The International X-ray Observatory IXO

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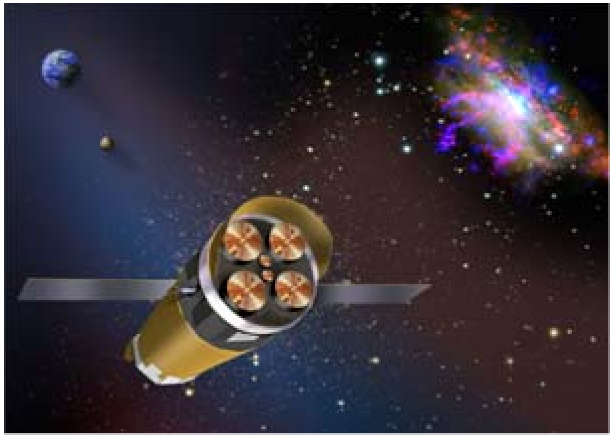
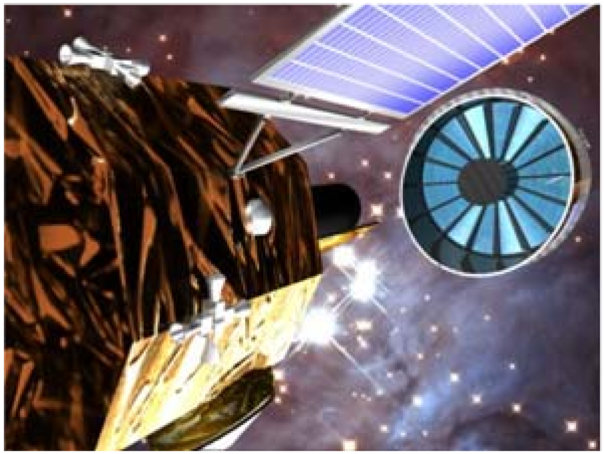
History





- The science case for a large X-ray Observatory 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 derived requirements and implementation approach
- Unlikely there will be two large X-ray missions at the same time, and it would be more cost effective to join forces
- Ongoing dialogue over many years had not resulted in an agreement to merge the missions

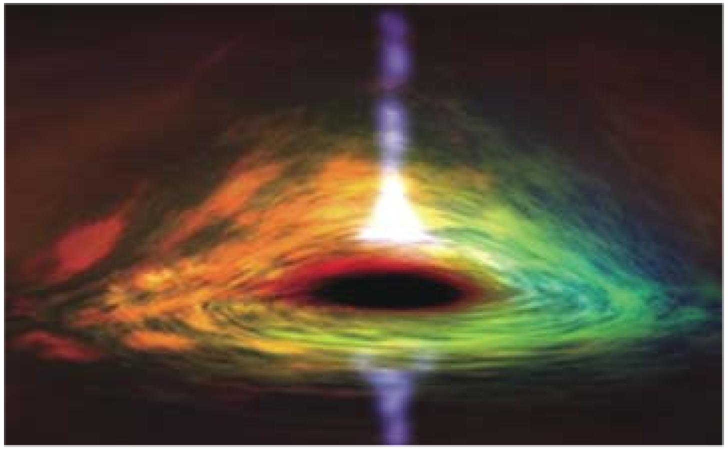
Recent events

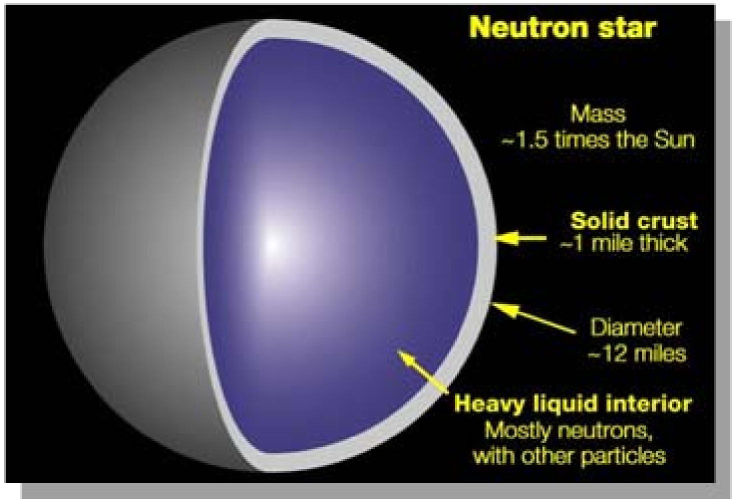
- Recent selection of *XEUS* as a candidate Cosmic Vision mission and upcoming US 2010 decadal survey which will reexamine the priority of *Con-X* made it timely to reconsider a merger
- In the spring of 2008, under the guidance and encouragement of ESA and NASA HQ, an effort began to see if we could 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 tri-agency study called the ***International X-ray Observatory***
- The result of this study will be submitted to the 2010 “Decadal Survey”, Cosmic Visions and the JAXA approval process

