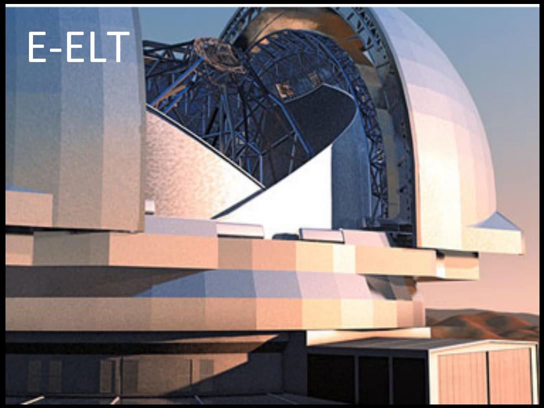
Future:
20 Ms each
of exposure

Wide Survey
+
Medium Survey
+
Deep Survey

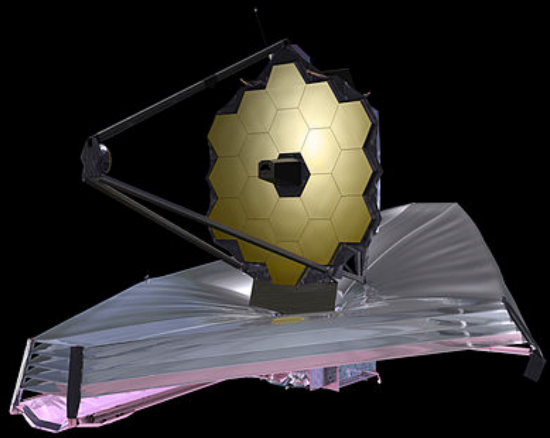
Adapted from Civano+ 2015

Landscape of Planned Ground and Space Next Generation Telescopes





JWST

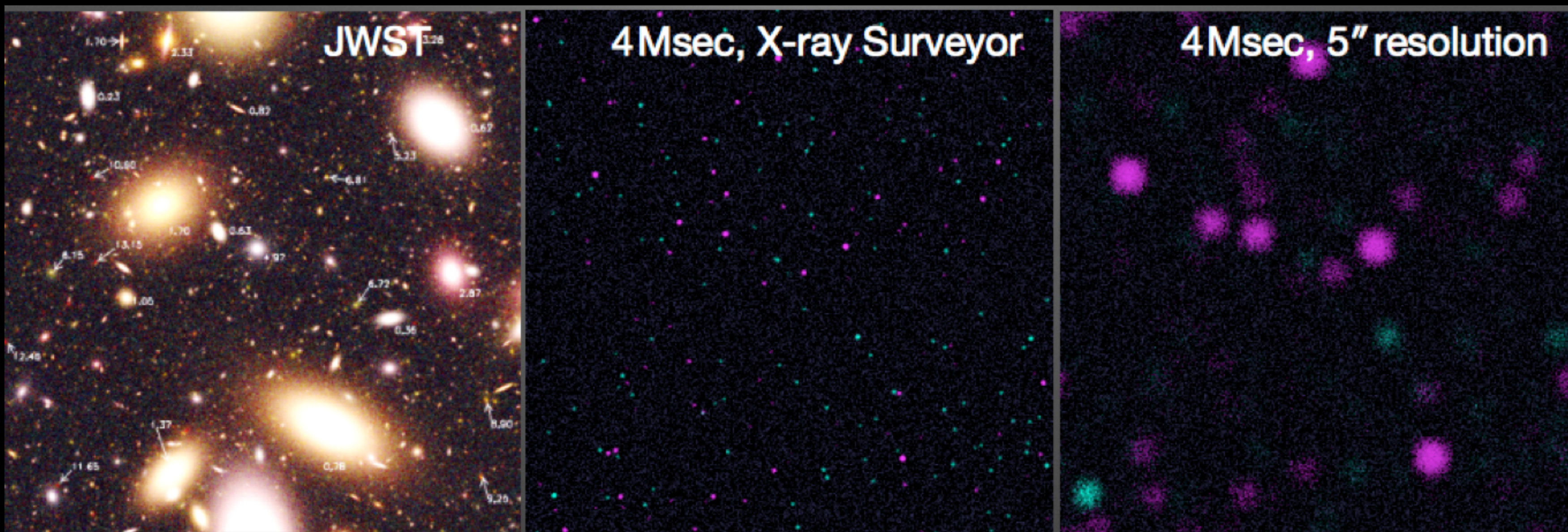


Nature of Black Hole seeds
First accretion light in the Universe

Vikhlinin et al 2015

2′

2′



JWST limit - Windhorst et al

