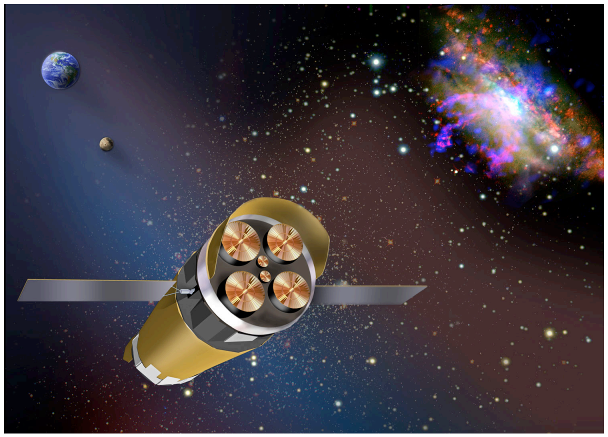
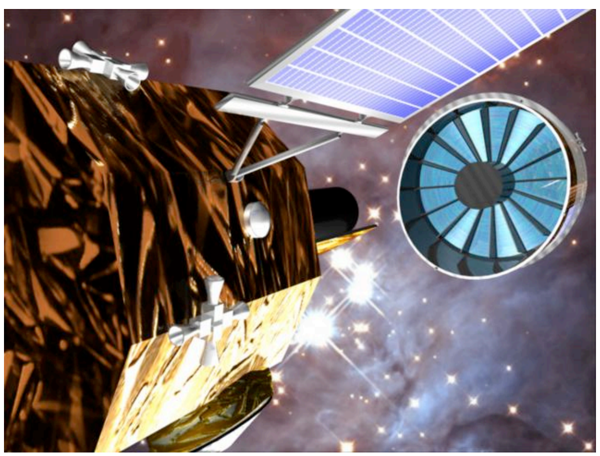
History





- The science case for an X-ray Observatory 10-100 times more capable than current or approved missions is compelling:
  - Con-X: NASA concept, number two in 2000 Decadal survey
  - XEUS: ESA with JAXA candidate as large Cosmic Vision mission
- Very similar science goals, very different implementation
- Unlikely there will be two large X-ray missions at the same time, and it would be more cost effective to join forces
- Previous attempts failed……

Recent events

- Recent selection of *XEUS* as a candidate Cosmic Vision mission and upcoming US 2010 decadal survey which will reexamine the priority of *Con-X* make it timely to re-examine a merger
- In the spring of 2008, under the guidance of ESA and NASA HQ, an effort began to see if we could merge the two missions
  - *Which agency would lead a joint mission was NOT discussed*
- An ESA/JAXA/NASA coordination group was formed and met twice, once at ESTEC and again at CFA: agreement was reached on a path forward, and was accepted at an ESA-NASA bilateral 2008, July 14
- The Con-X and XEUS studies will be replaced by a single three agency study called the ***<u>International X-ray Observatory</u>***
- The result of this study will be submitted to the 2010 “Decadal Survey” and Cosmic Visions, as well as the JAXA approval process

The International X-ray Observatory IXO

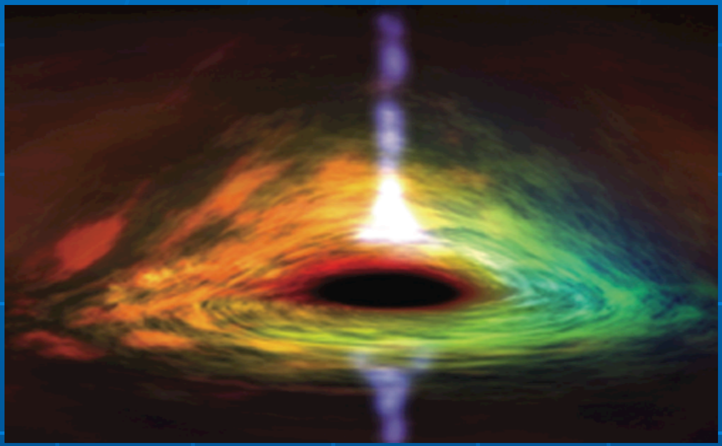
Nicholas White, NASA
Arvind Parmar, ESA
Hideyo Kunieda, JAXA

IXO Science Topics

Three driving science topics:

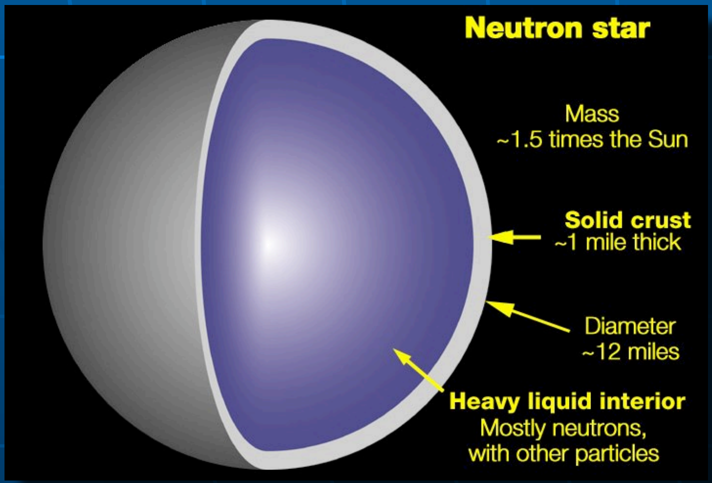
1. Black Holes and Matter under Extreme Conditions
2. Galaxy Formation, Galaxy Clusters and Cosmic Feedback (Dark Matter, Dark Energy, Black Hole energetics)
3. Life Cycles of Matter and Energy

Black Holes and Matter under Extreme Conditions



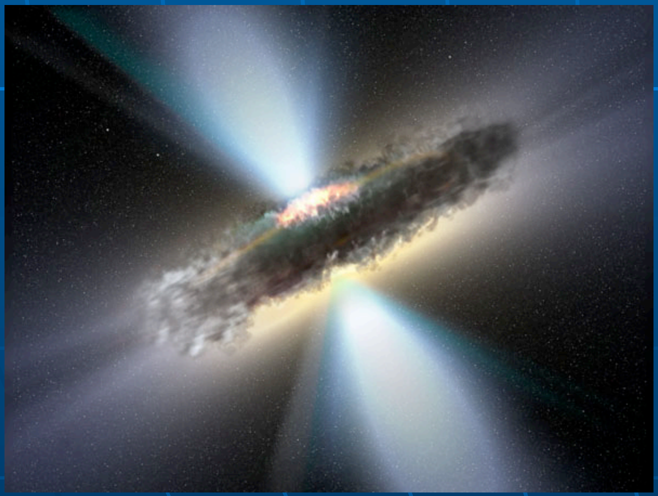
How do super-massive Black Holes grow and evolve?

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



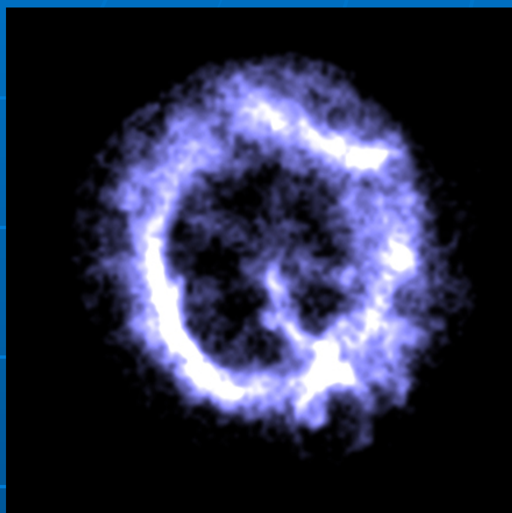
What is the Equation of State of matter in Neutron Stars?

Galaxy Formation, Galaxy Clusters and Cosmic Feedback



- 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?

Life Cycles of Matter and Energy



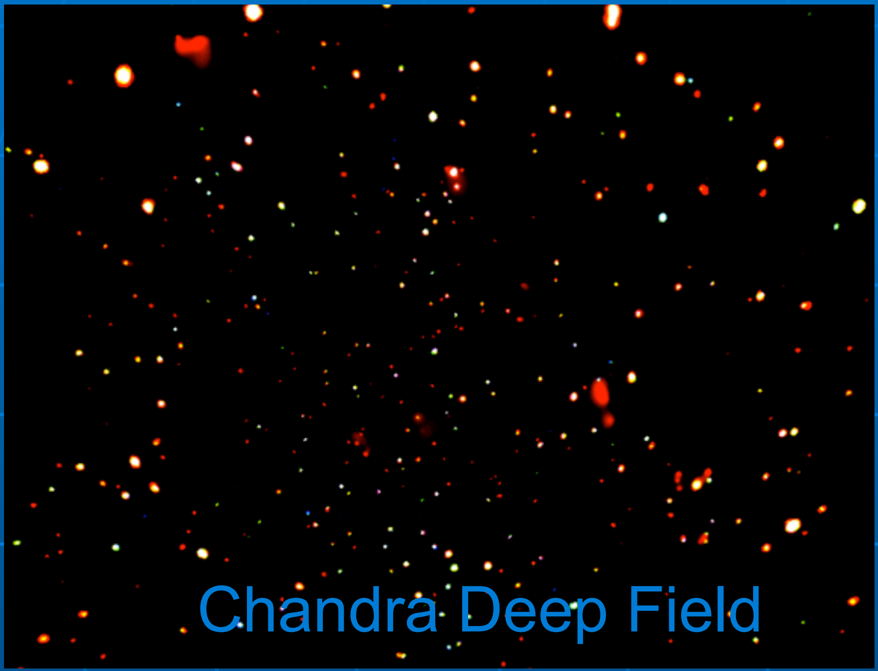
When and how were the elements created and dispersed?

How do high energy processes affect planetary formation and habitability?

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

How are particles accelerated to extreme energies producing shocks, jets and cosmic rays?

