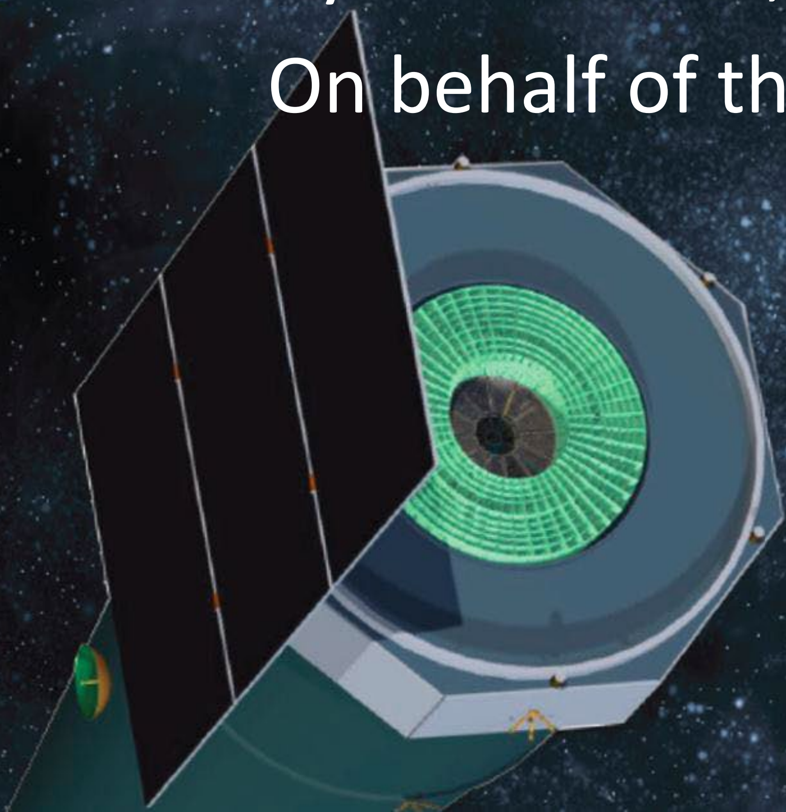
AXSIO

Jay Bookbinder, Randall Smith
On behalf of the AXSIO Team



Outline

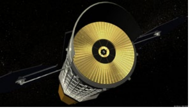
AXSIO Science

AXSIO Mission Summary

AXSIO Instruments & TRLS

AXSIO Costs

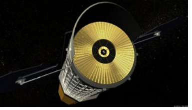
RFI Questions and Answers



The Decadal View of IXO

- "Large-aperture, time-resolved, high-resolution X-ray spectroscopy is required for future progress on all of these fronts, and this is what IXO can deliver." (p. 214)

- "The key component of the IXO focal plane is an X-ray microcalorimeter spectrometer—a 40 × 40 array of transition-edge sensors covering several arcminutes of sky that measure X-ray energy with an accuracy of roughly 1 part per 1,000 (depending on energy)." (p. 214)



AXSIO Capabilities on IXO's Science Case

Topics specifically listed for IXO in the 2010 Decadal Science Plan

Topics called out in the Origin, Cosmic Order, or Frontiers of Knowledge Questions.

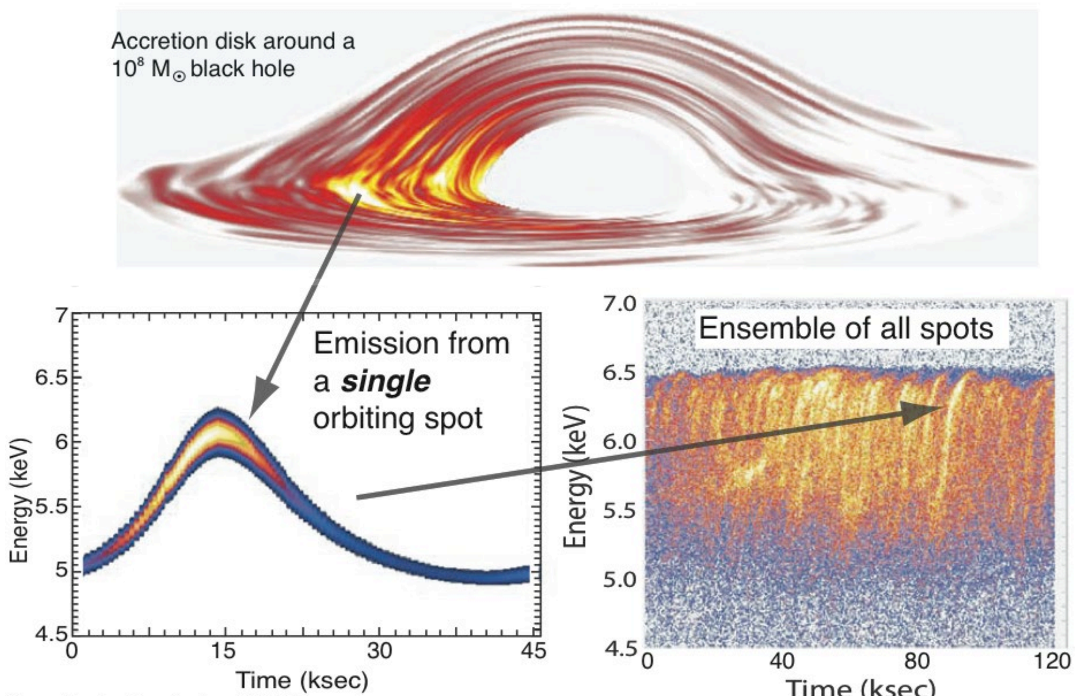
Not possible as envisioned; capabilities limited by PSF and/or FOV

Major impact on science due to PSF and increased obs. time due to lower eff. area.

