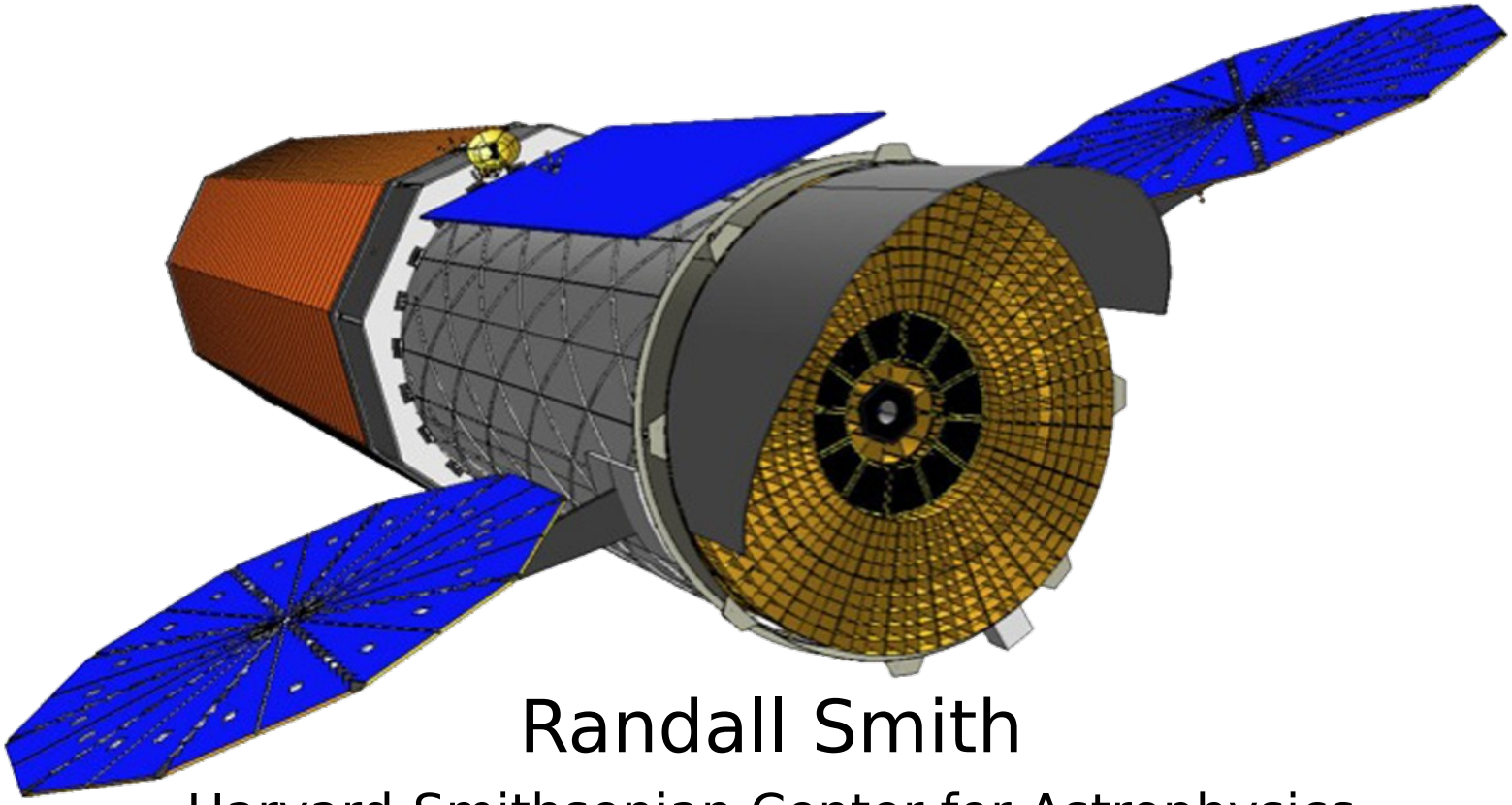
The International X-ray Observatory

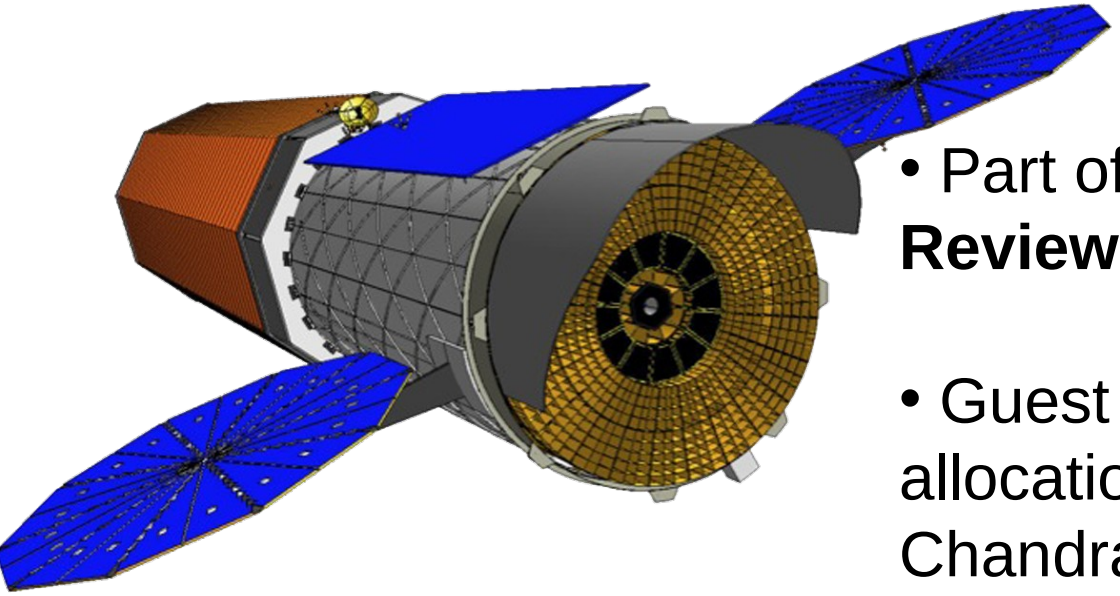


Randall Smith

Harvard-Smithsonian Center for Astrophysics

For the IXO Team

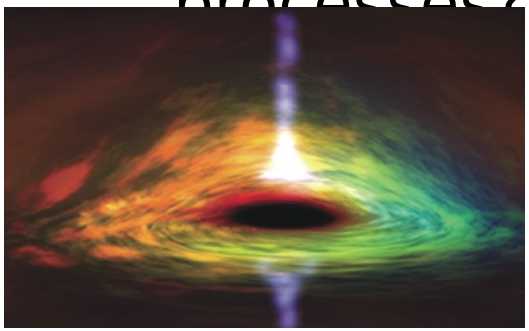
Basic Facts about IXO



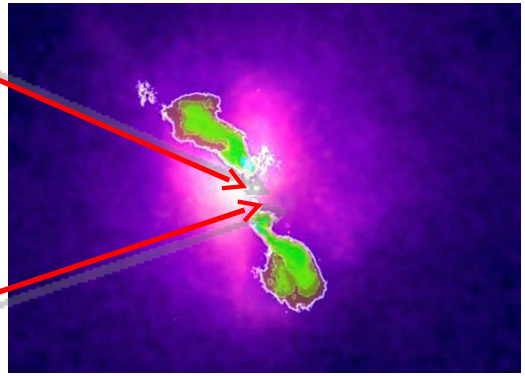
- Merger of ESA/JAXA XEUS and NASA's Constellation-X missions
- Part of US Astro2010 **Decadal Review** and ESA **Cosmic Visions**
- Guest Observatory, with time allocation done as with Hubble, Chandra, Spitzer
- Launch planned ~2021

The International X-Ray Observatory (IXO) will address fundamental and timely questions in astrophysics:

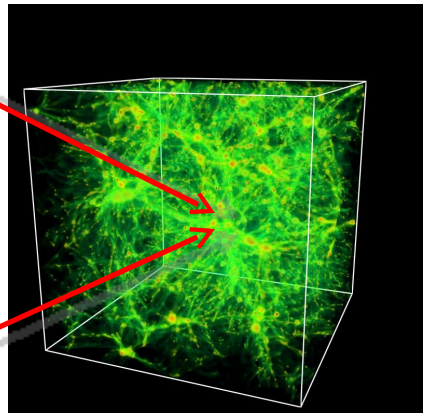
- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?



