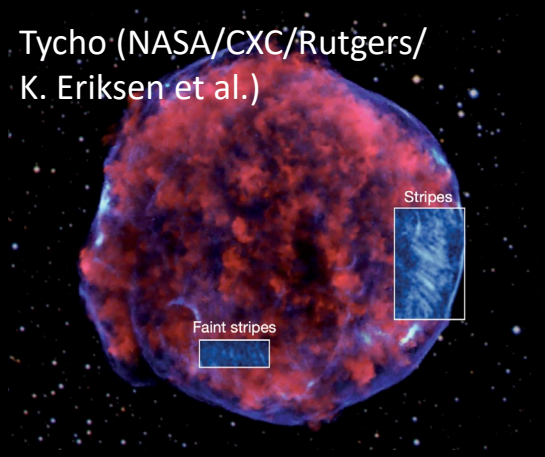
Advanced X-ray Imaging Satellite
An Overview

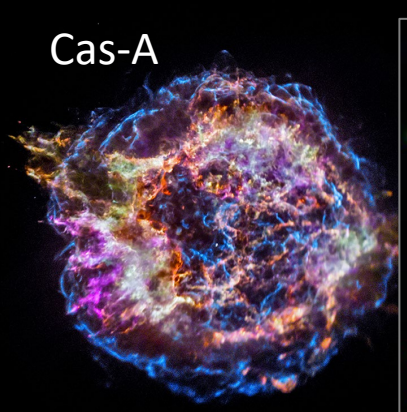
Chris Reynolds (PI)

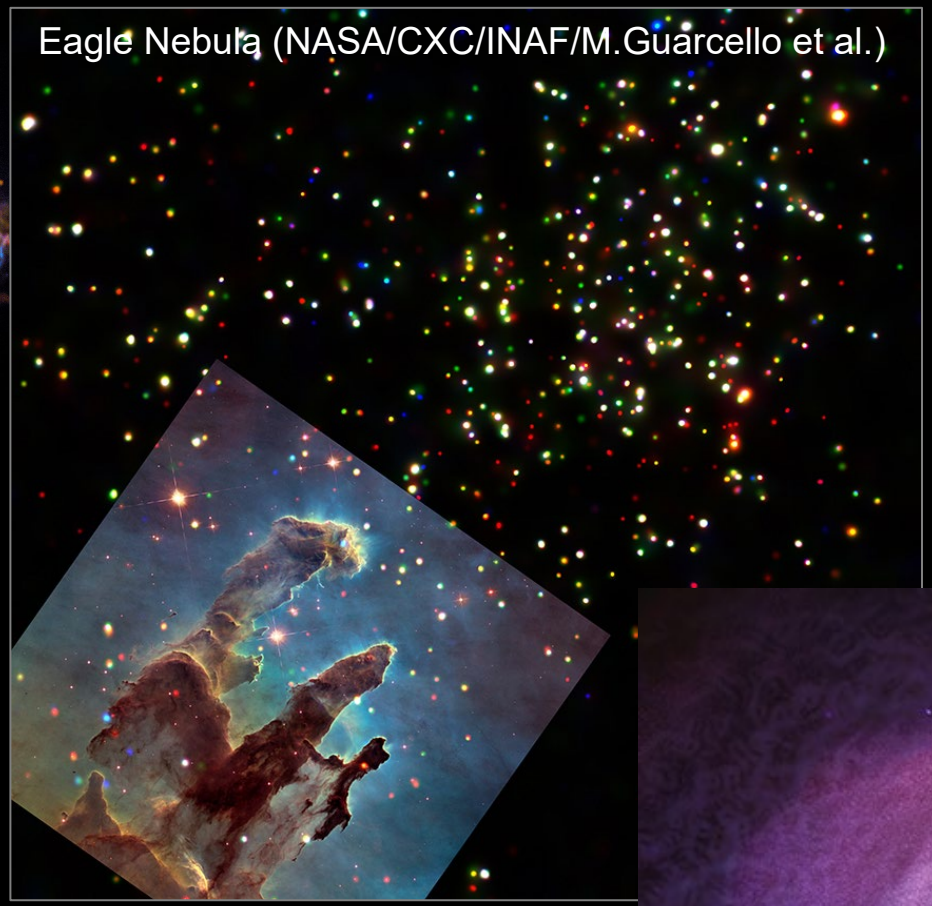
Erin Kara (DPI)

