The International X-ray Observatory IXO

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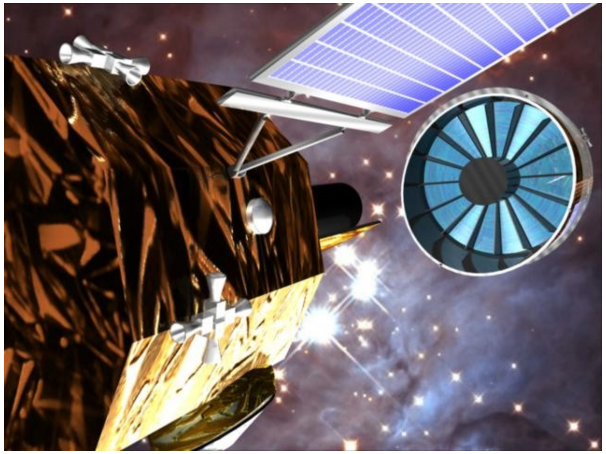
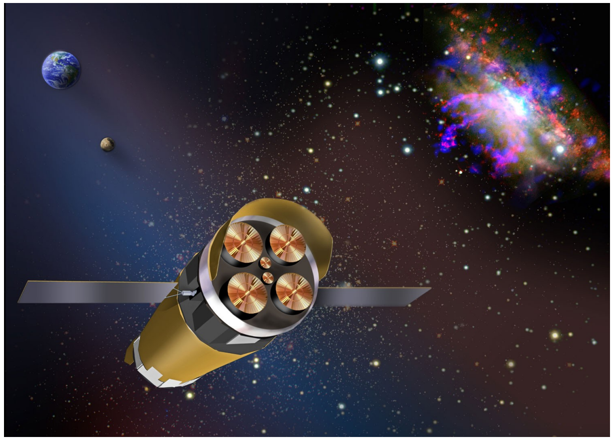
History





- The science case for a large X-ray Observatory is compelling:
  - XEUS: ESA with JAXA candidate as large Cosmic Vision mission
  - Con-X: NASA concept, number two in 2000 Decadal survey
- 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
- However, this recently changed…

Recent events

- Recent selection of XEUS as a candidate L-class Cosmic Vision mission and upcoming US 2010 decadal survey which will re-examine 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 HQs, 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, with JAXA concurrence
- The Con-X and XEUS studies will be replaced by a single tri-agency study called the *International X-ray Observatory*

Cosmic Vision Selection

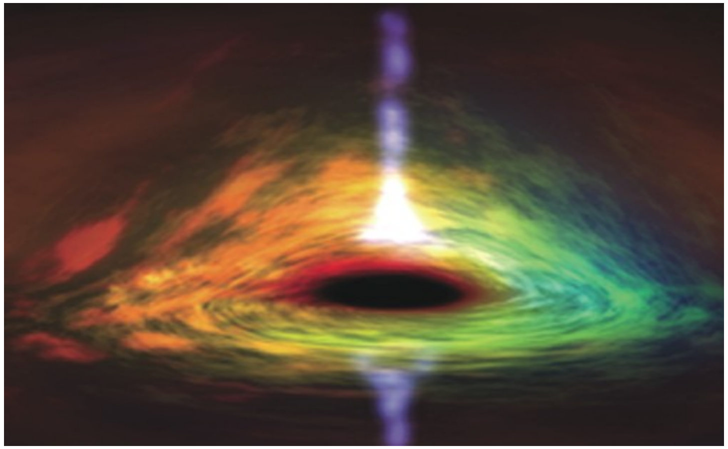
CV selection provides XEUS/IXO with:

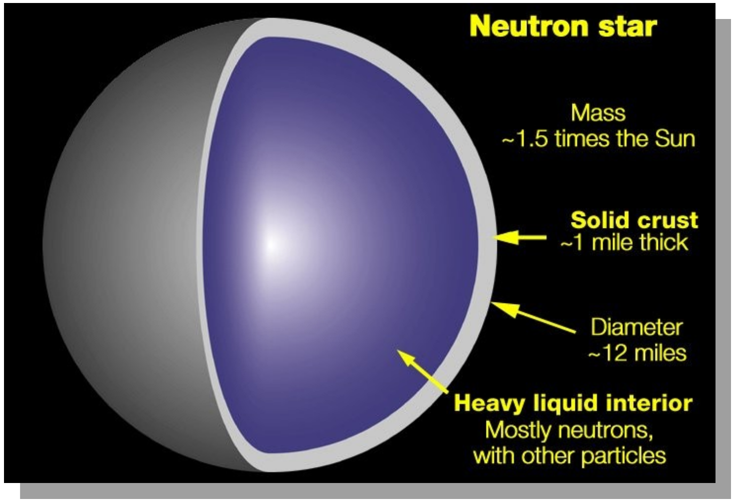
4. Visibility within the ESA Science Programme
5. Access to ESA funding for further technology development
6. Establishment of a science advisory structure
7. Access to funding for an industrial level assessment study following internal evaluation in the CDF (Coordinated Design Facility ≈ NASA's MDL)
8. Chance to compete for a Definition Study (3 => 2 down selection with 2 studies in parallel) sometime in ~2010.

IXO Science Objectives

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

Black Holes and Matter under Extreme Conditions



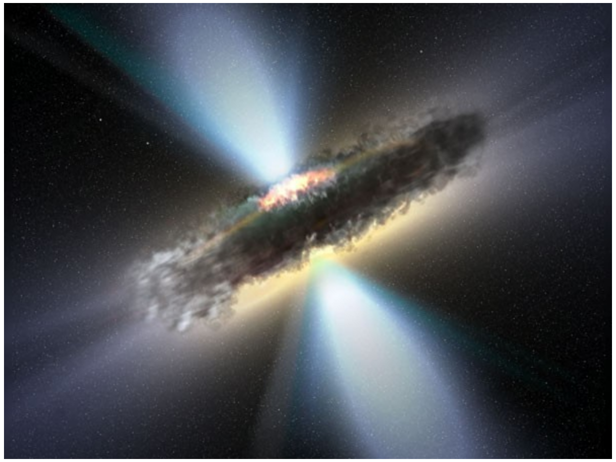


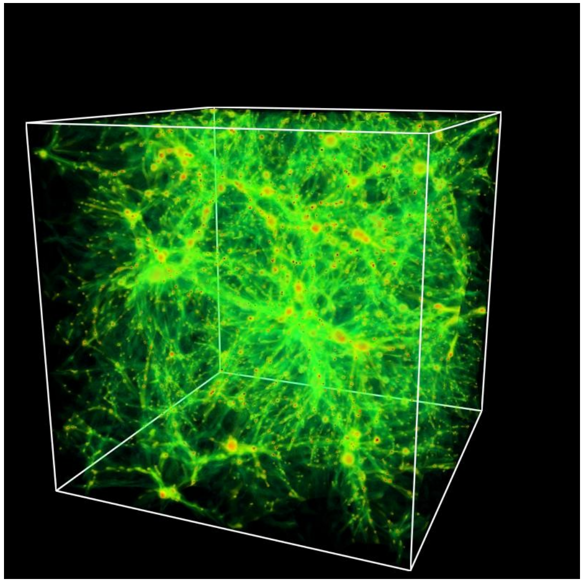
How do super-massive Black Holes grow and evolve?