IXO Opening a new window

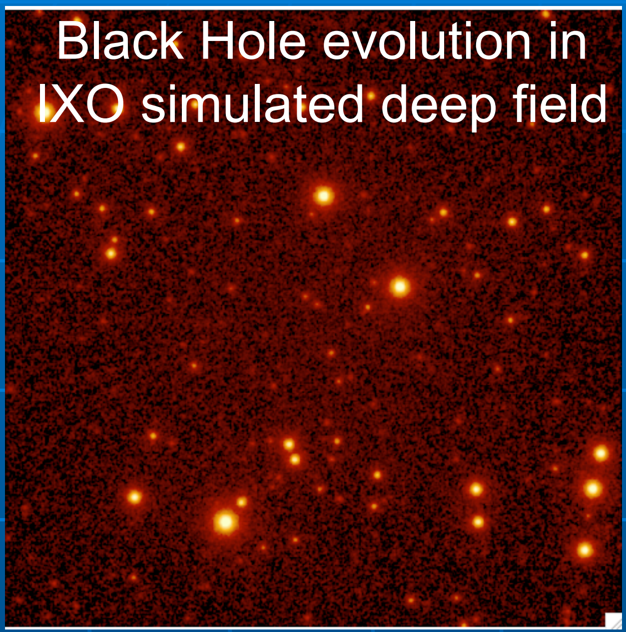


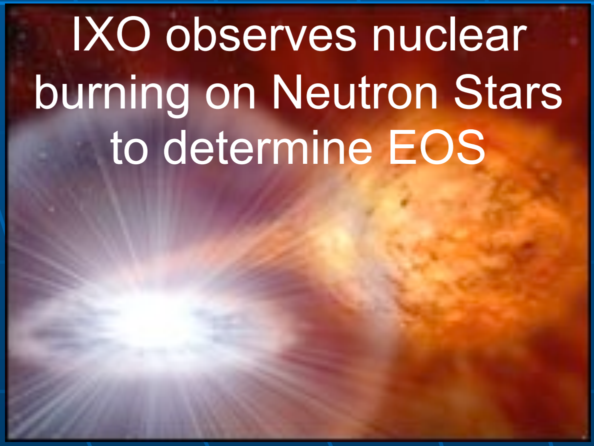
- Chandra and XMM-Newton provide our deepest view of the X-ray Universe, revealing a rich diversity of sources
- Most X-ray spectra currently available have moderate resolution CCD spectra $E/\Delta E < 30$, insufficient for diagnostics routinely available in other wavebands
- The X-ray band is rich in diagnostic features for the elements with atomic number from Carbon through to Zinc

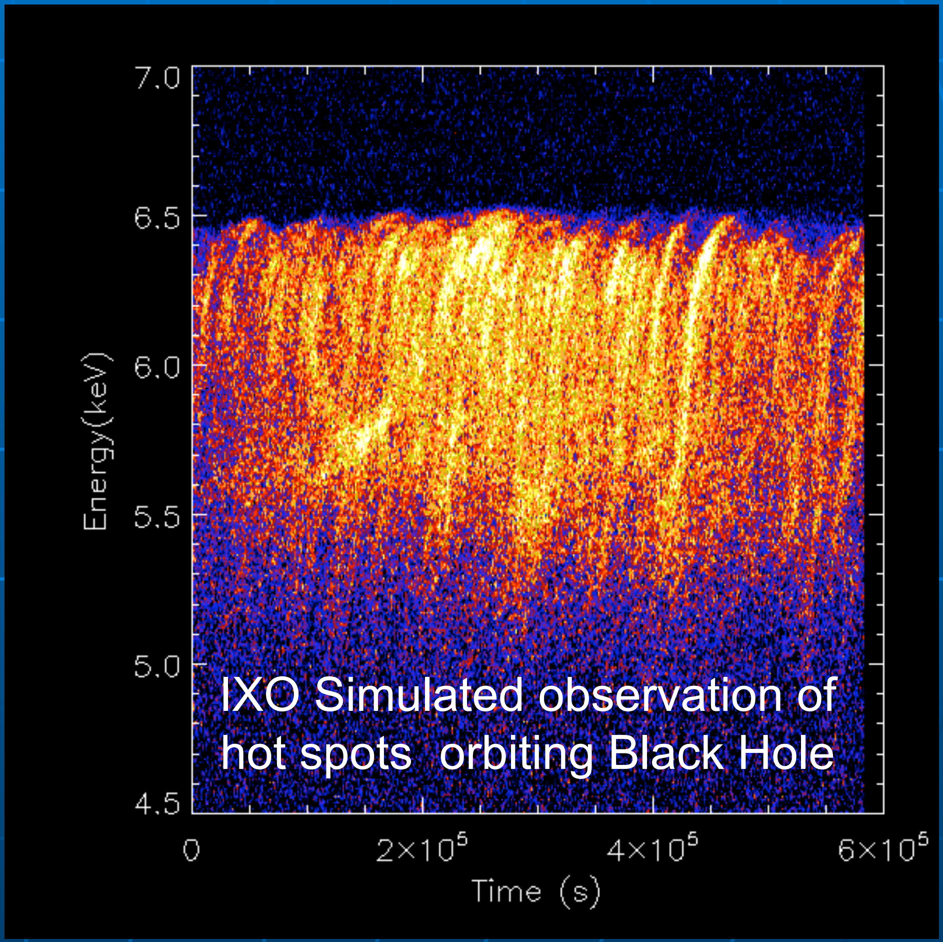
To meet the IXO science objectives requires a factor of 10-100 increase in effective area with high spectral resolution:

- Telescope area: ~ 3 m^2 @ 1 keV, ~ 1 m^2 @ 6 keV, ~ 0.07 m^2 @ 40 keV
- Angular resolution of ~ 5 arc sec or better
- Spectral resolution ($E/\Delta E$) of ~ 1250-2400 (over 0.3 to 7 keV)
- FOV of ~ 5 arc min or better

Black Holes and Matter under Extreme Conditions



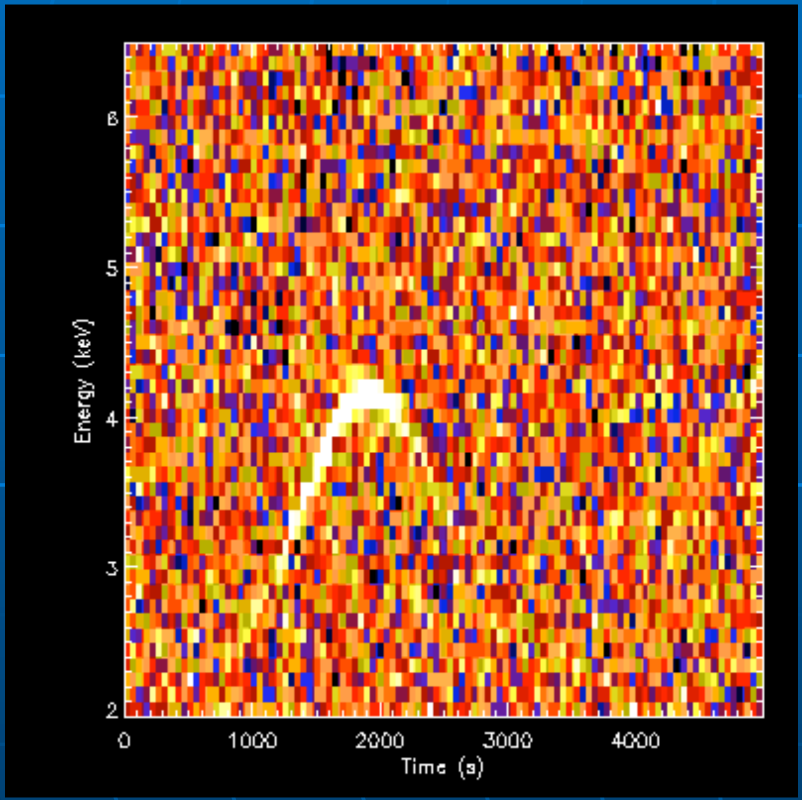


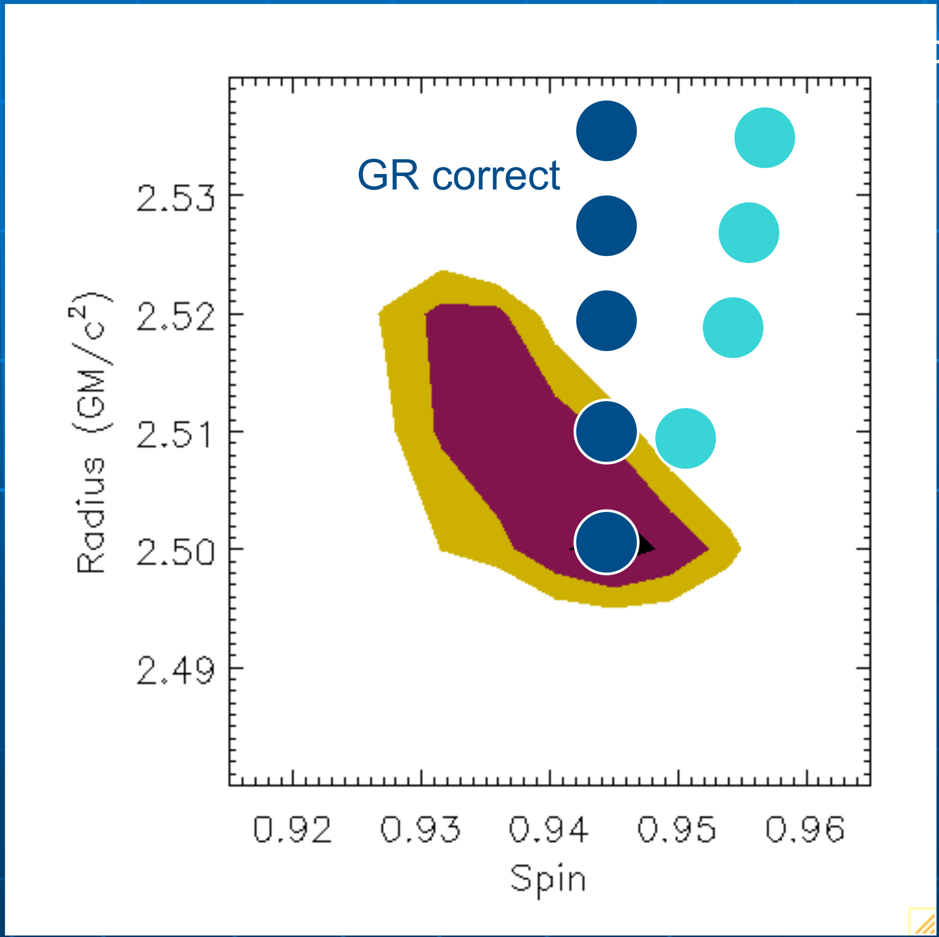


IXO Testing GR

X-ray iron K line bright spots in accretion disk surrounding Black Hole trace orbits that can be mapped with IXO