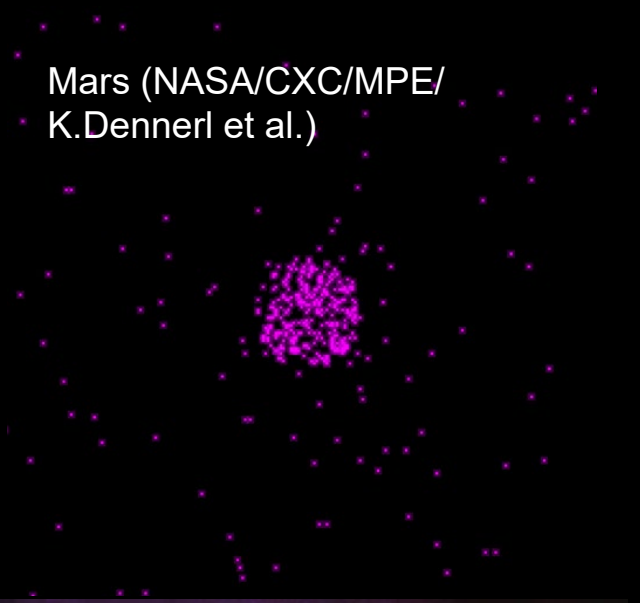
… on behalf of the whole AXIS Team

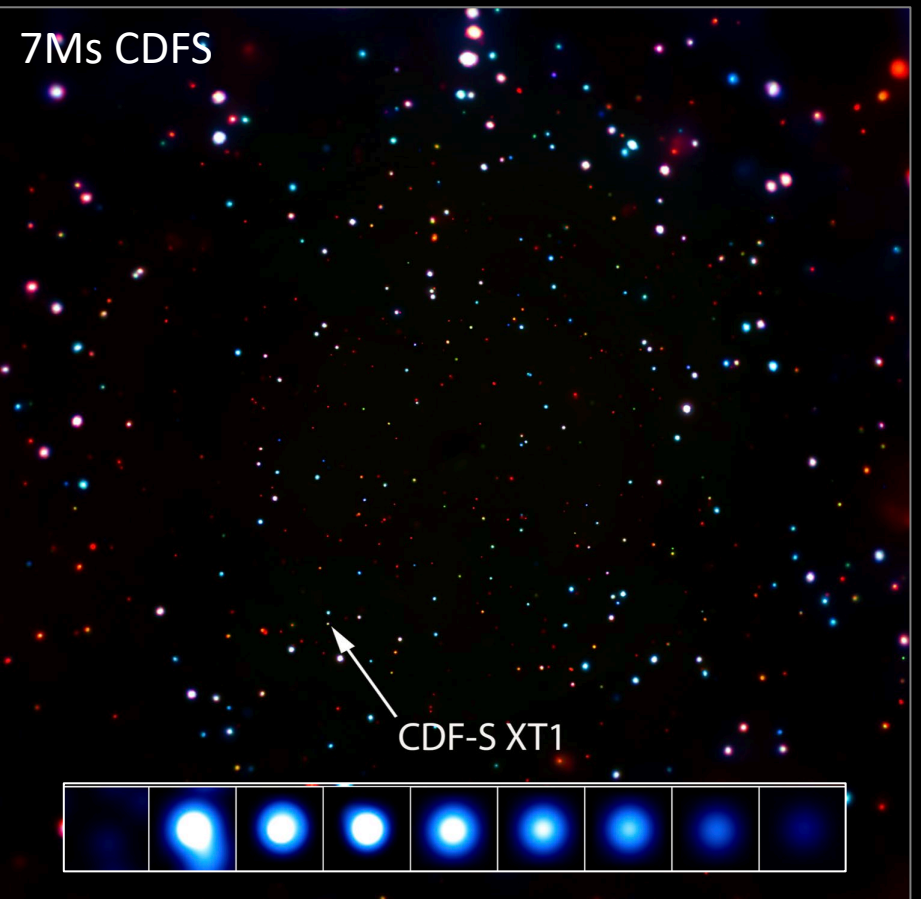

Launch of Chandra X-ray Observatory
(23rd July 1999)

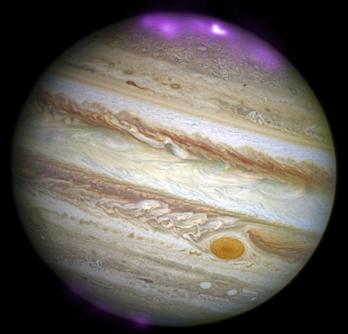

Tycho (NASA/CXC/Rutgers/
K. Eriksen et al.)
Stripes
Faint stripes

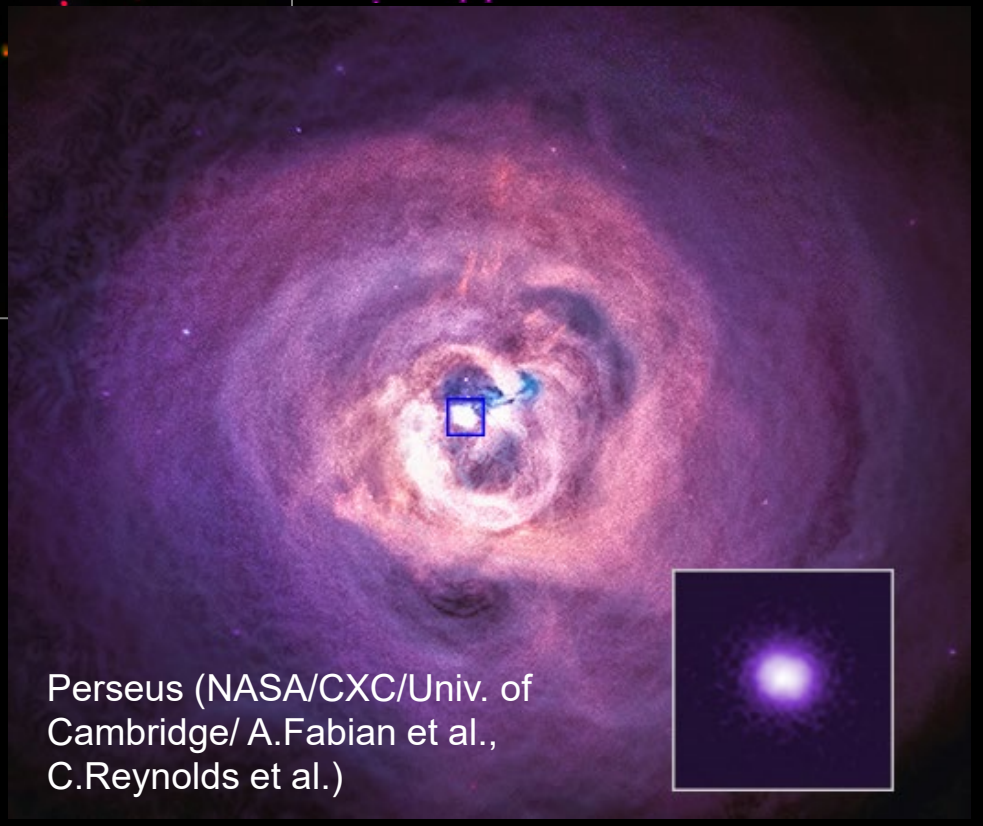

Cas-A


Eagle Nebula (NASA/CXC/INAF/M.Guarcello et al.)


Mars (NASA/CXC/MPE/
K.Dennerl et al.)

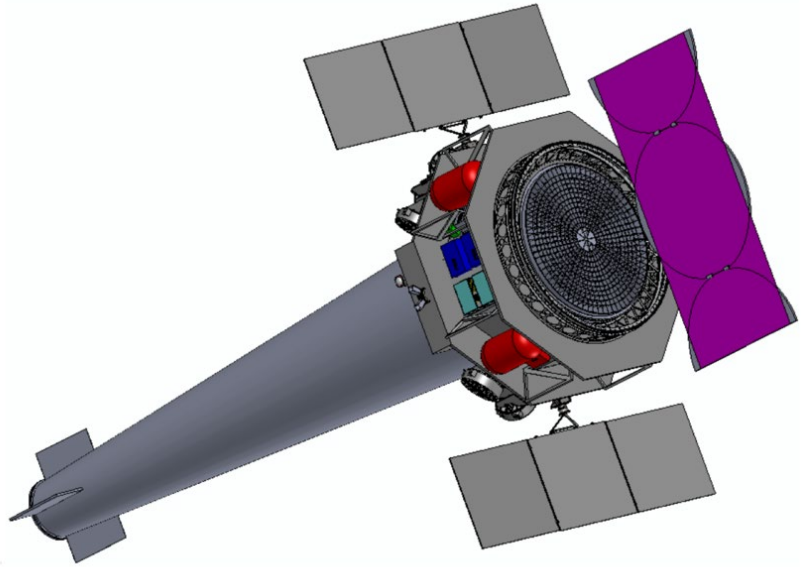

7Ms CDFS
CDF-S XT1

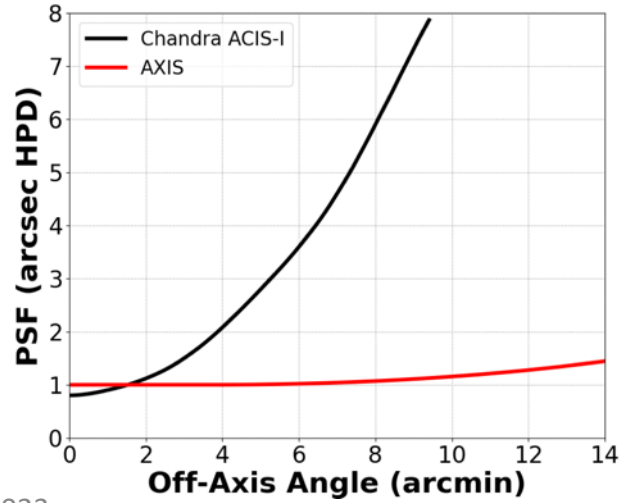

Jupiter (NASA/CXC/UCL/
W.Dunn et al.)