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



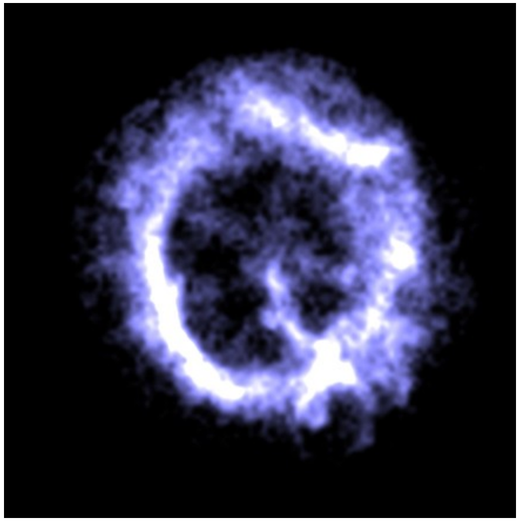


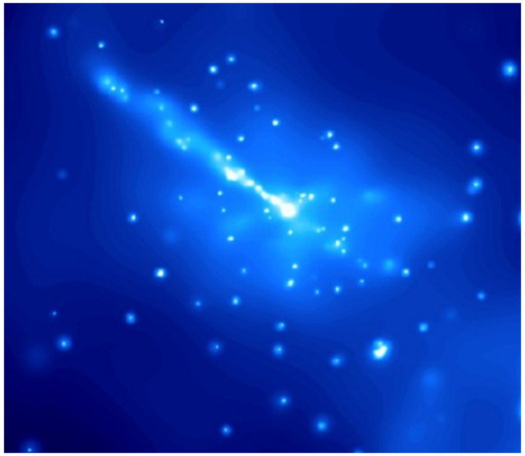
How does Cosmic Feedback work and influence galaxy formation?

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?

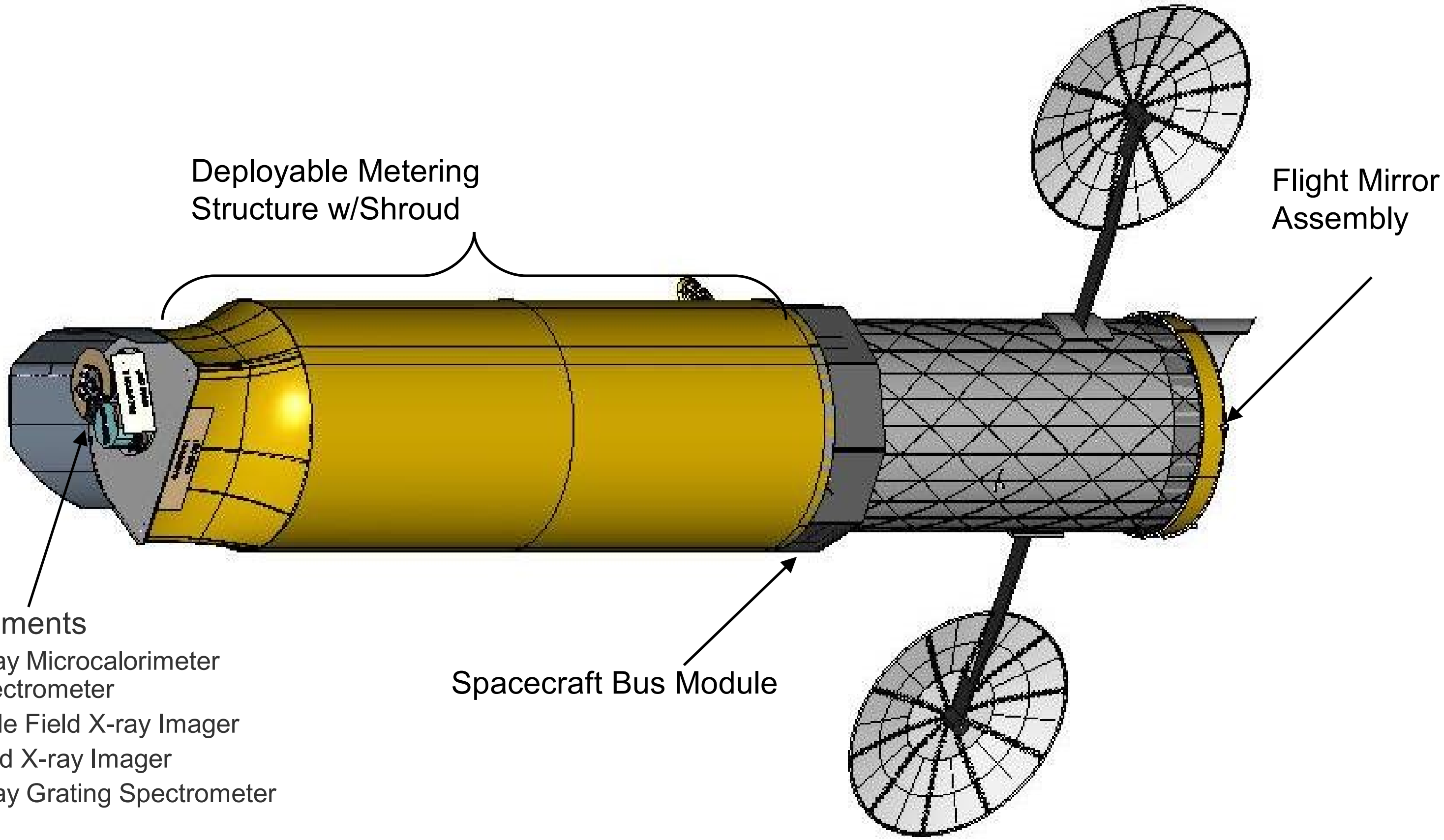
How do magnetic fields shape stellar exteriors and the surrounding environment?