If GR is correct, IXO measured spin and mass should be independent of radius of bright spot





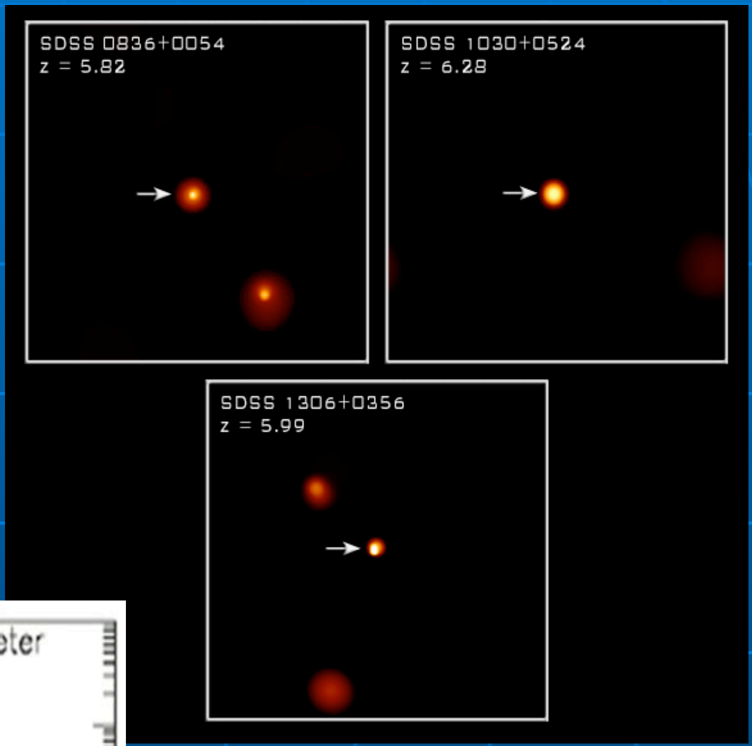
$F=5\times10^{-11}$ erg/s/cm2; EW=20eV; $M=6\times10^{7}$

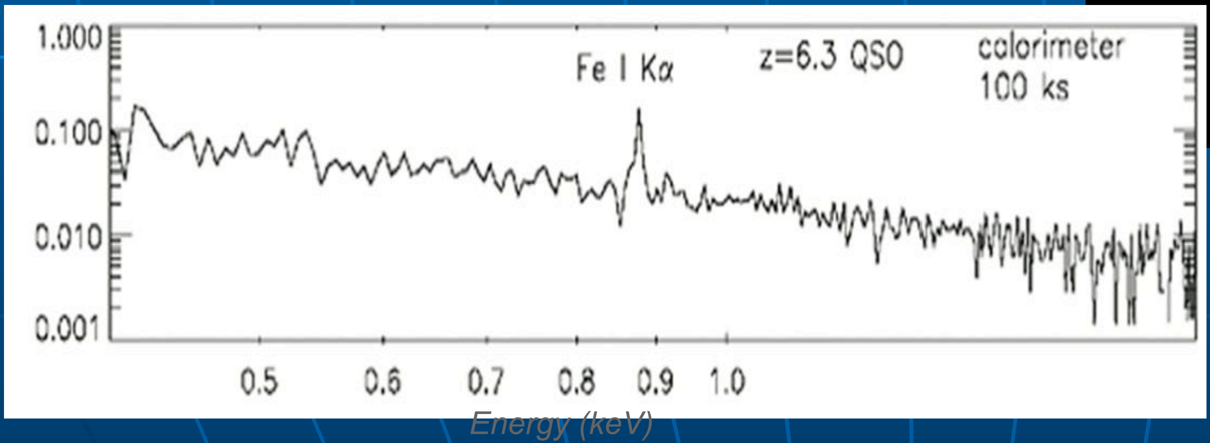
r=2.5 ; a=0.95 ; i=30 degrees

IXO High Redshift Quasars

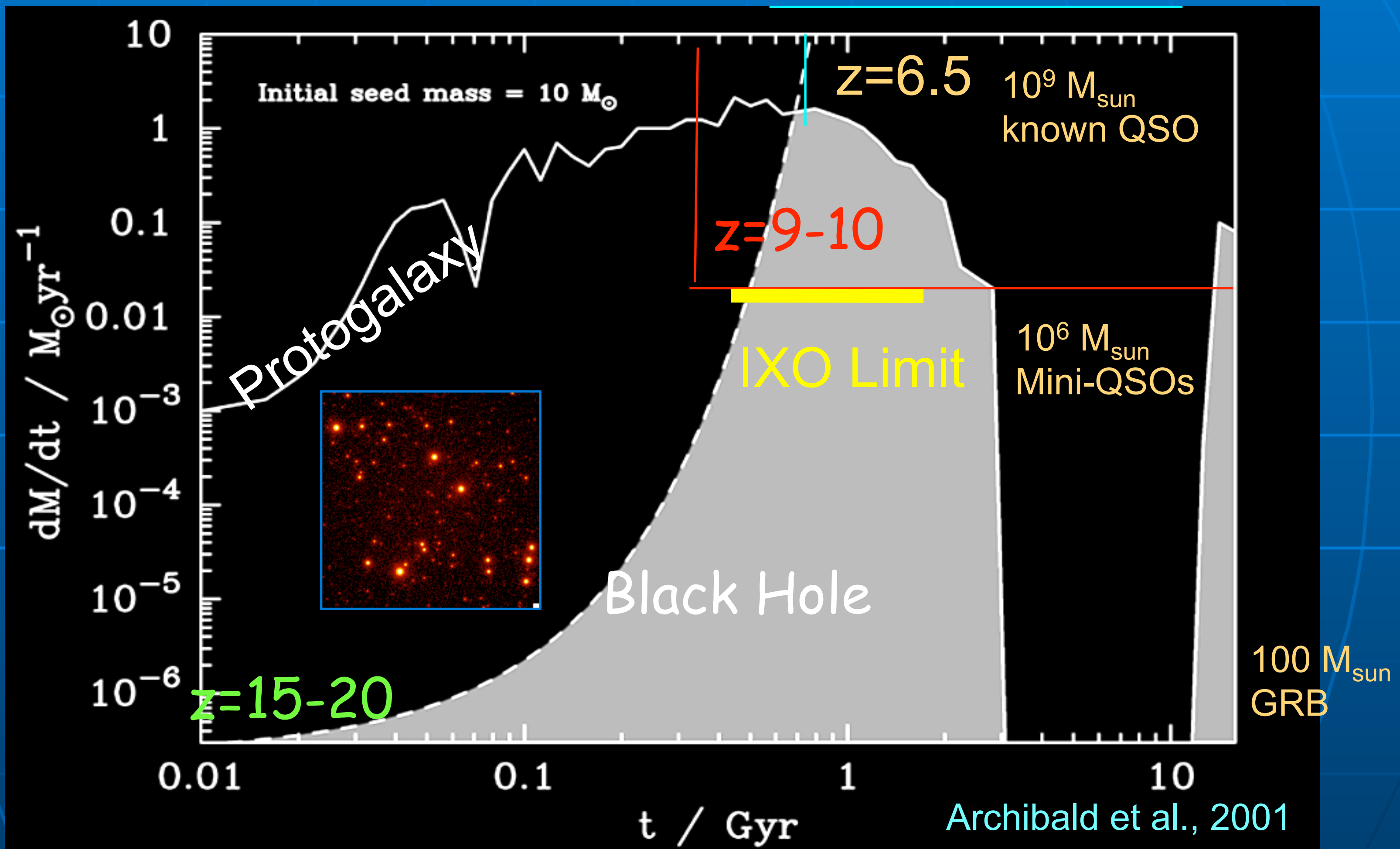
Chandra has detected X-ray emission from ~100 high redshift quasars at $z > 4$ (3 examples shown)

Flux is typically 2-10 x 10^{-15} erg cm^{-2} s^{-1} beyond grasp of XMM-Newton and Chandra high resolution spectrometers, but within the capabilities of IXO