Perseus (NASA/CXC/Univ. of
Cambridge/ A.Fabian et al.,
C.Reynolds et al.)

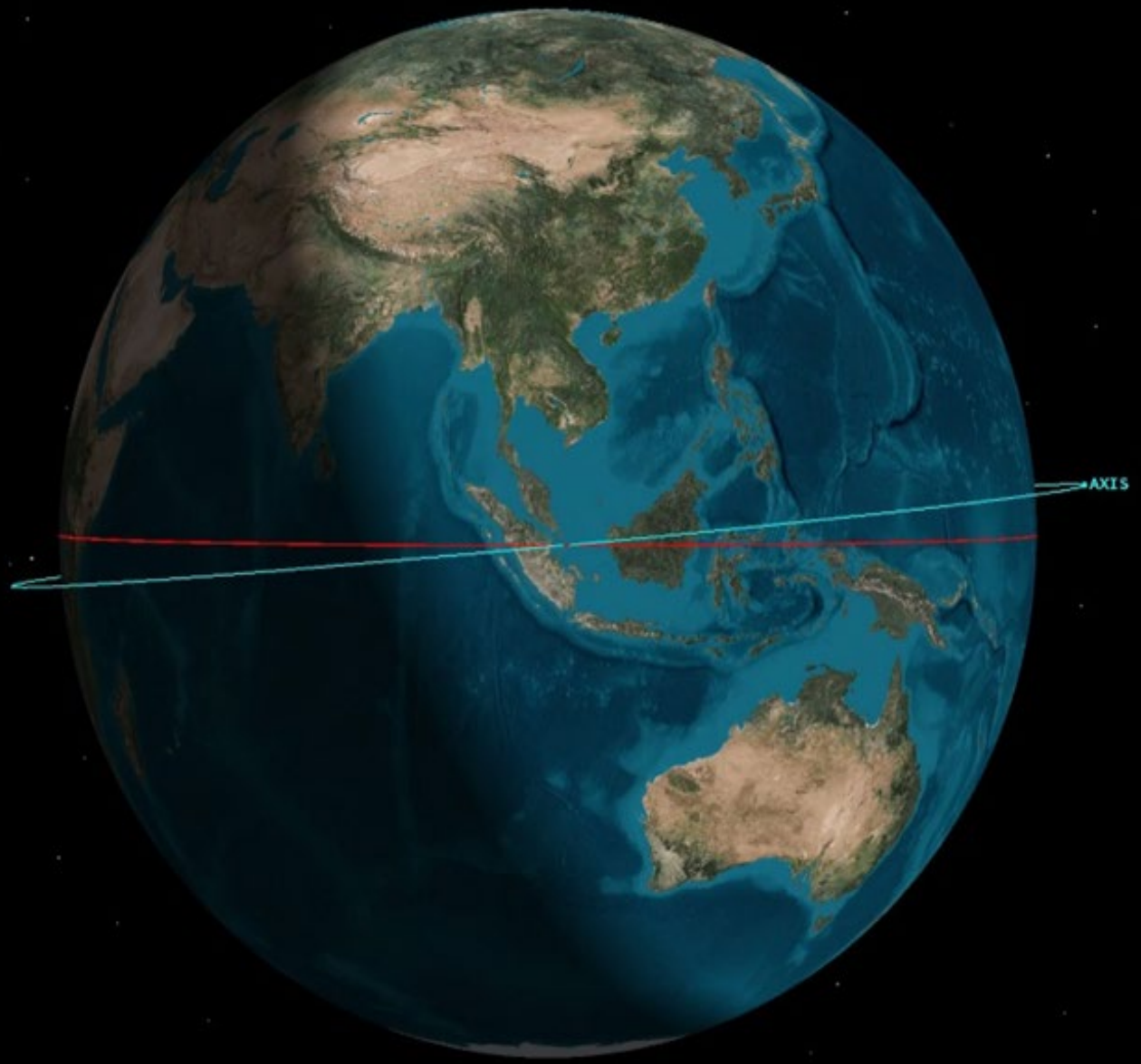
AXIS in a Nutshell

Parameter	Requirement
PSF	1” on-axis, 1.5” at 15’ off-axis (HPD)
Effective Area (incl. detector)	5700 cm^2 at 1 keV; 1250 cm^2 at 6 keV
FoV	24’ square
Bandpass	0.2-12 keV
Readout rate	>5 fps
Slew rate	120 deg. / 5 min.
Orbit	Low-inclination LEO