2×10^6 galaxies/deg^2 →

X-ray Surveyor

0.03 galaxy/0.5″ resolution

Limit 1×10^{-19} erg cm^{-2}s^{-1}

$L_X = 1 \times 10^{41}$ erg s^{-1} @ z=10

$M_{BH} \sim 10^4$ Msun

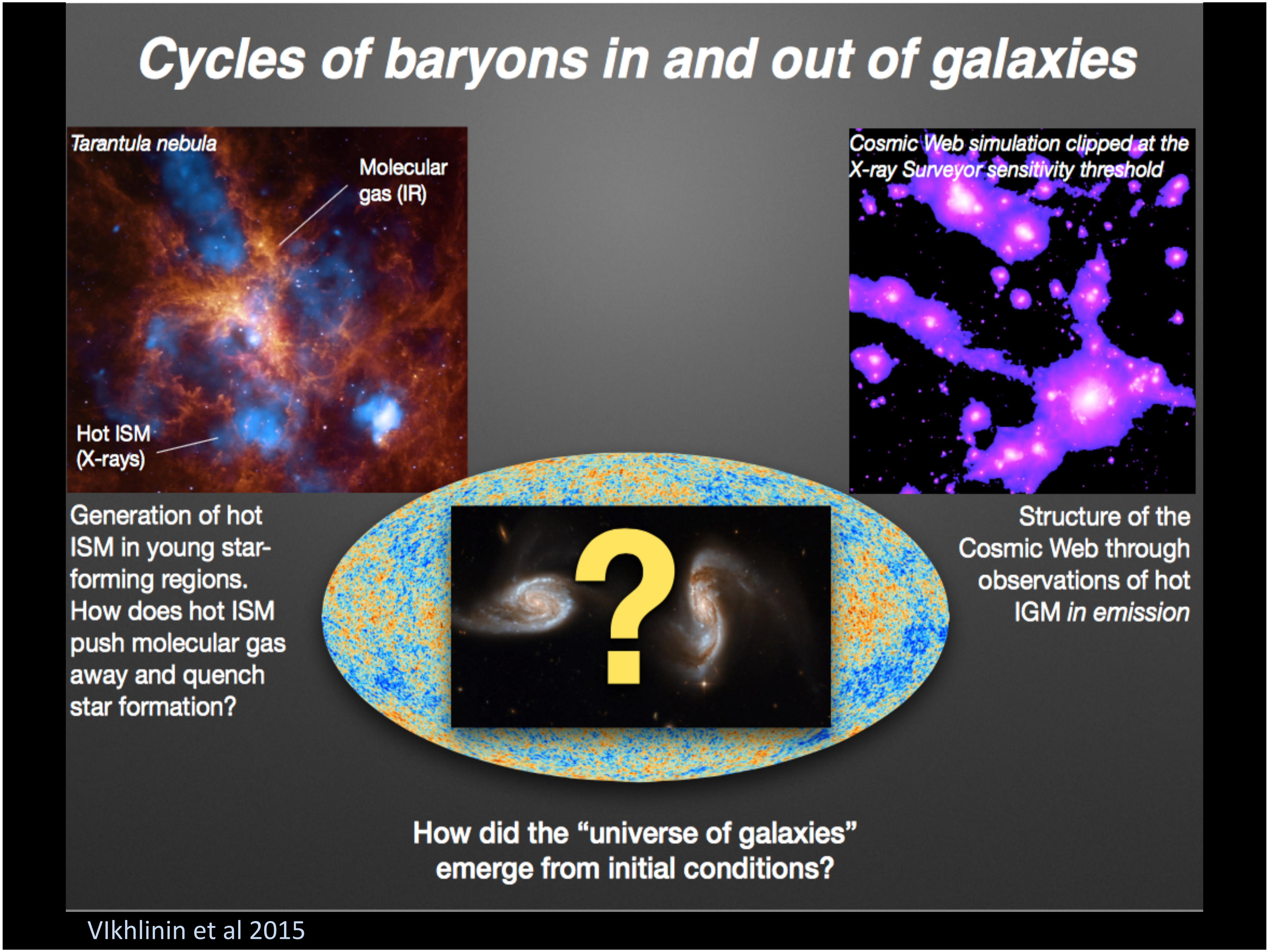
Athena

3 galaxies/5″ resolution

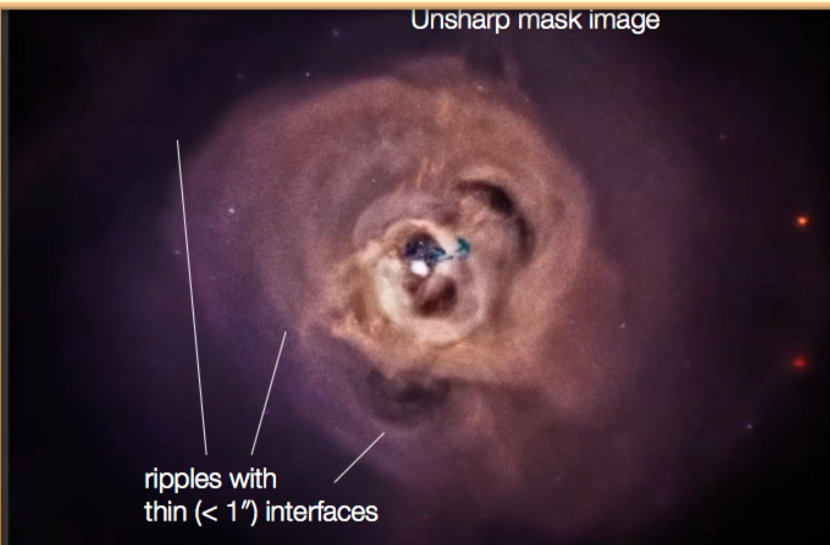
Limit 2.5×10^{-17} (x5 worse CDS)

$M_{BH} \sim 3 \times 10^6$

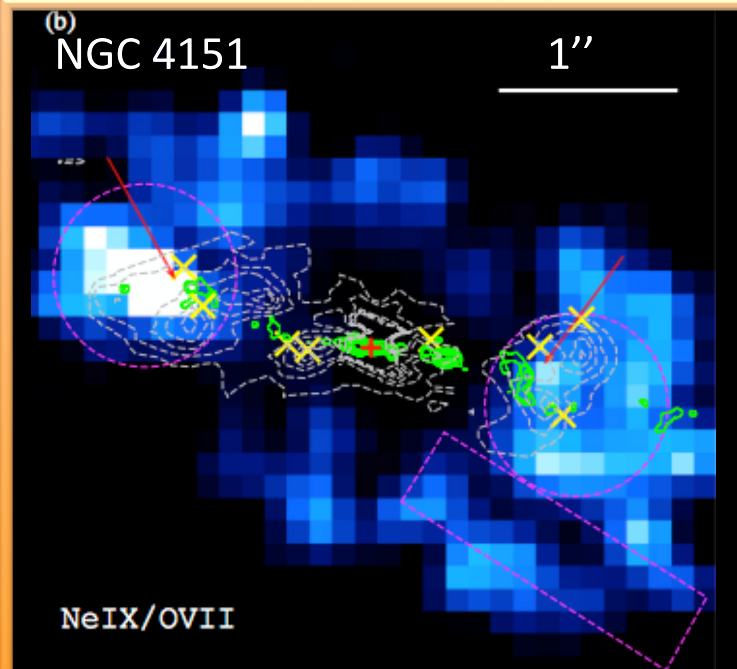
[Athena team: $M_{BH} \sim 10^7$ @ z=8]