IXO Science Objectives

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

Black Holes and Matter under Extreme Conditions



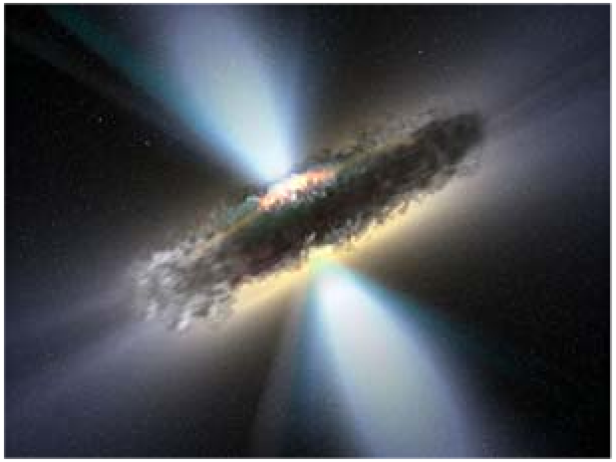


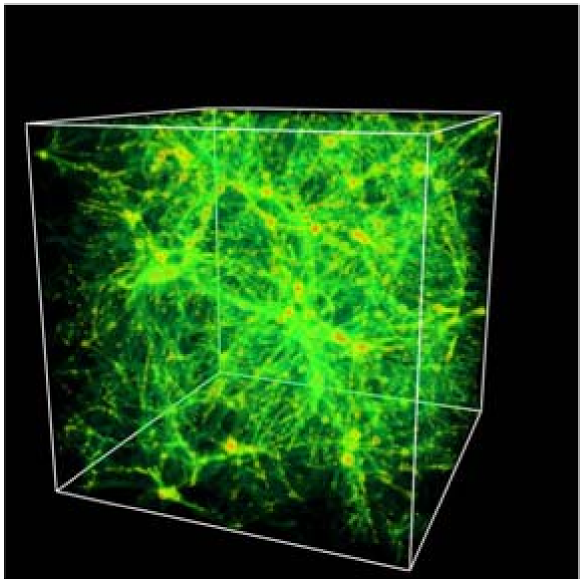
How do super-massive Black Holes grow and evolve?

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?

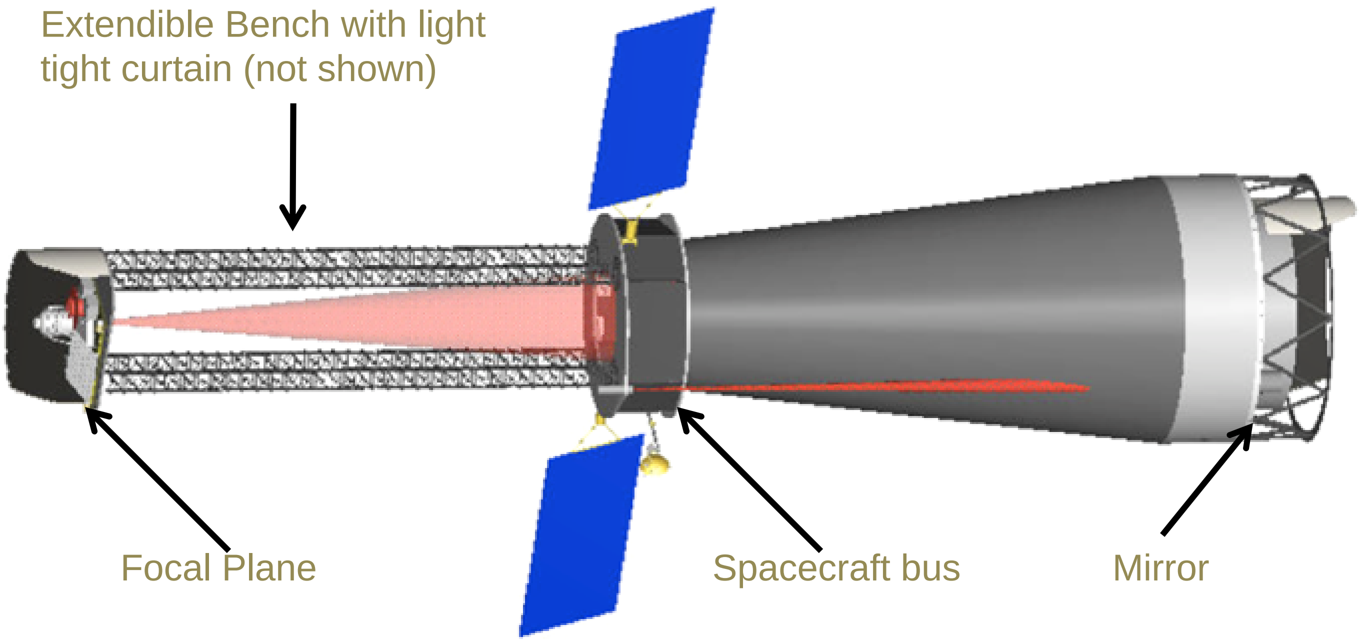
How do magnetic fields shape stellar exteriors and the surrounding environment?

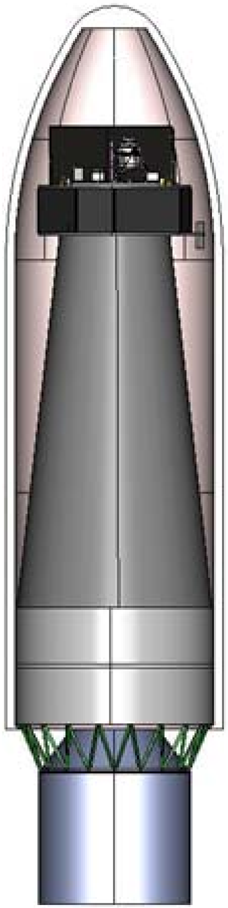
How are particles accelerated to extreme energies producing shocks, jets and cosmic rays?

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 select 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

Preliminary IXO Mission Concept (May 2008)



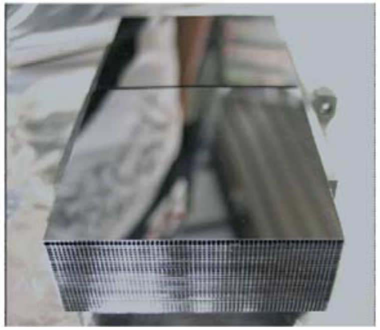


- L2 Orbit; 700,000 km radius halo orbit
  - High operational efficiency
  - Uninterrupted viewing
  - Stable temperature
- 5 year life; 10 years on consumables