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

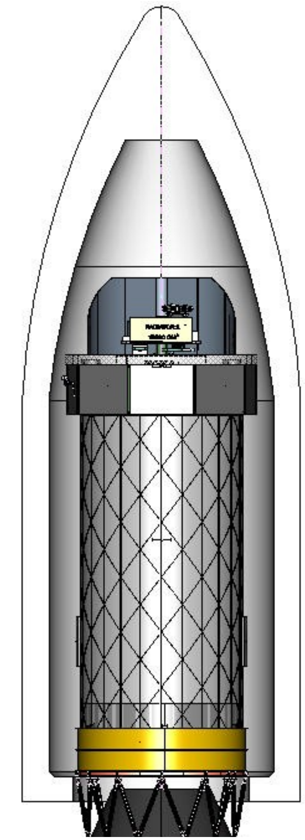
Agreed Baseline Concept

- Focal length of 20-25m with extendible optical bench
- Concept must accommodate both glass (NASA) and HPO silicon (ESA) optics technology (with final select at the appropriate time)
- Concept compatible with Ariane 5 and Atlas V 551
- Core instruments to include:
  - Wide Field Imager including Hard X-ray Imager
  - X-ray Micro-calorimeter/Narrow Field Imager
  - X-ray Grating Spectrometer
  - Allocation for further modest payload elements such as a high time resolution instrument and a

Preliminary IXO Mission Concept (from NASA MDL)



Instruments
- X-ray Microcalorimeter Spectrometer
- Wide Field X-ray Imager
- Hard X-ray Imager
- X-ray Grating Spectrometer



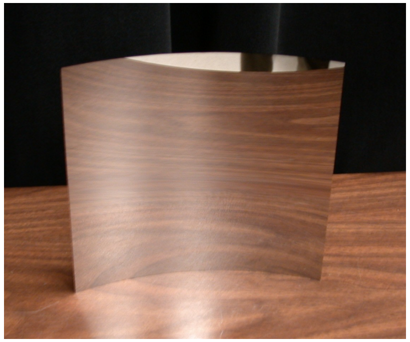
Atlas V 551 Medium Composite Fairing

- 5 year life; 10 years on consumables

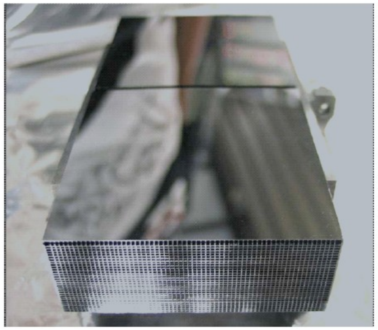
X-ray Mirror Baseline

- Key requirements:
  - Effective area ~3 m^2 @ 1.25 keV ; ~1 m^2 @ 6 keV (TBD)
  - 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 and choice will be made at the appropriate time