		Topics	Typical Targets	Length	# Obs	Total Time
				ksec		Msec
Galaxies and Black Hole Evolution						**30.6**
First SMBH		**2**	CDF-S	300	38	11.4
Obscured Growth of SMBH		**1**	NGC 4051 / z=0.02-0.1	50	200	10.0
Cosmic Feedback		**3**	cluster	183	50	9.2
Large Scale Structure						**45.0**
Cosmic Web of Baryons		**1**	QSO B1426+428	600	25	15.0
Cluster Physics		**2**	z=0.1-2 cluster	160	94	15.0
Cosmology		**2**	z~0.5-2 cluster	15	1000	15.0
Matter Under Extreme Conditions						**22.4**
Stellar-Mass Spin		**1**	GRS1915+105	50	120	6.0
Strong Gravity Effects		**8**	MCG-6-30-15	200	40	8.0
Neutron Star Equation of State		**1**	EXO0748-676	32	170	5.4
QED Tests from Magnetars		**1**	SGR 1900+14	30	100	3.0
Life Cycles of Matter and Energy						**12.2**
SNR		**2**	Tycho SNR	100	80	8.0
Characterizing the Galactic ISM		**1**	MCG-6-30-15	seren.	100	0.0
Galactic Center		**2**	Sgr A* / GM 238	250	4	1.0
Stars & Planets		**5**	Ophiucus	20	160	3.2
Total		**32**				**110.2**

Based on both IXO Yellow Book science plan and SDT observation plan developed for Astro2010 RFI#1.

What happens close to a black hole?

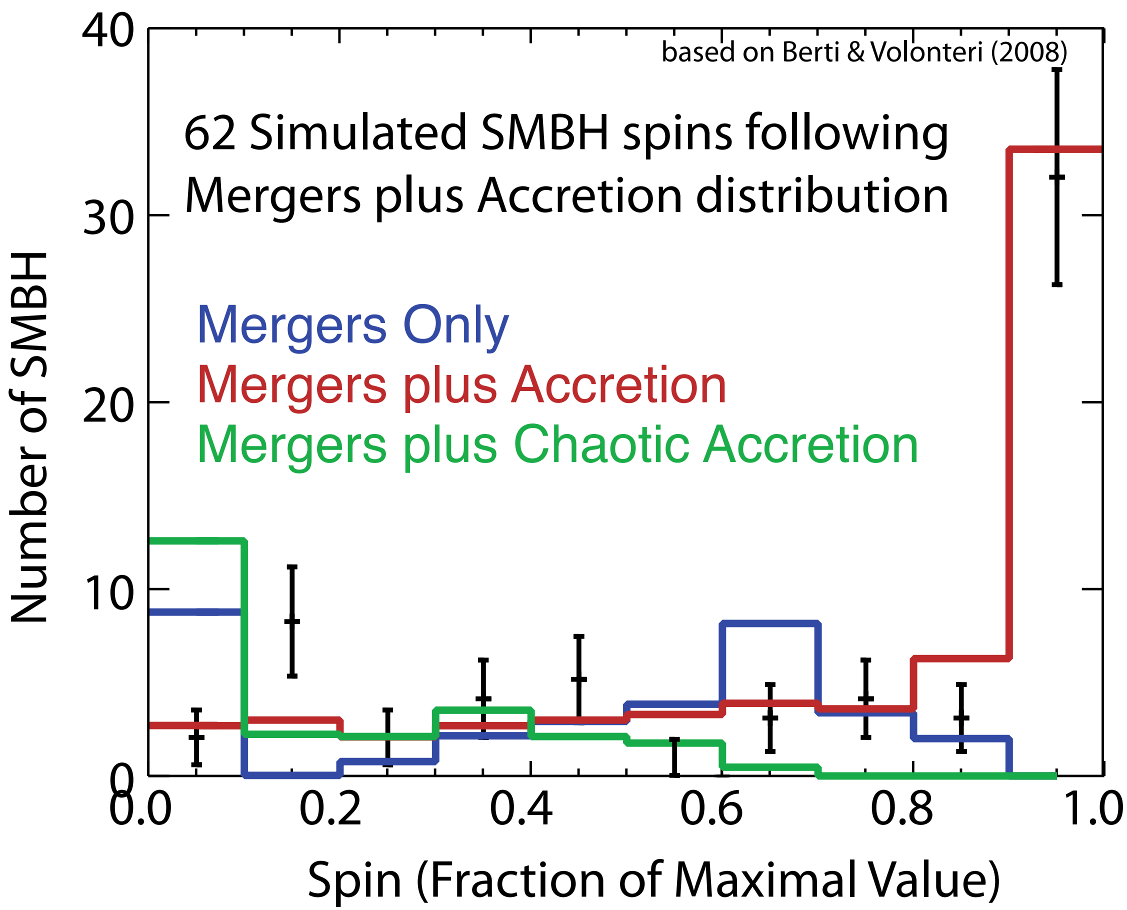


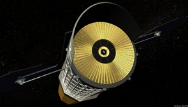
Based on Armitage & Reynolds 2003

AXSIO's reduced effective area requires higher mass SMBH, but 10's of suitable SMBH ($>10^8 M_\odot$) exist.