X-ray Mirror Baseline

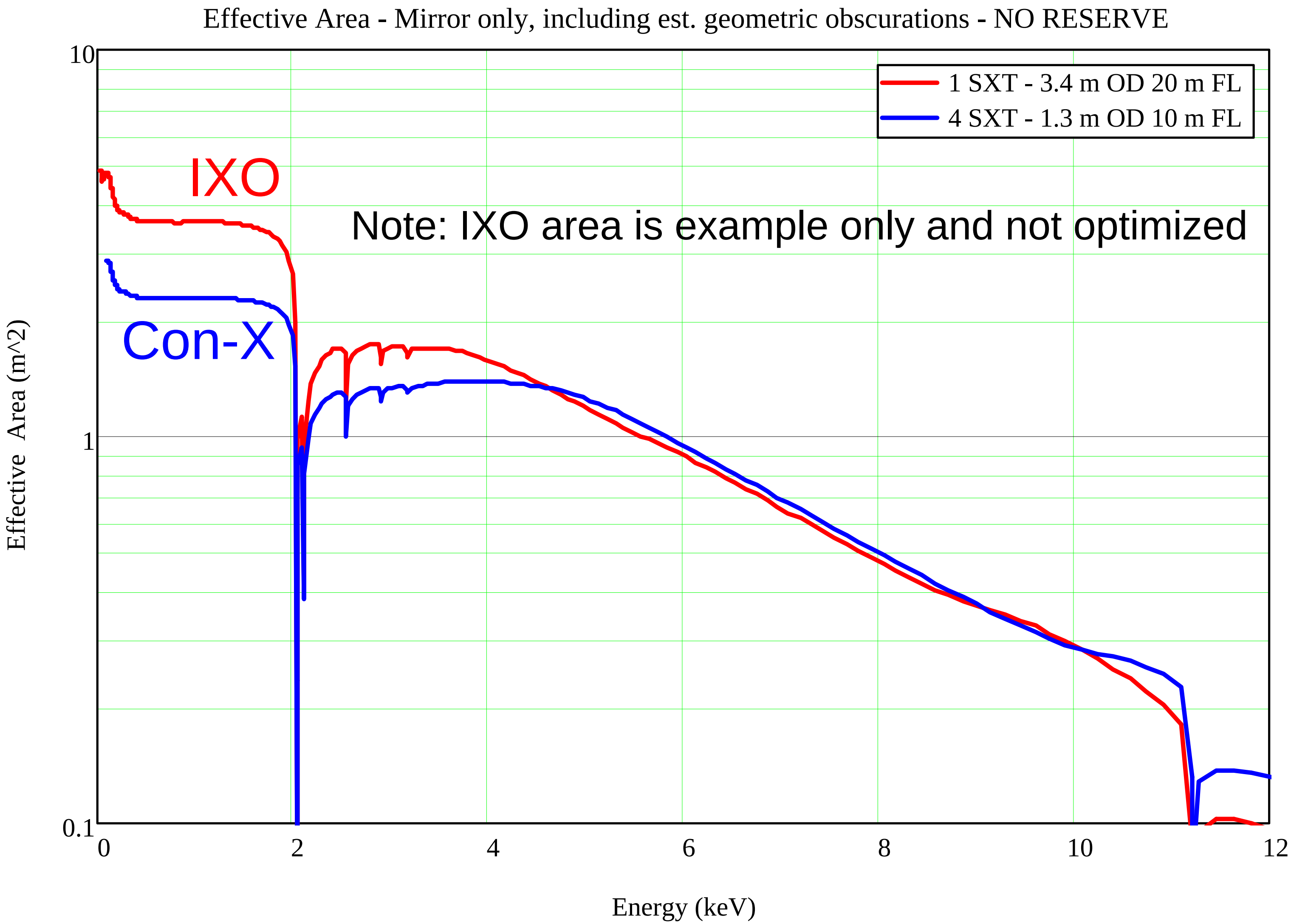
Glass

Silicon

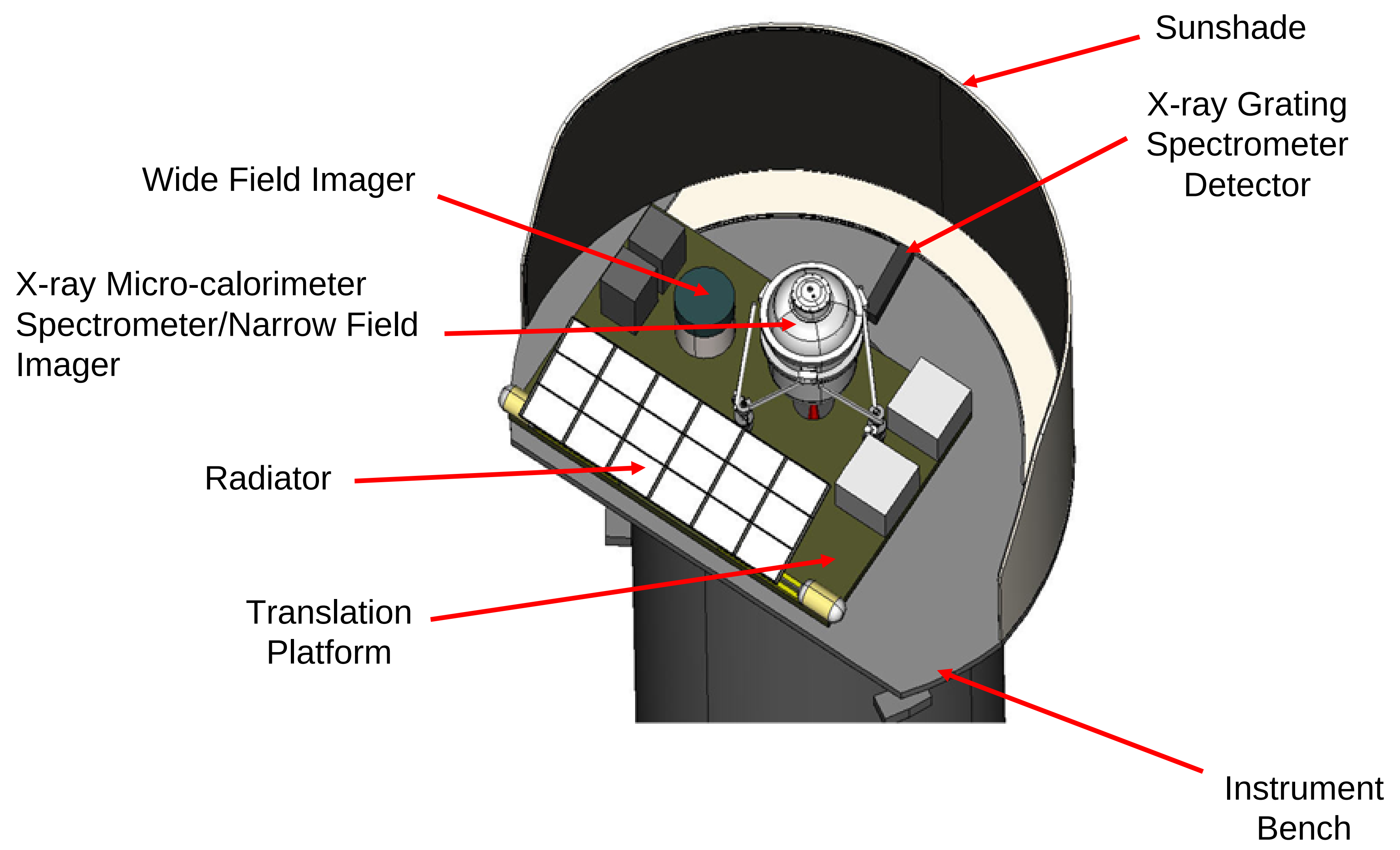


- Key requirements:
  - Effective area ~3 m^2 @ 1.25 keV ; ~1 m^2 @ 6 keV
  - Angular Resolution <= 5 arc sec
- Single segmented optic with design optimized to minimize mass and maximize the collecting area ~3.2m diameter
- Two parallel technology approaches being pursued
  - Silicon micro-pore optics – ESA