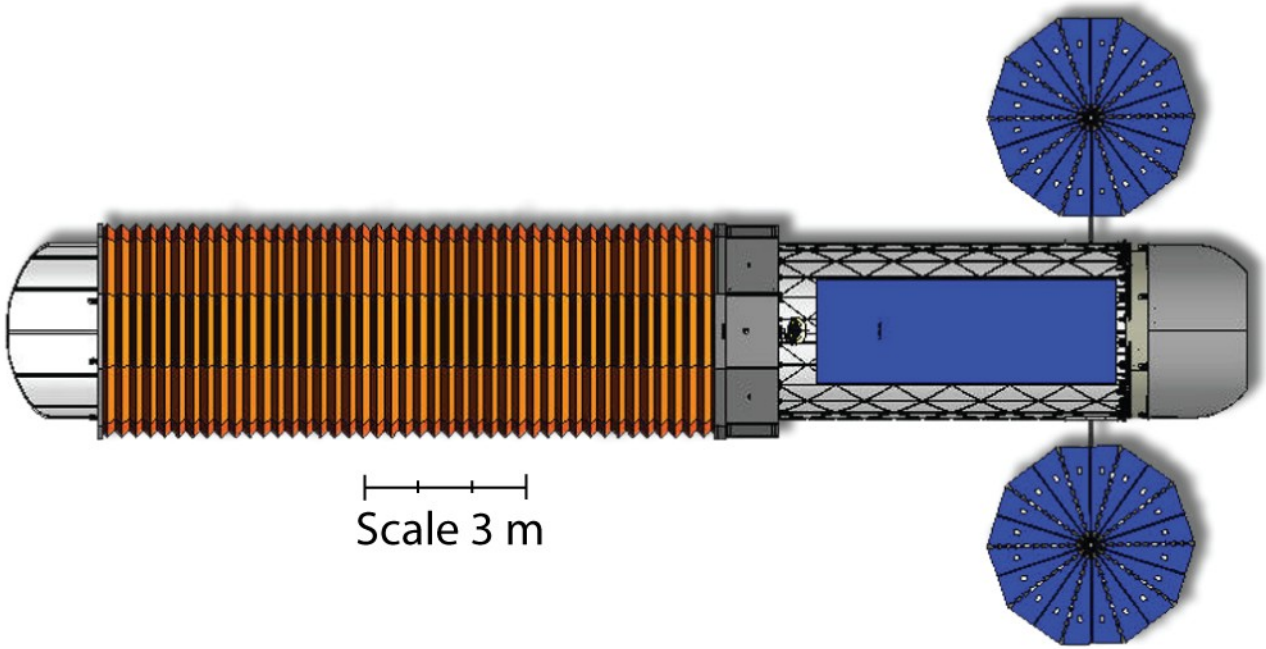
Black Hole Accretion

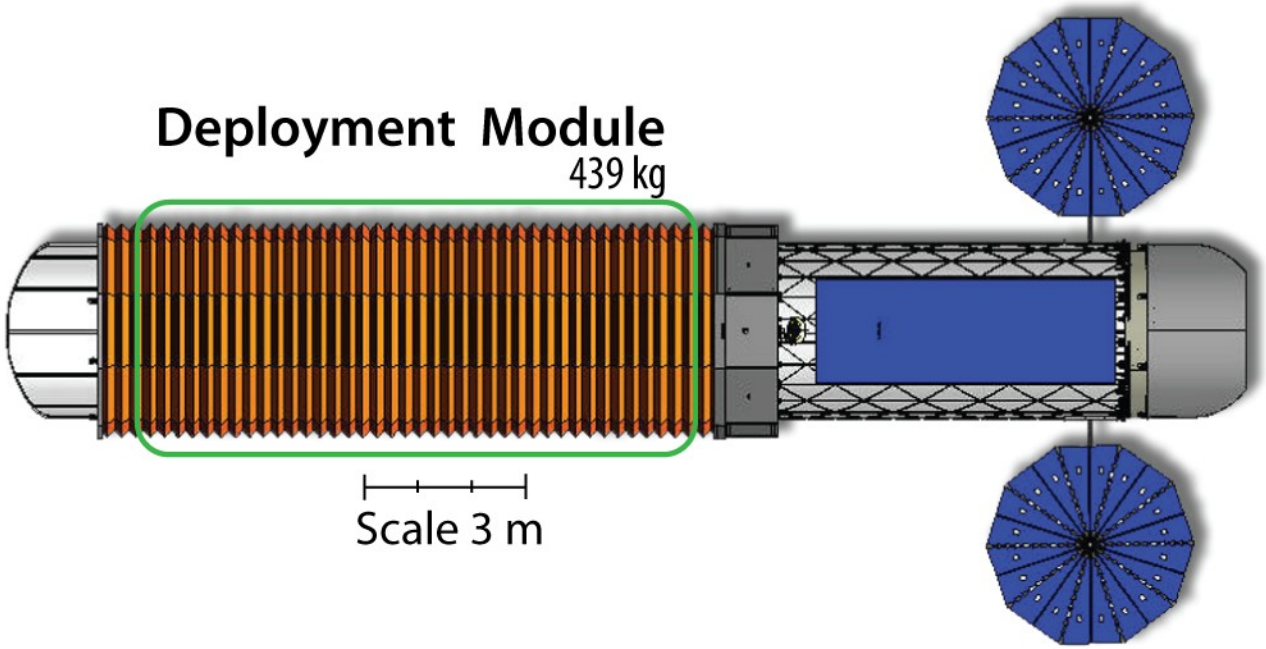


Hydra A Galaxy Cluster

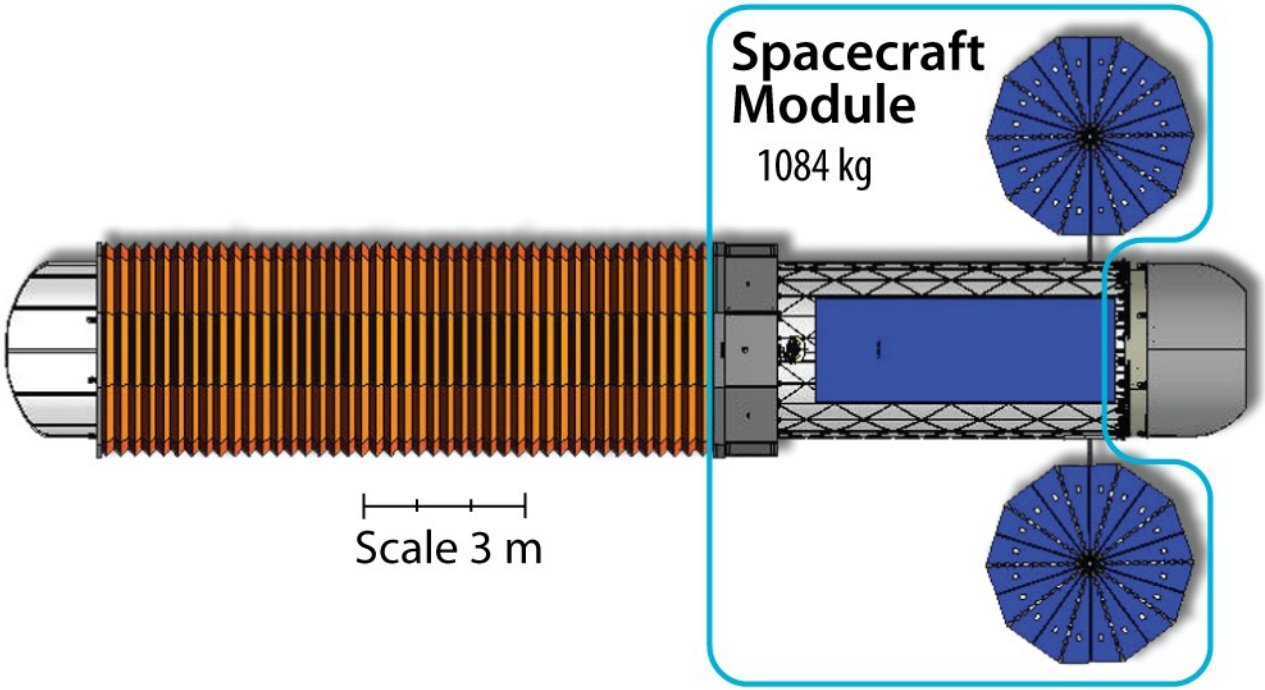


Cosmic Web


Scale 3 m



All mass values are CBE



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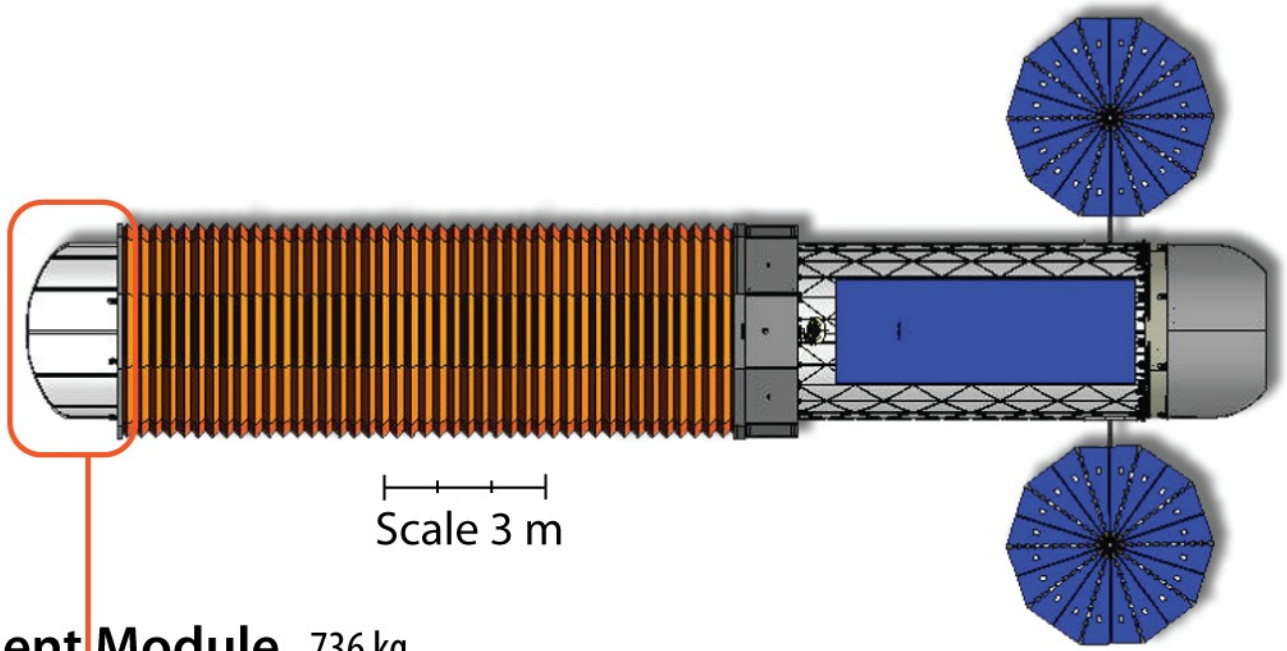
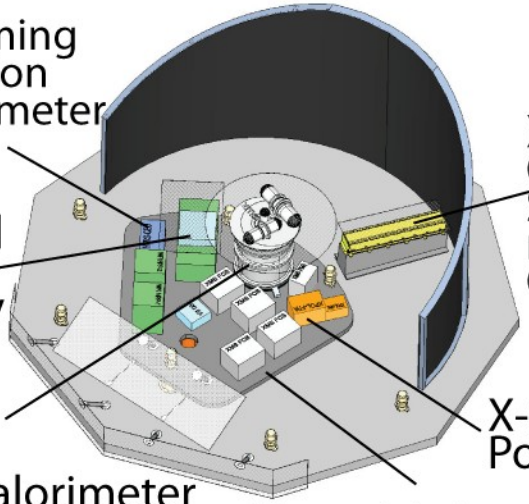


Instrument Module 736 kg



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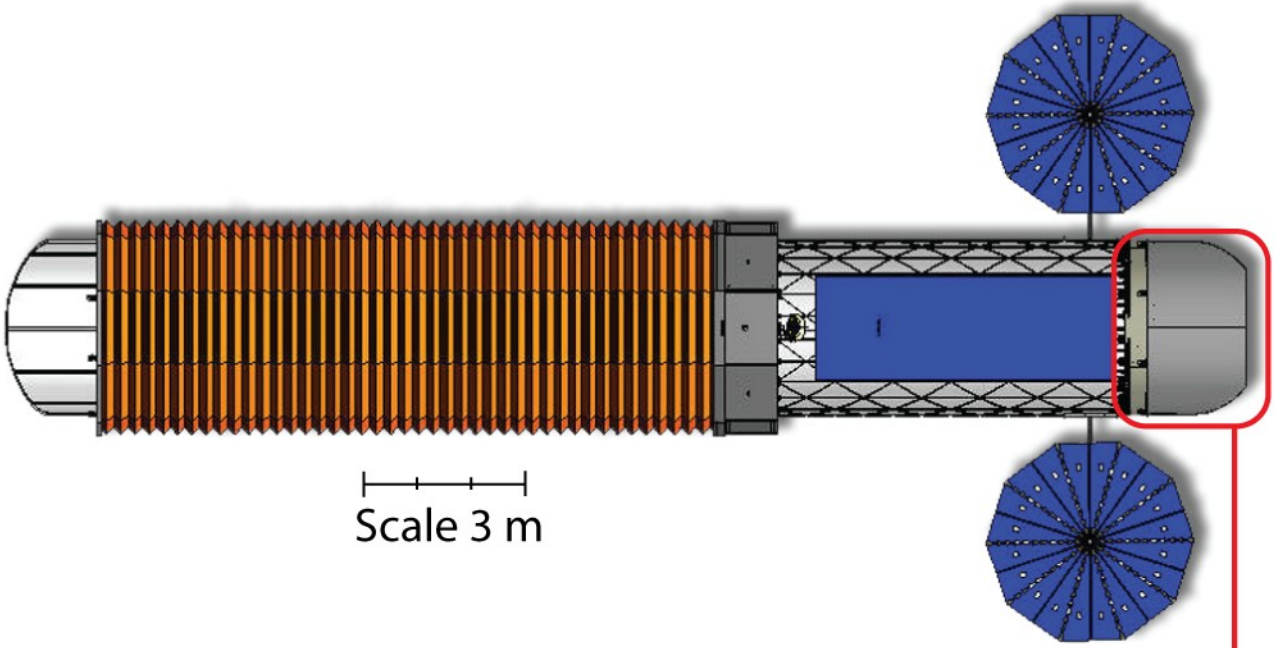
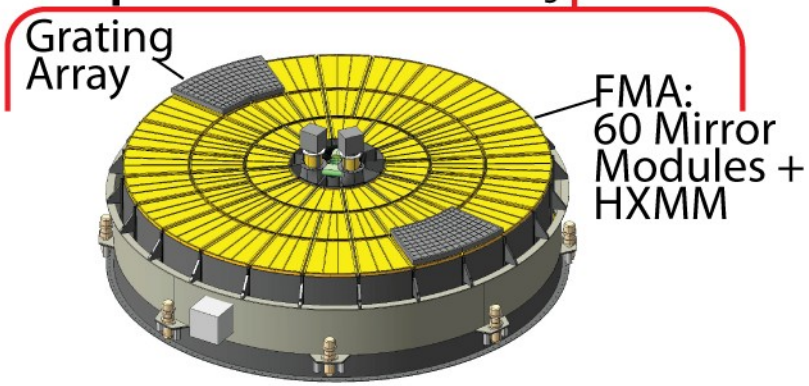


Optics Module 1952 kg



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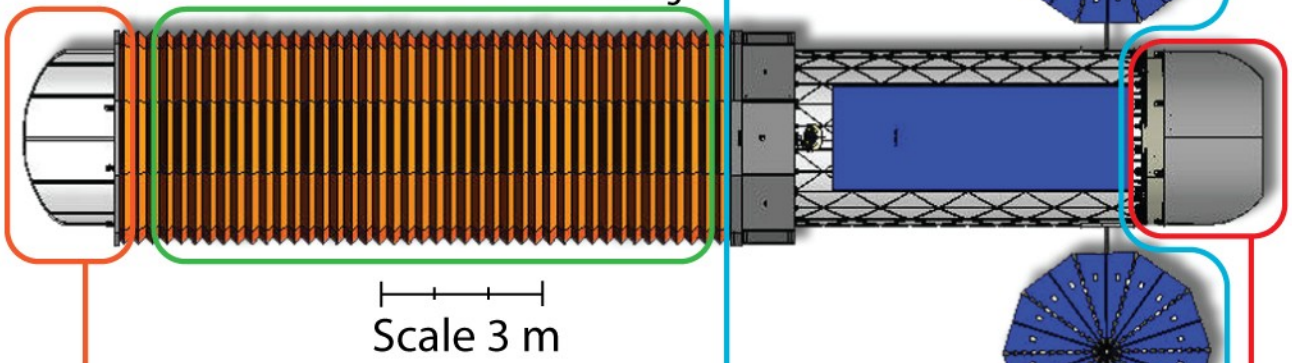

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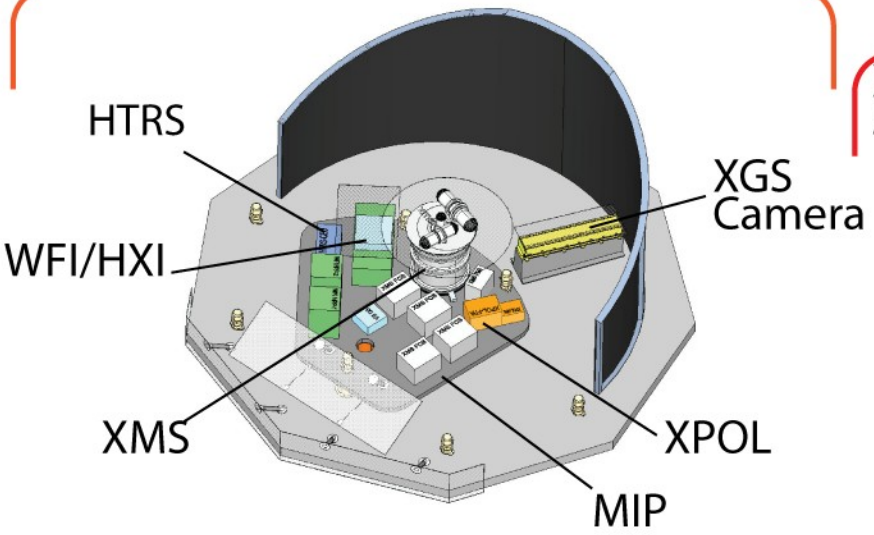