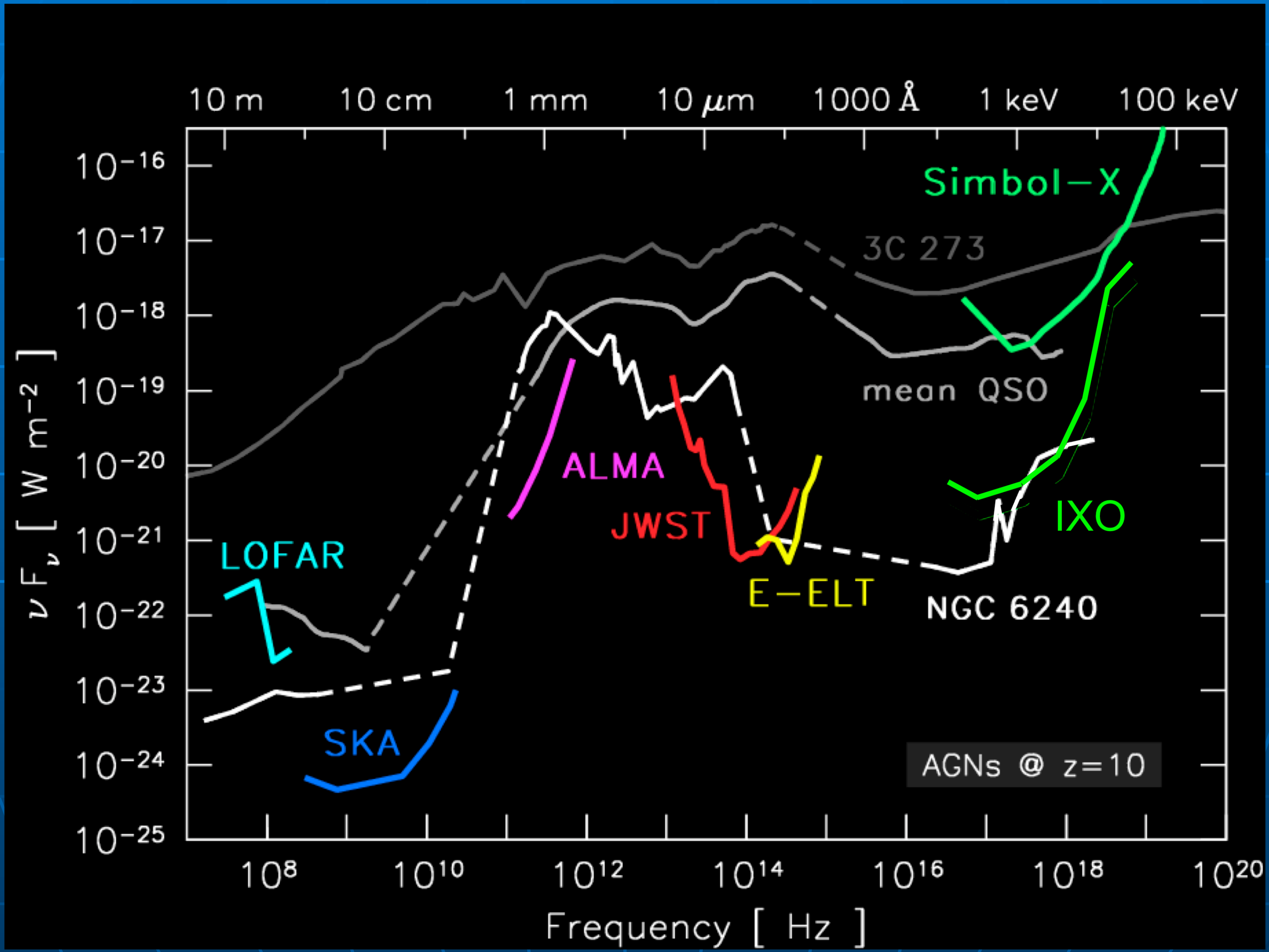


IXO First Black Holes



10^6 M_o @ redshift of 10 is detectable by IXO

IXO Multi-λ Power of future facilities @ z=10

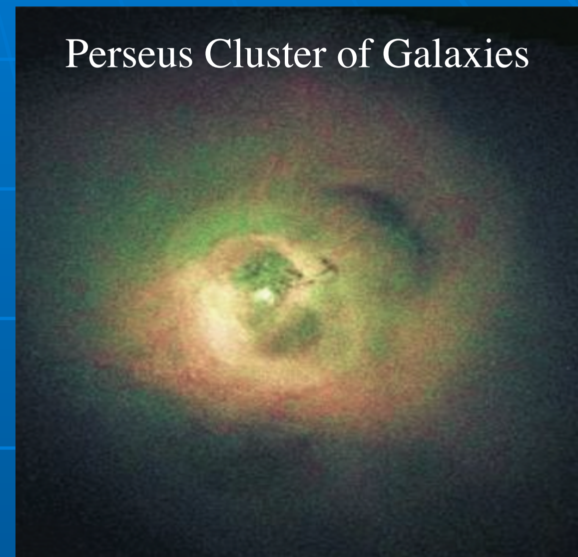


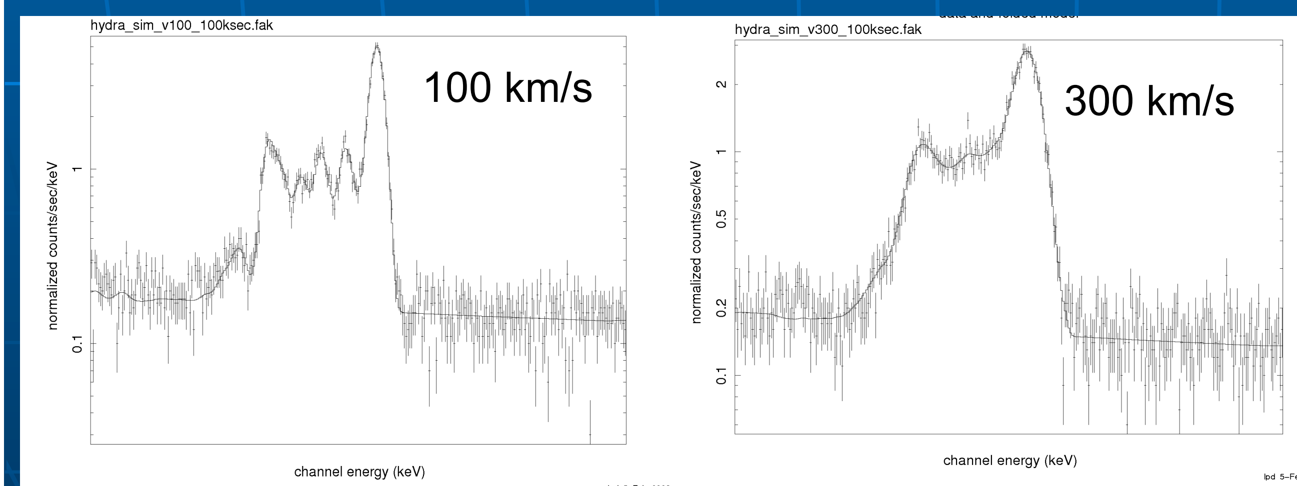
IXO Cosmic Feedback

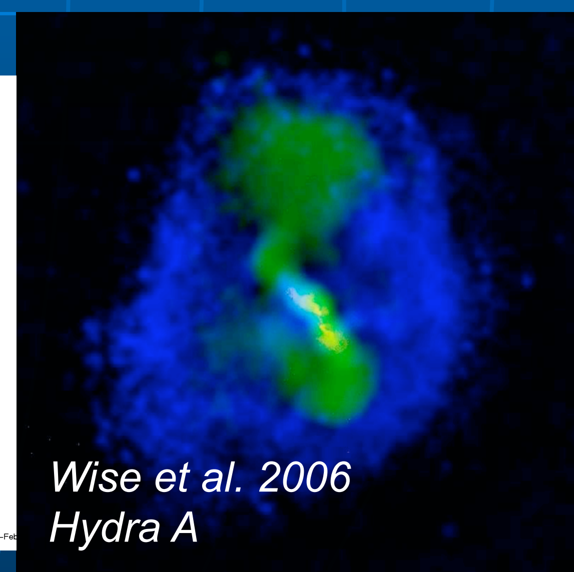
Large scale-structure simulations require AGN feedback to regulate the growth of galaxies and clusters of galaxies

Velocity measurements crucial to determine heating and state of Intra-cluster medium

IXO will probe the hot ICM/IGM through velocity measurements to the required ~100 km/s