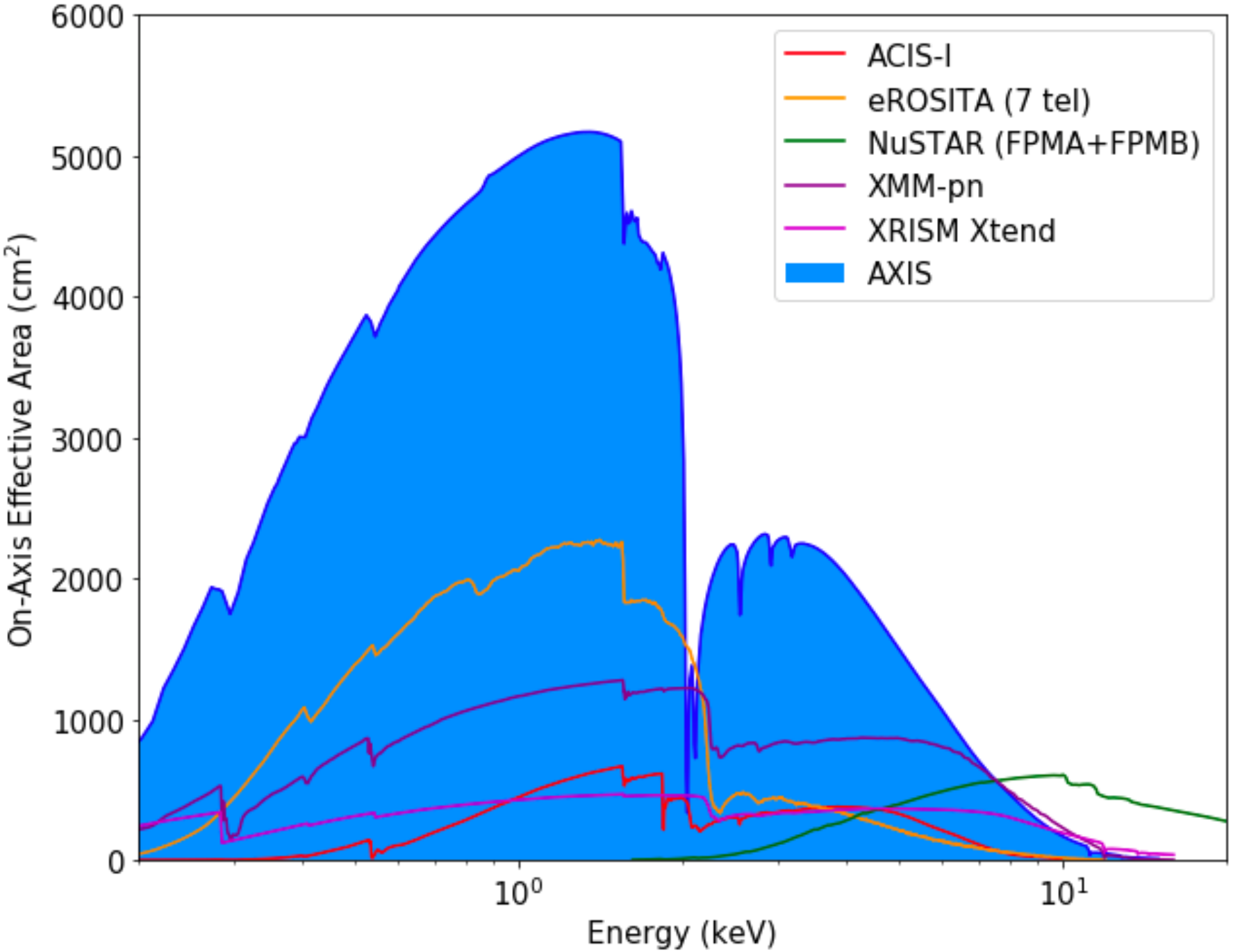


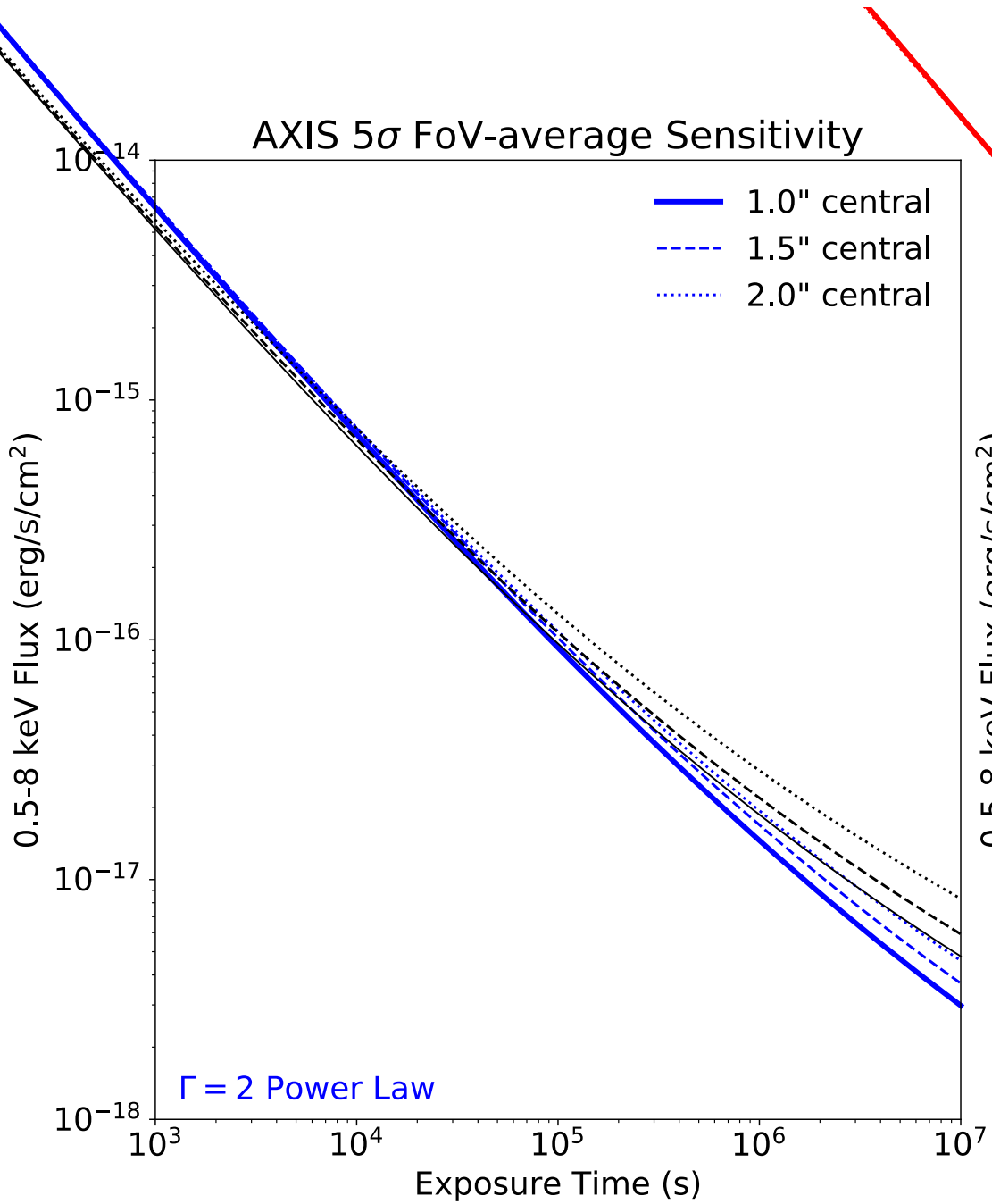


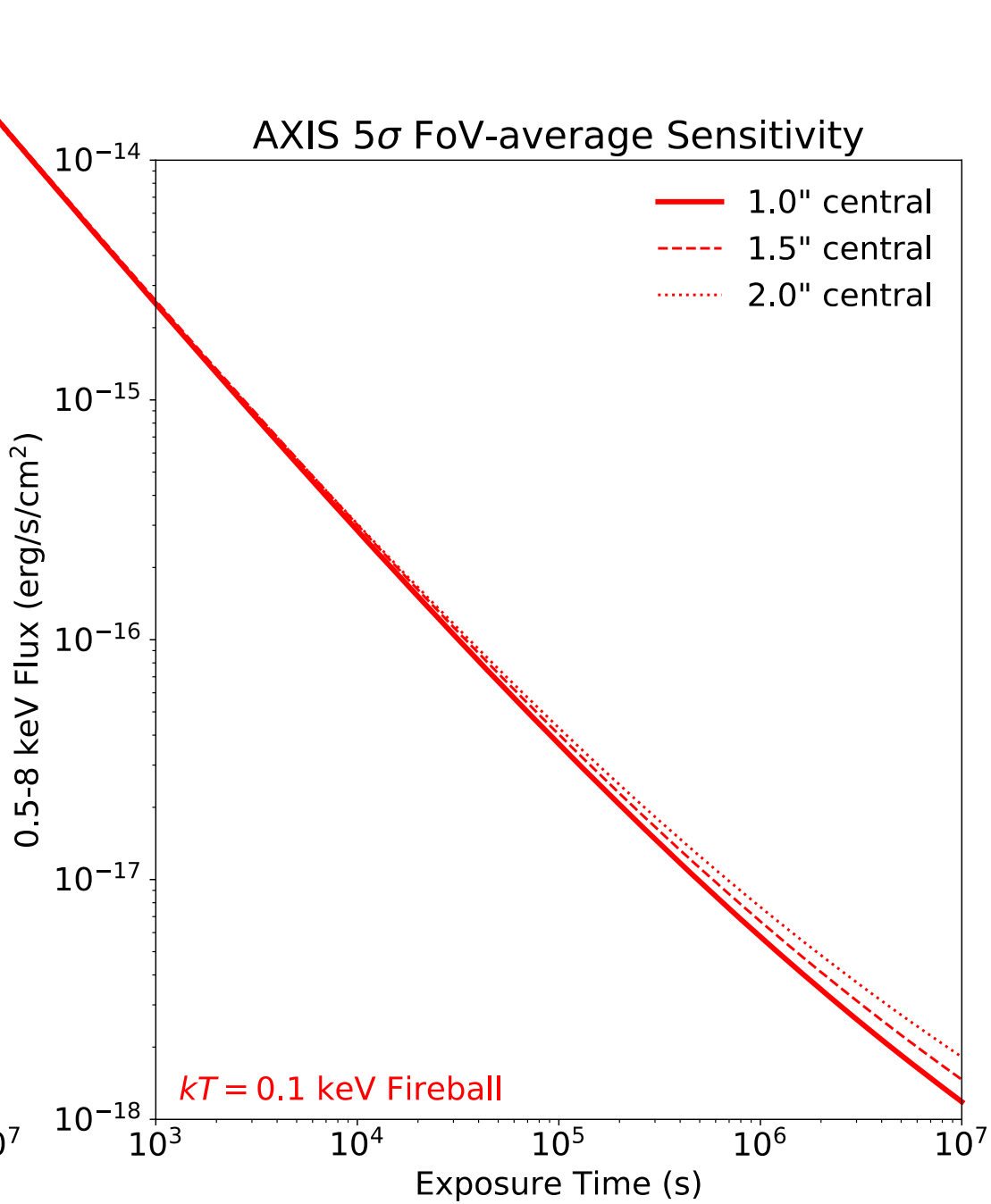
- Simple, single instrument design
- 5 year prime mission; design for 10 year goal
- Combination of **PSF, effective area, low-background**, gives exquisite point source sensitivity ($F_{0.5\text{-}2.0keV}$=2x10^{-18}erg/s/cm^2 FOV-ave in 5Ms)
- Powerful facility for **transient science**; ~2 hour response time to alerts + onboard rapid transient detection.
- True community facility; >70% time for Guest Observers