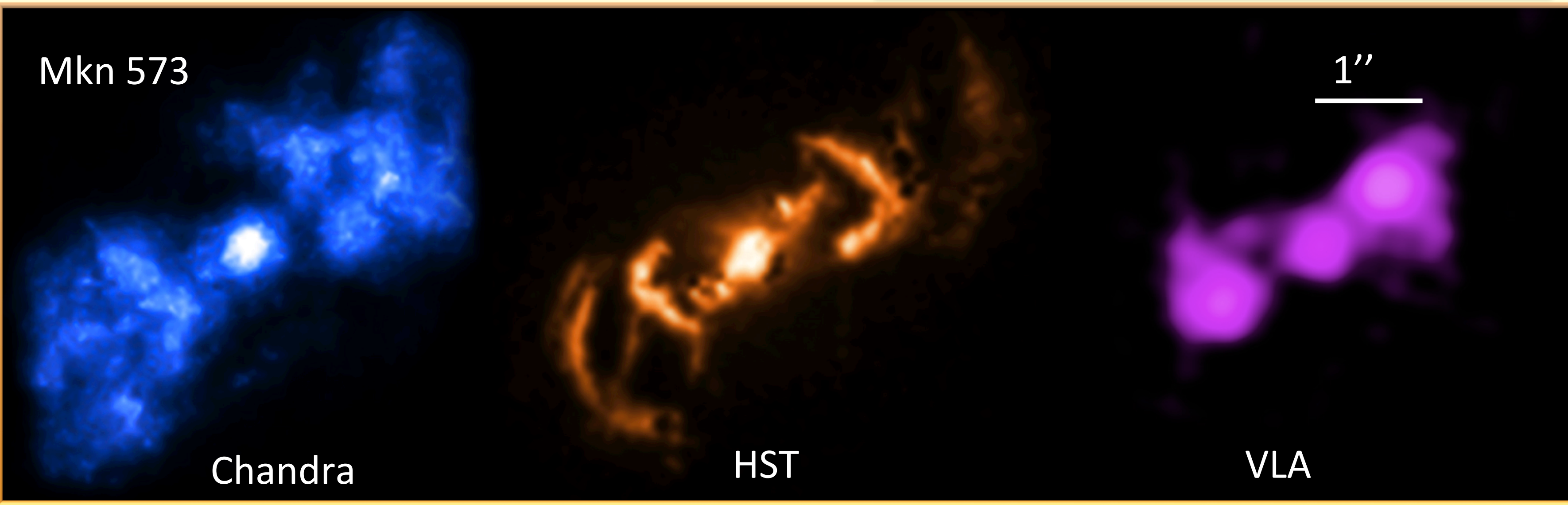

Cycles of baryons in and out of galaxies
Tarantula nebula
Molecular gas (IR)
Hot ISM (X-rays)
Generation of hot ISM in young star-forming regions. How does hot ISM push molecular gas away and quench star formation?
Cosmic Web simulation clipped at the X-ray Surveyor sensitivity threshold
Structure of the Cosmic Web through observations of hot IGM in emission
?
How did the "universe of galaxies" emerge from initial conditions?
VIkhlinin et al 2015