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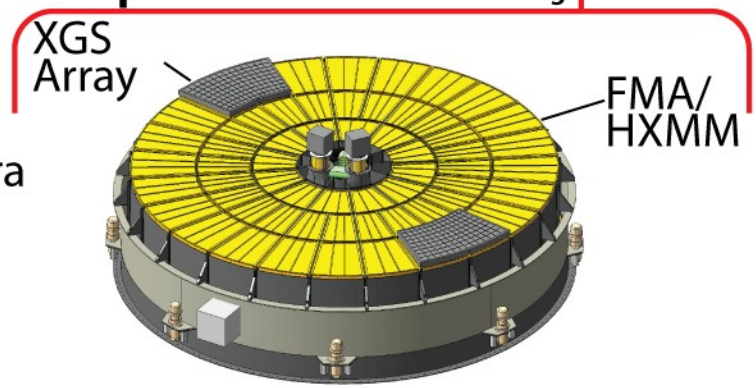
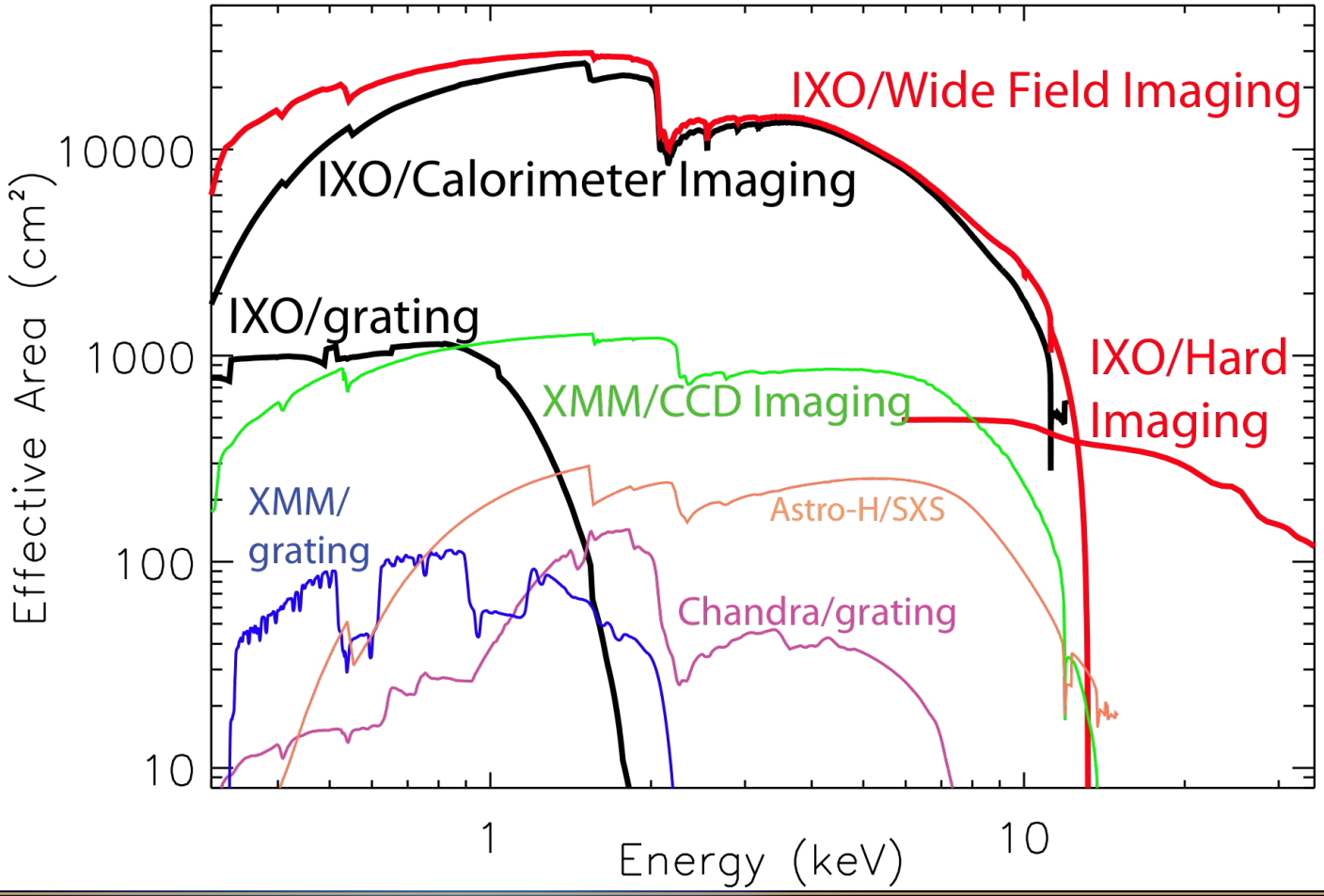


All mass values are CBE

Existing Missions ➔ IXO

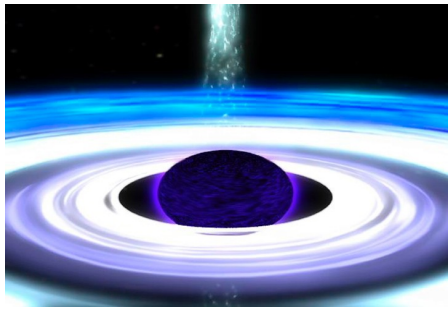
Palomar 200 inch ➔ **20 meter telescope**

Spectral band imaging ➔ **Integral field spectrograph**

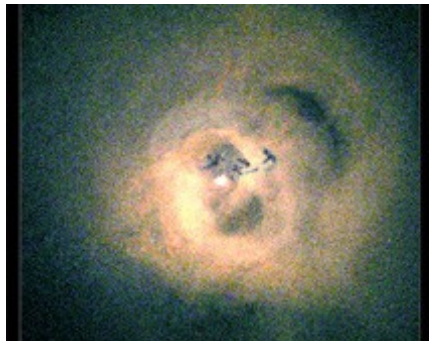


Main Science Topics

- **Matter under Extreme Conditions**

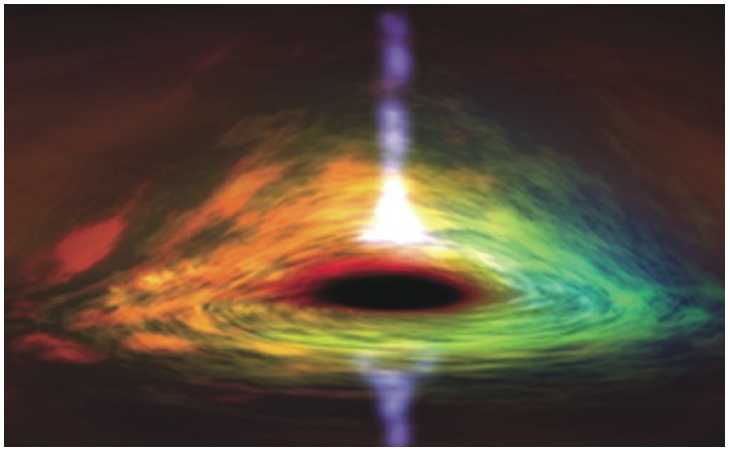


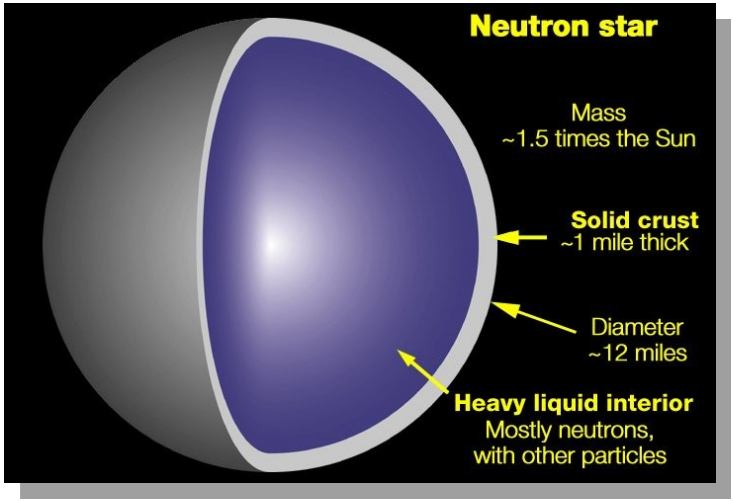
- **Black Hole Evolution and the Evolution of Galaxies, Clusters, and Large Scale Structure**



- **Life Cycles of Matter and Energy**

Black Holes and Matter under Extreme Conditions





Does matter orbiting close to a Black Hole event horizon follow the predictions of General Relativity?

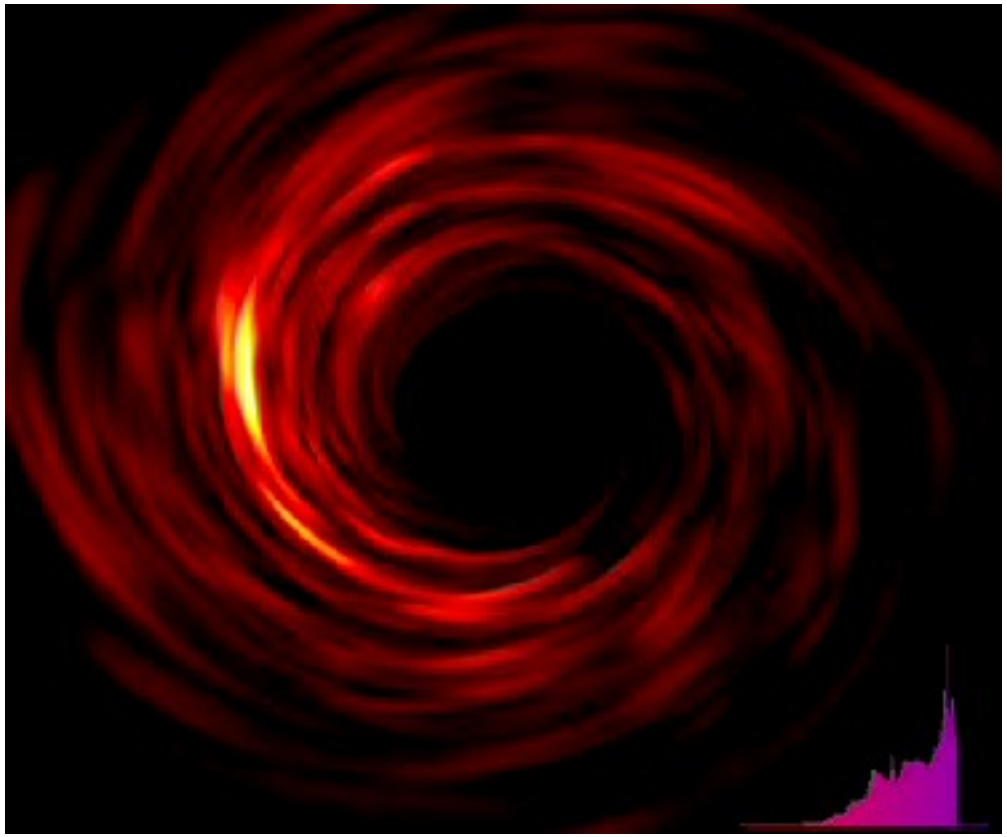
How do super-massive Black Holes grow? Does this change over cosmic time?

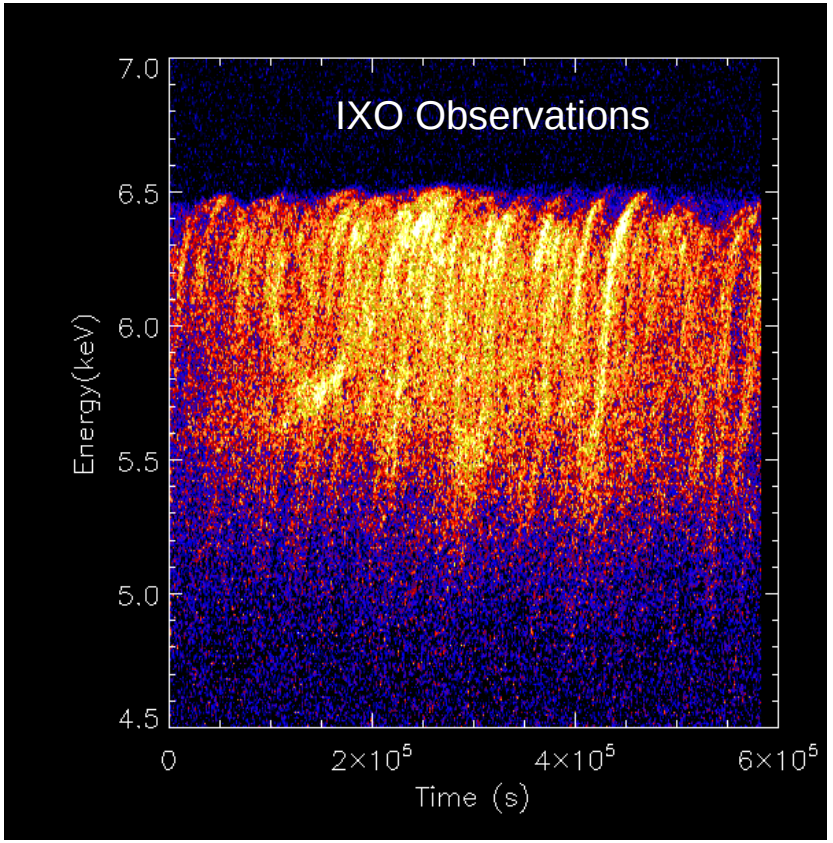
What is the Equation of State of matter in Neutron Stars?

Testing GR: Black Hole Spin

IXO will study detailed line variability on orbital times scale close to event horizon in nearby supermassive Black Holes:

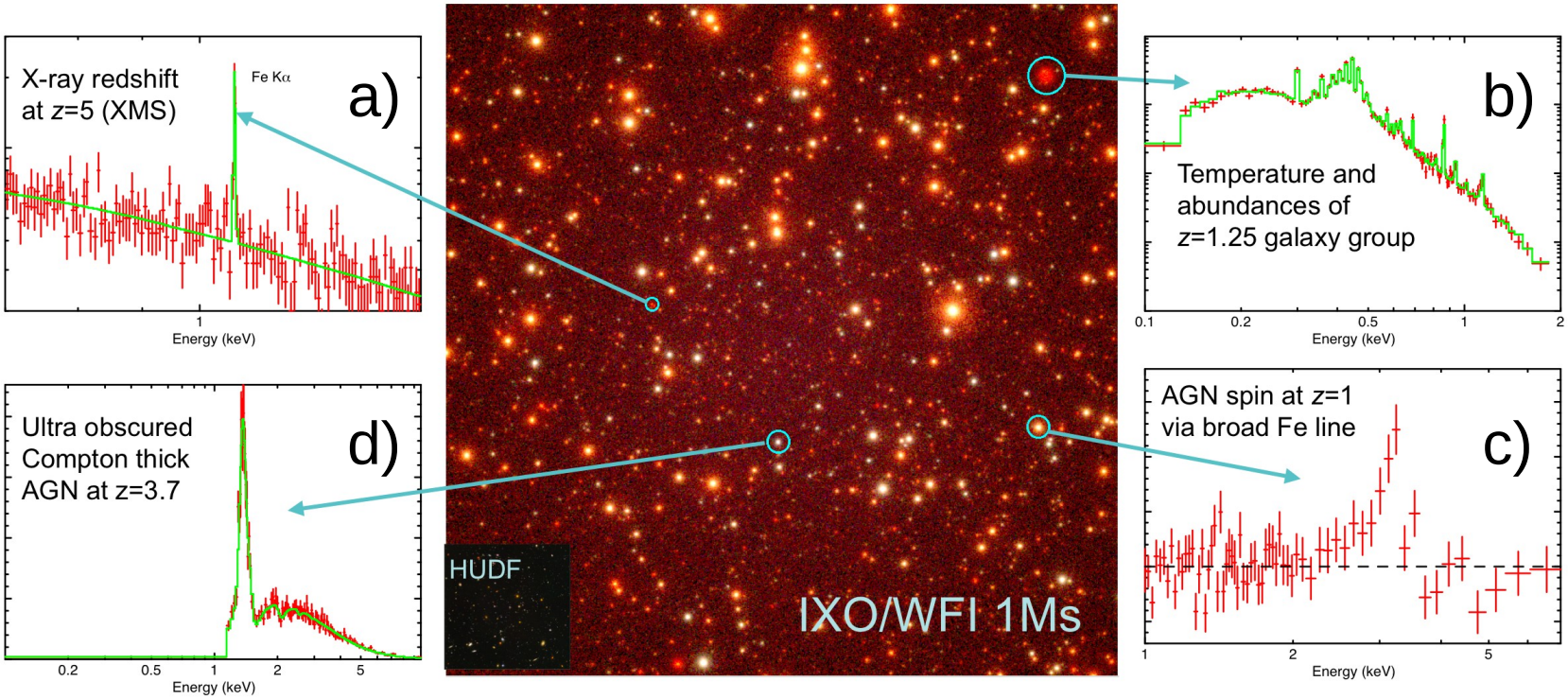
- ✓ **Dynamics of individual "X-ray bright spots" in disk to determine mass and spin**
- ✓ **Quantitative measure of orbital dynamics: Test the Kerr metric**





