# High Resolution X-ray Calorimetry (plus a short update on IXO)

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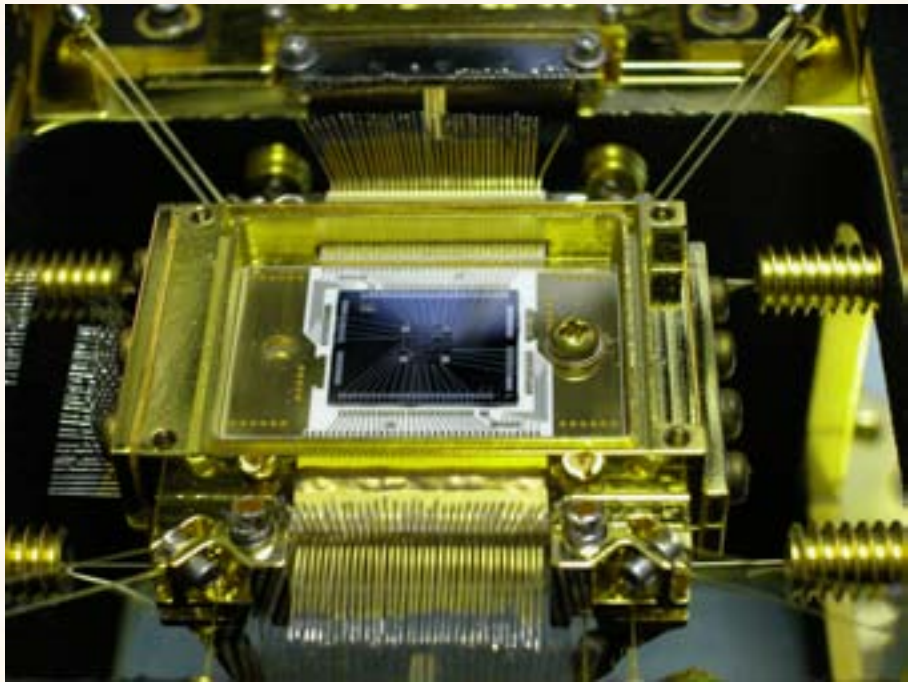
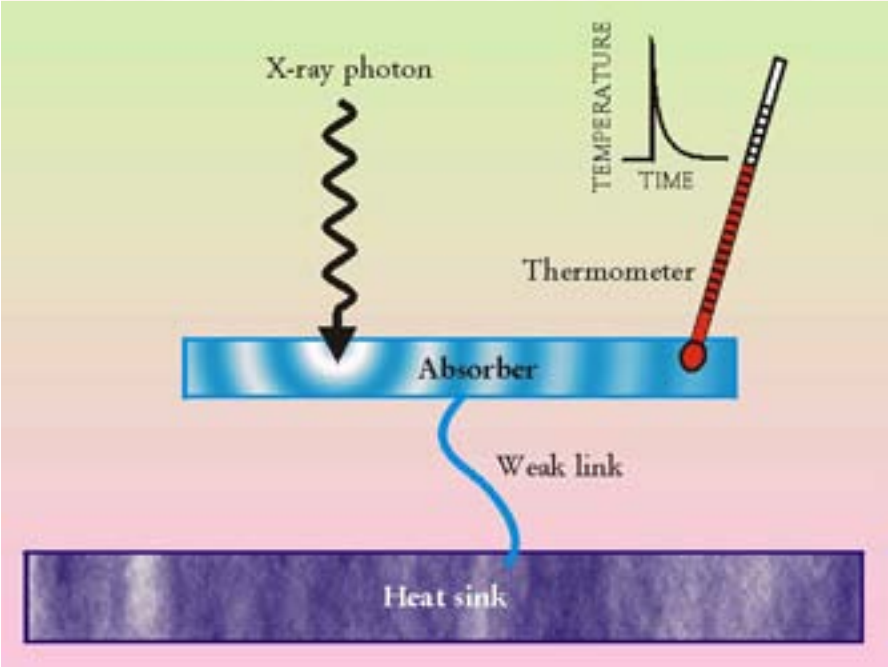
Thanks to F. Scott Porter (NASA/GSFC) and Greg Brown (LLNL), who provided the figures for the EBIT Lab Astrophysics discussion.