The physics of AGN feedback

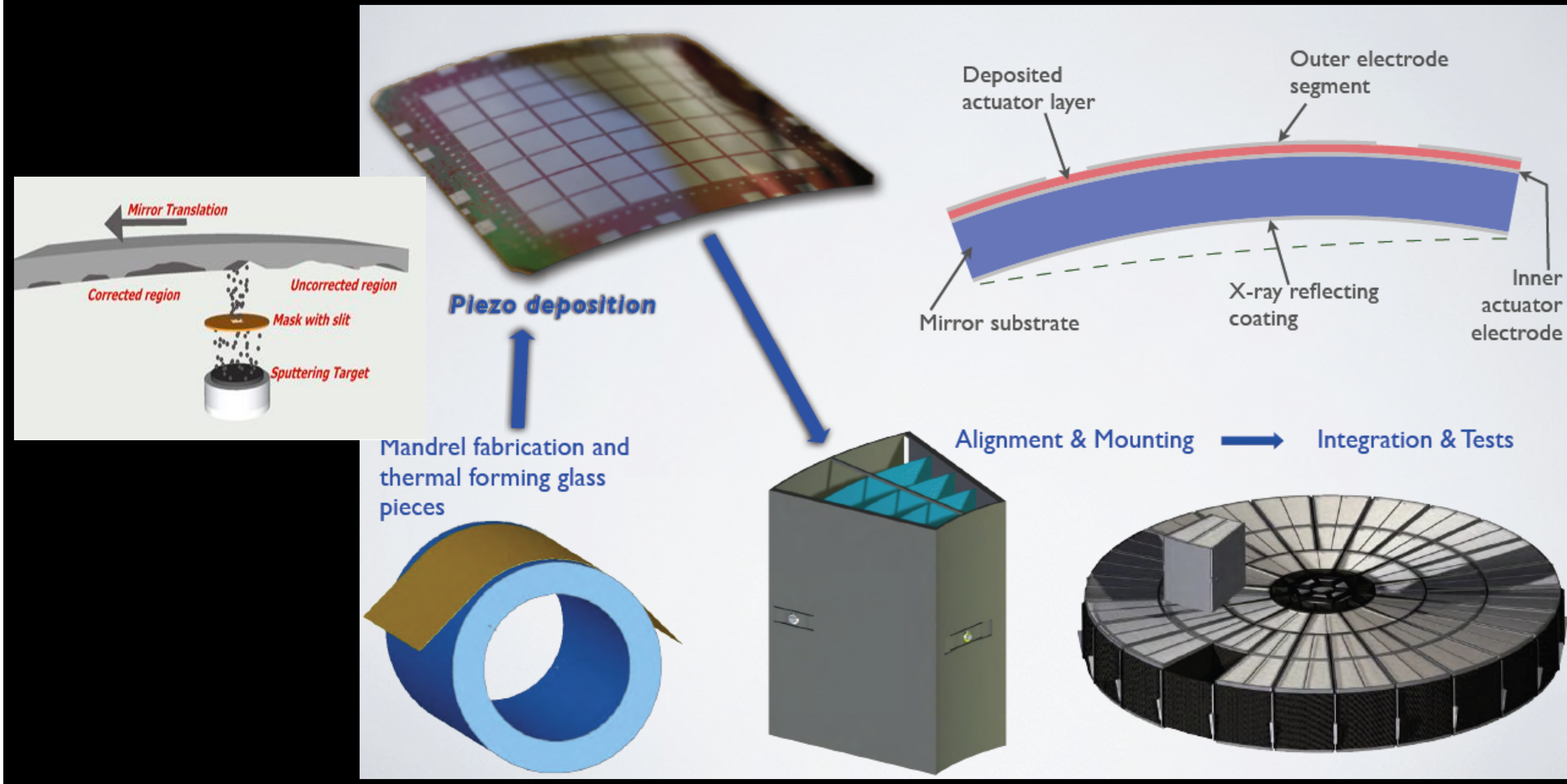


Chandra image of Perseus cluster: energy output from supermassive black hole balances radiative cooling.