Magneto-hydro-dynamic simulations of accretion disk surrounding a Black Hole (Armitage & Reynolds 2003)

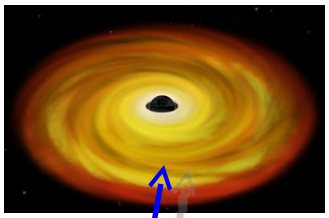
Black Hole and Large Scale Structure Evolution with IXO

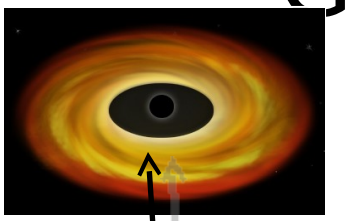


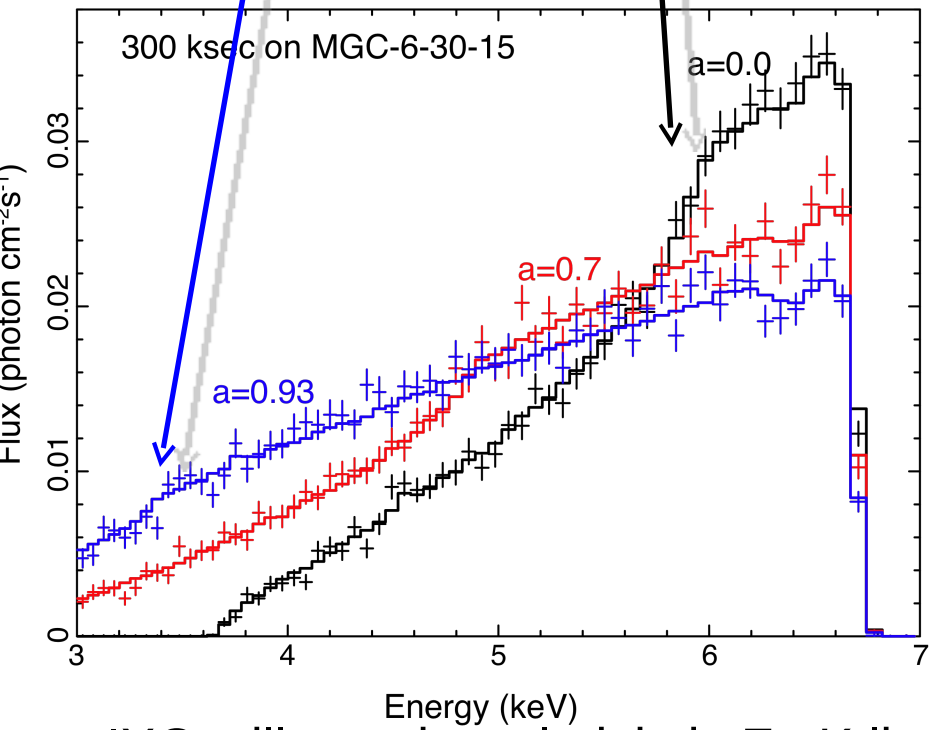
IXO has the ability to characterize the extragalactic Universe:

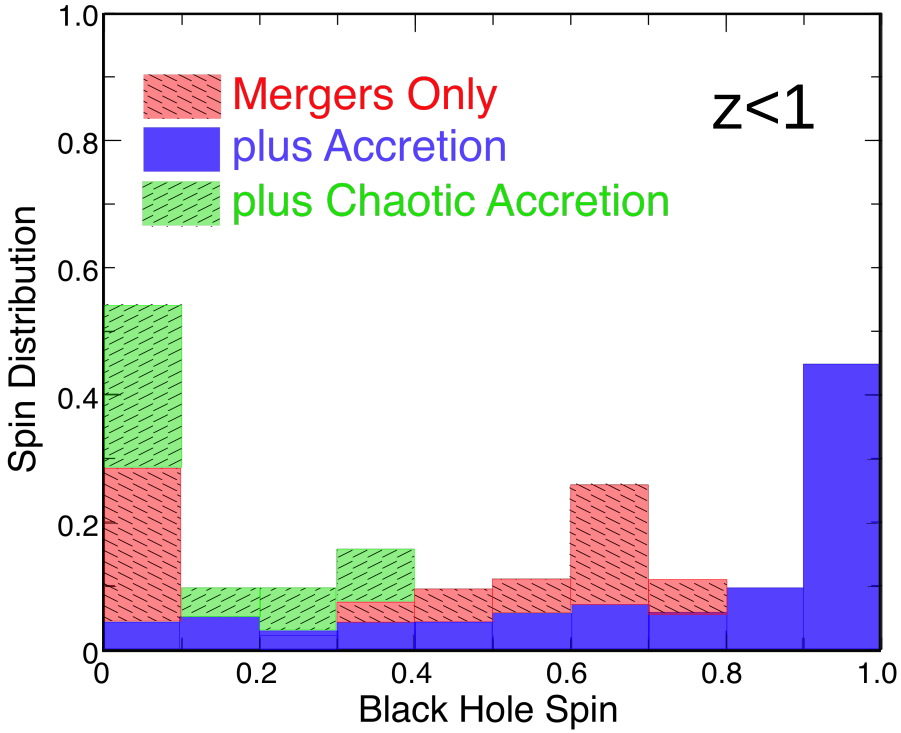
c) determine redshift autonomously in the X-ray band
d) determine temperatures and abundances even for low luminosity galaxy groups
e) make spin measurements of AGN to a similar redshift
f) uncover the most heavily obscured, Compton-thick AGN

Super-massive Black Hole Spin & Growth









Based on Berti & Volonteri (2008)

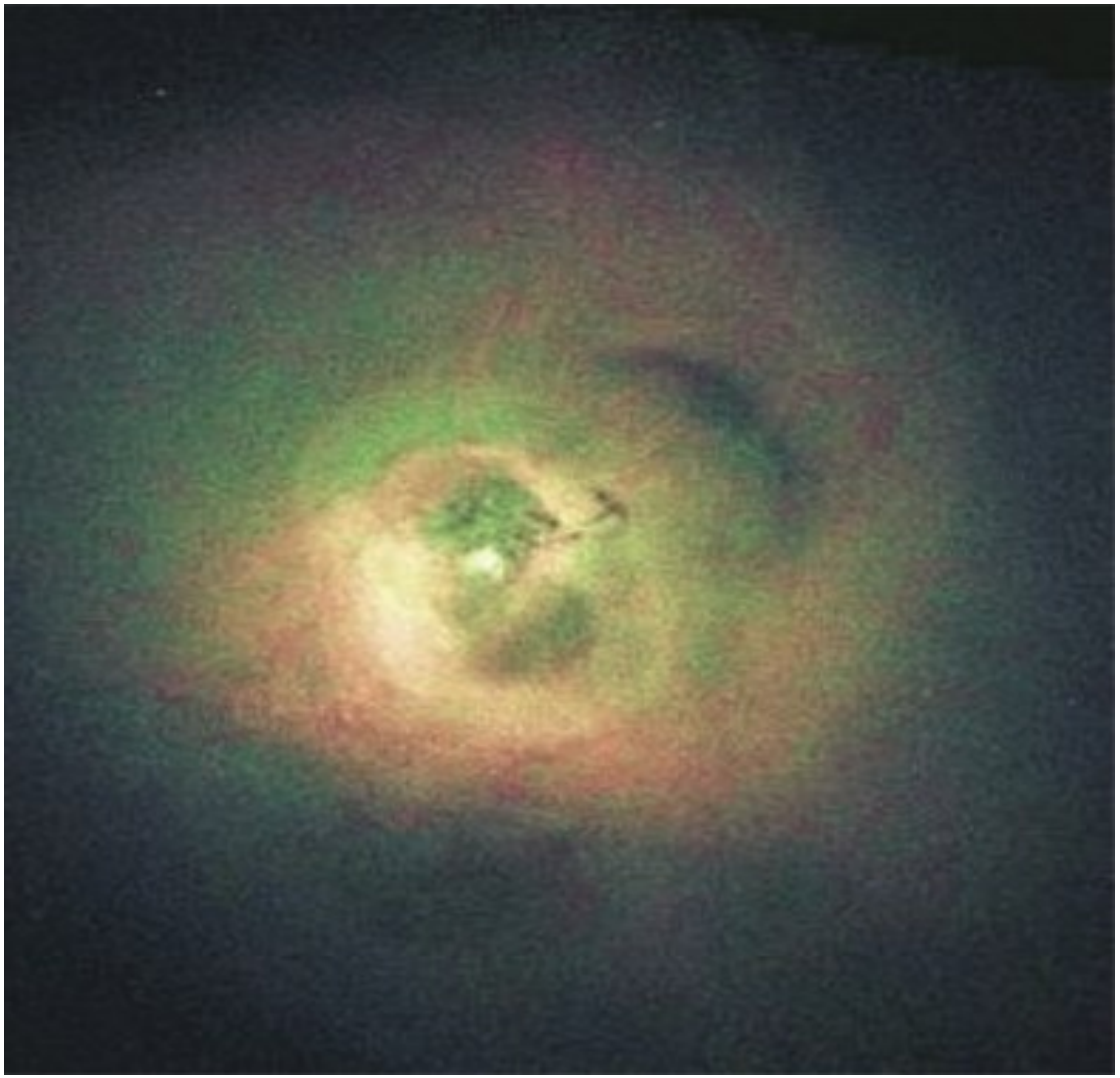
IXO will use the relativistic Fe K line to determine the black hole spin for 300 AGN within z < 0.2 to constrain the SMBH merger history

Cosmic Feedback

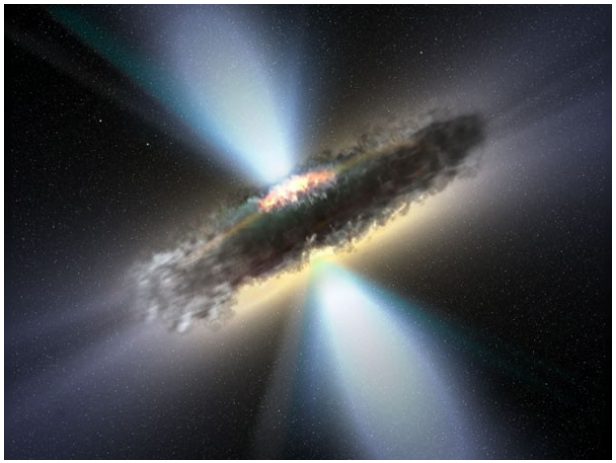
Supermassive black hole feedback must regulate the growth of galaxies and clusters of galaxies

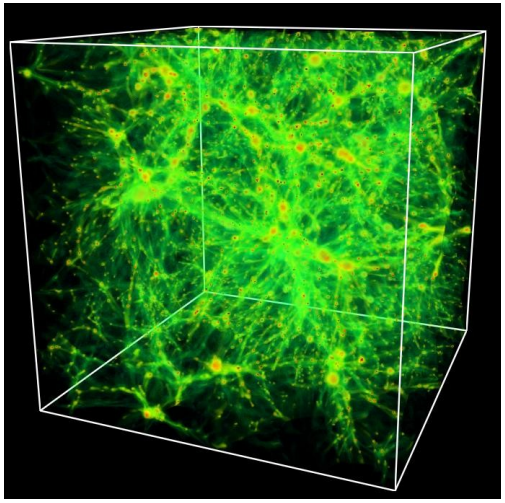
Velocity measurements crucial to determine heating and state of hot gas found within clusters of galaxies

IXO will probe this hot gas through velocity measurements accurate to the required ~100km/s



Formation and Evolution of Galaxies, Clusters, and Large Scale Structure





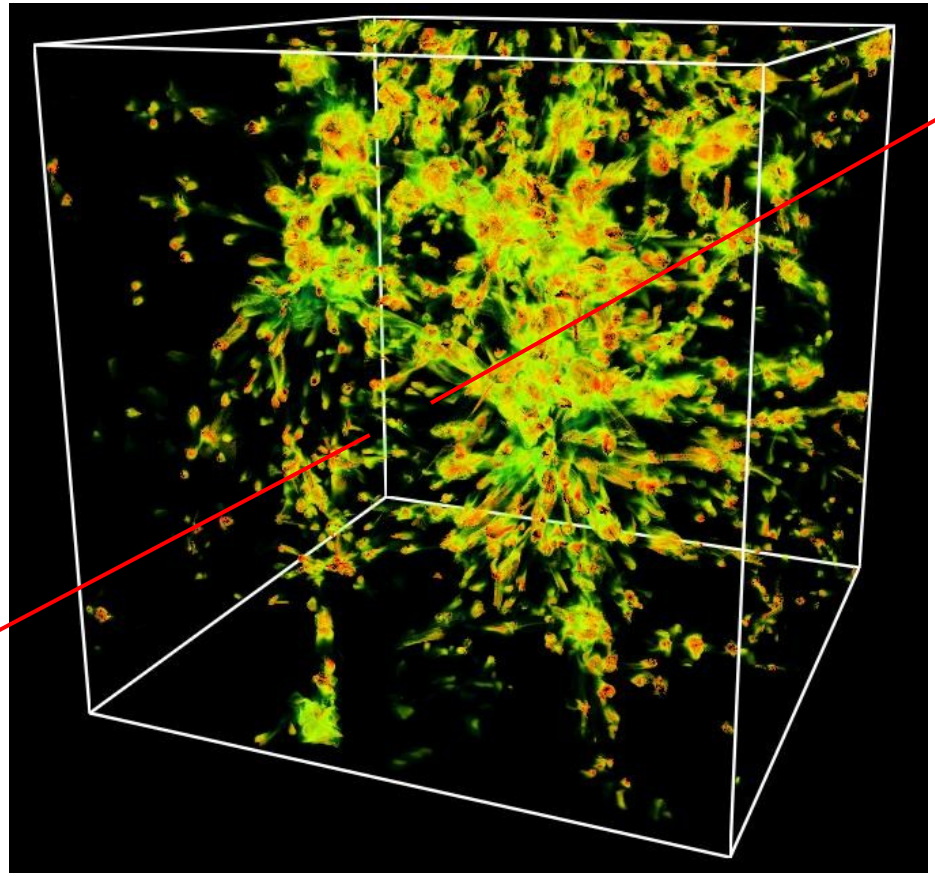
How does Cosmic Feedback work and influence galaxy formation?