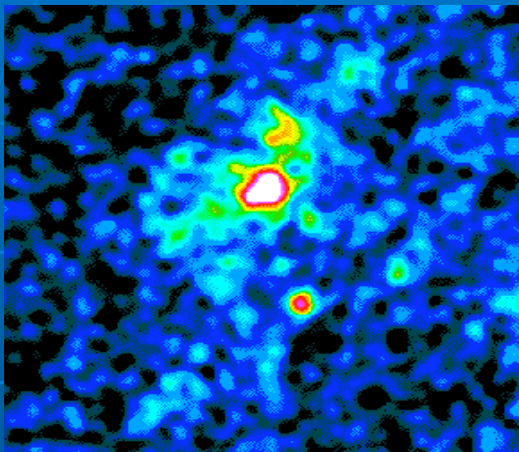




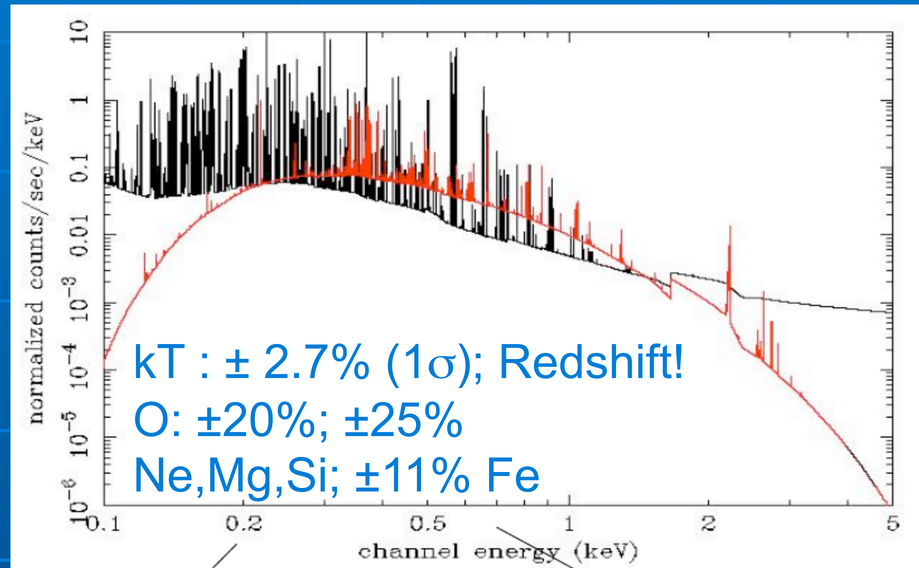


Constellation-X Simulation

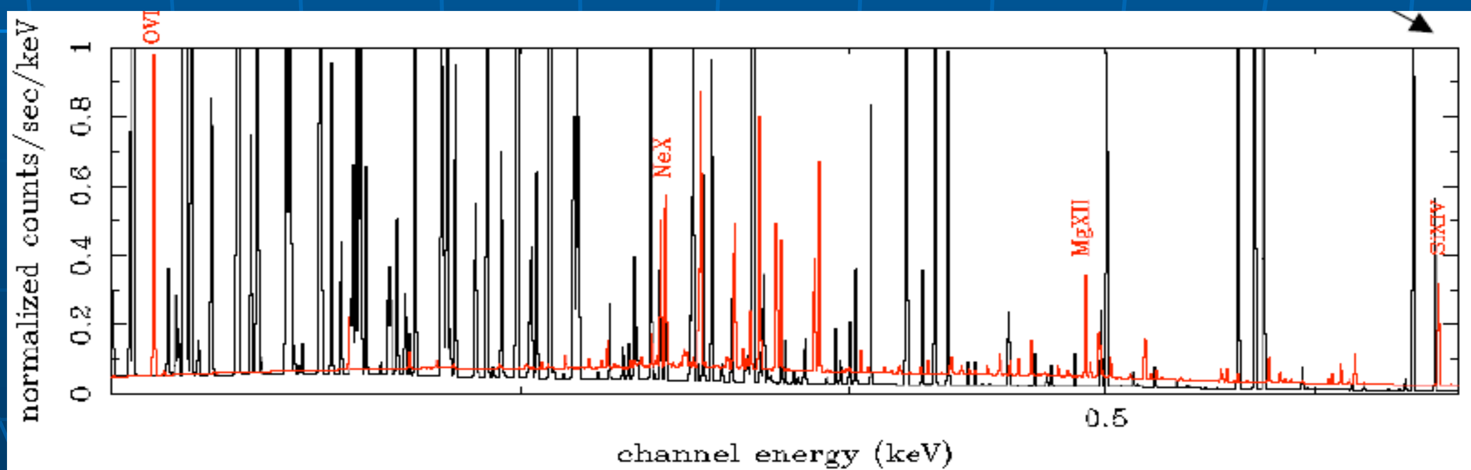
IXO First Groups of Galaxies



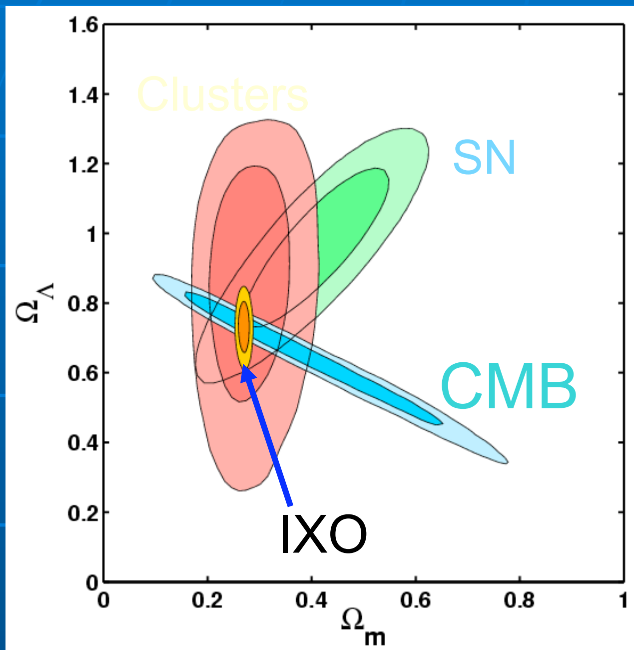
2 keV
log L_{bol}=43.7
z=2
300 ksec

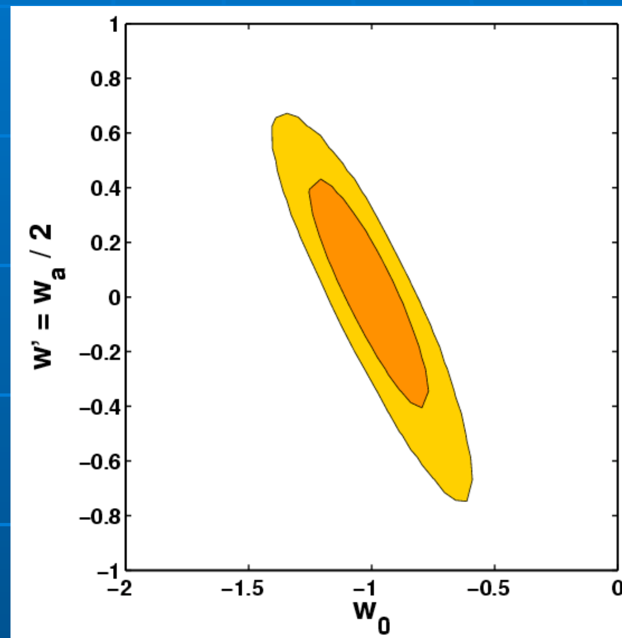


Credit: H. Bohringer + M. Arnaud



IXO Dark Energy





IXO gives a factor of ten improvement

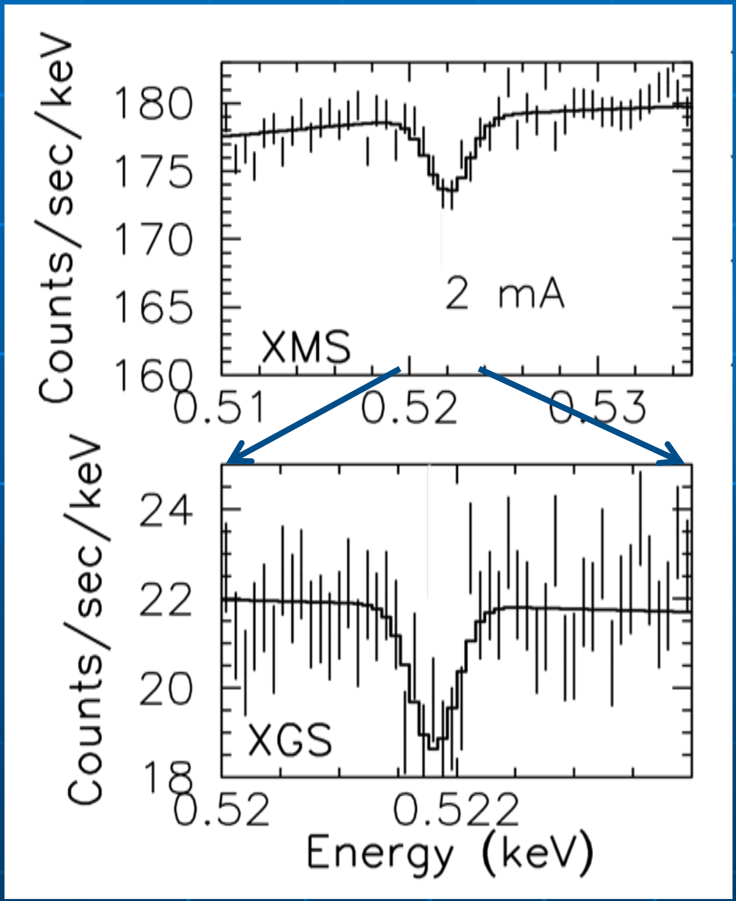
In the terms of the Dark Energy Task Force Figure of Merit this is a Stage IV result

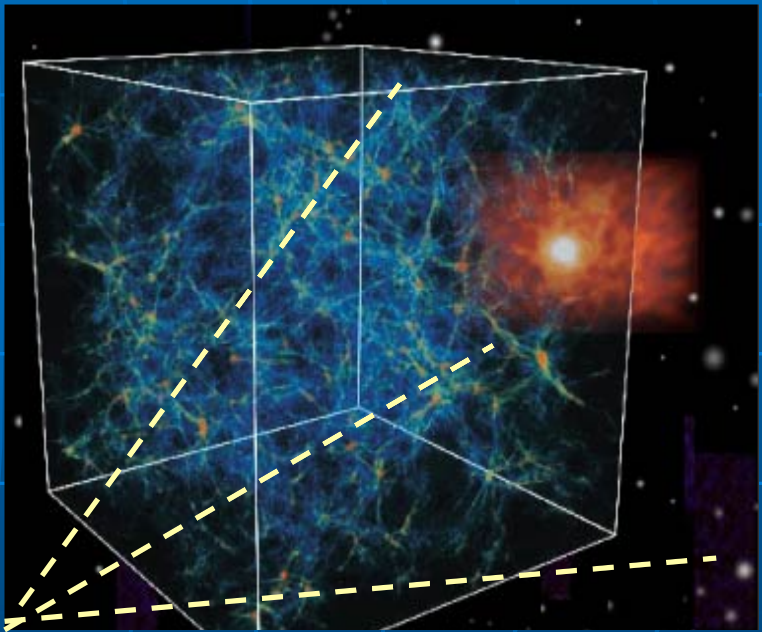
Rapetti, Allen et al 2006 (Astro-ph/0608009)

- Using the gas mass fraction as a standard ruler measures f_{gas} to 5% (or better) for each of 500 galaxy clusters to give Ω_M=0.300±0.007, Ω_Λ=0.700±0.047
- Cluster X-ray properties combined with sub-mm data measure absolute cluster distances via the S-Z effect and cross-check f_{gas} results with similar accuracy
- Determining the evolution of the cluster mass function with redshift reveals the growth of structure and provides a powerful independent check

Galaxy Formation, Galaxy Clusters and Cosmic Feedback

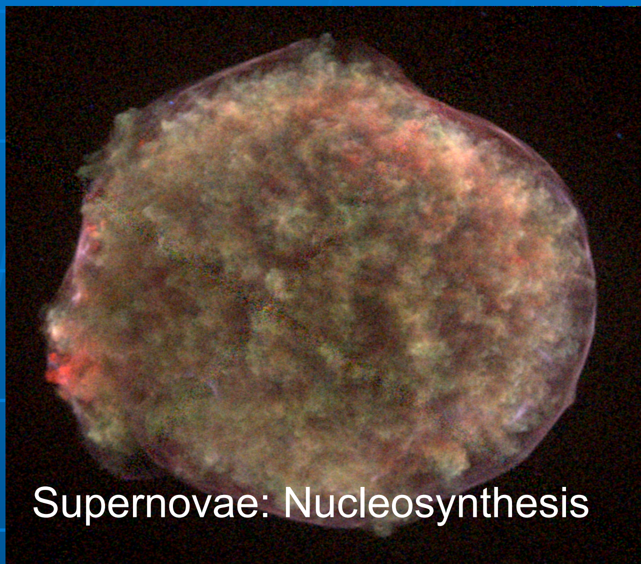
40% of the Baryons in the local Universe are missing and are thought to be caught in a hot plasma