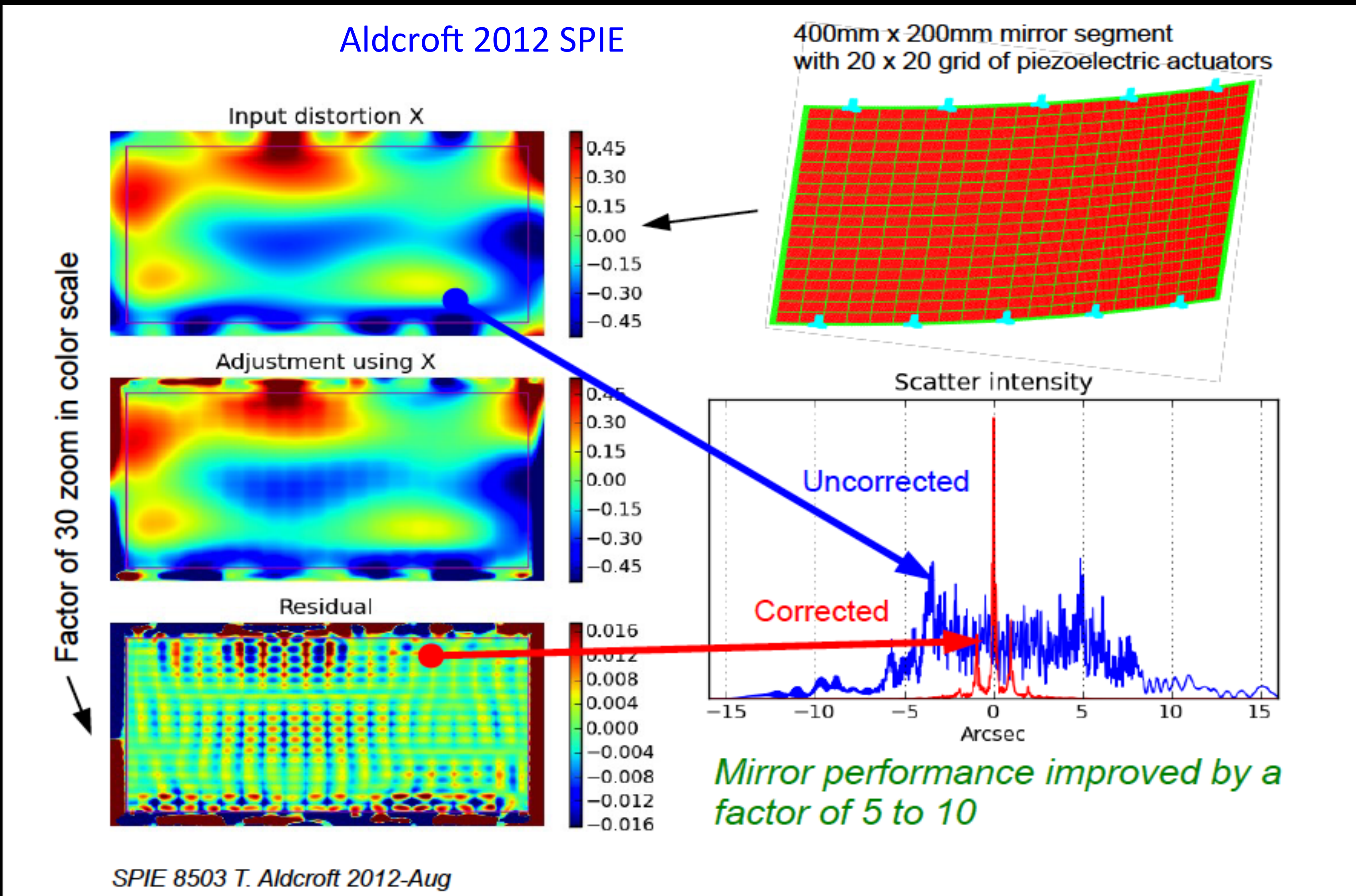


Path to large-area sub-arcsec mirrors



Vikhlinin et al 2015
Weisskopf et al 2015