  - Slumped glass – NASA
- Both making good progress

Telescope area compared to Con-X configuration



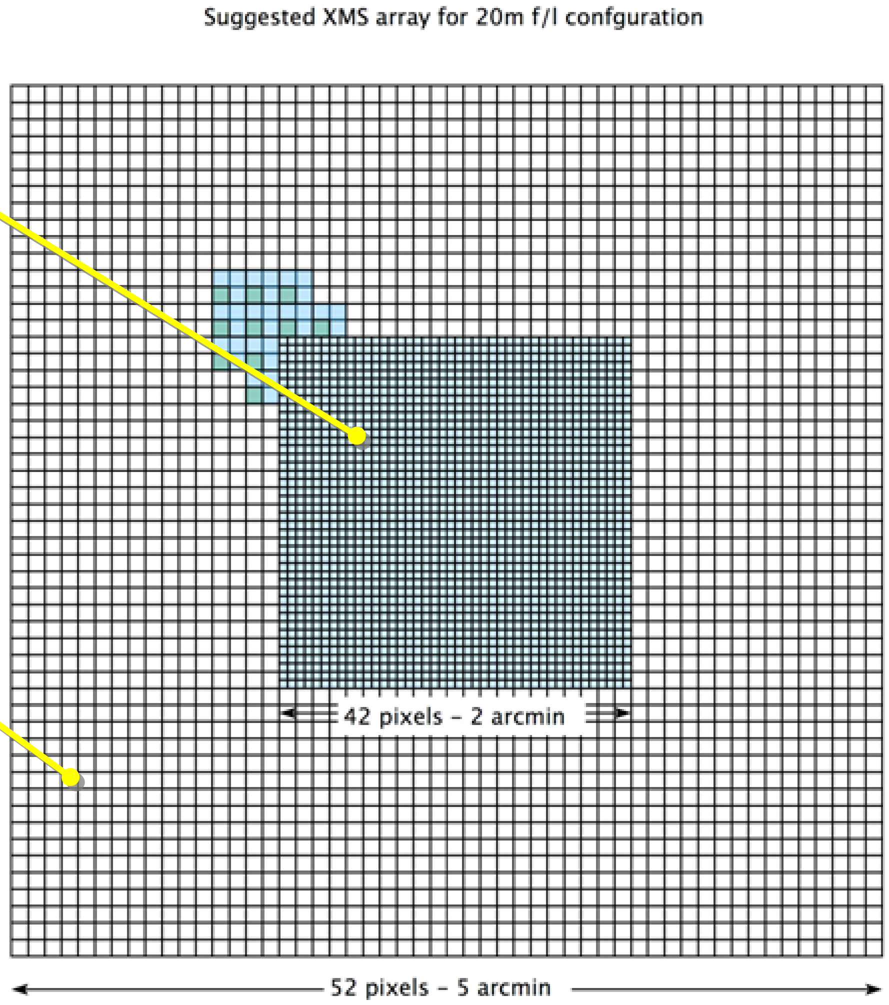
Focal Plane - Preliminary Layout (May 2008)



X-ray Micro-Calorimeter Spectrometer

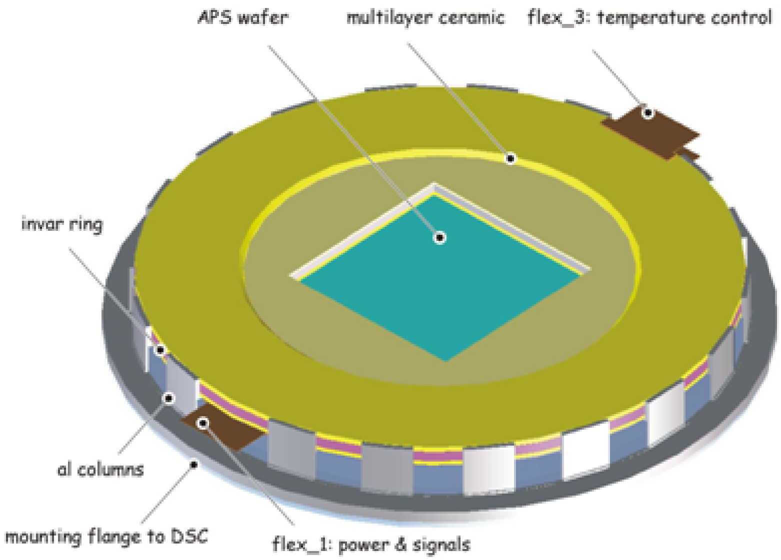
- **Central, core array:**
  - **Individual TES**
  - **42 x 42 array with 2.9 arc sec pixels**
  - **2.0 arcmin FOV**
  - **2.5 eV resolution (FWHM)**
  - **~ 300 μsec time constant**