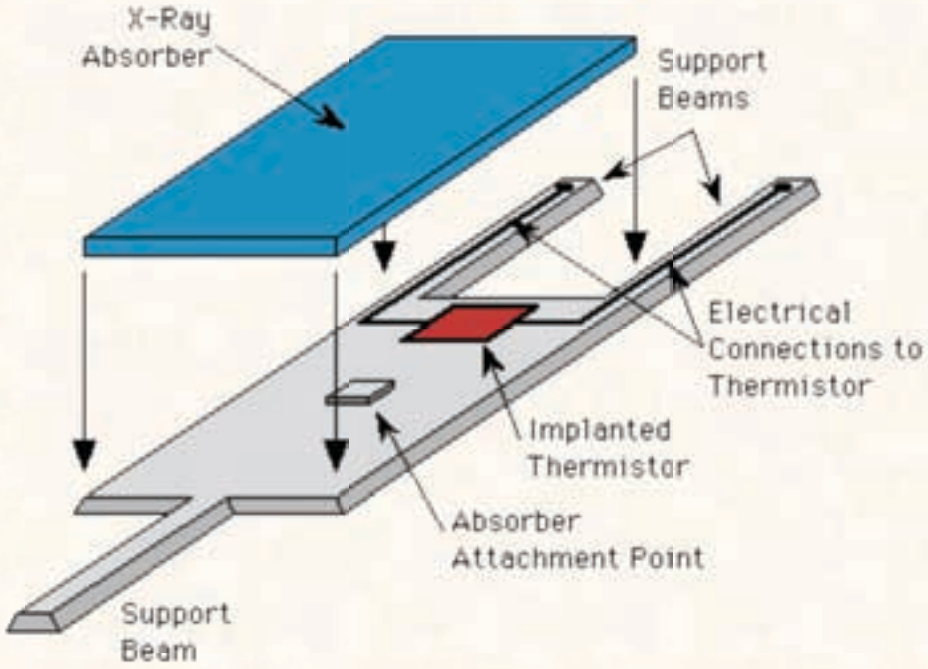
# Overview

- What is a X-ray microcalorimeter
- …it's use in the lab?
- …and in satellites?