Piezo-controlled X-ray optics



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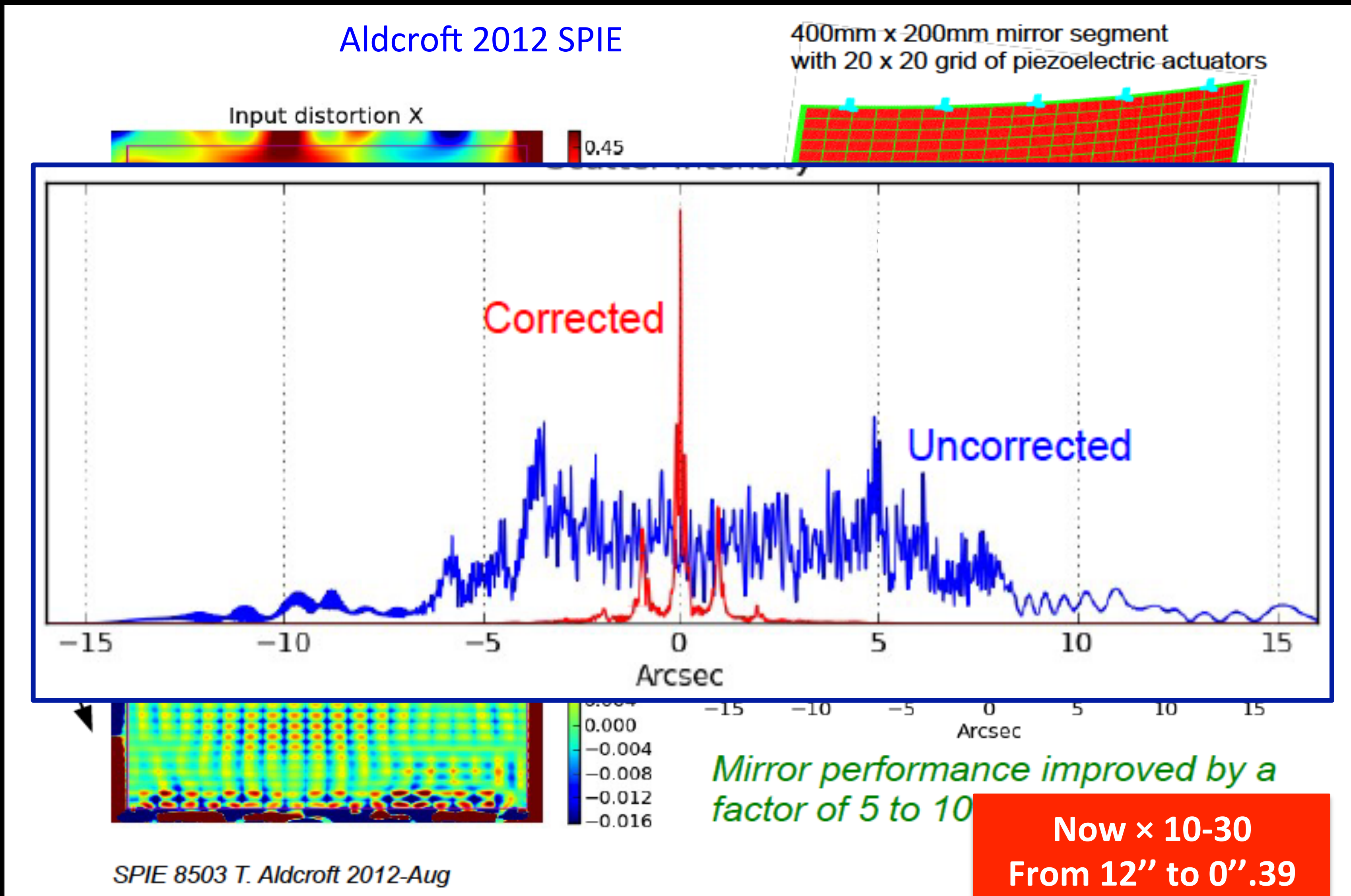