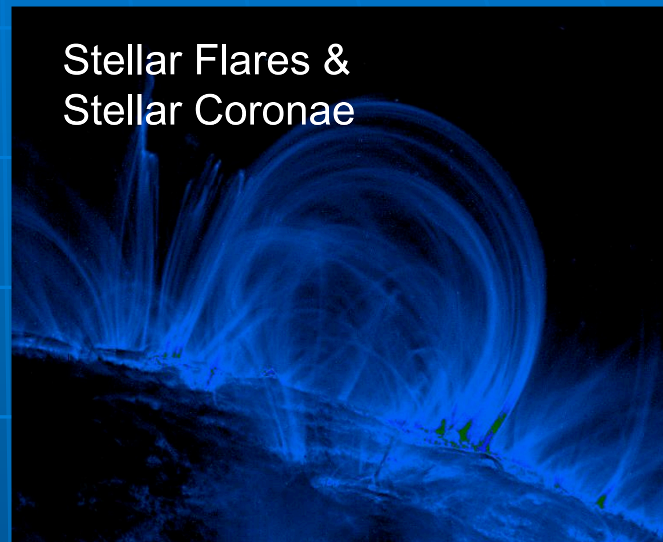


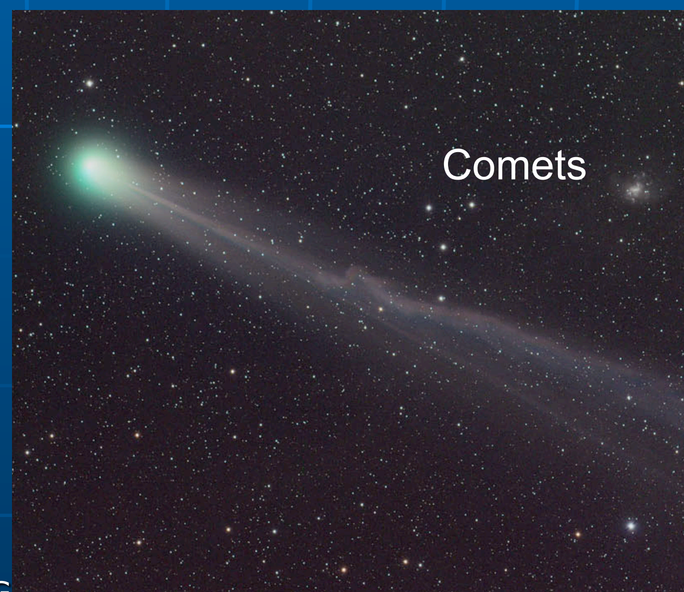


IXO will detect ionized gas in the hot IGM medium via OVII absorption lines in spectra of many background AGN to detect the missing Baryons and characterize them

Life Cycles of Matter and Energy



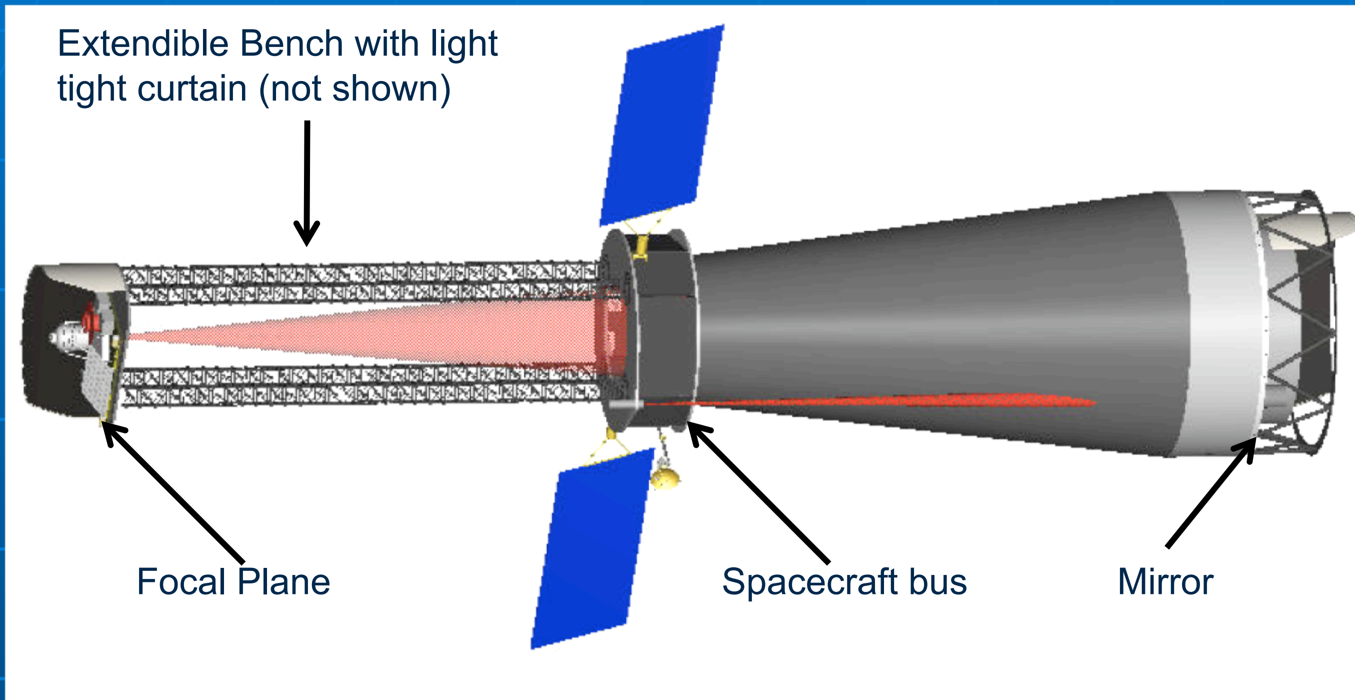


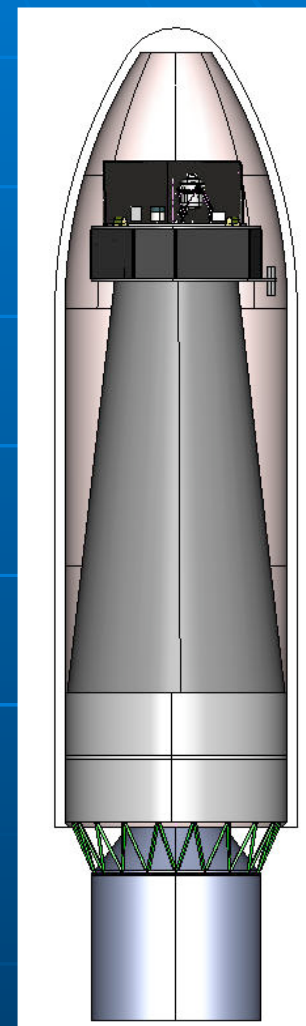


IXO Baseline Agreed Concept

- Focal length of 20-25m with extendible optical bench
- Concept must accommodate both glass (NASA) and silicon (ESA) optics technology (with final selection at appropriate time)
- Core instruments to include:
  - Wide Field Imager
  - X-ray Micro-calorimeter/Narrow Field Imager
  - X-ray Grating Spectrometer
  - Allocation for further modest payload elements
- Concept compatible with Ariane V and Atlas V 551

IXO Preliminary Mission Concept

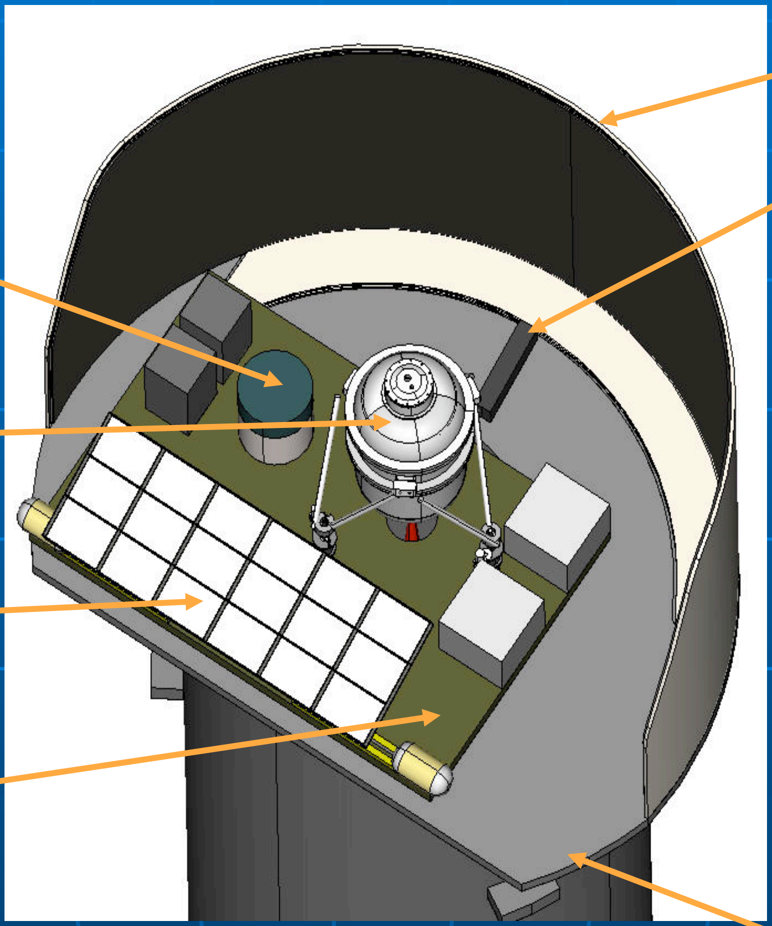




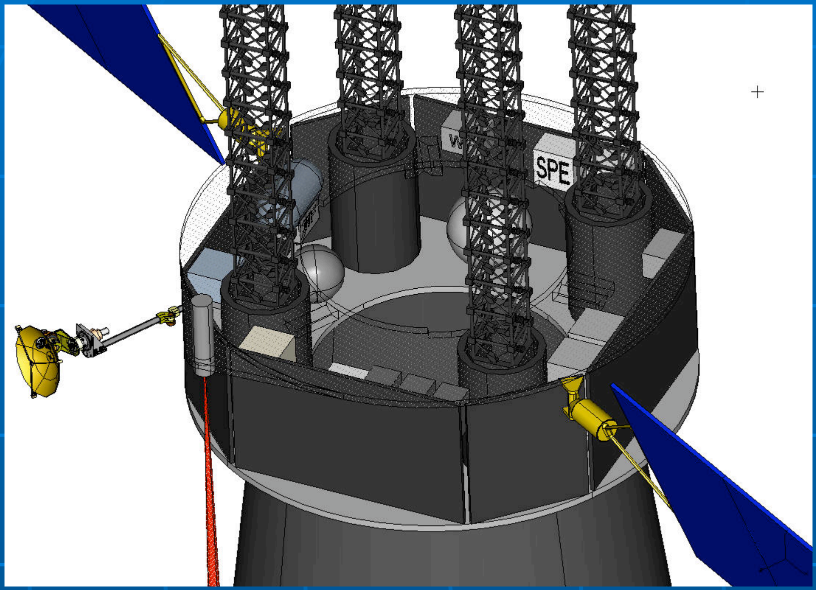
- L2 Orbit; 700,000 km radius halo orbit
  - High operational efficiency
  - Uninterrupted viewing
  - Stable temperature
- 5 year life; 10 years on consumables