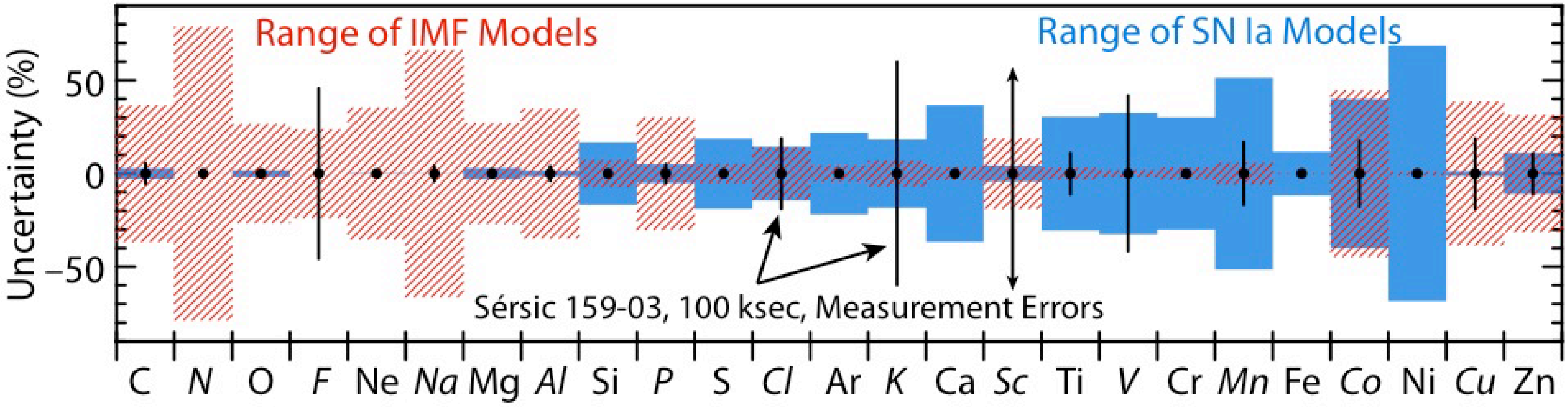
Spin Distributions: The "Tree Rings" of Black Hole Growth

With as few as 50-60 spin measurements, AXSIO will distinguish between three possible super-massive black hole growth scenarios.

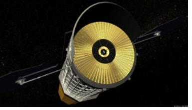




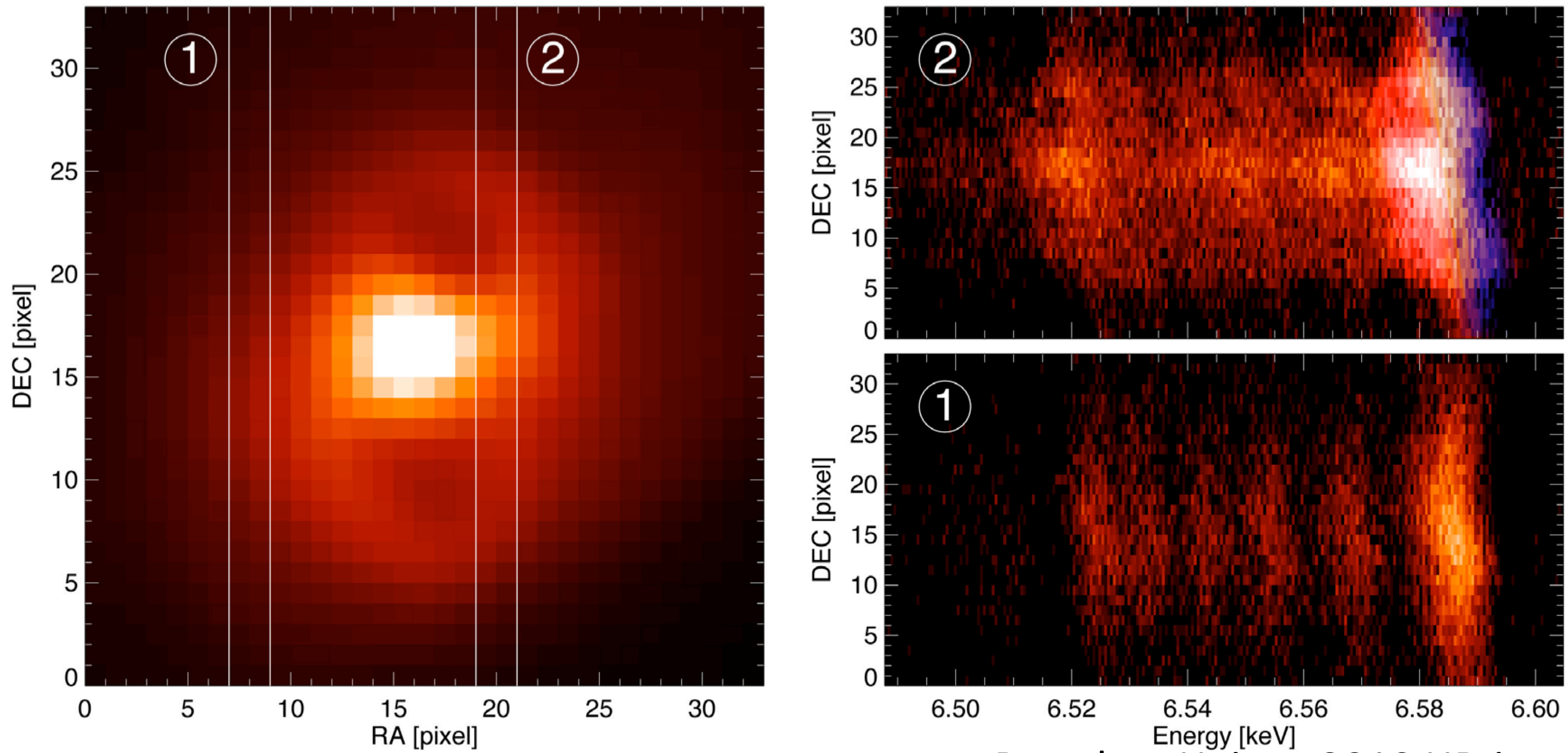
How does large scale structure evolve?