How does galaxy cluster evolution constrain the nature of Dark Matter and Dark Energy?

Where are the missing baryons in the nearby Universe?

The Missing Baryons

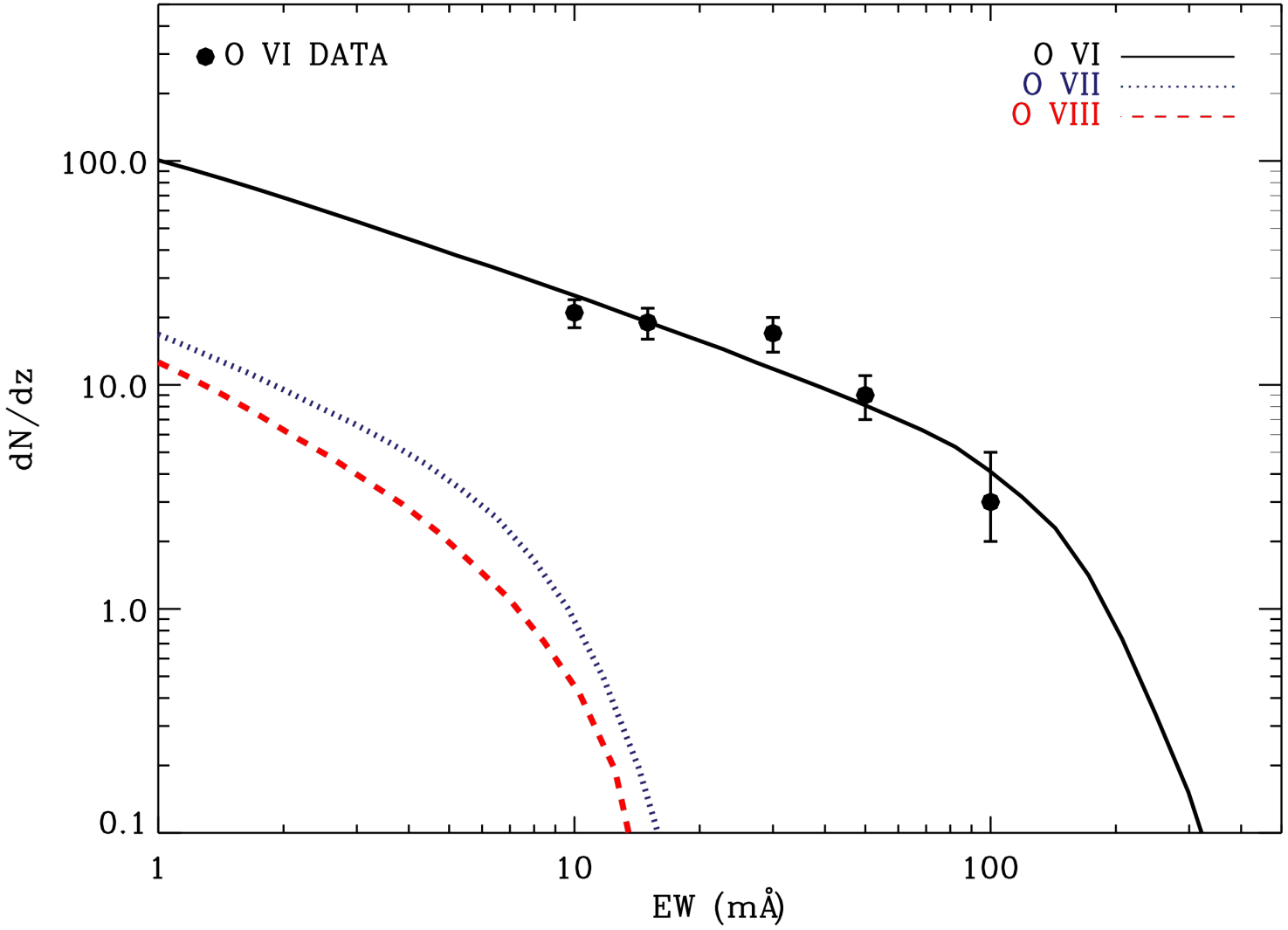
Key features are OVII and OVIII (1s-2p transition at 574 eV, Lyα line at 654 eV)



Background AGN

2.Are the missing baryons in the hot phase of the Cosmic Web?
3.How is the hot gas distributed relative to the galaxies?
4.What are the connections of the web filaments to groups and clusters?

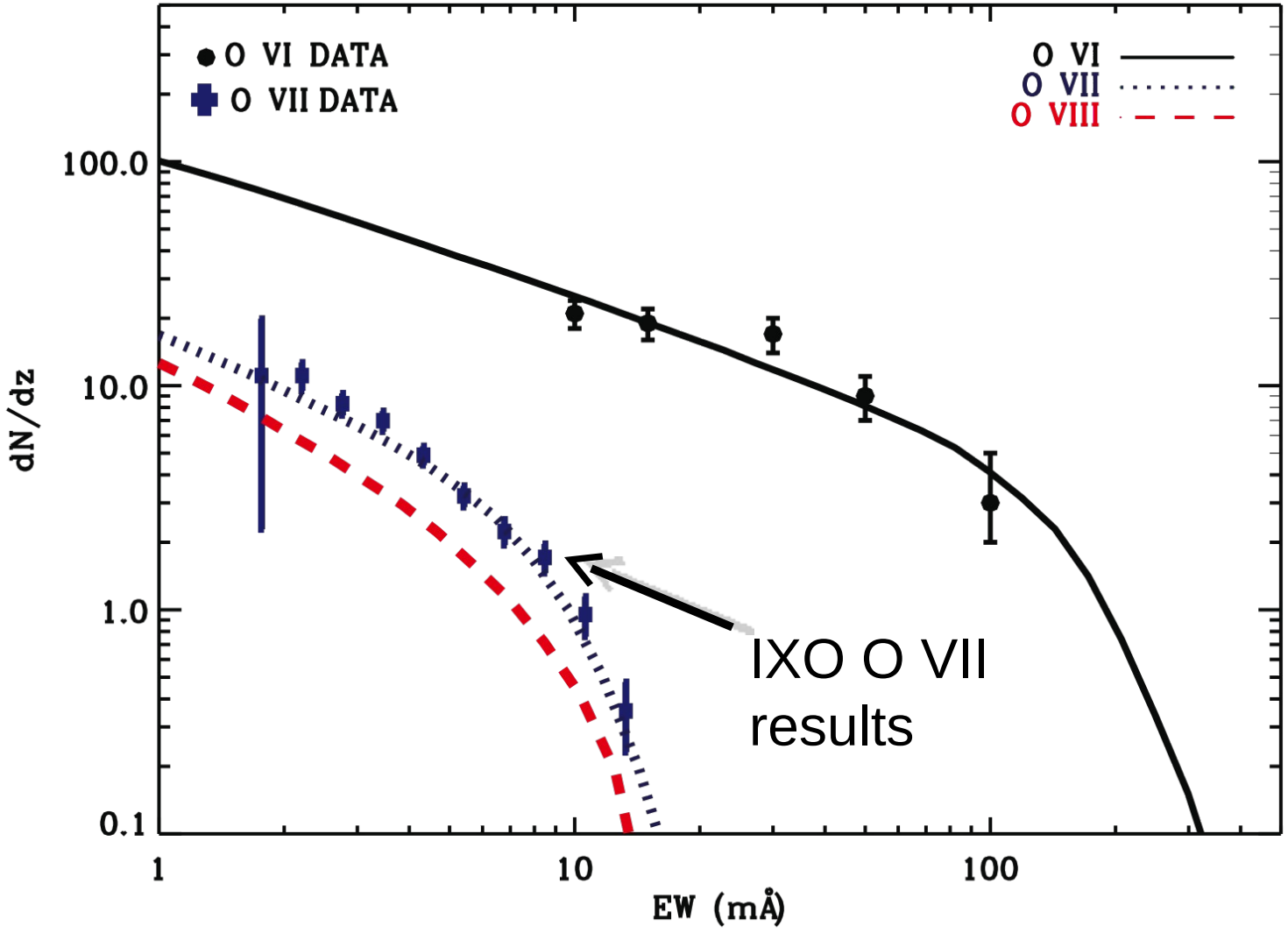
The Missing Baryons



Using existing surveys, 30+ suitable sources.

Expect ~ **3-10 Metal Systems** per line of sight in **200-300 ks** with IXO Gratings

The Missing Baryons



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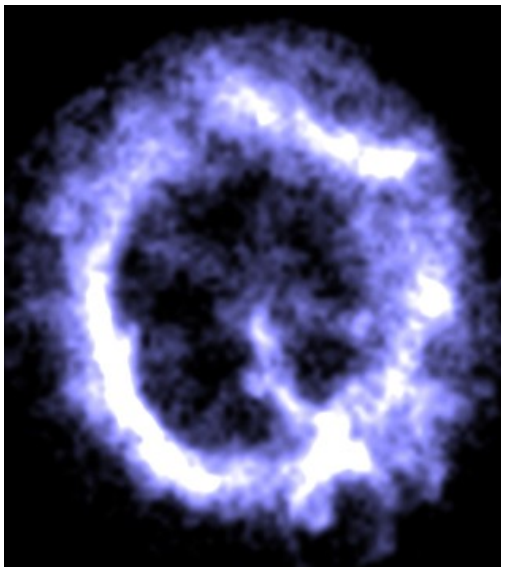
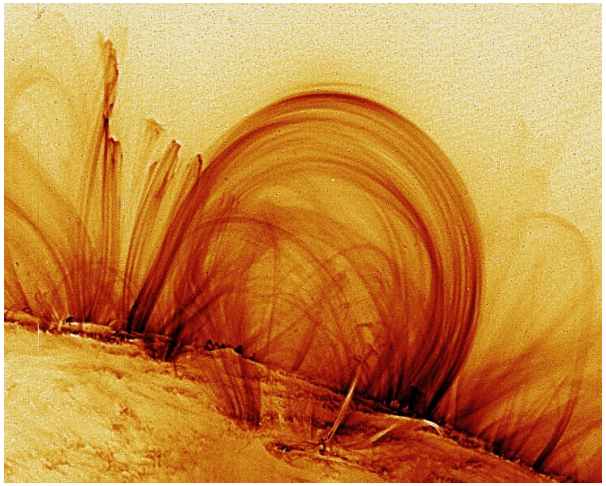
Life Cycles of Matter and Energy



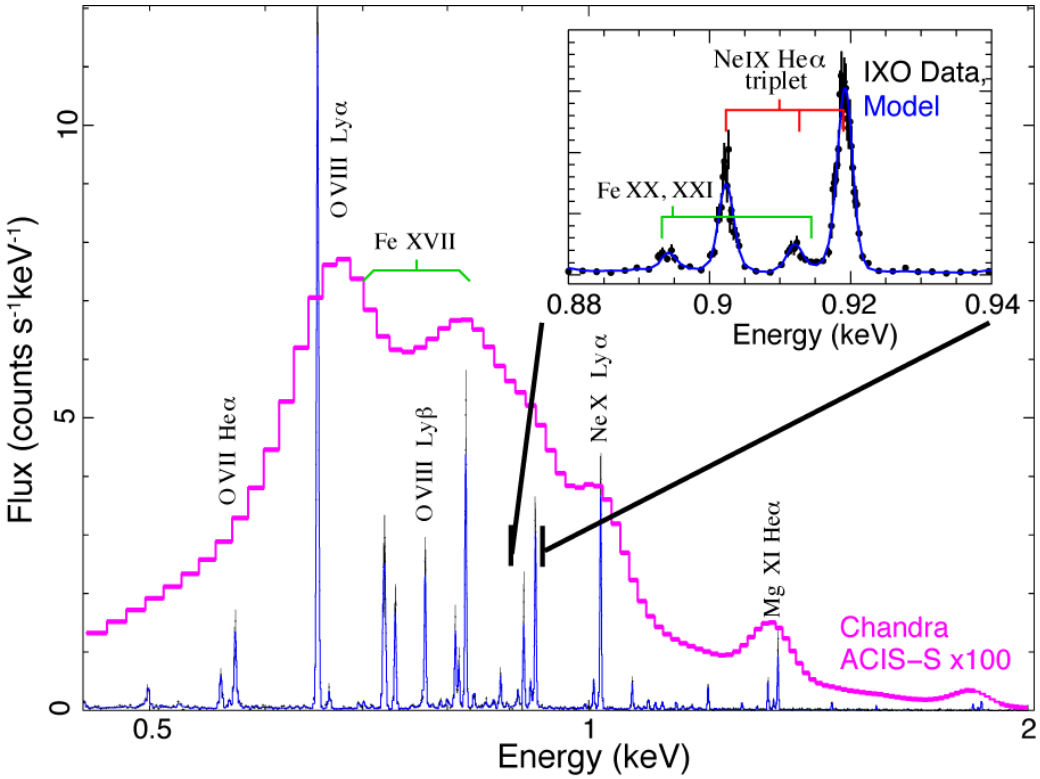


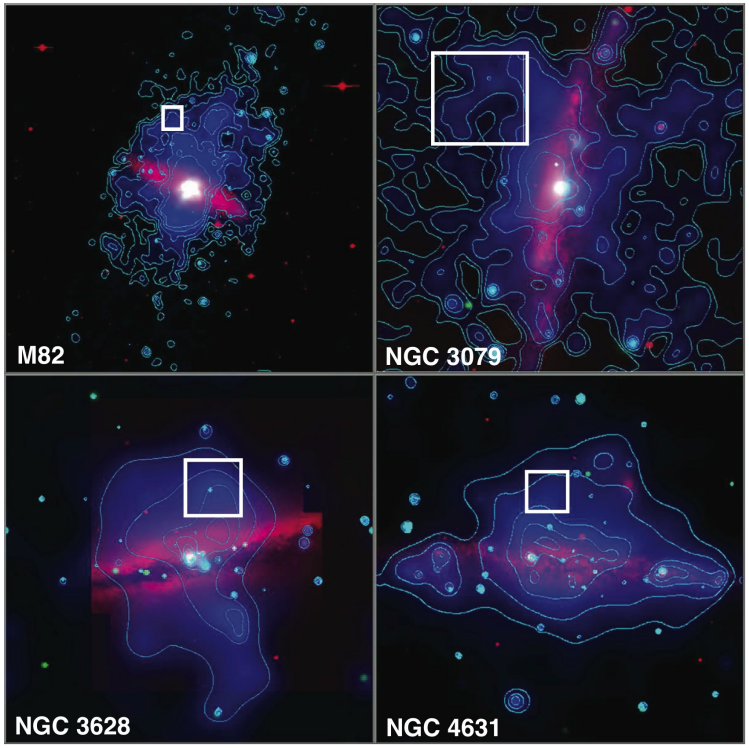
When and how were the elements created and dispersed?