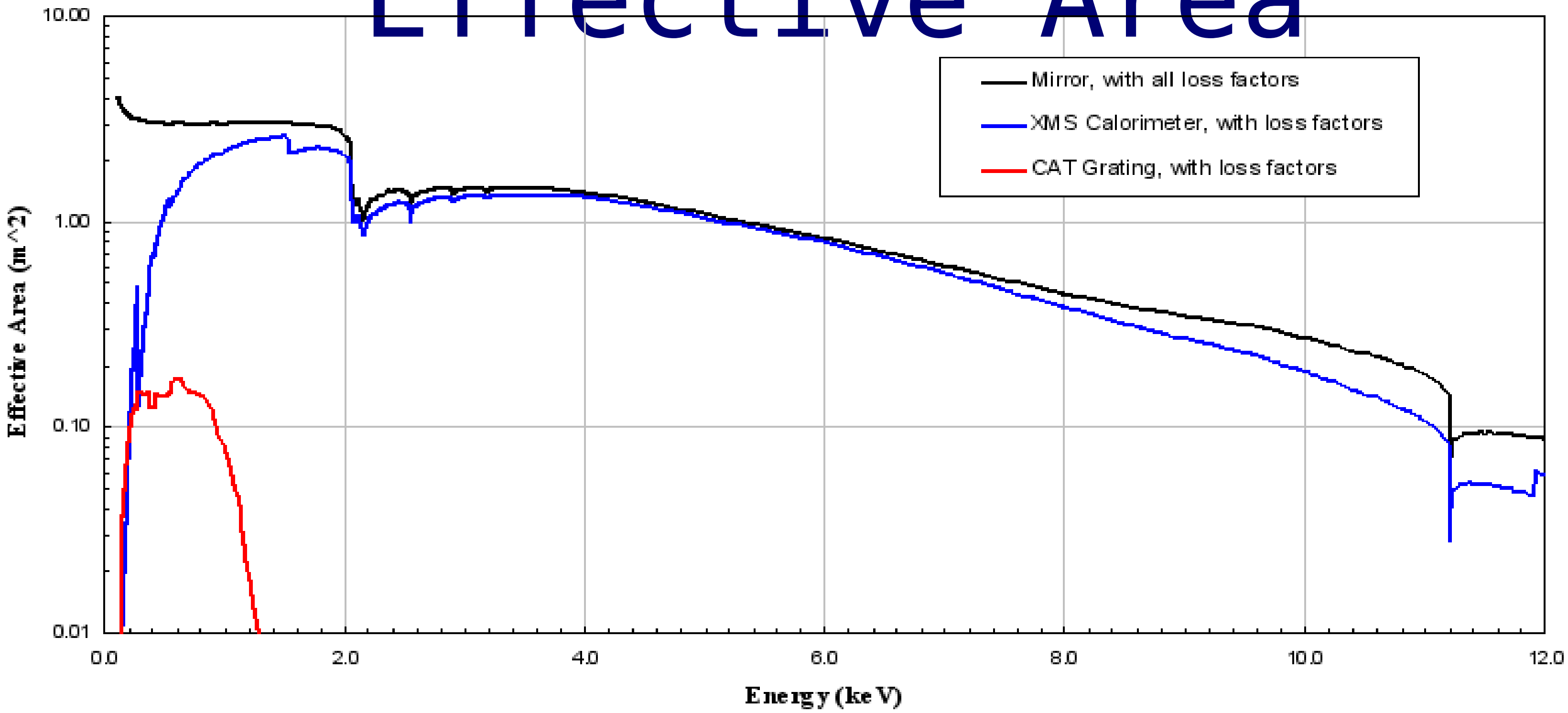
Glass



Silicon



Current Mission Effective Area

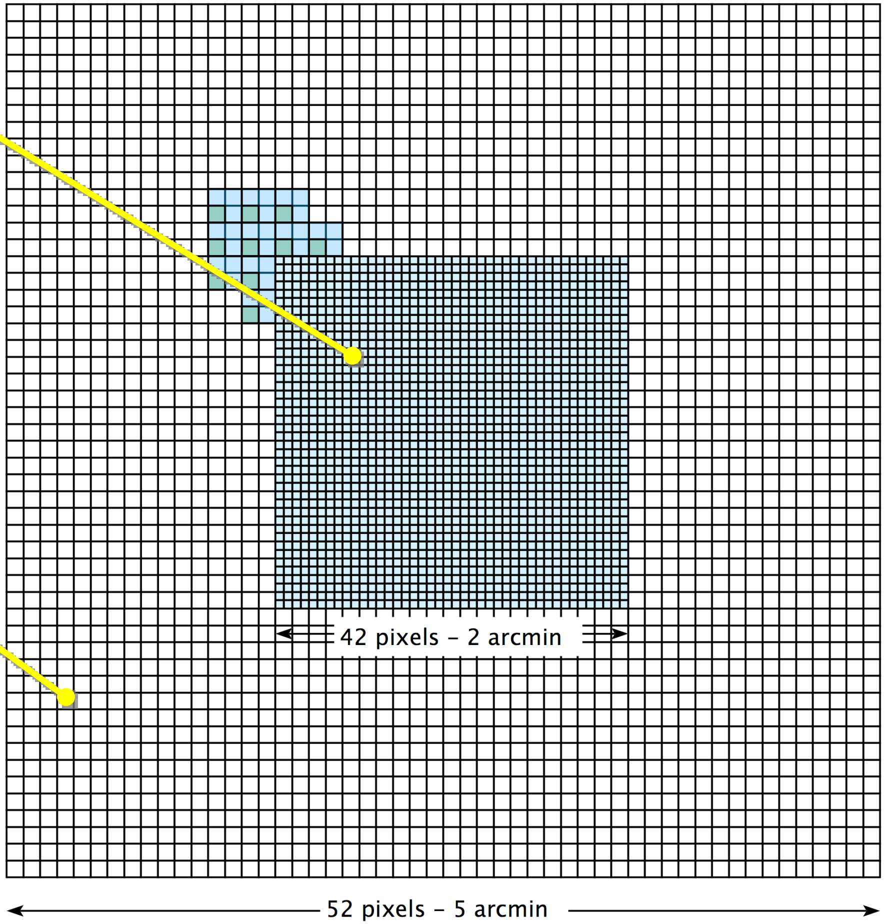


- Flight Mirror Assembly (Glass optics)
  - 3.3 m overall outer diameter (3.2 m largest diameter on optical surface)
  - 20 m focal length
  - Effects of multi-coating, optimising the focal length and inner radius etc under investigation

X-ray Micro-Calorimeter Spectrometer

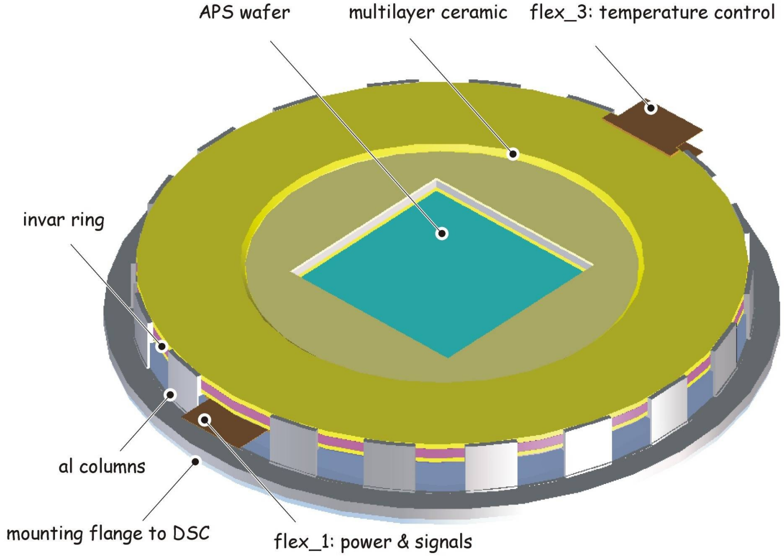
- Central, core array:
  - Individual TES
  - 42 x 42 array with 2.9 arc sec pixels
  - 2.0 arcmin FOV
  - 2.5 eV resolution (FWHM)
  - ~ 300 μ sec time constant
- Outer, extended array:
  - 4 absorbers/TES
  - Extends array to 5 arcmin FOV
  - 52 X 52 array with 5.8 arcmin pixels
  - <10 eV resolution
  - <2 msec time constant

Suggested XMS array for 20m f/l confguration

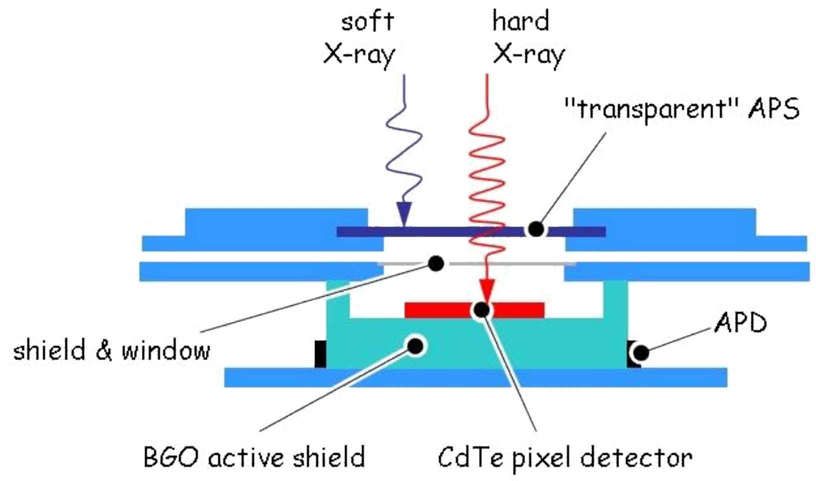


Wide Field and Hard X-ray Imagers

Wide field imager (WFI):
Silicon active pixel sensor
- field of view: 14 arcmin
- energy range: 0.1 to 15 keV
- energy resolution: <150 eV @ 6 keV
- count rate capability: 8 kcps (< 1% pileup)

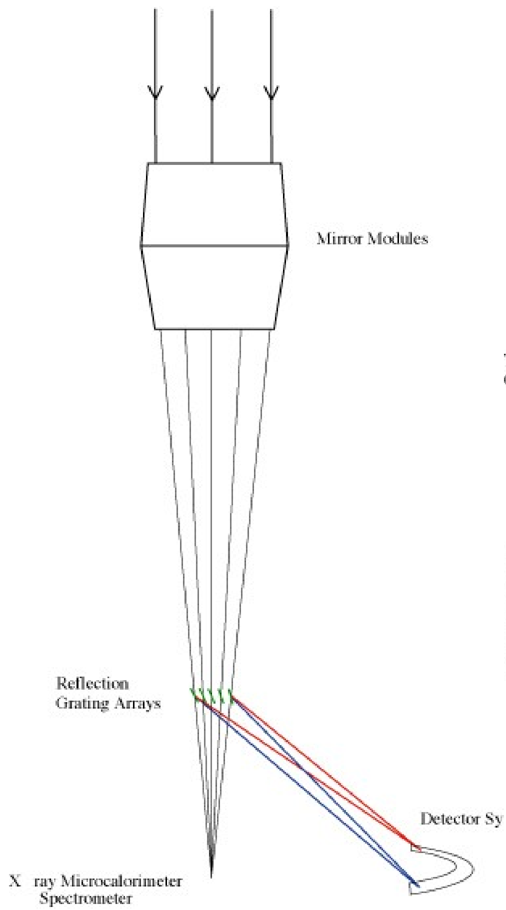


Hard X-ray imager (HXI):
Cd(Zn)Te pixel array located behind WFI
- Energy range extension to 40 keV
- field of view: 8 arc min