- **Outer, extended array:**
  - **4 absorbers / TES**
  - **Extends array to 5 arcmin FOV**
  - **52 X 52 array with 5.8 arcmin pixels**
  - **<10 eV resolution**
  - **<2 msec time constant**

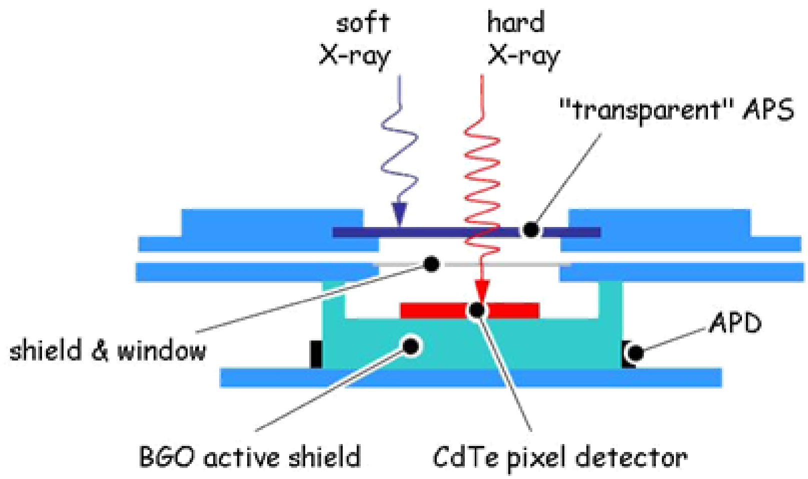


Wide Field and Hard X-ray Imagers

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)

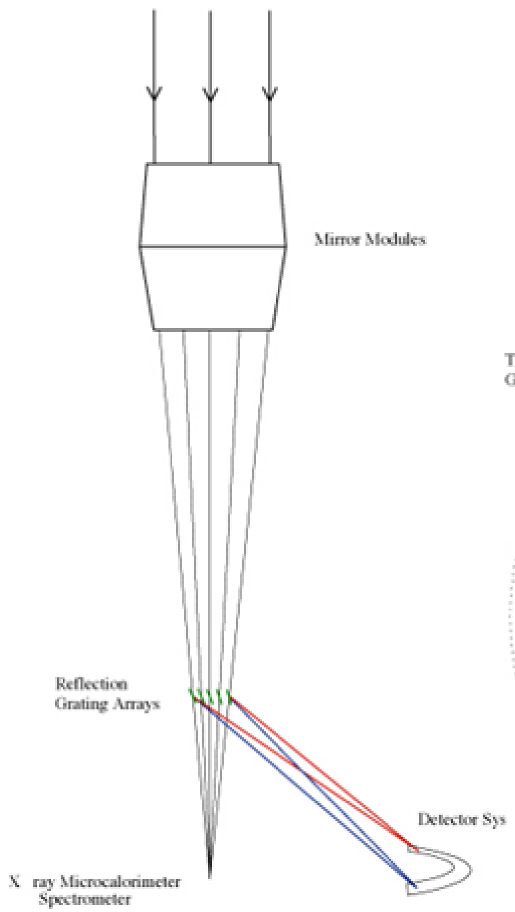


Hard X-ray imager (HXI):
Cd(Zn)Te pixel array located behind WFI
- Energy range extension to 40 keV
- field of view: 8 arc min

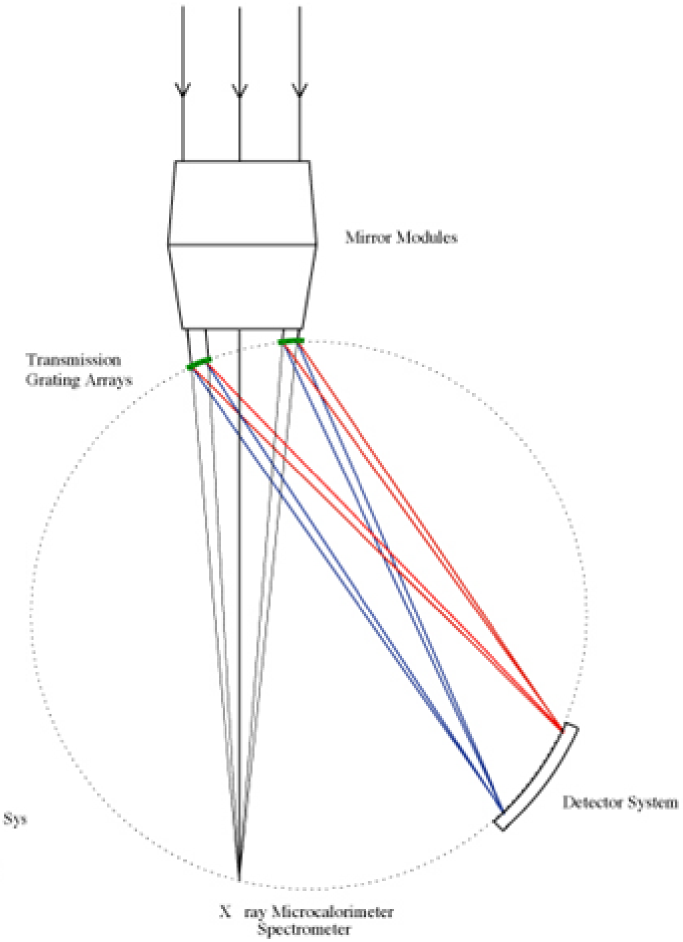


X-ray Grating Spectrometer

- Gratings provide high spectral resolution at low energies
- 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