How do high energy processes affect planetary formation and habitability?

How do magnetic fields shape stellar exteriors and the surrounding environment?

Starburst Superwinds





100 ksec observation of a small region in a typical superwind. Direct measurements of the velocity, abundances, and ionization state of the outflowing gas will allow mass, metal and energy ejection rates to the IGM to be measured.

IXO and the Astro 2010 Decadal Review

International X-ray Observatory (IXO)

The International X-ray Observatory
Activity submission in response to the Astro2010 RFI#2

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Submitted on behalf of the IXO Study Coordination Group, whose members are

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Mark Bautz (MIT, Cambridge)
Jay Bookbinder (SAO, Cambridge)
Joel Bregman (University of Michigan, Ann Arbor)
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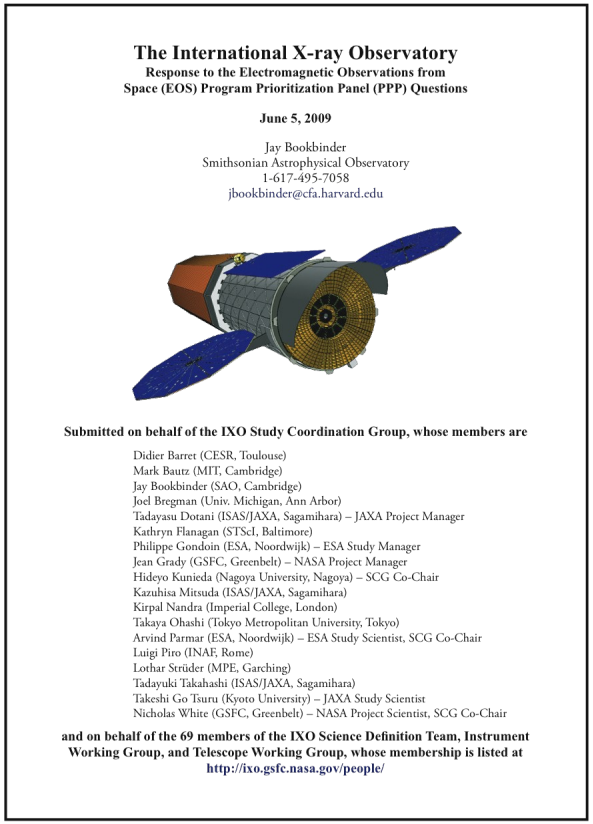
Takeshi Go Tsuru (Kyoto University) – JAXA Study Scientist
Nicholas White (GSFC, Greenbelt) – NASA Project Scientist, SCG Co-Chair

and on behalf of the 69 members of the IXO Science Definition Team, Instrument Working Group, and Telescope Working Group, whose membership is listed at http://ixo.gsfc.nasa.gov/people/



The International X-ray Observatory
Response to the Electromagnetic Observations from Space (EOS) Program Prioritization Panel (PPP) Questions

June 5, 2009

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The International X-ray Observatory
Activity submission in response to the Astro2010 Program Prioritization Panel RFI

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Two responses to Decadal Requests for Information (RFI1, RFI2) and answers to 4 specific questions from a Program Prioritization Panel are available at **http://ixo.gsfc.nasa.gov**

Summary

IXO addresses key and timely questions confronting Astronomy and Astrophysics

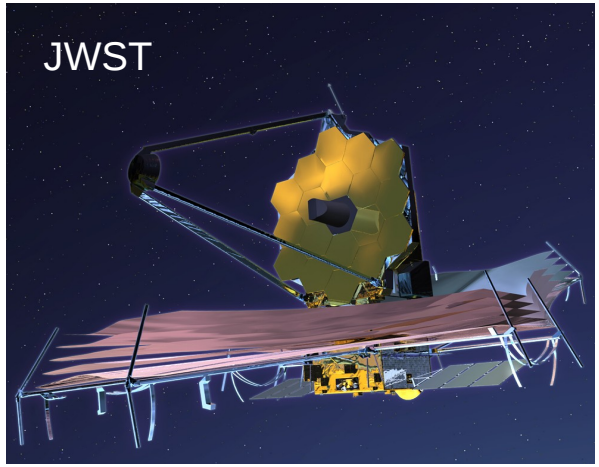
IXO will bring a factor of ten gain in telescope aperture combined with next generation instrument technology to realize a quantum leap in capability

Separate studies by ESA and NASA demonstrate that the mission implementation for a 2021 launch is feasible with no major show stoppers

IXO in action...

IXO: A Future Great Observatory

Sub-mm



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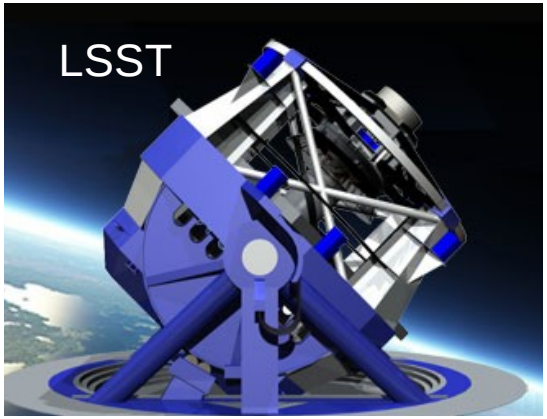
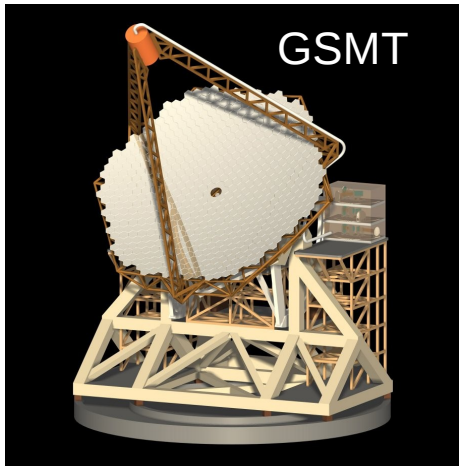
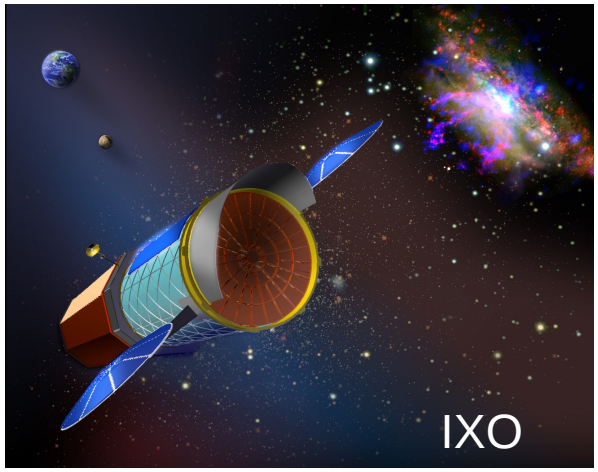






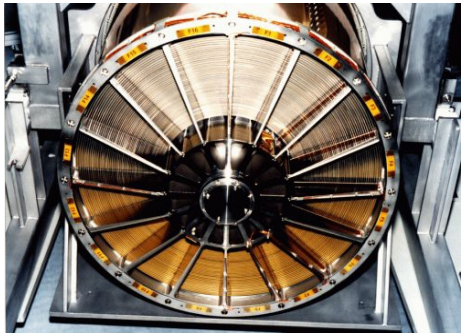
X-ray

Optical

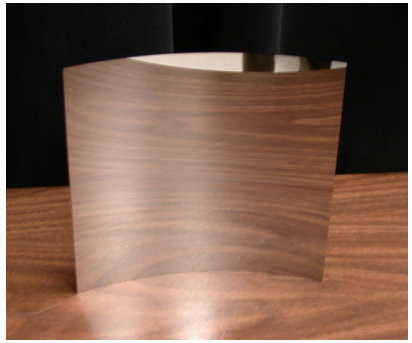
The two order of magnitude increase in capability of IXO is well matched to that of other large facilities planned for the 2010-2020 decade

Optics Technologies: Resolution and Mass

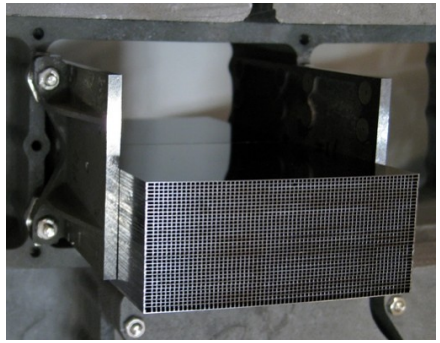
CHANDRA
0.5” HEW
18500 kg/m²



XMM-NEWTON
14” HEW
2300 kg/m²



Slumped Glass
5” HEW
~270 kg/m²



Si-HPO
5” HEW
~200 kg/m²

IXO Options

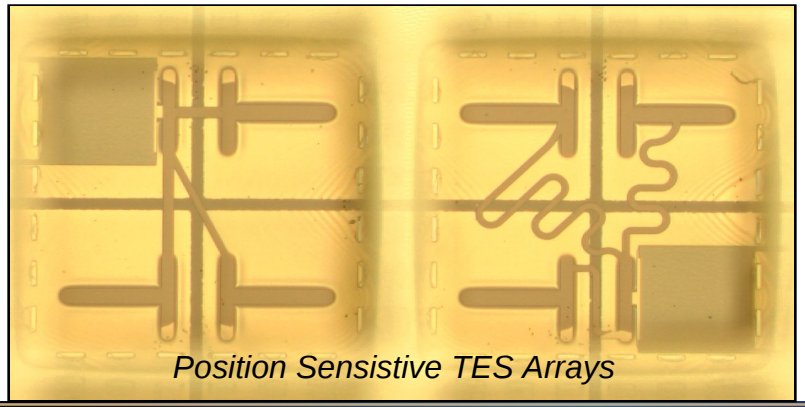
Micro-calorimeter Progress

Multiplexed Readouts are essential to reduce the number of amplifiers

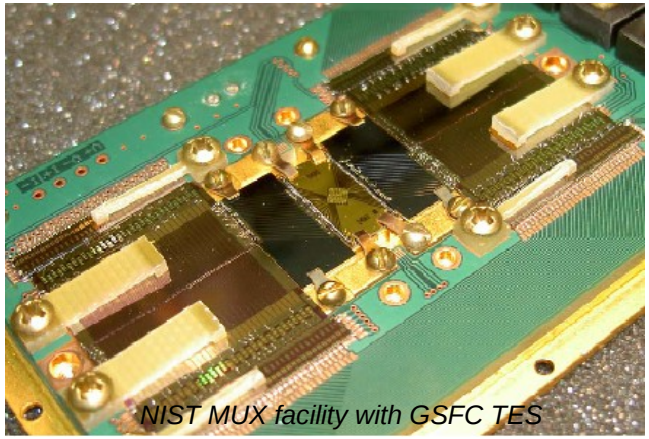
- Demonstrated a 2 x 8 time division readout with a spectral resolution of ~3 eV average (~2.6 eV best pixel)

For outer part of array require position sensitive arrays

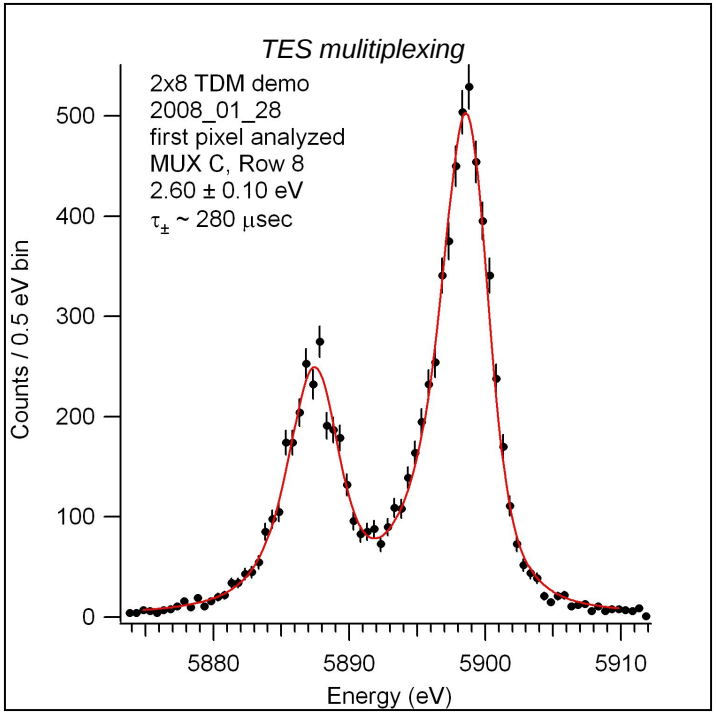
- fabricated and tested the first Position Sensitive TES's with spectral resolution 5 eV (meets requirement of <10 eV)