AXSIO will show **when** and **how** metals are produced, in particular the relative contribution of Type Ia and core-collapse supernovae, and the stellar sources of carbon and nitrogen.



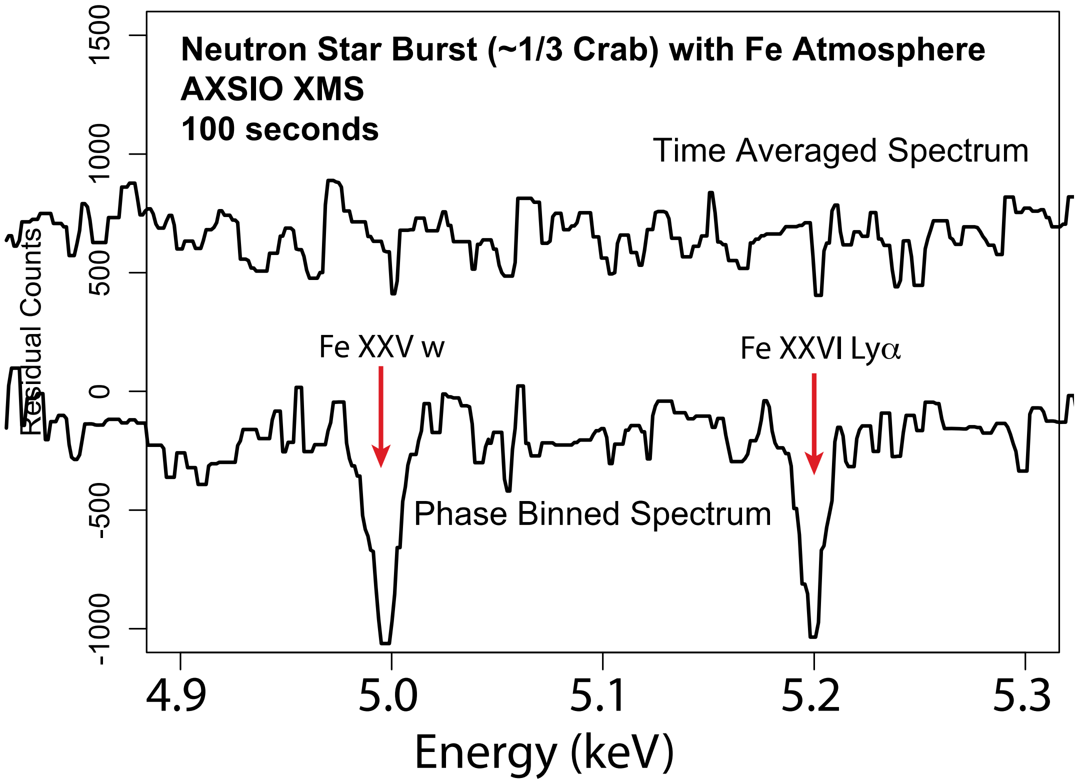
Cosmic Feedback



Based on Heinz+ 2010 HD jet model.

Perseus Cluster obseved for 250 ksec both at cavity edge (2) and offset (1); spectral effects are clearly evident. (Courtesy S. Heinz)

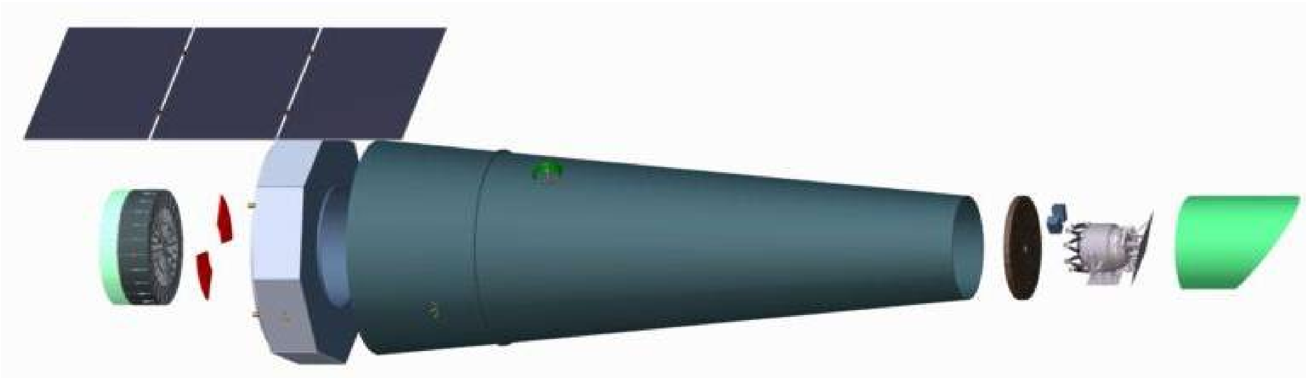
Matter at Very High Densities



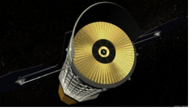
Phase-binning the data (bottom curve) reveals absorption lines invisible in the time-averaged spectrum (top curve), recovering the gravitational redshift and yielding the mass and radius of the neutron star.