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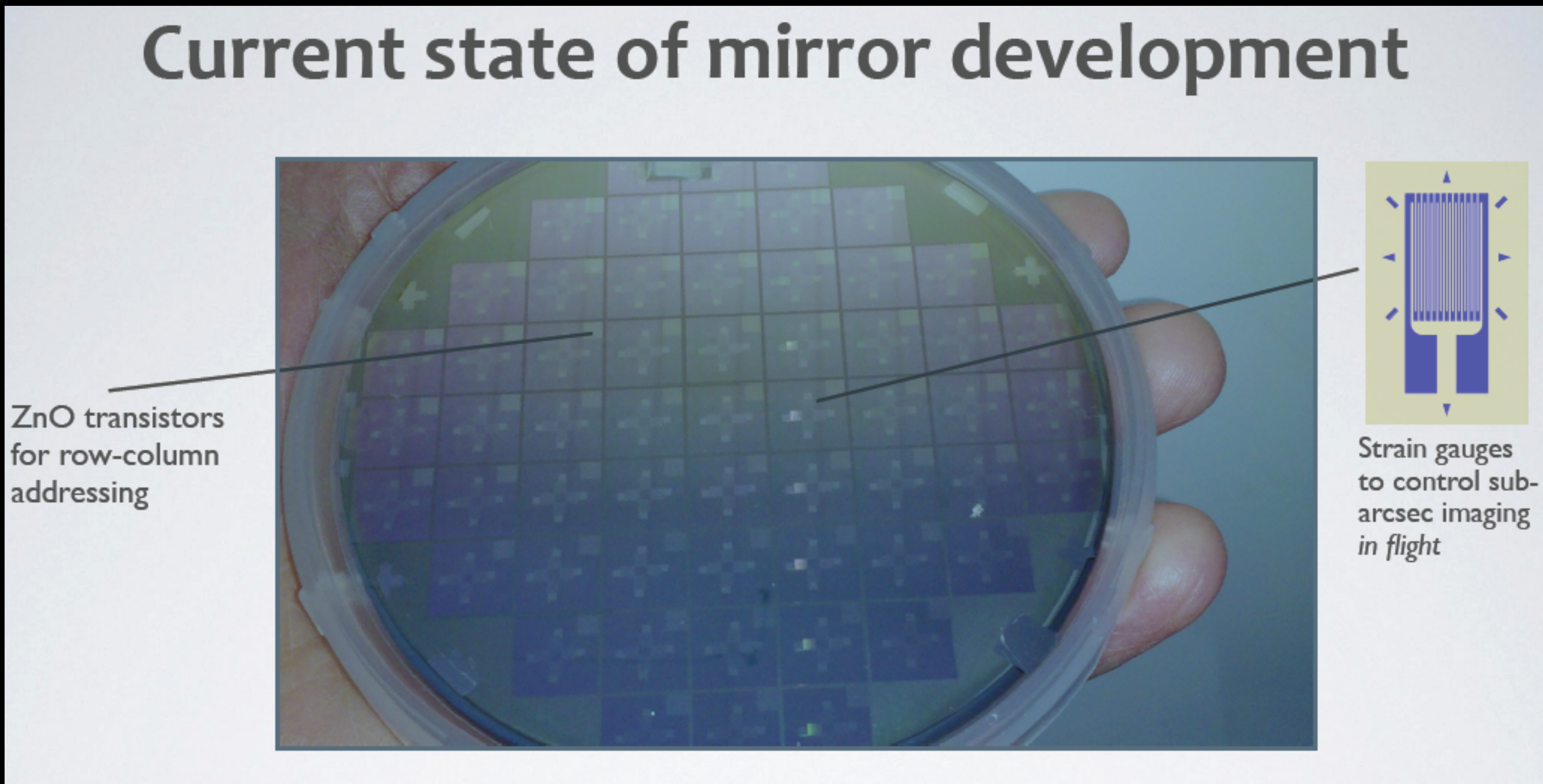
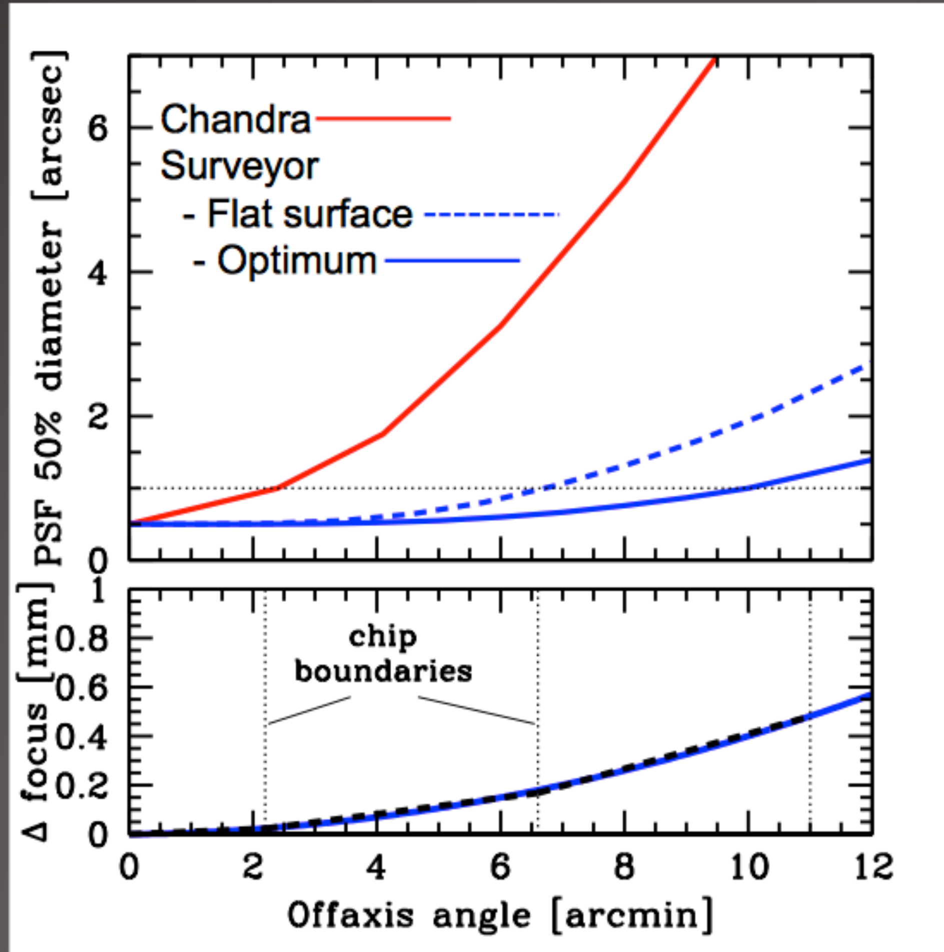