Position Sensistive TES Arrays



NIST MUX facility with GSFC TES



Energy resolution of 2.6 eV

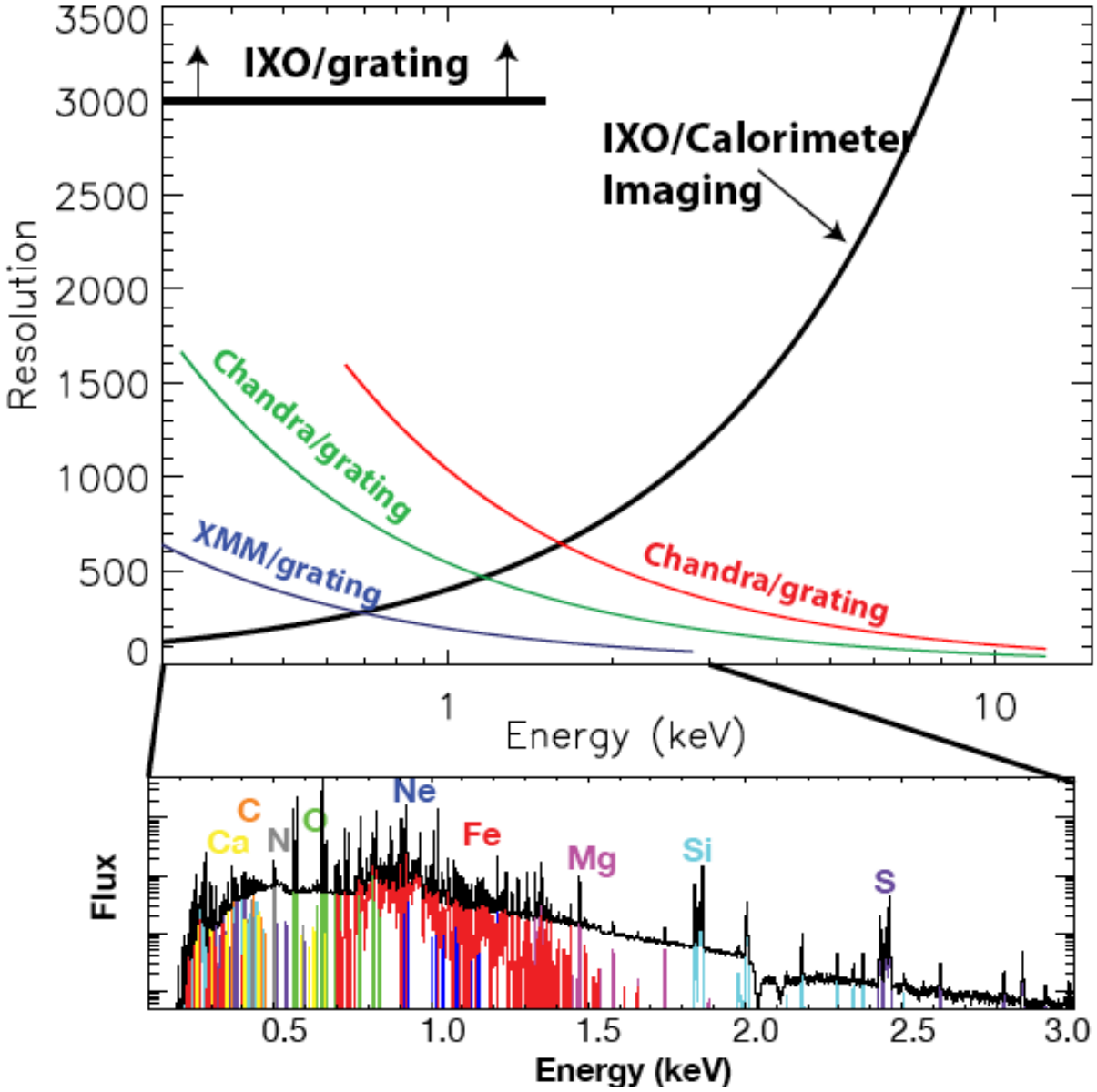
More information is available…

- Measuring the Gas and Dust Composition of the Galactic ISM and beyond
- Mass-Loss and Magnetic Fields as Revealed Through Stellar X-ray Spectroscopy
- Starburst Galaxies: Outflows of Metals and Energy into the IGM
- The Evolution of Galaxy Clusters Across Cosmic Time
- The Missing Baryons in the Milky Way and Local Group
- The Growth of Supermassive Black Holes Over Cosmic Time
- Stellar-Mass Black Holes and Their Progenitors
- Fundamental Accretion and Ejection Astrophysics
- X-ray Cluster Cosmology
- X-ray Studies of Planetary Systems
- The Cosmic Web of Baryons
- Spin and other relativistic phenomena around black holes
- The Behavior of Matter Under Extreme Conditions
- Cosmic Feedback from Massive Black Holes
- Formation of the Elements

See the Astro 2010 Decadal Web site
Or our site, http://ixo.gsfc.nasa.gov

Spectral Capability

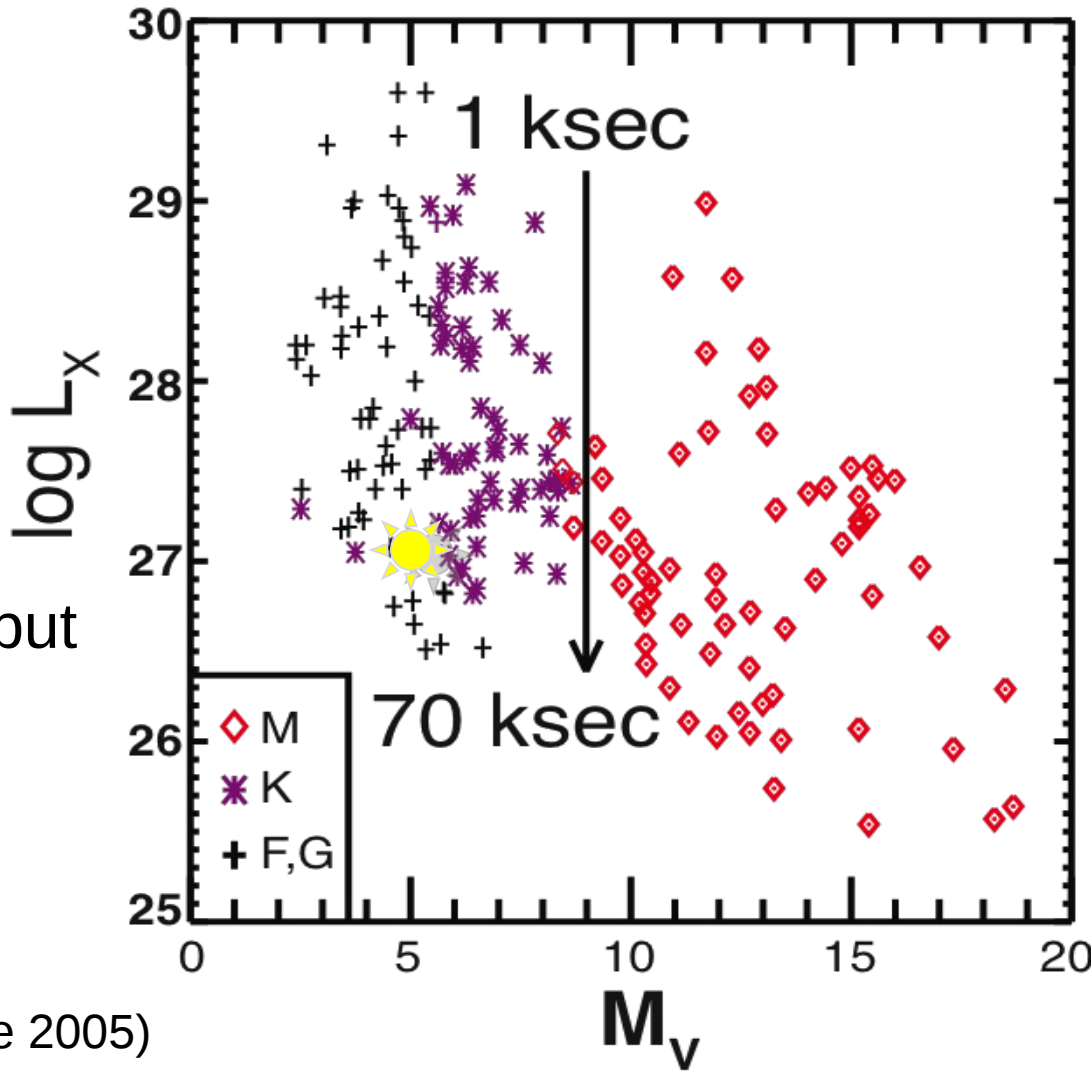
The IXO energy band contains the K-line transitions of 25 elements Carbon through Zinc allowing simultaneous direct abundance determinations using line-to-continuum ratios, plasma diagnostics and at iron K bulk velocities of 100 km/s



Is the Sun a Solar-type Star?

IXO will observe nearby (d ~ 20 pc) stars, including true ‘solar minimum’ stars in modest observing times with enough sensitivity to measure coronal densities.

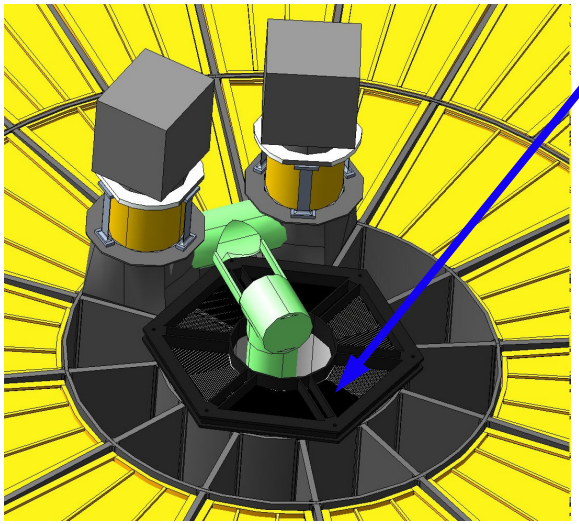
This **unbiased** survey will put the X-ray Sun “in context” with other stars for the first time.

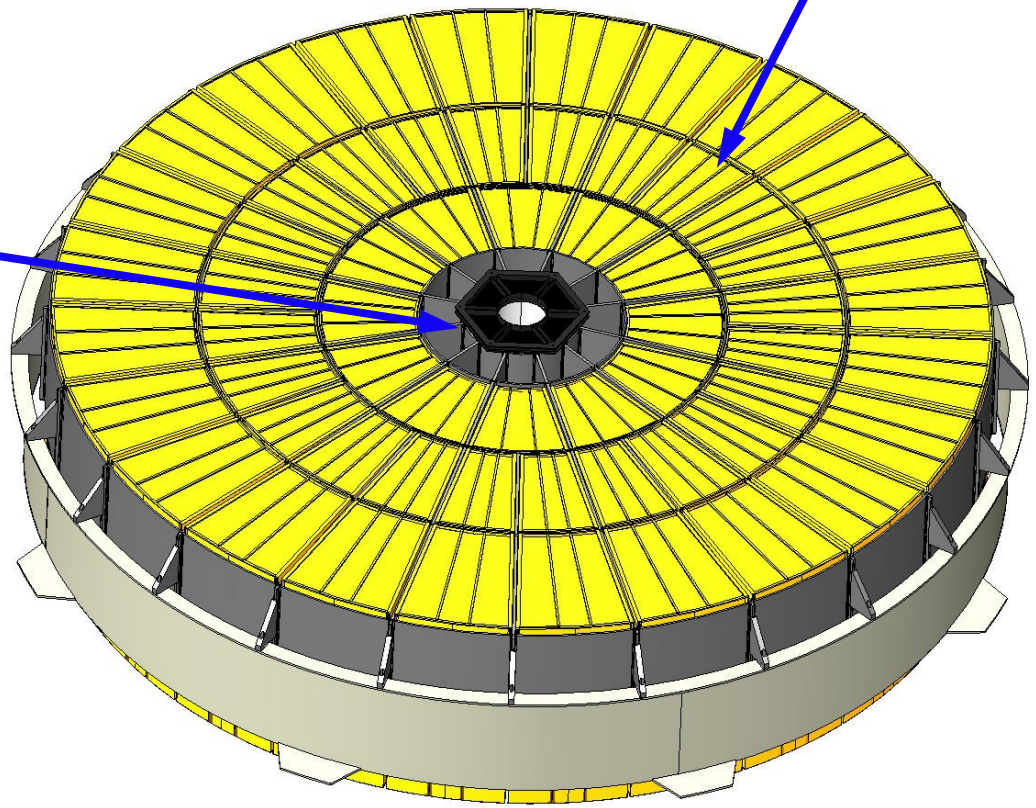


NEXXIS database (Schmitt & Liefke 2005)