Choice of low-inclination LEO driven by desire to reduce radiation/particle background, and comms associated with transient response.

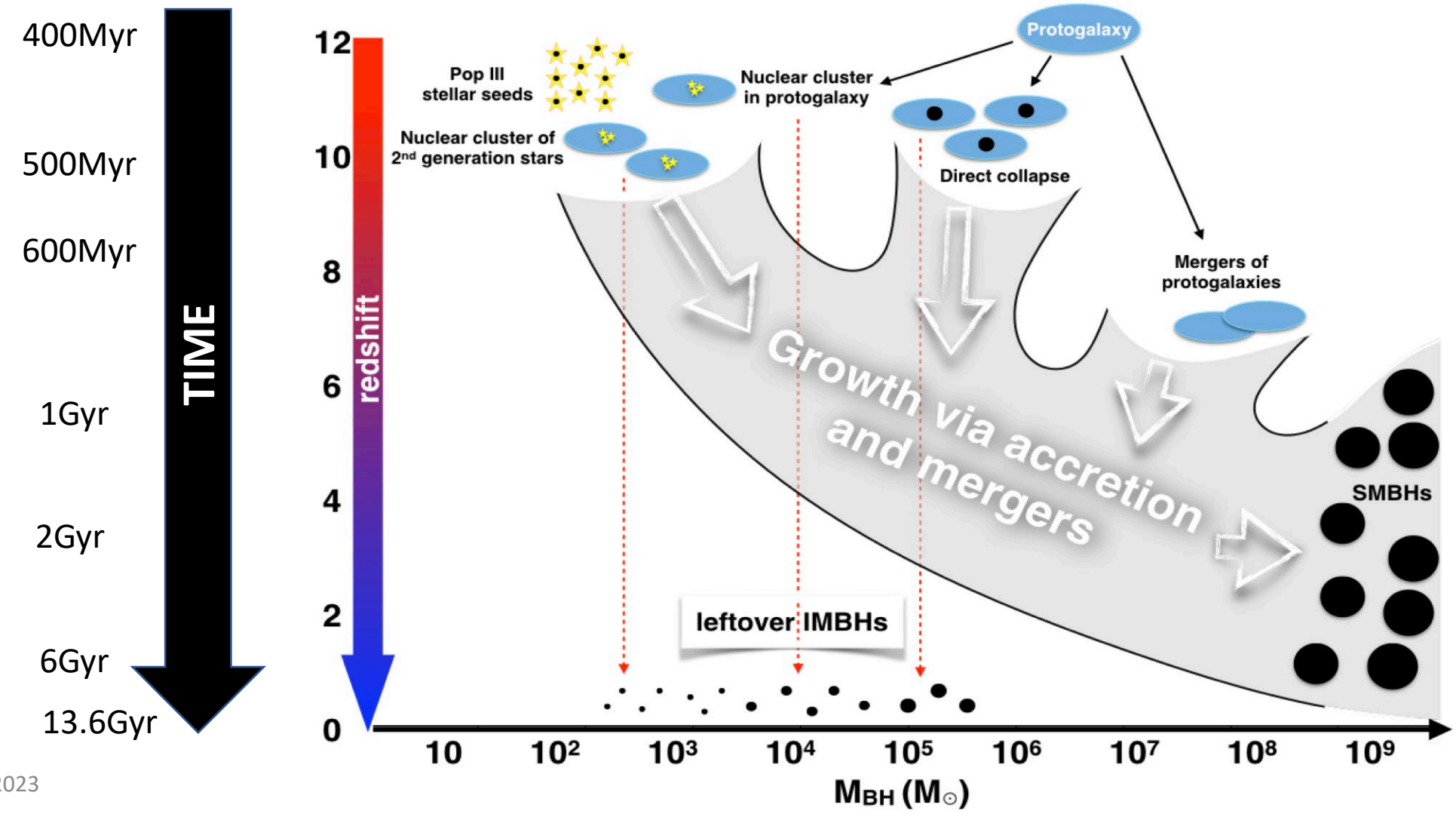

6000
5000
4000
3000
2000
1000
0
On-Axis Effective Area (cm^2)
10^0
10^1
Energy (keV)
ACIS-I
eROSITA (7 tel)
NuSTAR (FPMA+FPMB)
XMM-pn
XRISM Xtend
AXIS