AXSIO Mission Summary

- Facility Class
  - Robustly funded Guest Observer program
- L2 orbit yields >85% observing efficiency
- Atlas V-521 launch vehicle
- 5 year lifetime, 10 year consumables



	Expected Value	Reserve	Margin	Total Growth Allowance
Launch Mass (kg)	2292	18%	46%	72%
Power (W)	1935	30%	13%	47%

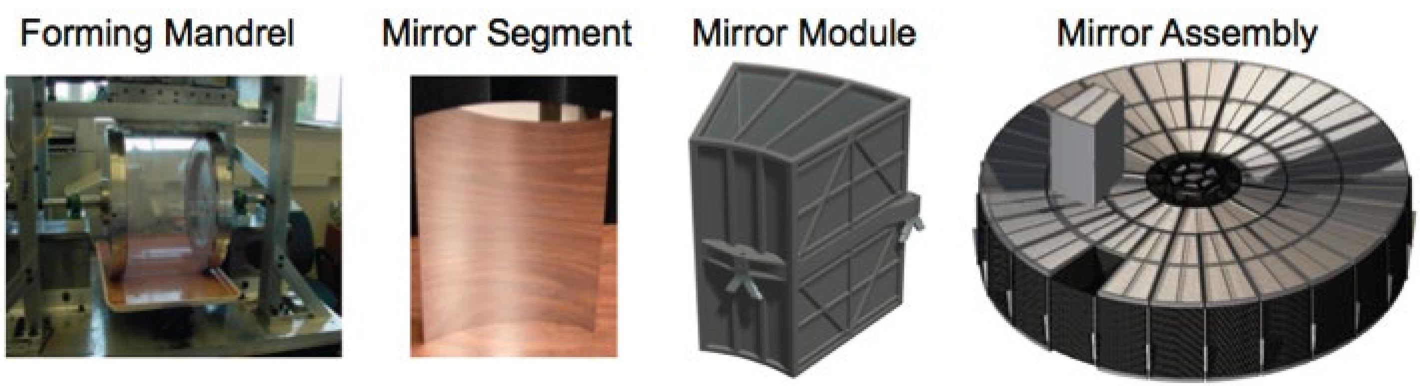


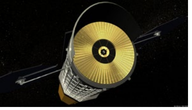
Some Key Changes from IXO

- Removal of several instruments (and mechanism):
  - Wide Field & Hard X-ray Imagers (WFI/HXI)
    - Not highest priority Decadal science
  - High Time Resolution Spectrometer (HTRS)
    - Largely recovered using Point Source Array (PSA) on XMS
  - X-ray Polarimeter (XPOL)
- Decreased high energy bandpass
  - Due to decreased focal length (eliminates EOB mechanism)
- More capable XMS with PSA (better energy resolution)
- Simplified mirror with fewer shells and relaxed (10’’) PSF
- Shifts more observing time to primary decadal science objectives (spectroscopy)
  - Partially offsets decrease in effective area