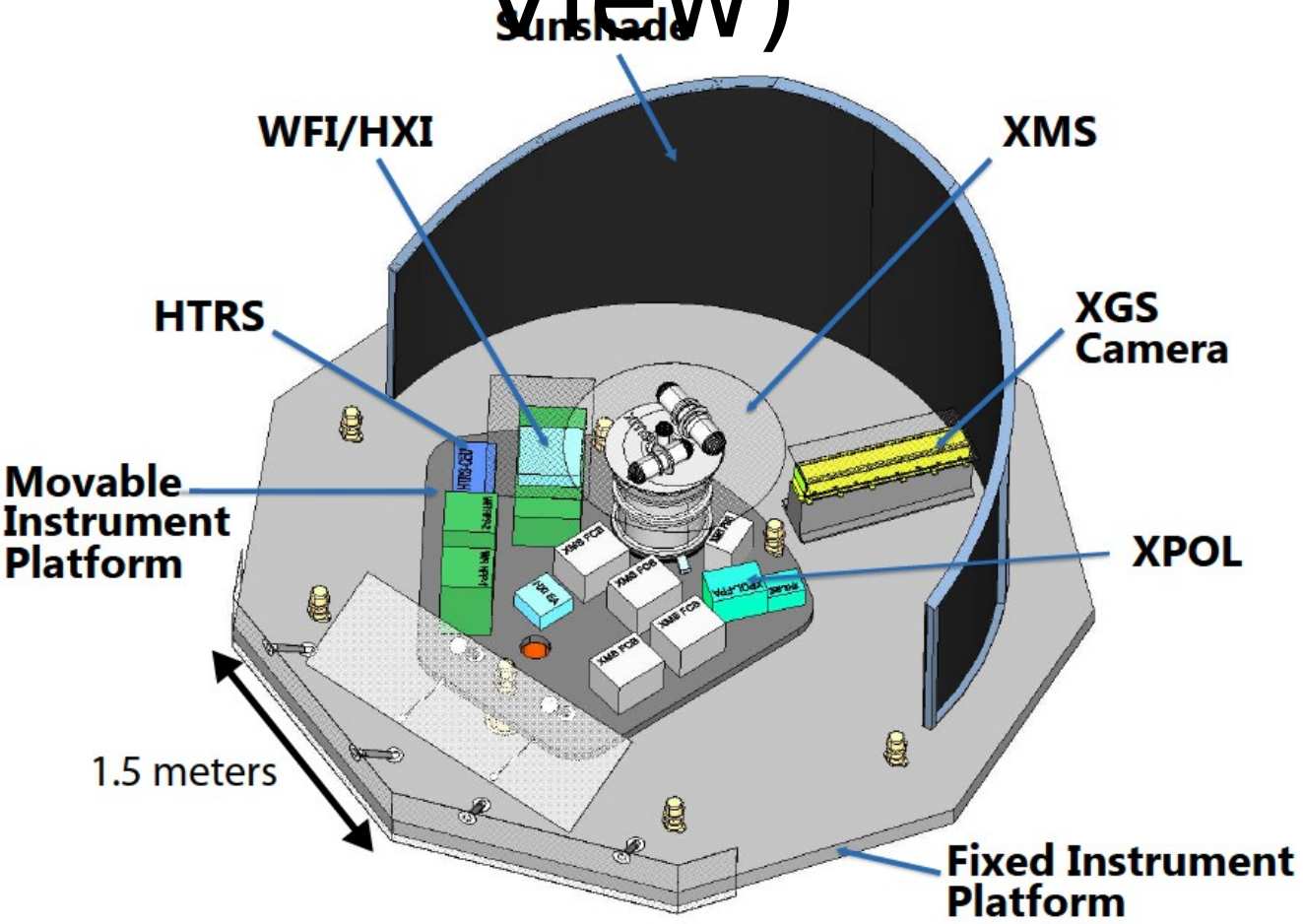
Flight Mirror Assembly

- **Soft X-Ray Telescope Modules**
- **Hard X-Ray Mirror Module**



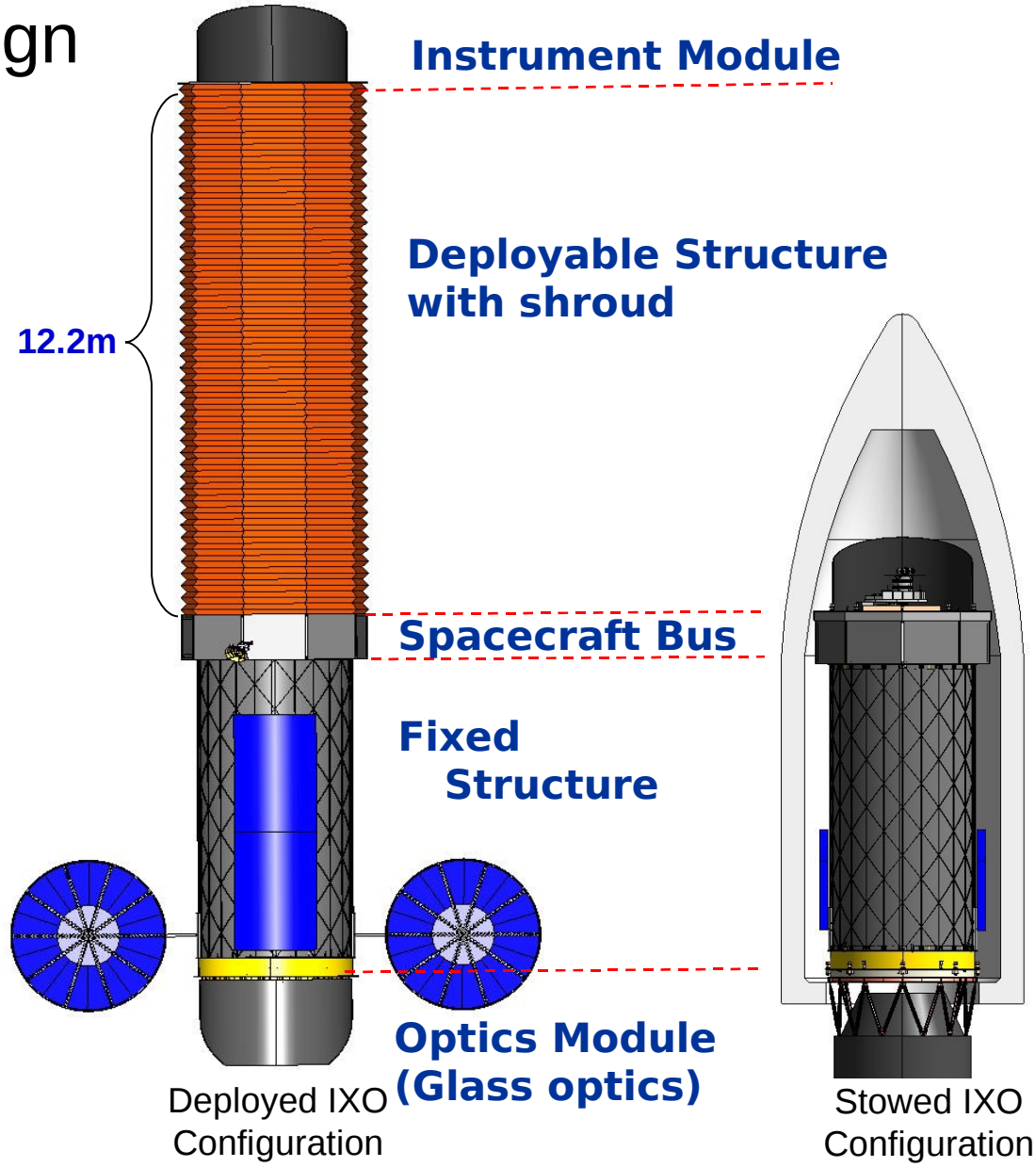


Focal Plane Layout (Aft View)



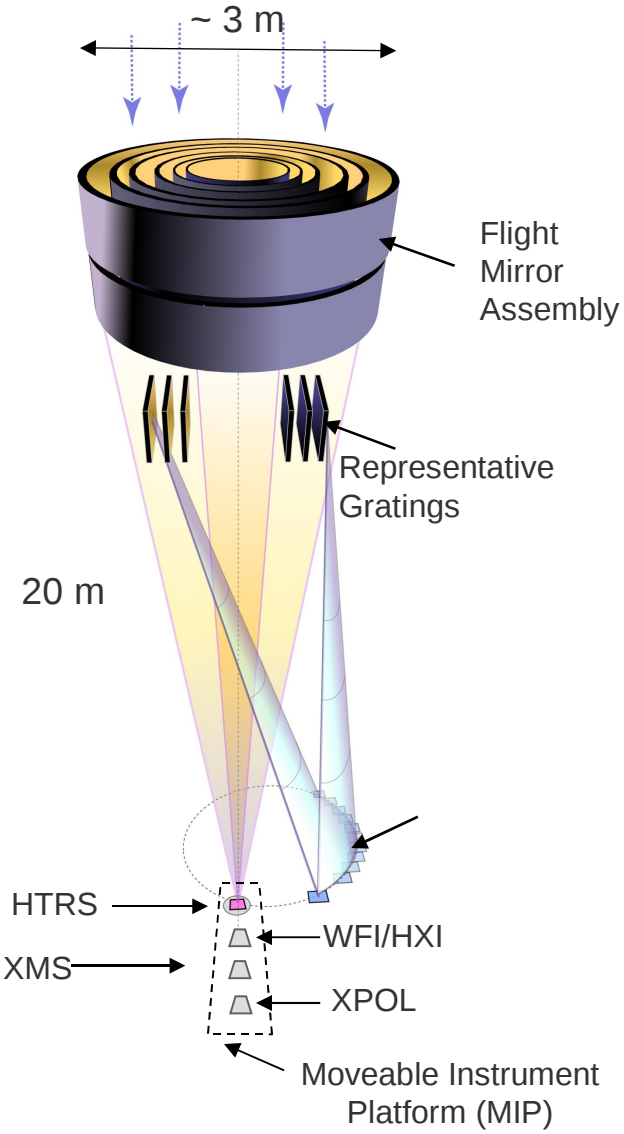
NASA Mission Design

- The observatory is deployed to achieve 20 m focal length
- Observatory Mass ~6100 kg (including 30% contingency)
- Launch on an Atlas V 551 or Ariane V
- Direct launch into an 800,000 km semi-major axis L2 orbit
- 5 year required lifetime, with expendables for 10 year goal



IXO Payload

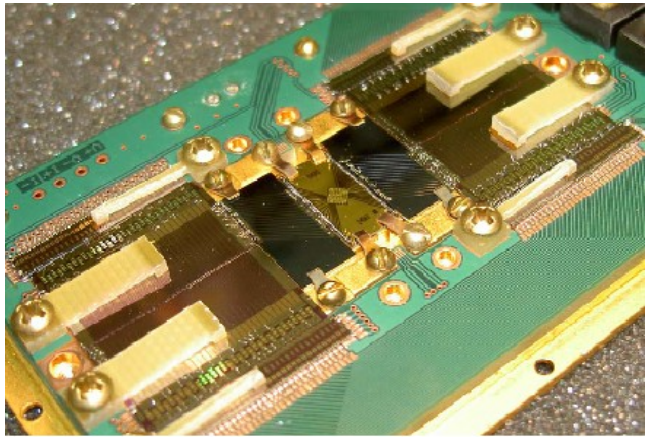
- Flight Mirror Assembly (FMA)
  - Highly nested grazing incidence optics
  - 3 sq m @ 1.25 keV with a 5'' PSF
- Instruments
  - X-ray Micro-calorimeter Spectrometer (XMS)
    - 2.5 eV with 5 arc min FOV
  - X-ray Grating Spectrometer (XGS)
    - R = 3000 with 1,000 sq cm
  - Wide Field Imager (WFI) and Hard X-ray Imager (HXI)
    - 18 arc min FOV with CCD-like resolution
    - 0.3 to 40 keV
  - X-ray Polarimeter (X-POL)
  - High Time Resolution Spectrometer

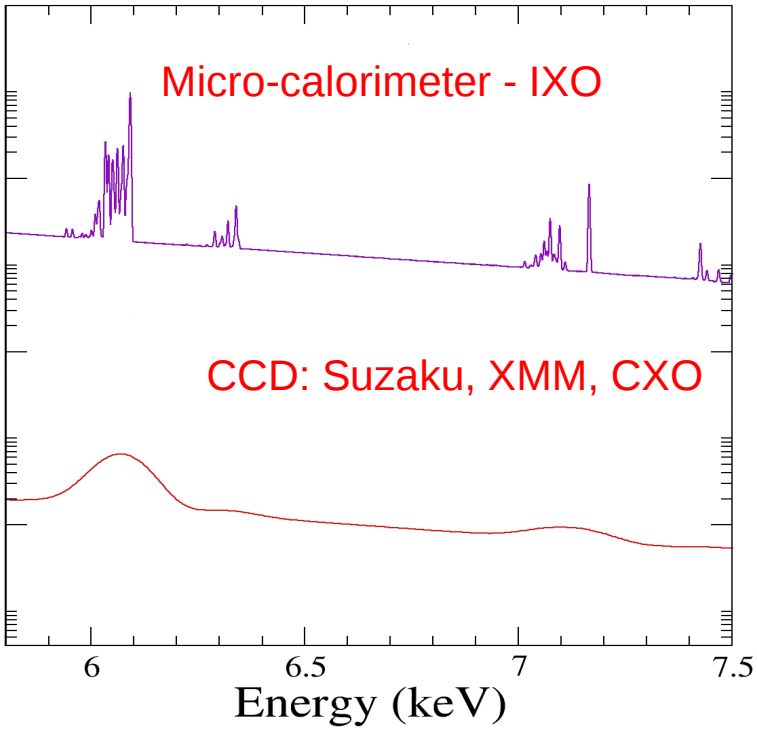


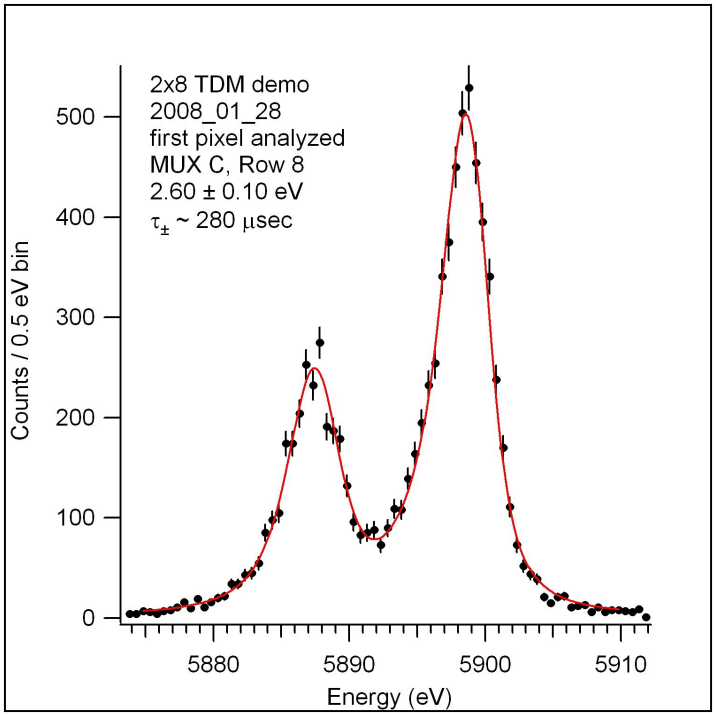
Example of Next Generation Instrument Capability: X-ray Micro-calorimeter Spectrometer (XMS)

- Thermal detection of individual X-ray photons
  - High spectral resolution

    ΔE very nearly constant with E
  - High intrinsic quantum efficiency
  - Imaging detectors







Energy resolution of 2.6 eV