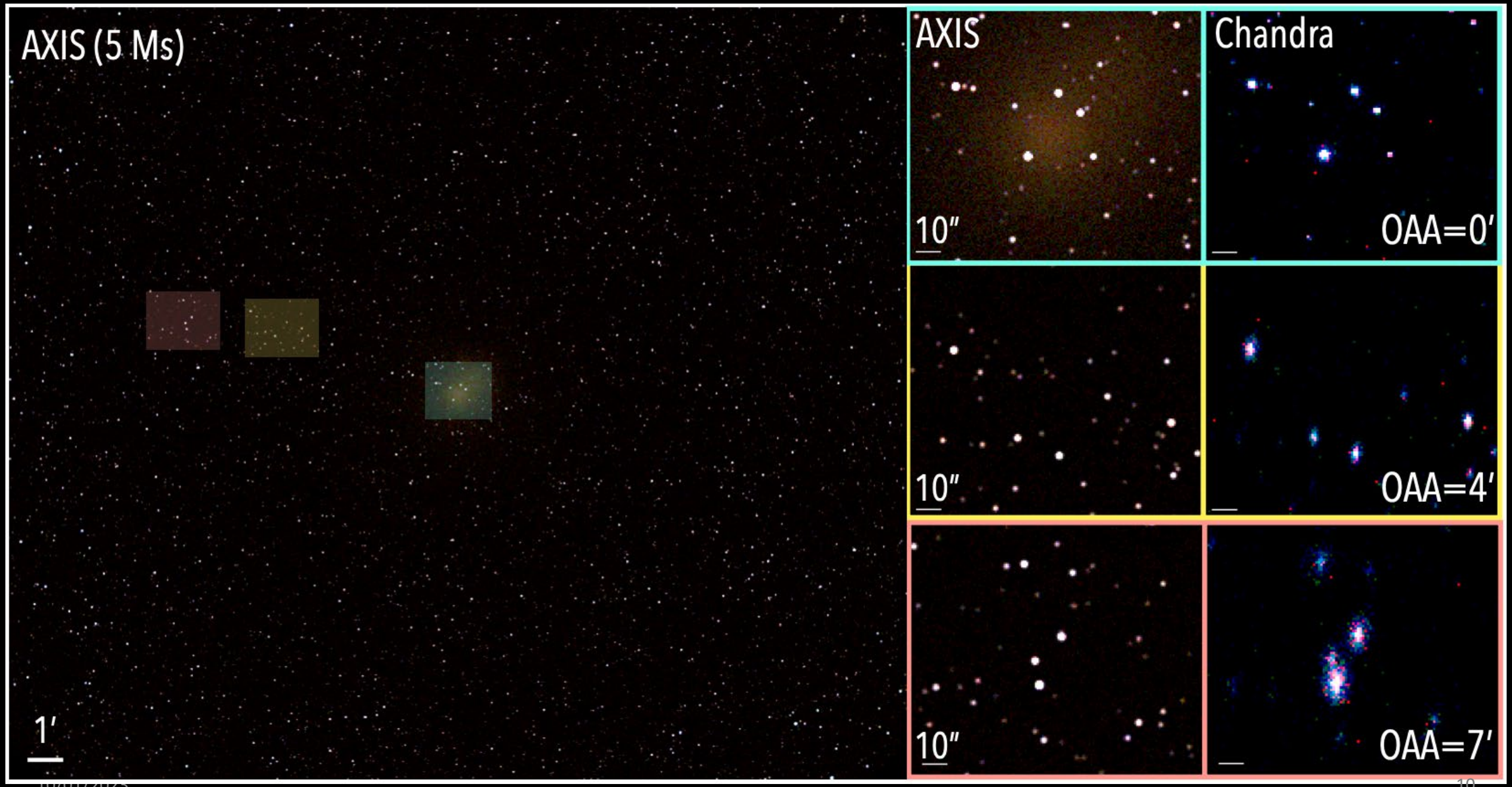

AXIS 5σ FoV-average Sensitivity
1.0" central
1.5" central
2.0" central
Γ = 2 Power Law
0.5-8 keV Flux (erg/s/cm²)
Exposure Time (s)


AXIS 5σ FoV-average Sensitivity
1.0" central
1.5" central
2.0" central
kT = 0.1 keV Fireball
0.5-8 keV Flux (erg/s/cm²)
Exposure Time (s)

Decadal Theme	Top Questions related to AXIS	AXIS Measurements	Required Mission Specs
	"What seeds supermassive black holes, and how do they grow?"	Luminosity functions of black holes in first Gyr	PSF, effective area
		SMBH merger rates from dual AGN detections	PSF, effective area
	"How do gas, metals, and dust flow into, through, and out of galaxies?"	X-ray observations of cluster outskirts, connection to Cosmic Web	Low particle background, PSF, FoV
	"Discovery Area: Mapping the IGM, CGM in Emission"	Mapping/thermodynamics of hot ISM, CGM, IGM	PSF, soft effective area, low particle background (note MW dominates NXB at 0.6 keV)
	"What powers the diversity of explosive phenomena across the electromagnetic spectrum?"	Rapid and late time follow-up of transients of many types (NS-NS mergers, SLSNe, FRBs, FBOTS, Type II SNe)	Fast slew, Large FoV, Large soft band effective area
		Rapid follow-up of short GRBs and neutrino events (potentially from blazars and TDEs).	Fast slew, Large FoV, Large soft band effective area
	"What seeds supermassive black holes, and how do they grow?"	close-separation SMBHBs detected through X-ray variability and/or LISA GWs	Large FoV, sensitivity, PSF
	"How do habitable environments arise and evolve within the context of their planetary systems?"	Population study of flaring from magnetically active M-dwarfs to construct first full record of X-ray heating of exoplanet atmospheres.	Soft X-ray effective area, PSF for crowded fields
	"How does multiplicity affect how a star lives and dies?"	X-ray photometric and spectroscopic observations of ultracompact binaries and joint detection of GWs with LISA.	Soft X-ray effective area, large FoV, PSF, fast slew

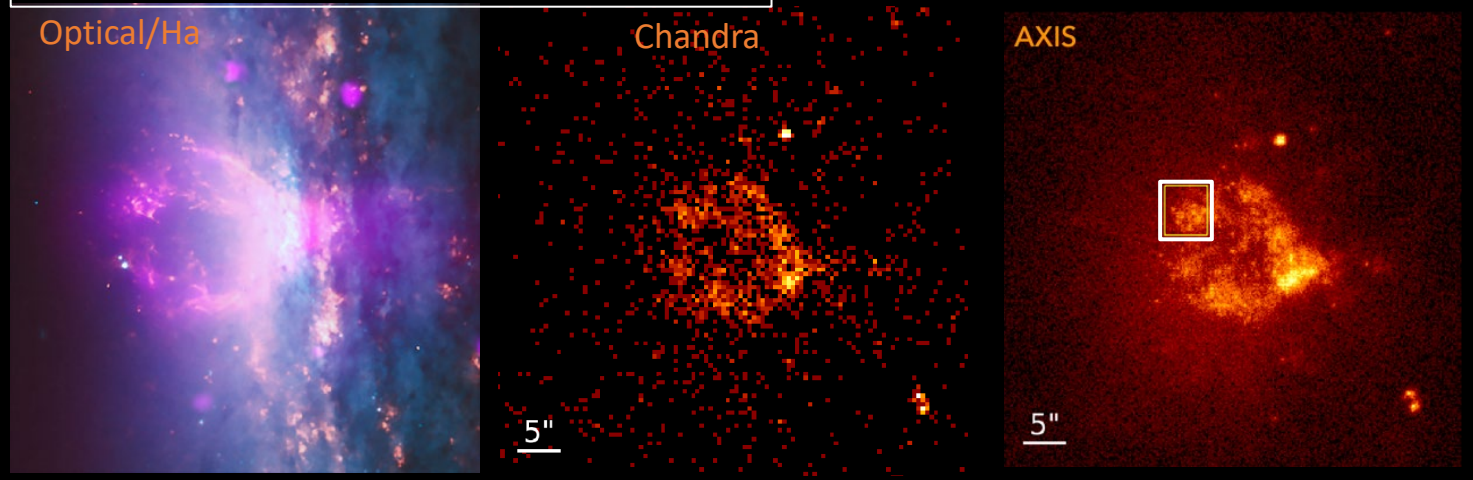
Astro2020 asks: "What seeds supermassive black holes, and how do they grow?"