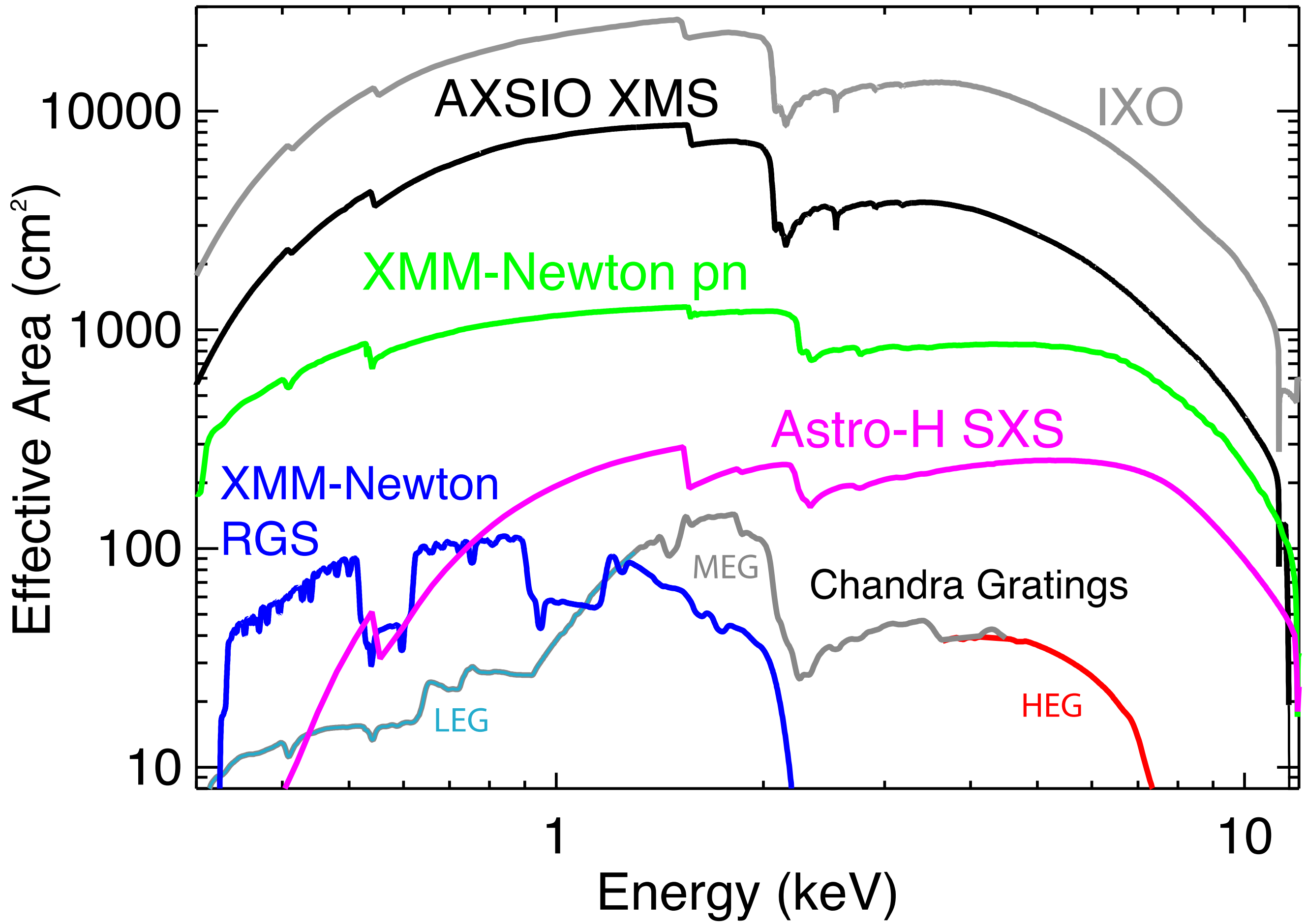
Optics

- Optics: ~10 m focal length
  - 0.9m^2 at 1.25 keV
  - 0.2m^2 at 6 keV
  - 10” resolution (5” goal)
  - 0.2 – 10 keV bandpass





AXSIO XMS Effective Area



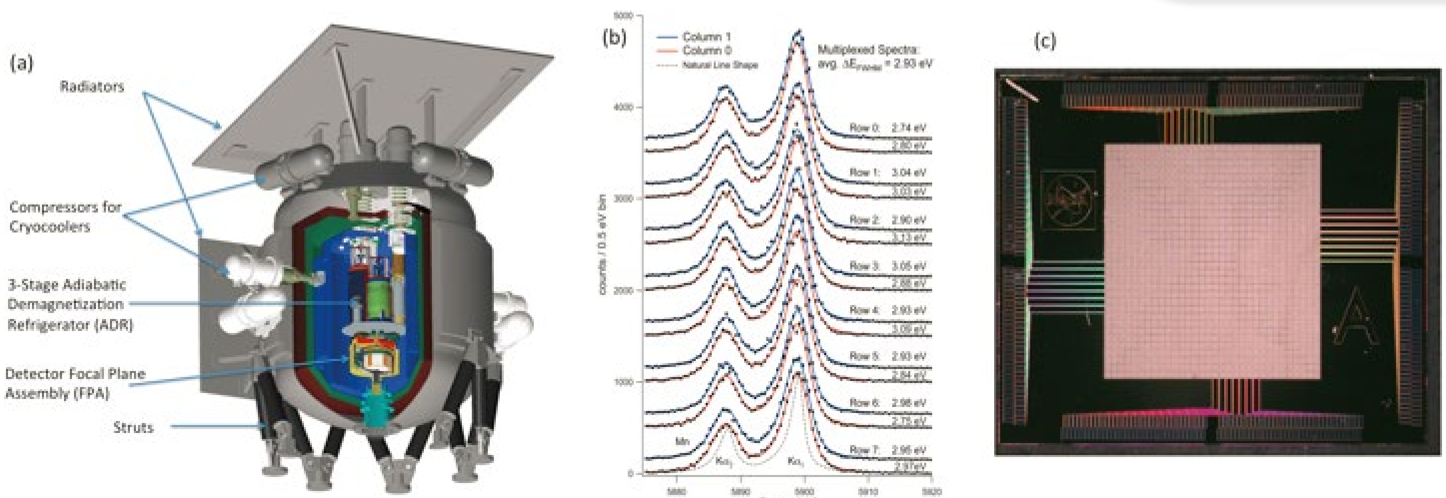
Compared to IXO plus existing and planned imaging missions such as Chandra, XMM-Newton, and Astro-H.

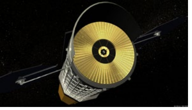
XMS Instrument

Calorimeter – XMS

- Central array: 24x24 pixels
  - 1.5” pixels (75 micron)
  - Energy resolution <2eV (FWHM)
- Extended array 40x40 pixels
  - 6” pixels (300 micron) for 4’x4’ FoV
  - Energy resolution < 3eV (FWHM)

The central ‘Point Source Array’ (PSA) is a recent improvement that oversamples the PSF with small pixels to enable high count rates (15,000 cts/s,or 100 mCrab!) at $\Delta E<2$ eV resolution – *HTRS-type science with much higher energy resolution and no extra detector needed.*





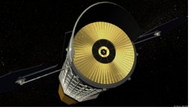
Grating Instrument

- Gratings/CCD – XGS
  - Nominally retractable
  - Two potential approaches:
    - Off-plane (OP)
    - Critical-angle transmission (CAT)
    - Significant difference in packaging
  - Sub-aperturing used to improve spectral resolution
  - Spectral resolution $\lambda/\Delta\lambda$ >3000
  - Effective area ~1000cm^2 from 0.3 to 1.0 keV

AXSIO Technology Summary

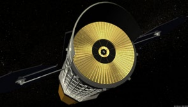
Primary technology development items:

- Optics
  - FMA – builds on IXO approach. Current TRL ~4
  - XGS gratings – several choices, both build on IXO approaches. Current TRL ~3 (CAT) and ~3 (OP)
- Detectors
  - XMS – builds on IXO approach. Current TRL ~4
  - CCDs – Current TRL 5+ (both OP and CAT)



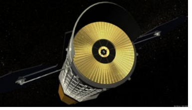
AXSIO Costing Methodology

- Based on recent MDL run at GSFC
- Tied cost and schedule together
  - June 2022 launch with 8 months of funded reserve
- Model:
  - Price-H cost model for spacecraft (with MEL)
  - Optics and Instrument costs developed separately
  - Wrap factors applied to WBS 1, 2, 3 (range from 5% – 8%)
  - WBS 4, 7, 9 done as pass-throughs with more realistic (ie., more costly) values
  - WBS 11 done as a wrap factor (1% excluding LV)
  - 30% reserves carried on most elements (~14% on science, 0% on EPO)