Angular resolution versus off-axis angle
E < 2 keV

Short segments and Wolter-Schwarzschild design yields excellent wide-field performance

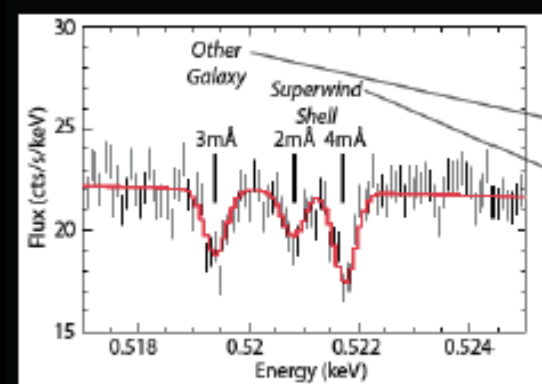


- 16×larger solid angle for sub arcsecond imaging
- 800×higher survey speed at the CDFS limit

Weisskopft et al 2015

X-ray Surveyor 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



X-ray Surveyor

the Next Generation X-ray Telescope

- Capability far exceeds
  - Chandra
    - × 50 area
    - × 800 increase in survey speed (× 16 solid angle, sub-arcsec PSF)
    - IFU, 5’×5’ f.o.v., R>500 (microcalorimeter)
    - × 250 area R=5000 spectroscopy for point and extended sources
  - Athena
    - ×~10 –20 better angular resolution
      i.e. it can go 100 times fainter (less bkg)
    - No gratings
- Same as going from Palomar to a 30m-class telescope
  - TMT, GMT, E-ELT
- Excellent match to JWST, ALMA, LSST, eVLA