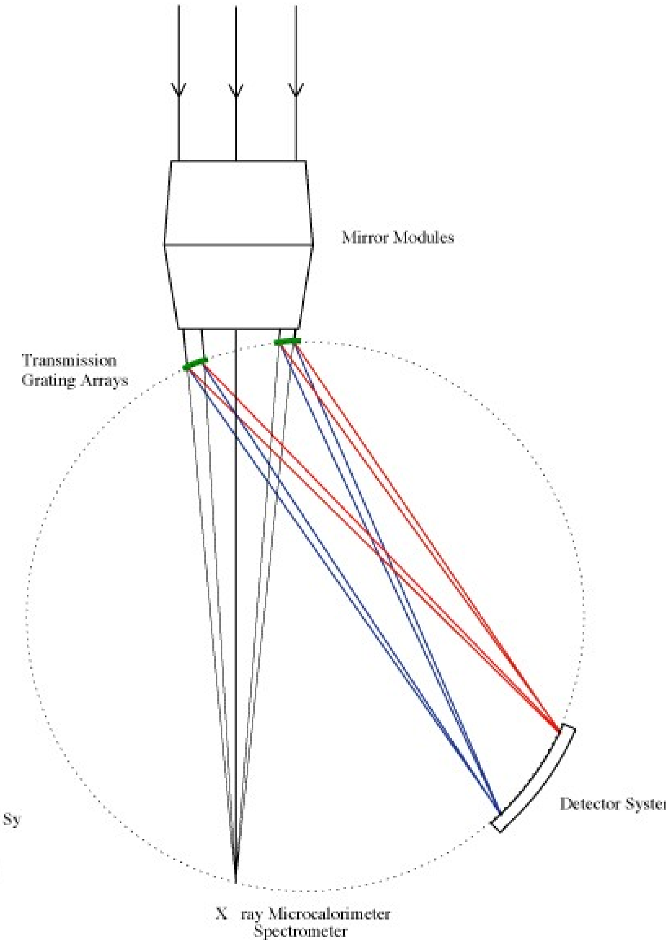


X-ray Grating Spectrometer

- 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

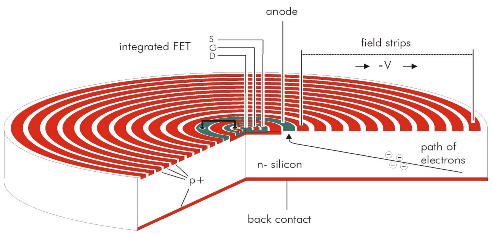
Further Payload Elements

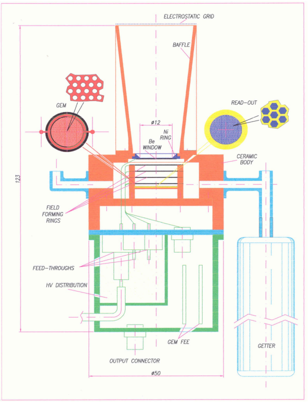
Additional modest payload elements could include:

3. X-ray polarimeter

- High time resolution, bright source capability

- Separate Hard X-ray Telescope

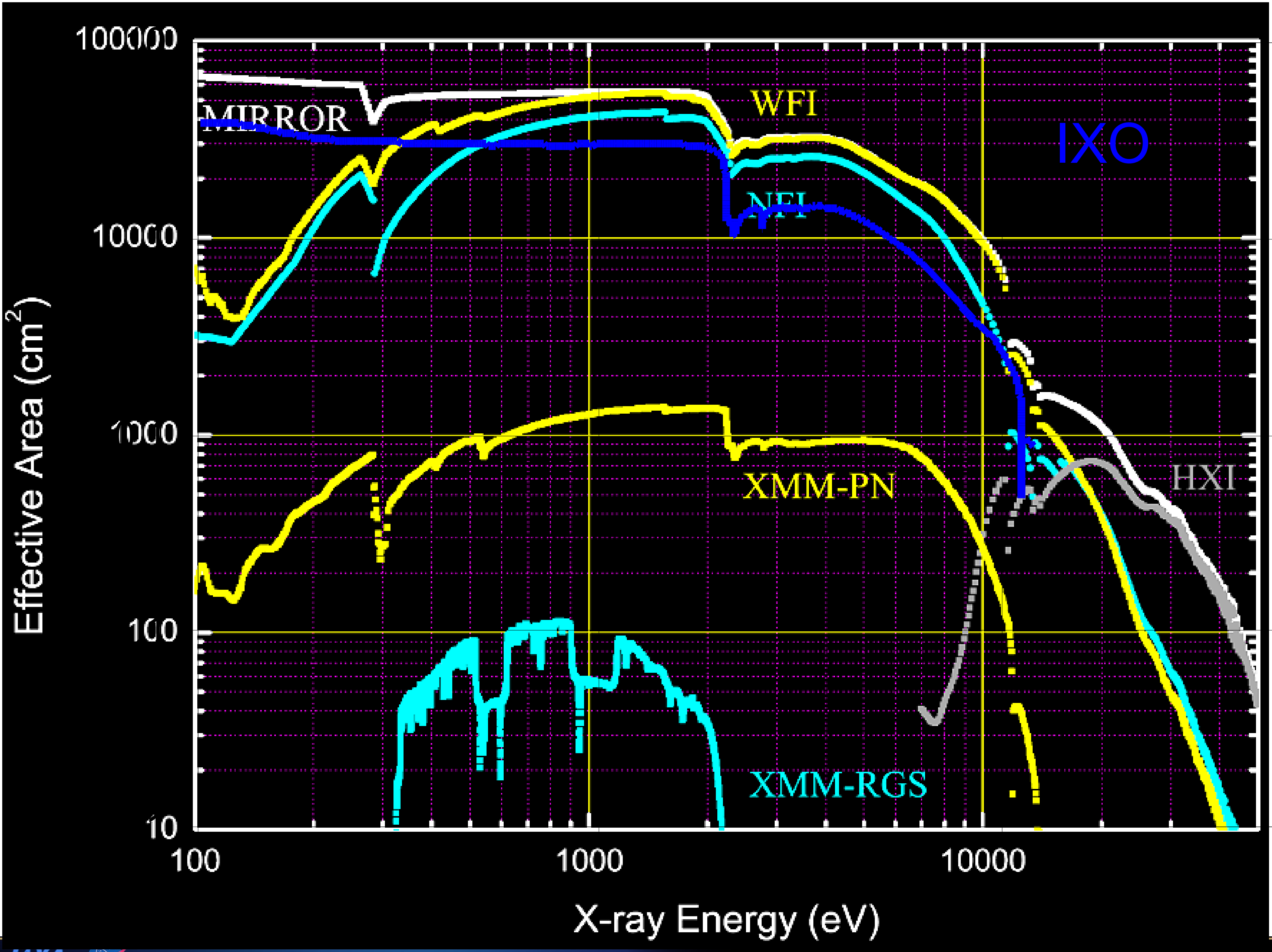




These capabilities may be part of the core instruments and/or an additional instruments