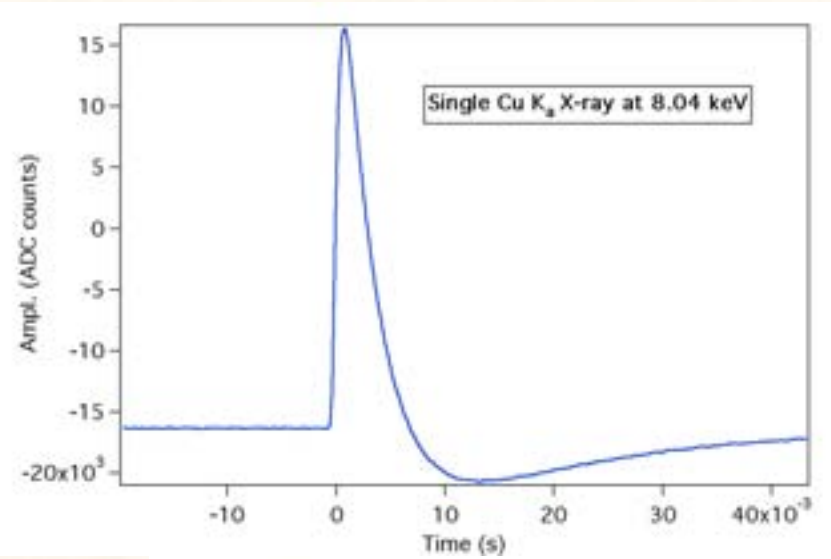
# The X-ray Microcalorimeter

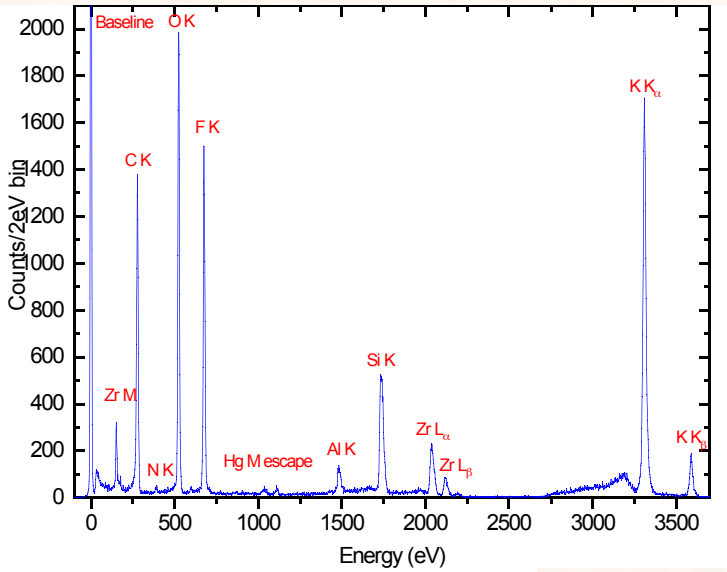


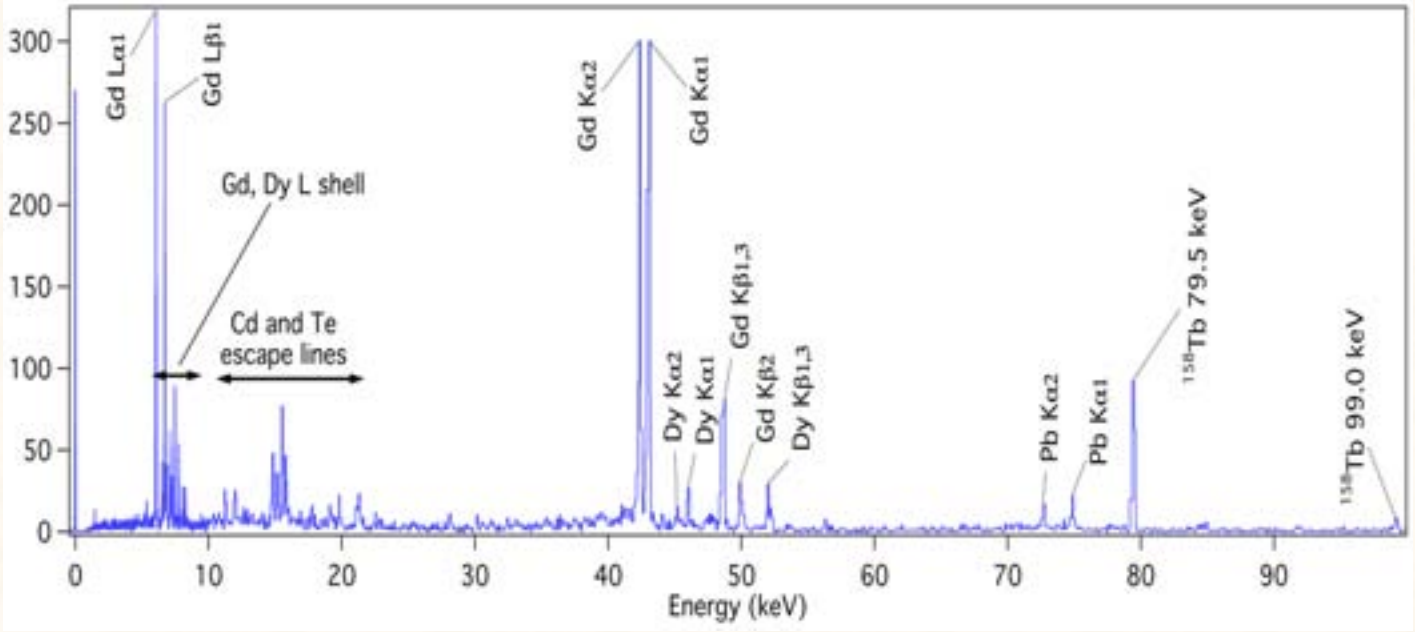




**How**: High sensitivity thermistor, low heat