Off-plane



Critical Angle Transmission

Further Payload Elements

Possible additional modest payload elements include:

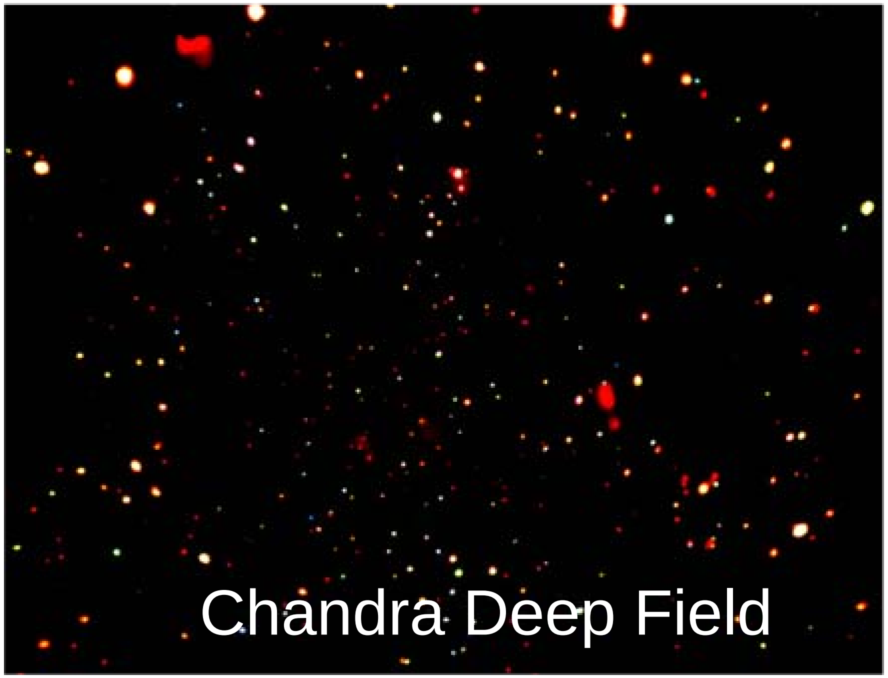
1. X-ray polarimeter
2. High time resolution, bright source capability
3. Separate Hard X-ray Telescope

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

Key Performance Requirements

Mirror Effective Area	**3 m^2 @1.25 keV** ~1 m^2 @ 6 or 7 keV 150-1000 cm^2 @ 40 keV	Black hole growth/evolution, large scale structure, cosmic feedback, EOS studies. Strong gravity, EOS studies Cosmic acceleration, strong gravity
Spectral Resolution	>1250 @ 0.3 – 1 keV (point sources > 1,000 cm^2) < 2.5 eV @ 0.5 - 2.0 keV (extended sources) 2400 @ 6 keV (< 2.5 x 2.5 arc min) >600 @ 6 keV (> 2.5 arc min)	Missing baryons using many tens background AGN Large scale structure Large scale structure
Angular Resolution	=<5 arc sec HPD (0.3 – 10 keV) 10-30 arc sec HPD (10 - 40 keV)	Large scale structure, cosmic feedback, black hole growth/evolution, missing baryons Strong gravity, black hole growth
Field of View	5 x 5 arc min with < 5 arc sec pixel >7 x 7 arc min with ~1 arc sec pixel	Large scale structure, cosmic feedback Black hole surveys
Count Rate	1 Crab with < 10% dead time	Strong gravity, X-ray bursts and QPOs

Black Hole Growth & Evolution



Chandra and XMM-Newton deep fields reveal that super-massive Black Holes are common throughout the Universe and that X-ray observations are a powerful tracer of their evolution

The origin and evolution of those Black Holes and their connection to galaxy formation remains a mystery

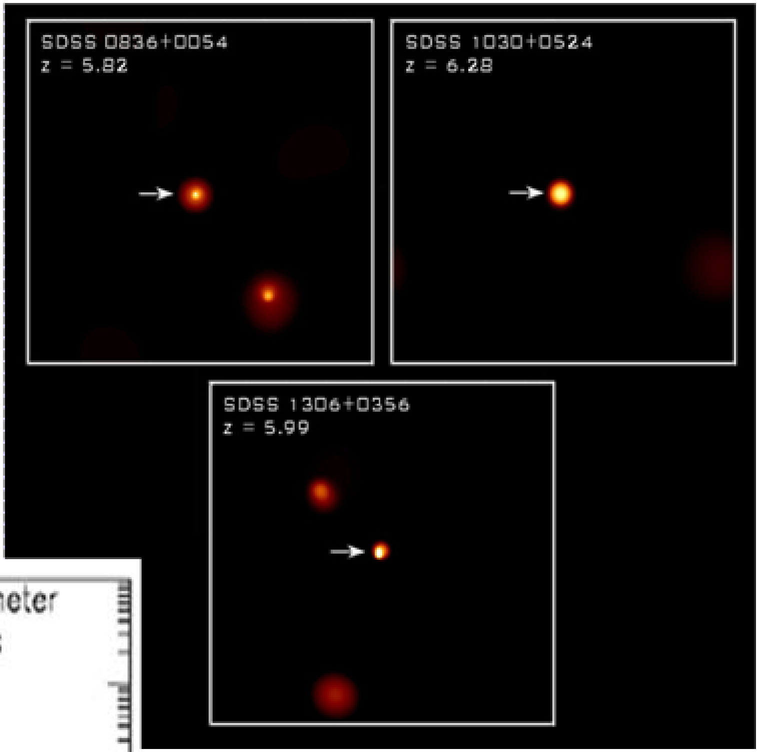
The challenge is that most X-ray observations have moderate resolution CCD spectra $E/\Delta E < 30$, insufficient for detailed diagnostics e.g. redshift measurements