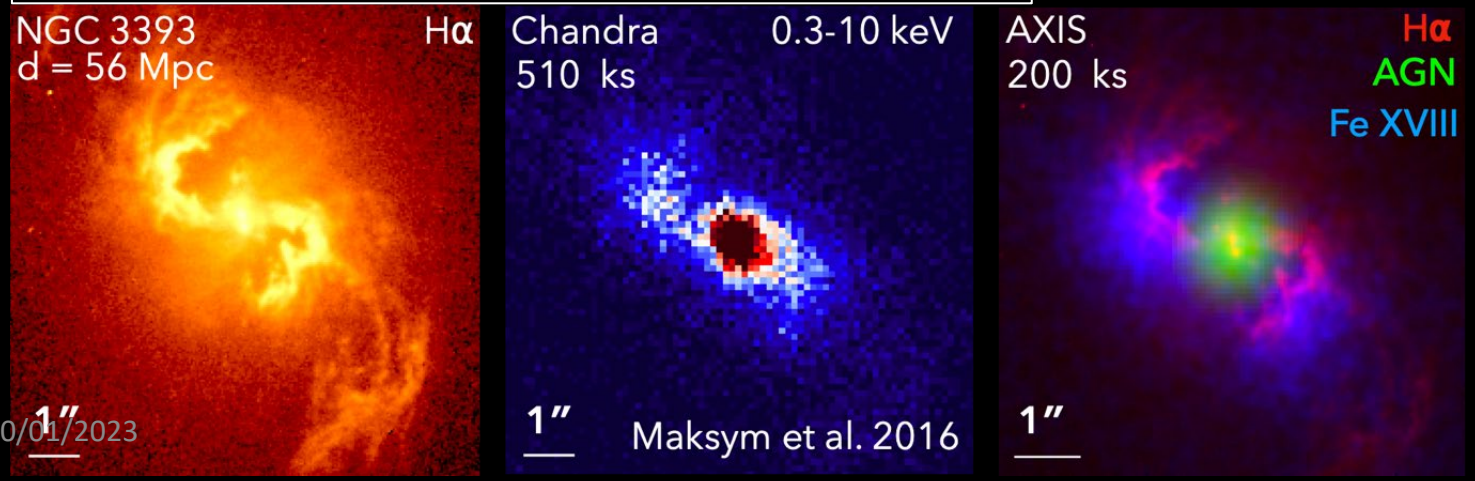

AXIS (5 Ms)
1′
AXIS
Chandra
10″
OAA=0′
10″
OAA=4′
10″
OAA=7′

Astro2020 asks :
“How do gas, metals and dust flow into, through, and out of galaxies?”
“How is the growth of black holes coupled to the evolution of their host galaxies?”

SUPERBUBBLE IN NGC 3079 (20Mpc)



AGN WIND-GALAXY INTERACTION IN NGC 3393



AXIS+Athena probes mass, metal and energy content of galactic-scale wind.

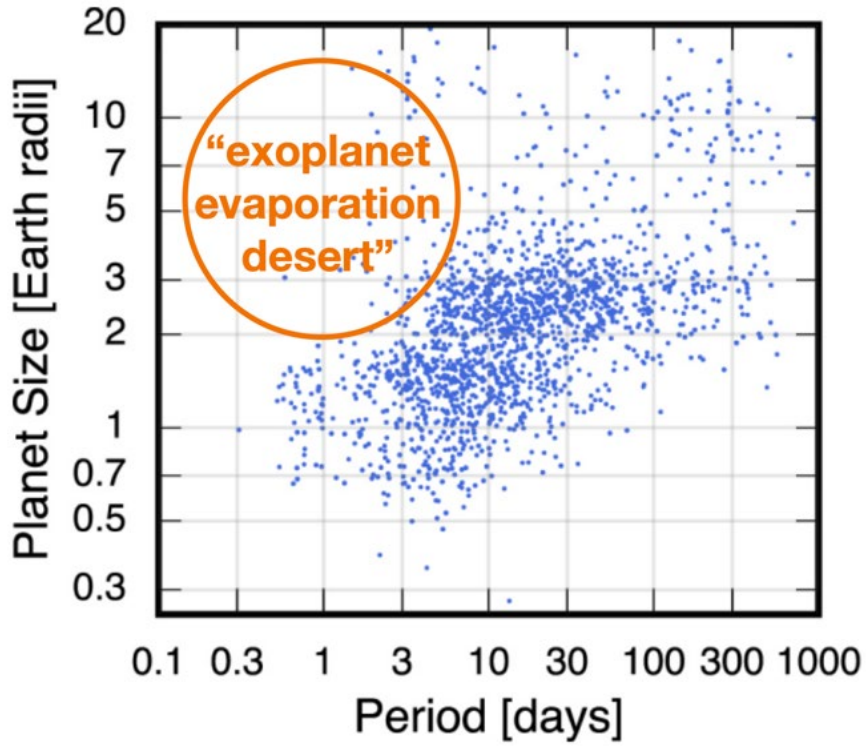
AXIS resolves fine wind structure out to 50Mpc; resolves galactic scales at all redshifts.

AXIS fast readout permits study of structure close to bright AGN

AXIS low background allows us to push to low-surface brightness emission in early-type galaxies

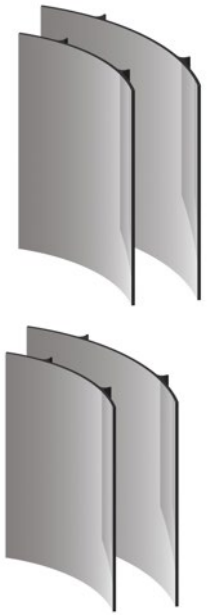
Astro2020 asks: "How do habitable environments arise and evolve within the context of their planetary systems?"

- X-ray activity from host stars affect the chemistry of exoplanet atmospheres and potential habitability.
- AXIS will perform population-scale studies of flaring, coronal mass ejections and X-ray driven exoplanet atmosphere loss across stellar lifetimes.
- Population studies of stellar flaring is best studied in X-rays because UV suffers from interstellar extinction and is limited to nearest or hottest stars.
- Science enabled by sharp PSF over a wide FoV and effective area.