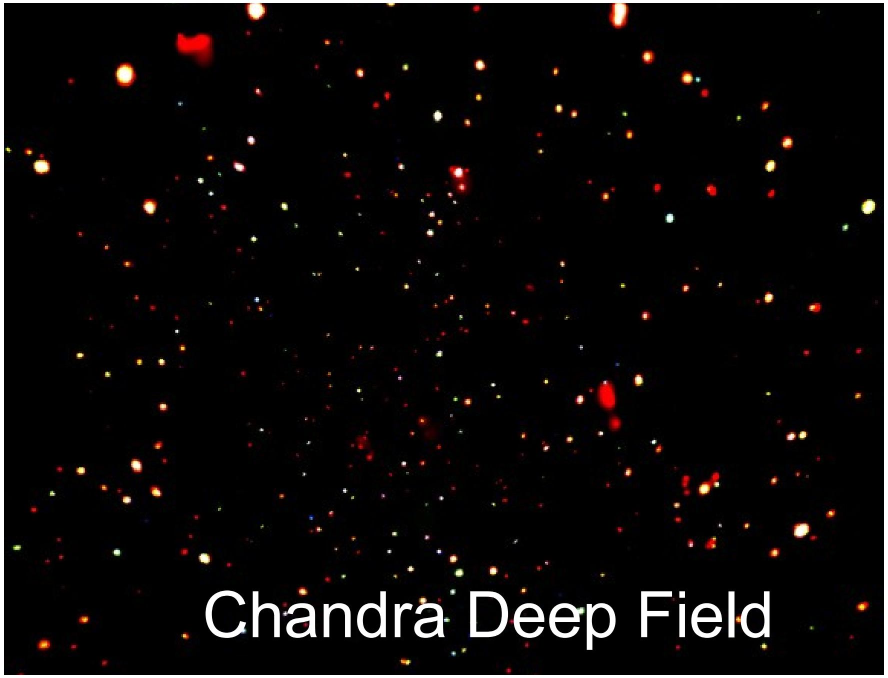
Key Performance Requirements

Mirror Effective Area	3 m² @1.25 keV ~1 m² @ 6 or 7 keV 150-1000 cm² @ 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 cm²) <2.5 eV @ 0.5 - 2.0 keV (extended sources) 2400 @ 6 keV (< 2.5 x 2.5 arcmin) >600 @ 6 keV (> 2.5 arcmin)	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 arcmin with <5 arc sec pixel >14 x 14 arcmin 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



100000
10000
1000
100
10
Effective Area (cm^2)
100
1000
10000
X-ray Energy (eV)
MIRROR
WFI
IXO
NFI
XMM-PN
HXI
XMM-RGS

Black Hole Growth & Evolution



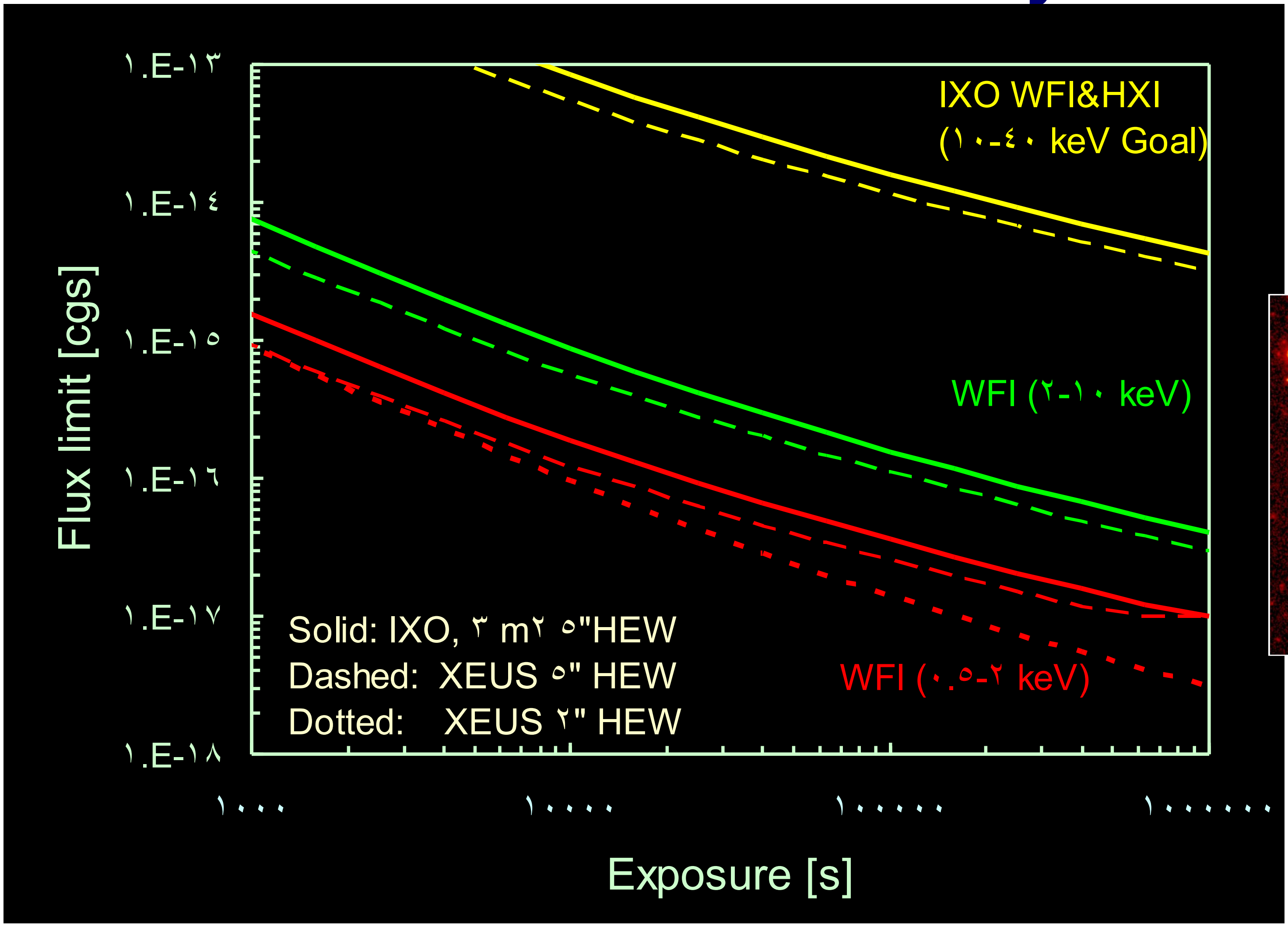
Chandra and XMM-Newton deep fields reveal that super-massive Black Holes are common throughout the Universe and that X-ray observations are a powerful tracer of their evolution