AXSIO Cost Estimate

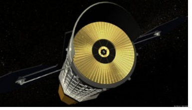
WBS	Description	Cost (with Reserve) ($M, FY12)
1	Project Management	$81
2	Systems Engineering	$81
3	Safety & MA	$50.5
4	Science	$279.7
5	Payload	$677.7
6	S/C Bus	$335.1
7	Mission Operations	$80.2
8	Launch Vehicle	$190.0
9	Ground Systems	$56.9
10	Systems I&T	$52.3
11	EPO	$13.5
	TOTAL	**$1898.2**



CST Q (and team A)

Q: How much longer exposures are needed to do SMBH spin measurements, since there is no area>10keV?

For IXO, we determined that 3-4x longer observations to accurately measure the continuum between 6- ~10 keV would compensate for the lack of 30 keV response. With 10^5 to 10^6 counts, spin can be measured to better than 10%. The largest variable is the amount of absorption. The cleanest systems (or cleaner) are the Seyfert 1.0s, and there are 198 of these in the BAT 58-month catalog. We estimate that 100+ can be done with a 10 Msec program.

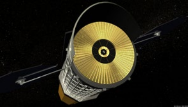


CST Q (and team A)

Q: How do you identify the 100 stellar mass black holes for spin measurement?

A: About 50 are known as of 2003 (see, for example, http://arxiv.org/abs/astro-ph/0307307).

The other 50 come from the hard sources in the Galactic plane that are being found by INTEGRAL right now - they have spectra indicating BHs.

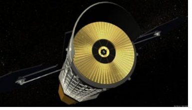


CST Q (and team A)

Q: With its small FOV, how will the target list for high-z AGN be determined to gain spin measurements beyond the local universe?

A: There is no plan to observe high(er)-z AGN, but to use the distribution in the local Universe to determine the integrated growth history. Theoretical predictions are that the distribution is largely fixed by $z\sim1$ in any event (e.g. Berti & Volonteri 2008).

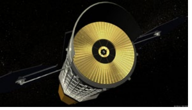
We note Just et al. (2007) has identified a number of X-ray bright $z>1$ AGN, and with AXSIO these might enable a few (<10) spin results, although the Fe K lines are uncertain and might be weak.



CST Q (and team A)

Q: What is the observing program for clusters (rastering, exposure time, etc.)? Please give more detail.

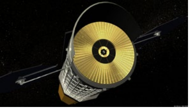
A: This has not yet been determined in detail.



CST Q (and team A)

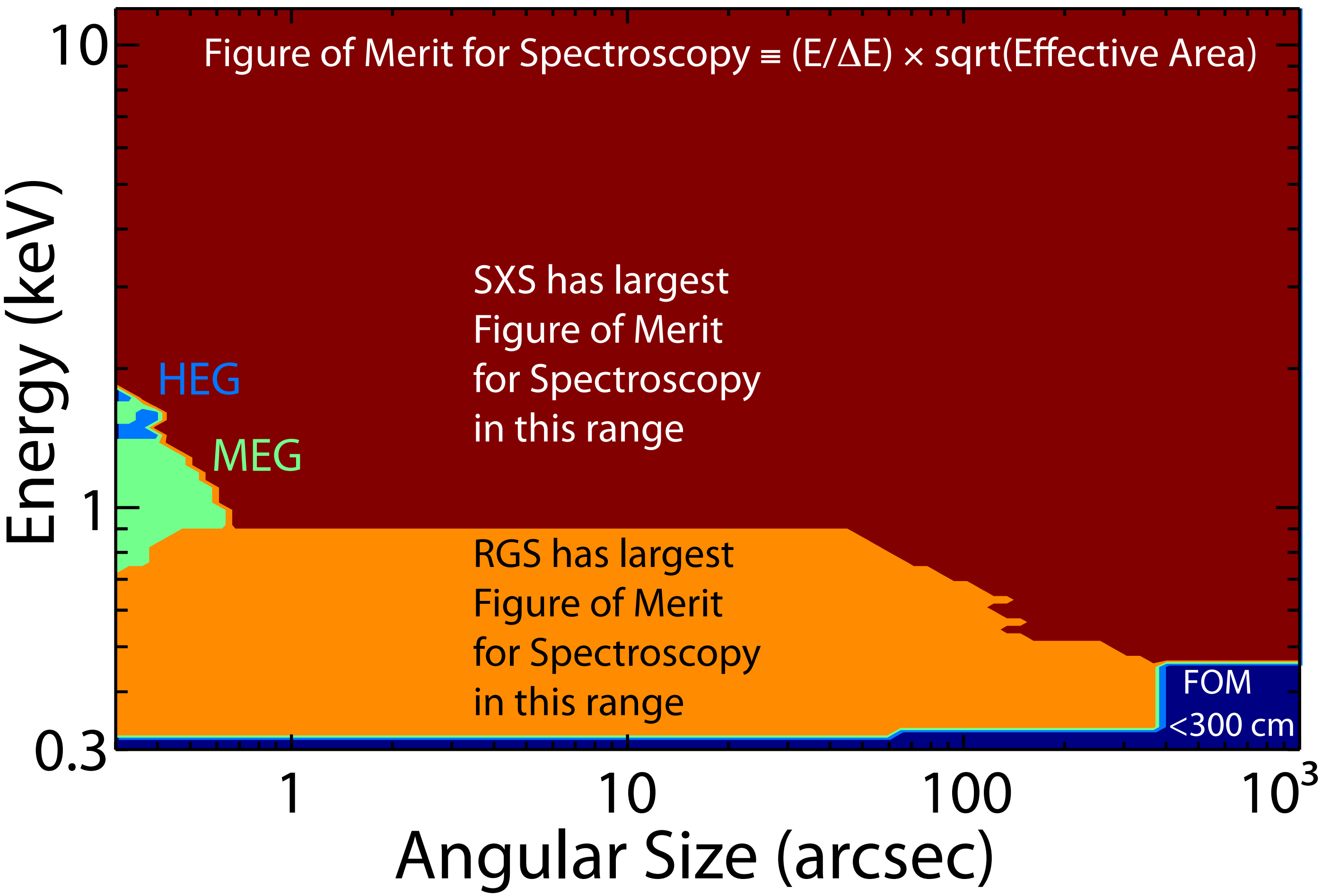
Q: How much more expensive would a 5" mirror be?