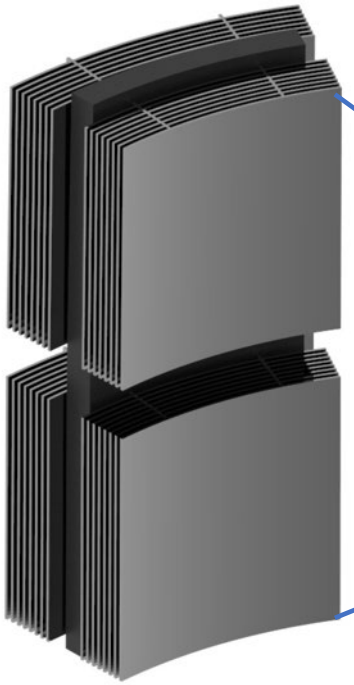


Wolk et al., Astro2020 WP

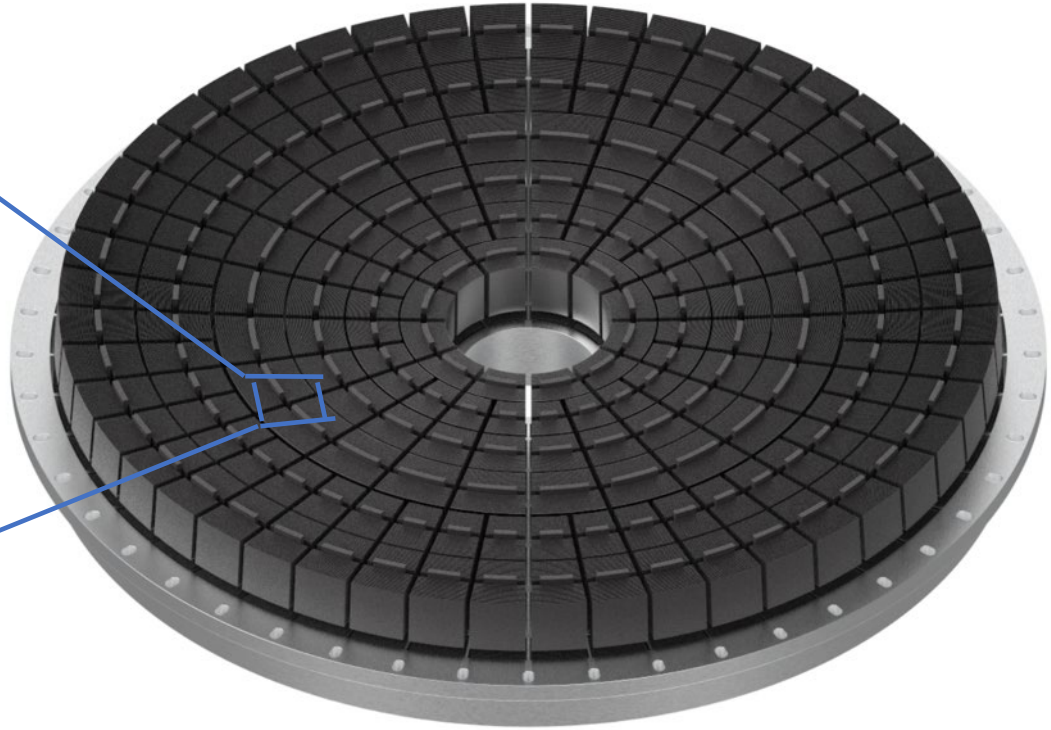
X-ray Mirror Assembly (Lead : Will Zhang, GSFC)



~10^4 Mirror Segments



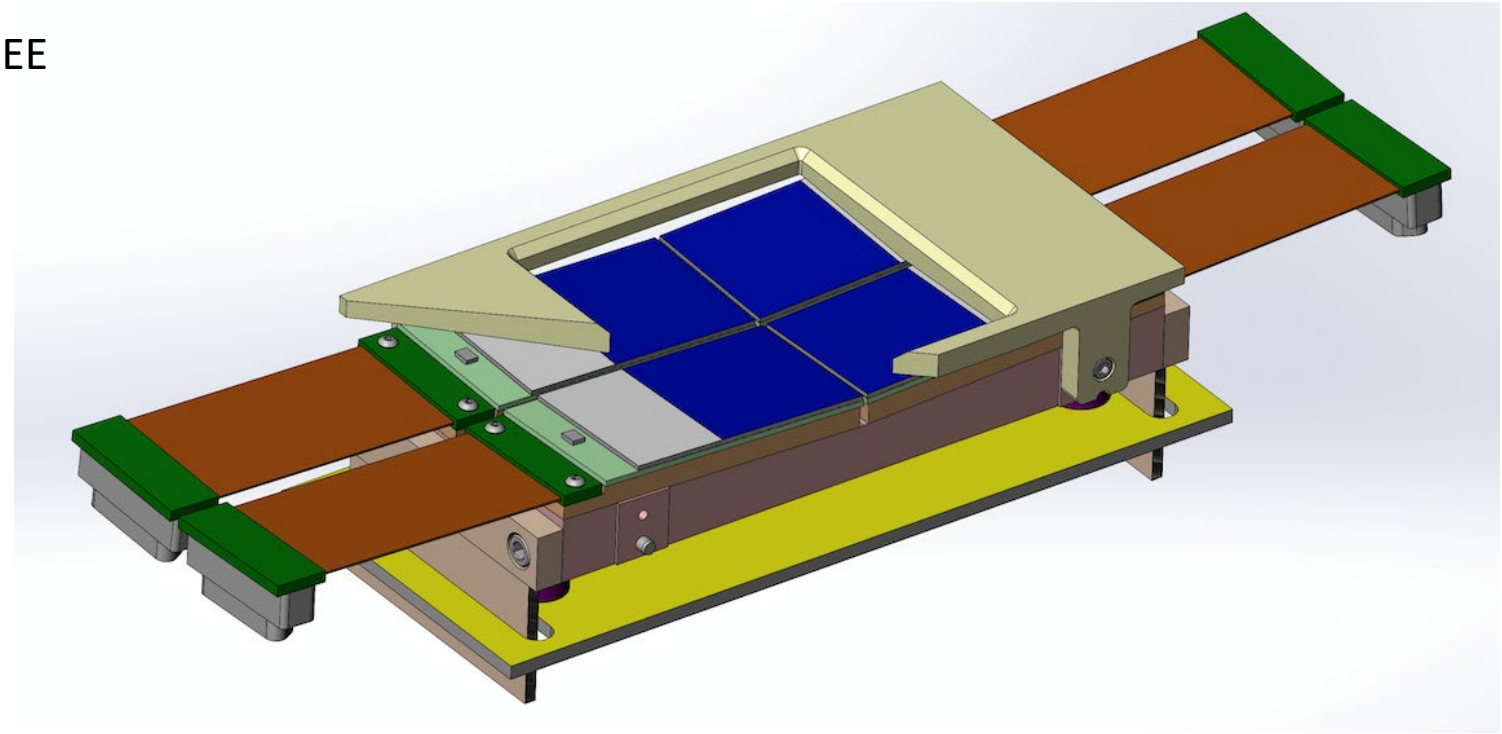
~10^2 Mirror Modules



10^0 Mirror Assembly

X-ray Camera Module (Lead : Eric Miller, MIT)

Detectors:
Baseline MIT Lincoln Lab DCCDs; Penn State BEE
24µm pixels (0.5arcsec)
2x2 tile to allow 24'x24' field of view
Readout >5 frames-per-second
Low noise (operate at -90C)



House detector in the **X-ray Camera Module**
Vacuum door for launch
Warm optical/contamination blocking filter
Focusing mechanism

Conclusion

- AXIS is a powerful next generation imaging X-ray observatory with broad reach across the Astro2020 themes and key questions
  - Deep X-ray studies high-z AGN, high-z star formation, high-z clusters, hot circumgalactic medium, activity in exoplanet hosts, GW counterparts, supernova breakout shocks…
- Simple, single-instrument design
  - AXIS Mirror Assembly (GSFC)
  - AXIS X-ray Camera Module (MIT, PSU, Stanford)
  - Spacecraft (Northrop Grumman)
- Community facility with 70% of science time to General Observers