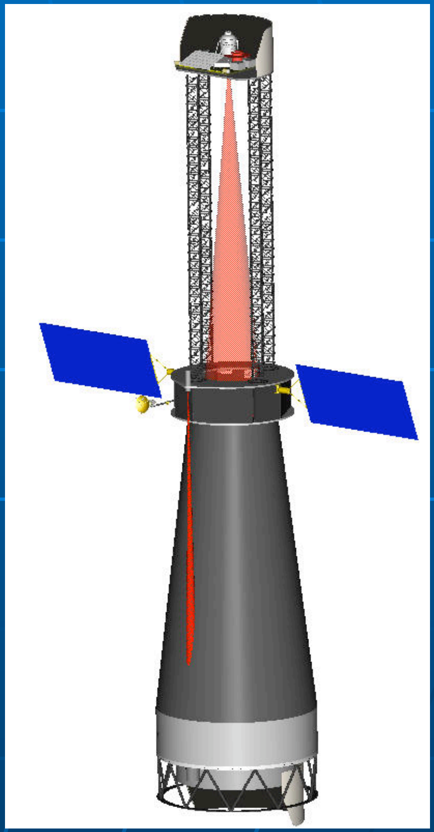
IXO in Atlas V 551fairing

Focal Plane - Preliminary Layout

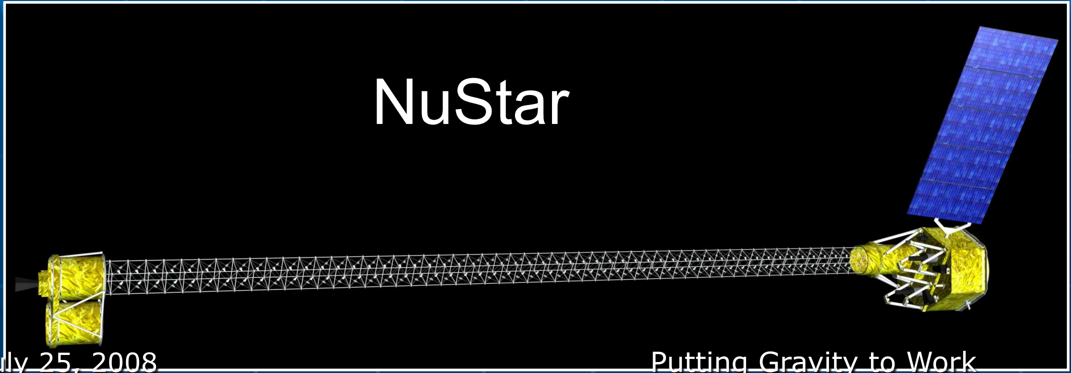


IXO ADAM Mast Deployable Concept

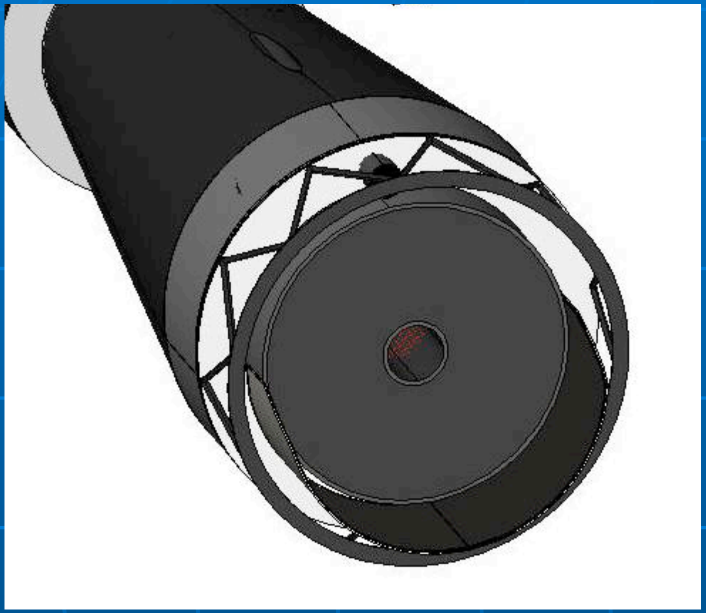




- ADAM masts, same as for NuStar
- Separate light-tight "shower curtain" shroud

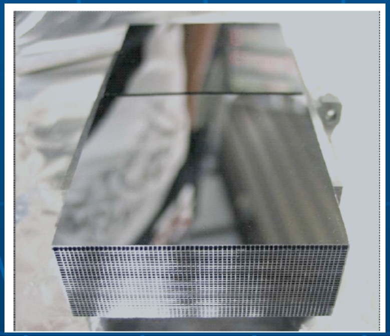


IXO X-ray Mirror Baseline



Glass

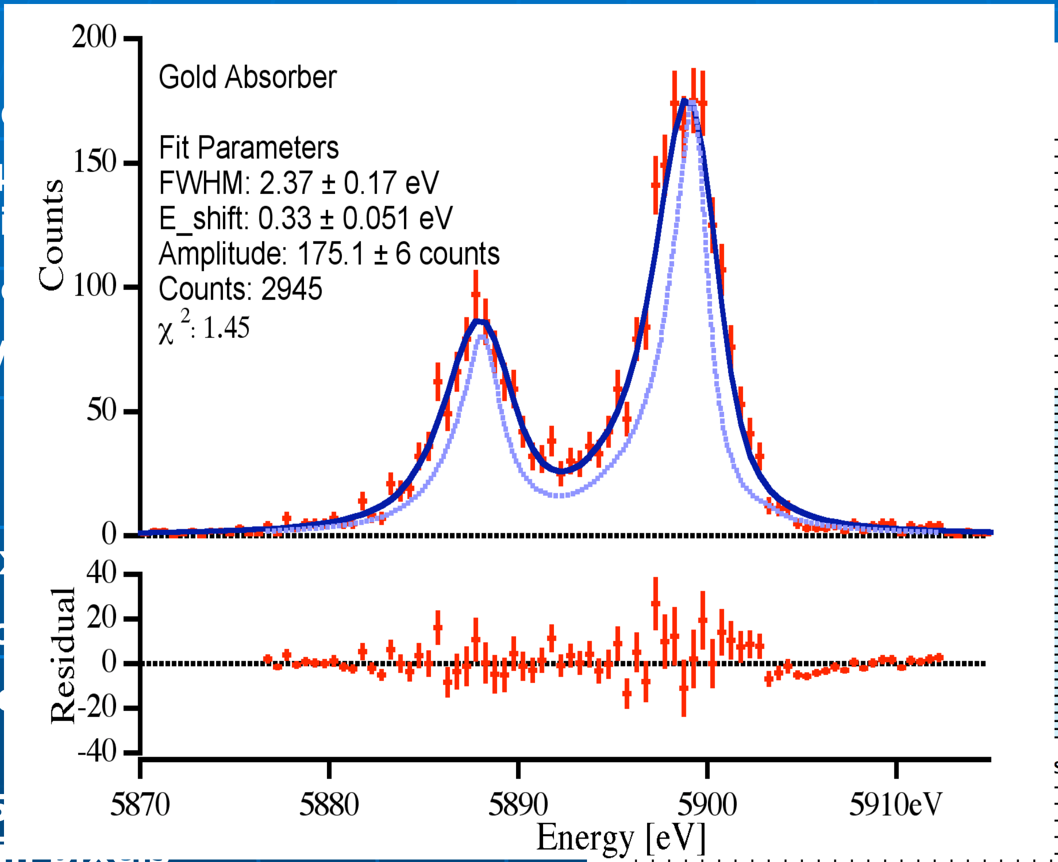
Silicon

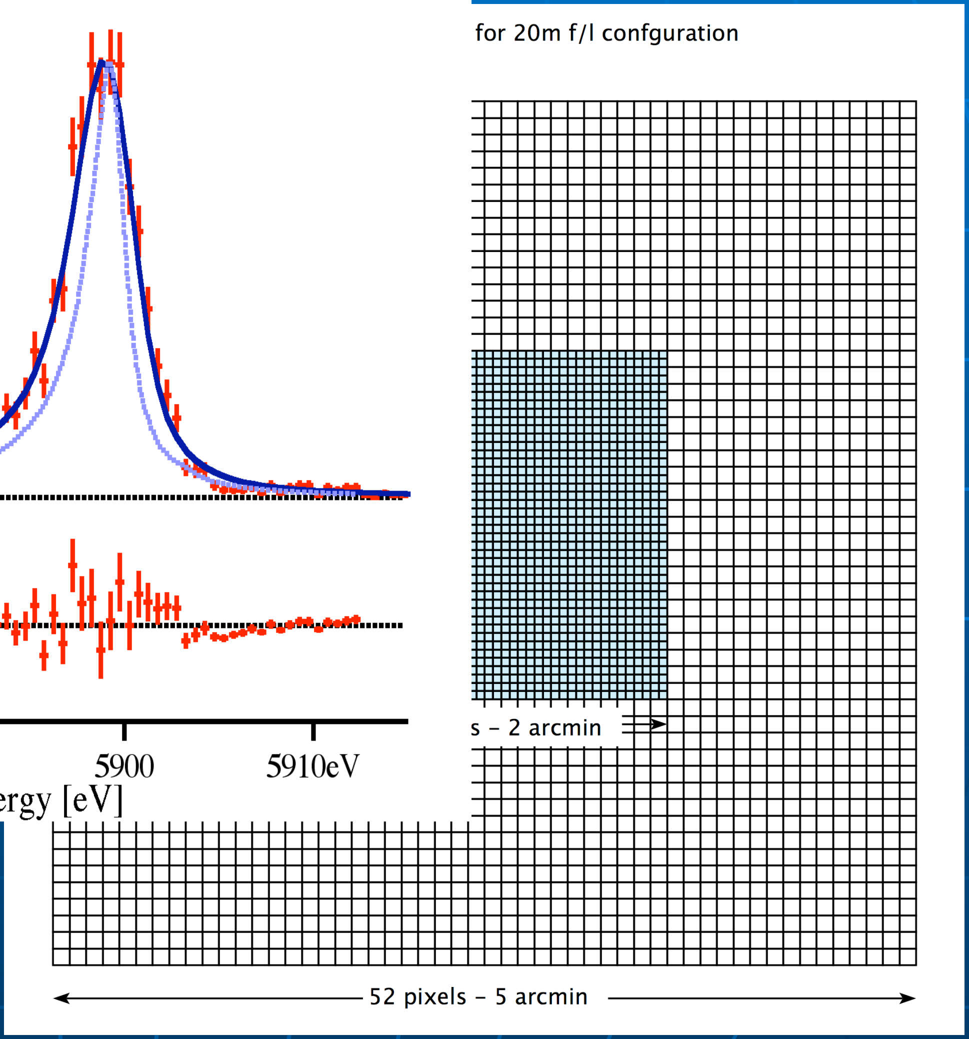


- Key requirements:
  - Effective area ~3 m^2 @ 1.25 keV ; ~1 m^2 @ 6 keV
  - Angular Resolution <= 5 arc se
- Single optic with design optimized to minimize mass and maximize the collecting area ~3.4m diameter
- Two parallel technology approaches being pursued
  - Silicon micro-pore optics – ESA
  - Slumped glass – NASA
- Both making good progress