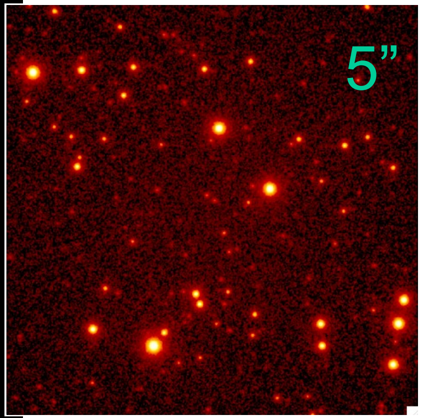
The origin and evolution of those Black Holes and their connection to galaxy formation remains a mystery

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 m^2 telescope area with 5 arc sec imaging combined with high resolution spectroscopy

IXO Point Source Sensitivity

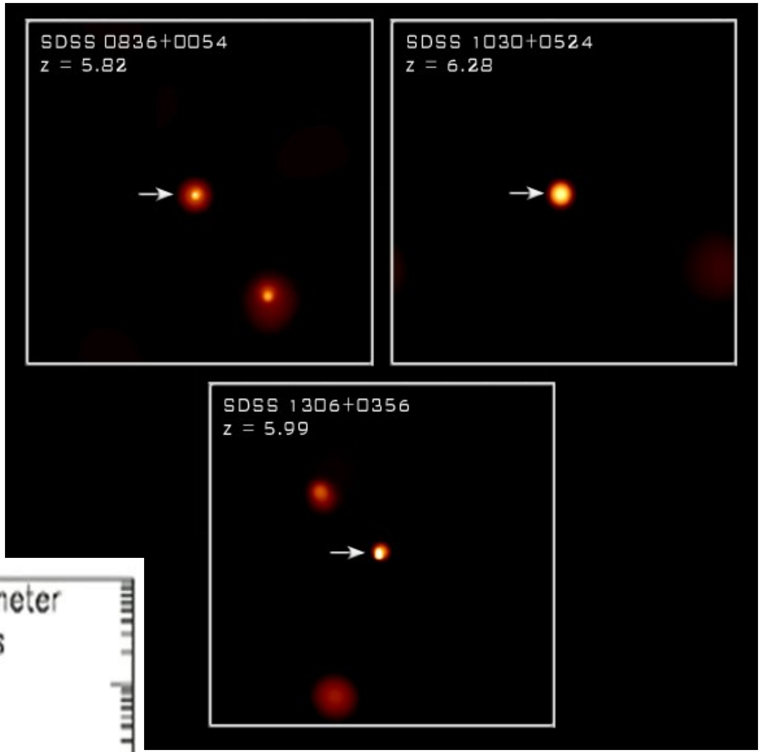


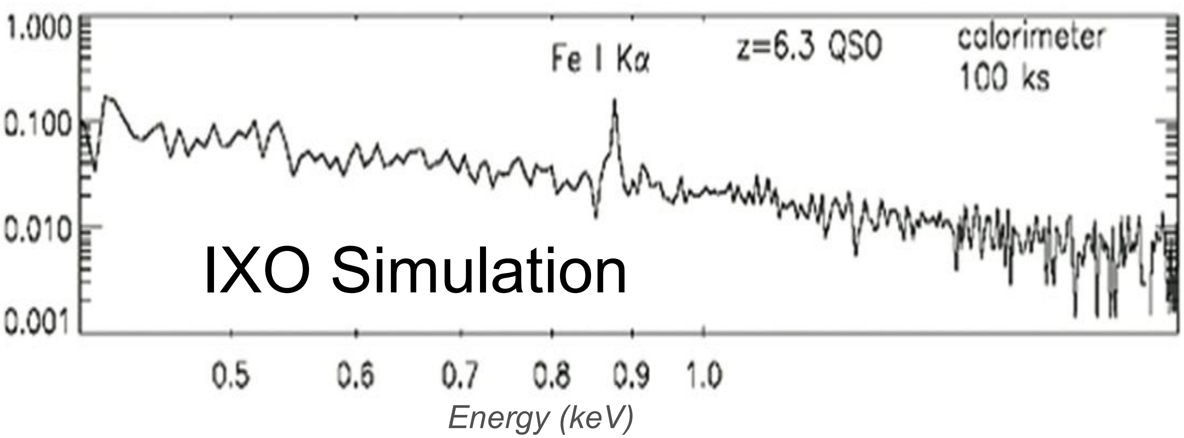


High Redshift Quasars

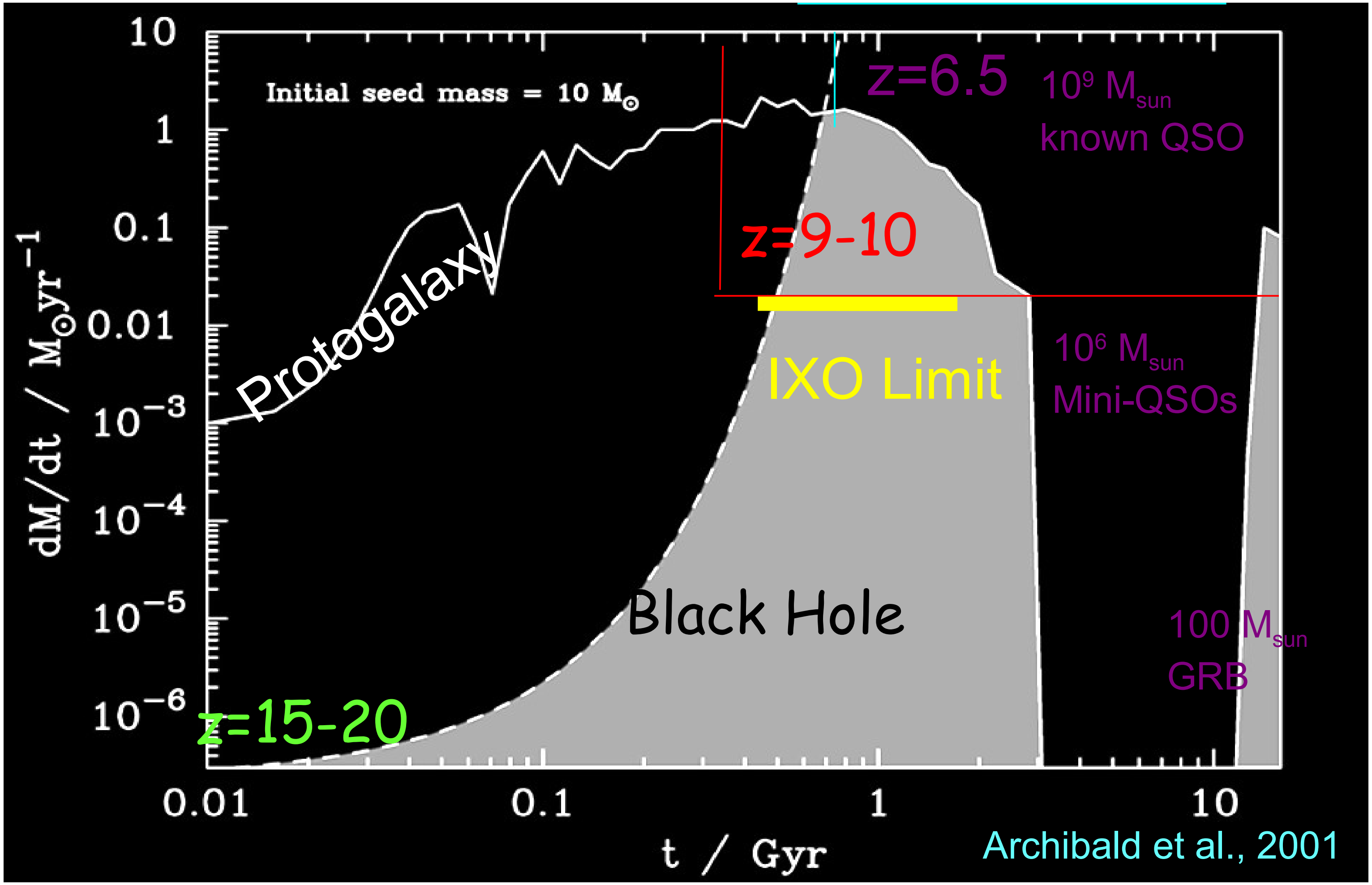
Chandra has detected X-ray emission from ~100 high redshift quasars at z > 4 (3 examples from the Sloan Digital Sky Survey shown)