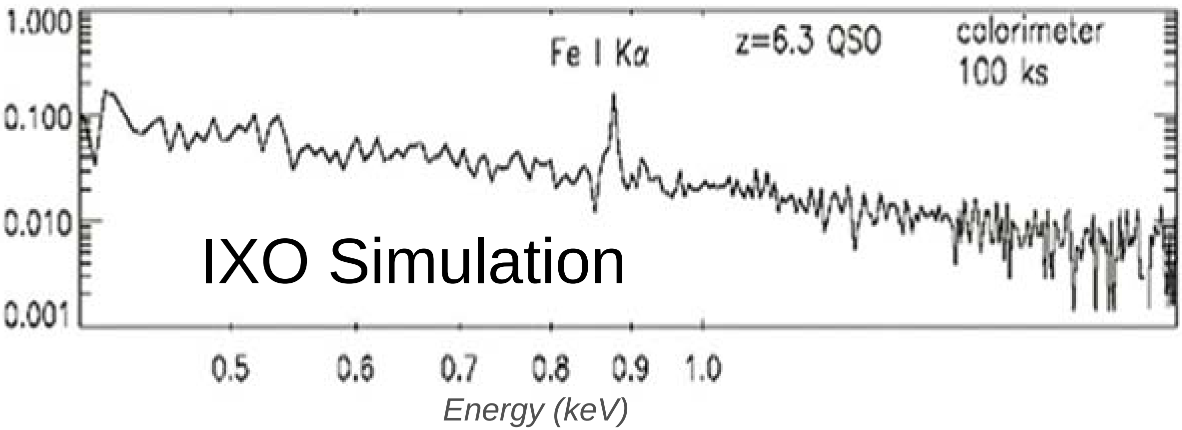
To meet this IXO Black Hole science goals requires ~ 3 sq m telescope area with 5 arc sec imaging combined with high resolution spectroscopy

High Redshift Quasars

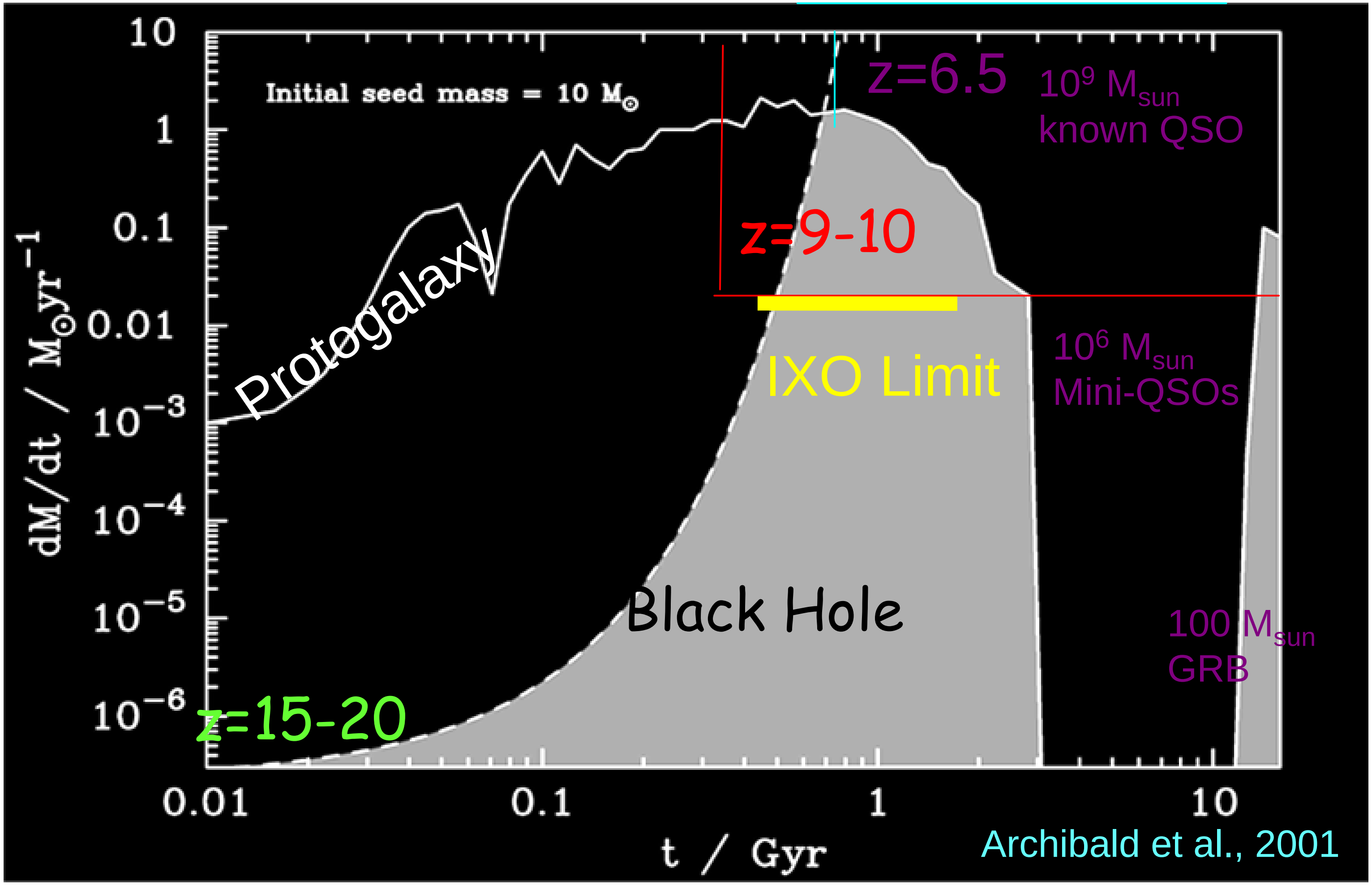
Chandra has detected X-ray emission from ~100 high redshift quasars at z > 4 (3 examples from SDSS shown)