X-ray Micro-Calorimeter Spectrometer

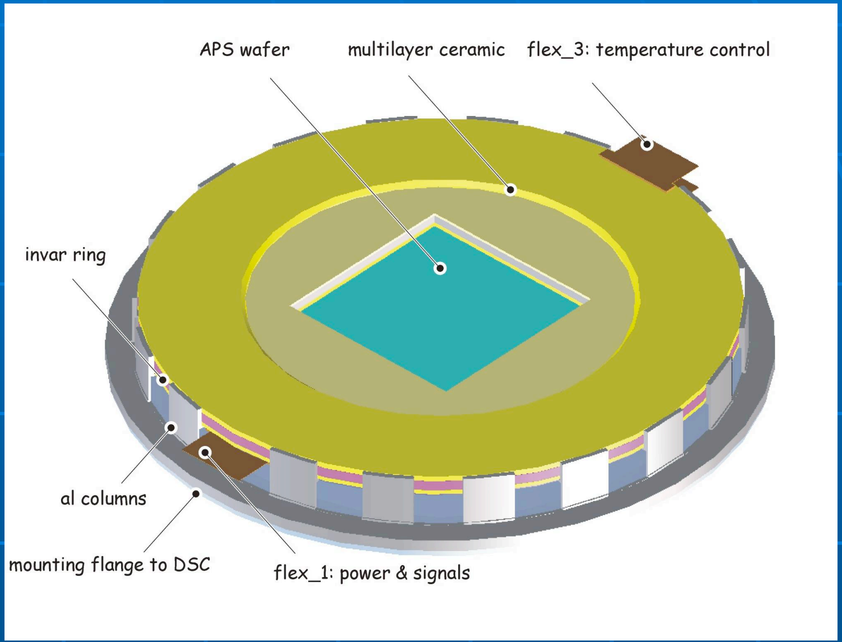
- Central,
  - Indivi
  - 42 x 4
    sec pi
  - 2.0 ar
  - 2.5 eV
  - ~ 300
- Outer, ex
  - 4 abso
  - Exten
    FOV
  - 52 X 5
    arcmin pixels
  - <10 eV resolution
  - <2 msec time constant



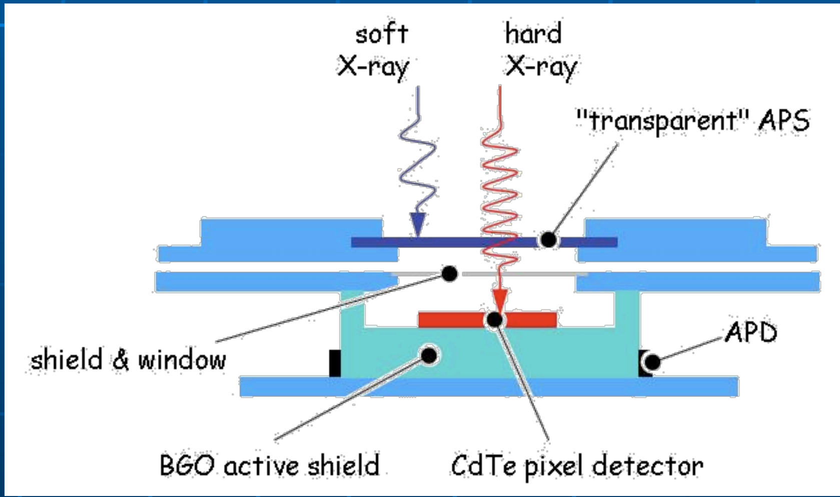


IXO Wide Field and Hard X-ray Imagers

Wide field imager (WFI):
Silicon active pixel sensor
- field of view: 12 arcmin
- energy range: 0.1 to 15 keV
- energy resolution: < 150 eV @ 6 keV
- count rate capability: 8 kcps (< 1% pileup)

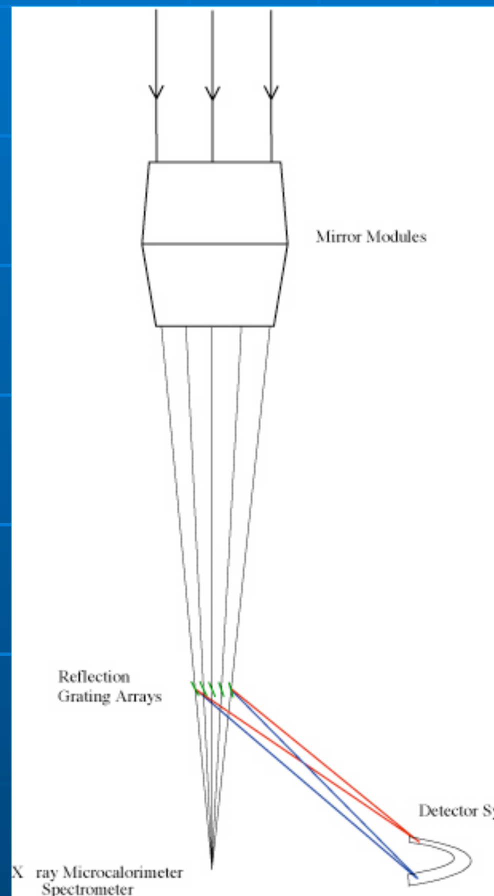


Hard X-ray imager (HXI):
Cd(Zn)Te pixel array located behind WFI
- energy range extension to 40 keV
- field of view: 8 arcmin

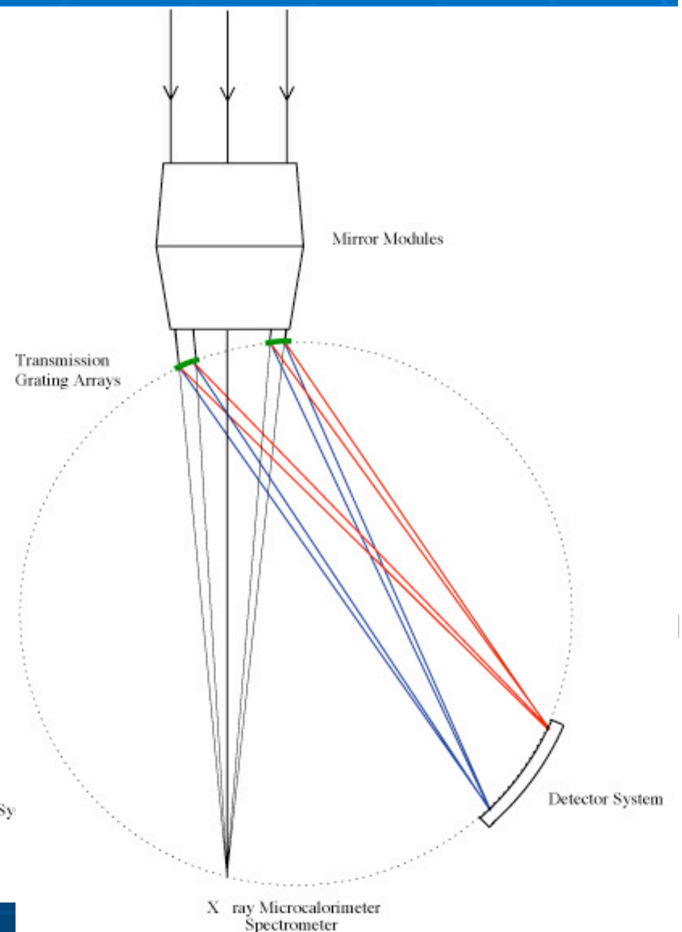


IXO X-ray Grating Spectrometer

- Two grating technologies are under study:
  - Critical Angle Transmission (CAT) grating
  - Off-plane reflection grating
- CCD detectors:
  - Back-illuminated (high QE below 1 keV),
  - Fast readout with thin optical blocking filters
  - Heritage from Chandra, XMM, Suzaku



Off-plane



Critical Angle Transmission

IXO Further Payload Elements

Possible modest payload elements include:

1. X-ray polarimeter
2. High time resolution, bright source capability

These capabilities may be part of the core instruments and/or an additional instrument

IXO Next Steps

- GSFC Mission Design Lab study of EOB concept in late July 2008, followed by more detailed studies through to Spring next year
- 2nd ESA Concurrent Design Facility study of EOB concept in Sept/Oct 2008, followed by 6-9 month industry study, with preliminary report in Spring 2009
- Formalize IXO coordination group until end of CV and Decadal process, broaden science membership by adding five new members (total 4 ESA, 4 NASA, 2 JAXA), in addition to Study Managers, Study Scientists and HQ representatives
- IXO US Facility Science Team meeting GSFC August 20-22
- IXO Workshop MPE Garching September 17-19
- IXO Coordination Group meeting MPE September 19-20
- Submit science case and concept to Decadal Survey and Cosmic Visions!

IXO Summary

- Agreement to proceed with a single large International X-ray Observatory, a factor 10-100 increase in capability
- The science case is very powerful and addresses key and topical questions
- The technology development is proceeding well
- We are on track to submit a very strong proposal to the US Decadal Survey and ESA Cosmic Visions process and know by 2010 the outcome