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



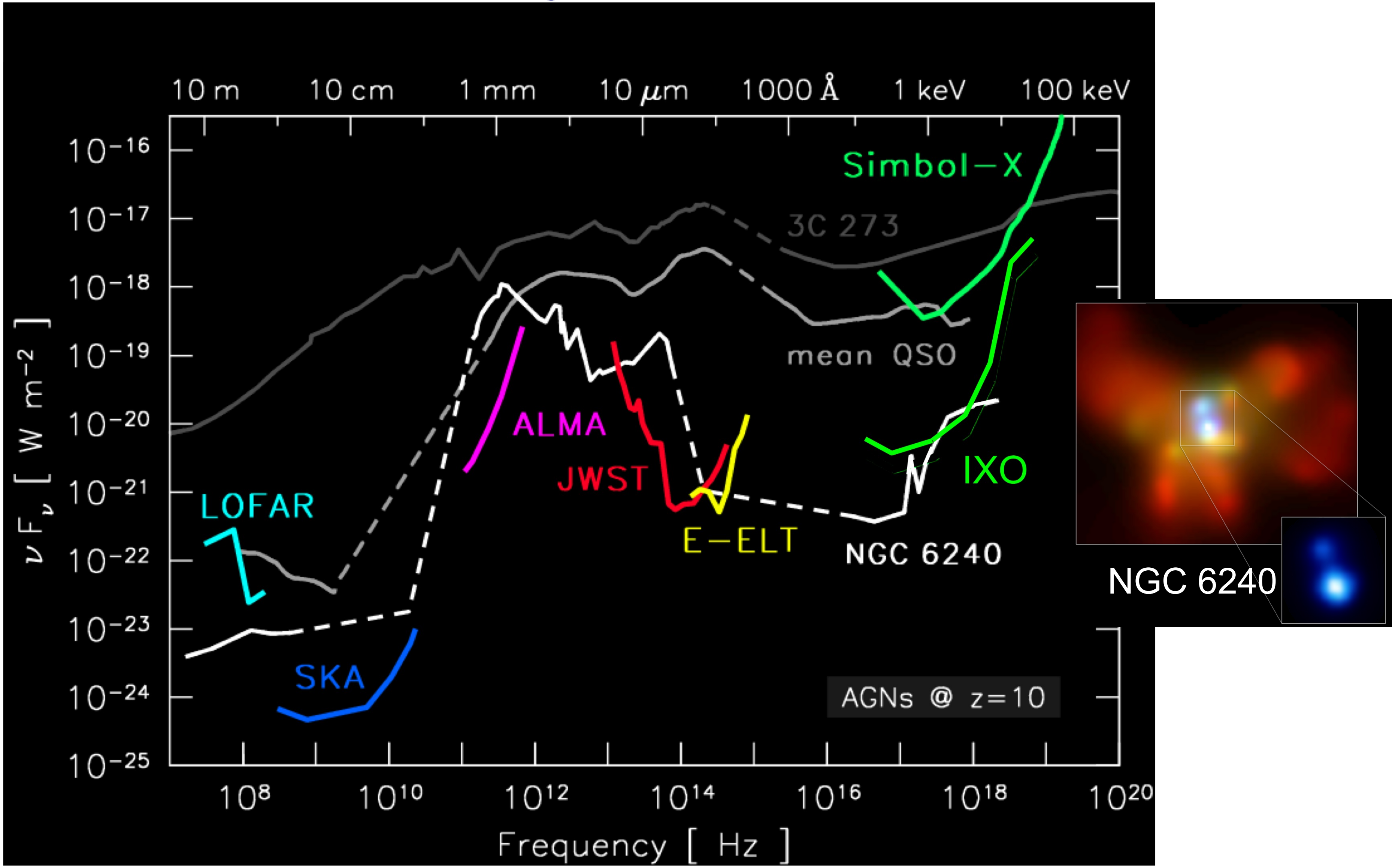


First Black Holes



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



IXO Study Coordination Group

European Members:

Didier Barret	CERS, Toulouse, F
Paul Nandra	IC, London, UK
Luigi Piro	INAF, Roma, I
Lothar Strüder	MPE, Garching, D
Philippe Gondoin	ESA Study Manager
Arvind Parmar	ESA Study Scientist (ESA chair)
Fabio Favata	CV Astronomy Coordinator

Together with NASA and JAXA members, tasks include defining the IXO science requirements, advising the agencies on mission implementation and scientific implementation, supporting the industrial activities etc. Will **not** discuss which agency will lead the mission.

Next Steps

- ESA IXO Concurrent Design Facility (CDF) study of EOB concept starting on 9 October 2008, followed by 6-9 month industry study, with preliminary report in Spring 2009.
- CDF study will concentrate on the new extendable bench design, paying particular attention to items such as mirror assembly structure (much easier to due to larger interface radius) and mechanisms.
- First IXO Study Coordination Group meeting MPE September 19-20, following this meeting.
- Once science requirements and implementation are agreed, a priority will be to produce the first IXO response matrices.
- Skeleton science case will be assembled by a small team (M. Begelman, A. Fabian, K.P. Nandra and a Japanese member) for review by IXO Science Definition Team and eventual submission to the

Summary

- ESA/JAXA/NASA agreement to proceed with the study of a single large International X-ray Observatory. Results of this study will be used as input to NASA's Decadal survey and ESA's Cosmic Vision processes.
  - The science case is very powerful and addresses key and topical questions
  - The technology development is proceeding well. Mission concept appears feasible and probably has lower risk than L-class competitors (LISA and Tandem/Laplace)
  - ESA contribution can be within the L-class cost cap (650 M€)
- With IXO we are on track to submit a very strong proposal to the Cosmic Vision process, Decadal Survey and Japan for eventual approval of IXO and launch sometime after 2018.