These are too faint for current and planned high resolution spectrometers, but easily within the capabilities of IXO to determine redshift and critical source diagnostics



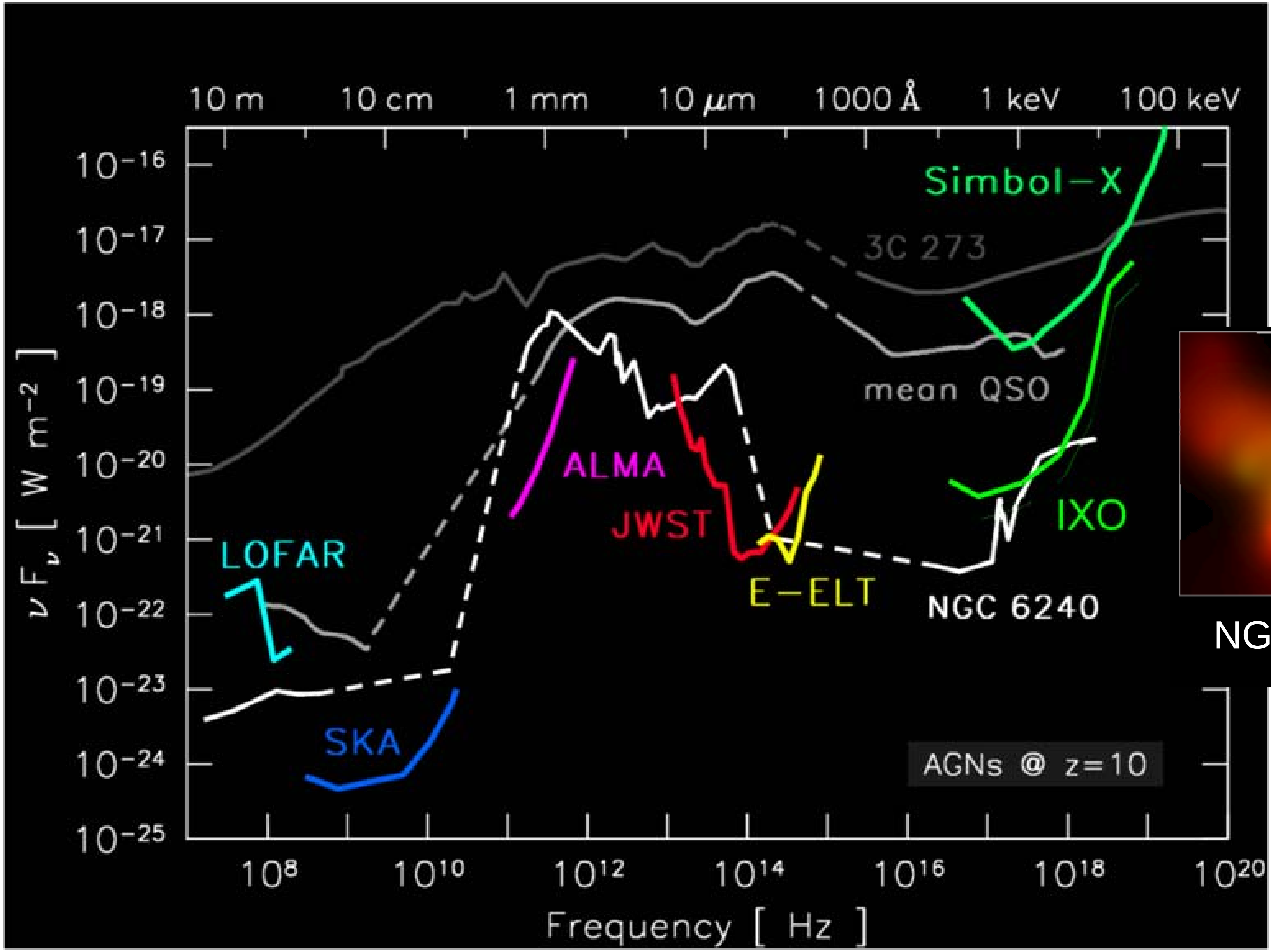


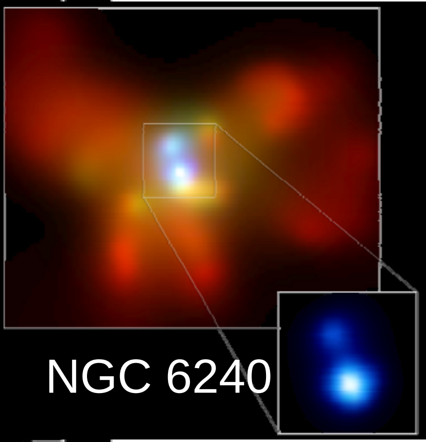
First Black Holes



A 10^6 M_o Black Hole accreting at the Eddington limit @ redshift of 10 can be detected by IXO

Multi-λ Power of future facilities @ z=10





NGC 6240

Next Steps

- GSFC Mission Design Lab study of EOB concept in late July 2008, followed by more detailed studies through to Spring next year (see Jean Grady talk)
- ESA IXO Concurrent Design Facility study of EOB concept in Oct/Nov 2008, followed by 6-9 month industry study, with preliminary report in Spring 2009
- IXO coordination group science membership will be broadened by adding five new members (total 4 ESA, 4 NASA, 2 JAXA), in addition to Study Managers, Study Scientists and HQ representatives for each agency
- IXO Facility Science Team meeting GSFC August 20-22
- IXO Workshop MPE Garching September 17-19
- Next IXO Coordination Group meeting MPE September 19-20
- ……….
- Submit science case and concept to Decadal Survey and Cosmic Visions!

Summary

- Agreement to proceed with a tri-agency ESA-JAXA-NASA study of an International X-ray Observatory
- The science case is very powerful and at the frontier of current hot science topics
- The IXO mission concept is robust and the technology development is proceeding well
- We are on track to submit a strong tri-agency proposal to the US Decadal Survey and ESA Cosmic Visions process