A: Costs would need to be carefully assessed for a 5" mission, since there are mission impacts (ie., to the spacecraft) beyond just the optic. As the optics technology development efforts proceed, it will be worthwhile to perform these estimates.



BACKUP

Current Capabilities



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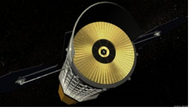
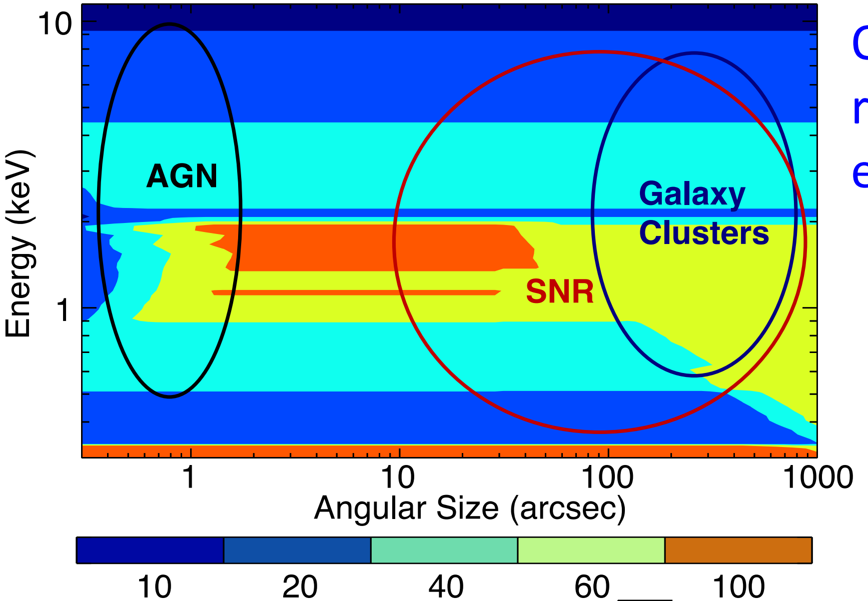


AXSIO: The Advanced X-ray Spectroscopic Imaging Observatory

Science Questions

- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?

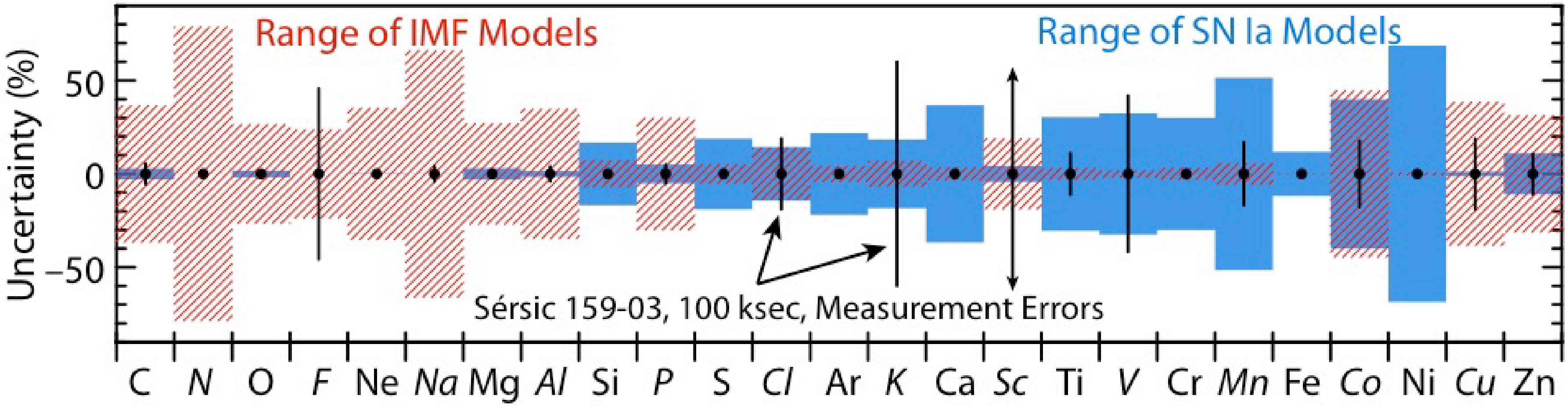


Orders of magnitude increase in high-resolution spectroscopic imaging over existing and planned missions

- ~10 m focal length
- Mass ~2200 kg (incl. 40% margin)
- Atlas V 551 Launcher
- L2 orbit
- 5 year lifetime; 10 year goal

Approved for public release

How does large scale structure evolve?



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