capacity materials, low temperatures (~50mK)

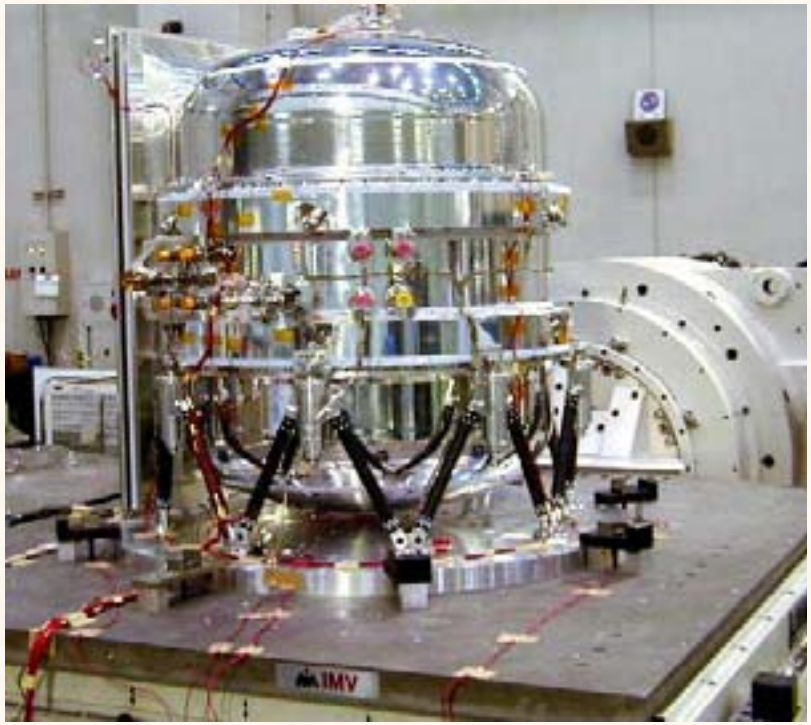
# Extremely Versatile Spectrometer

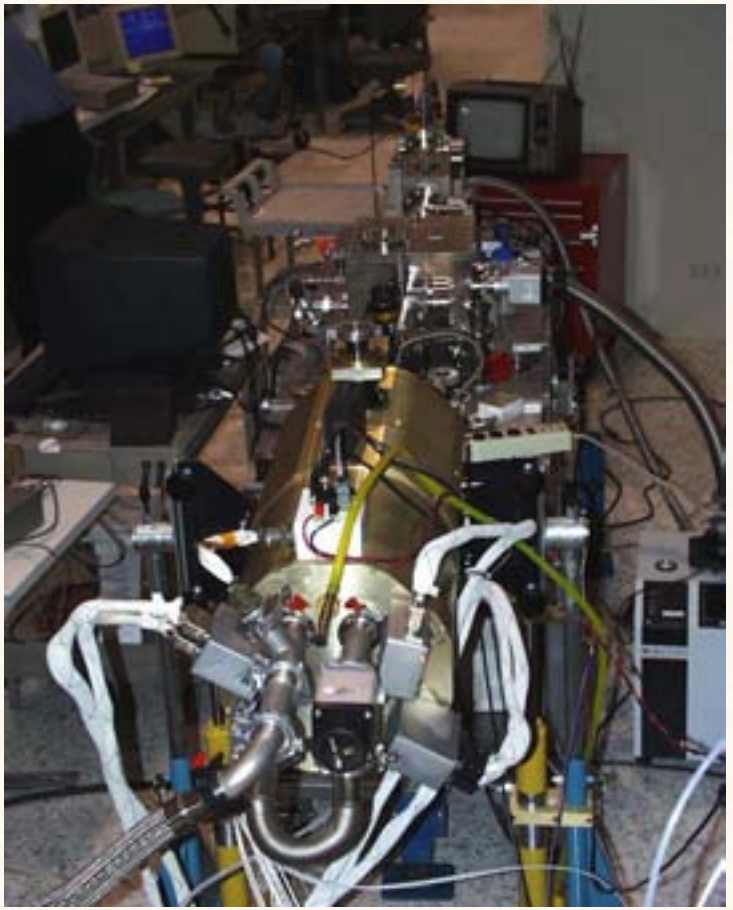


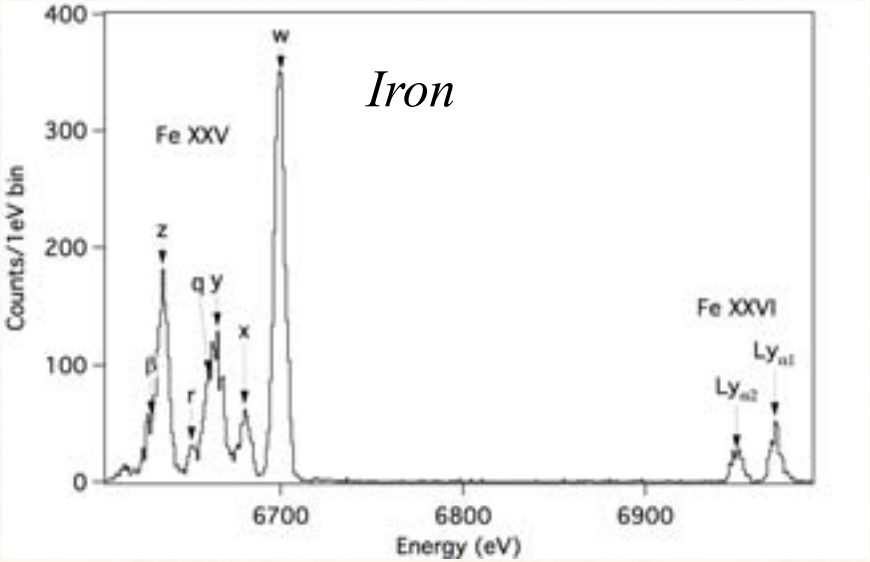



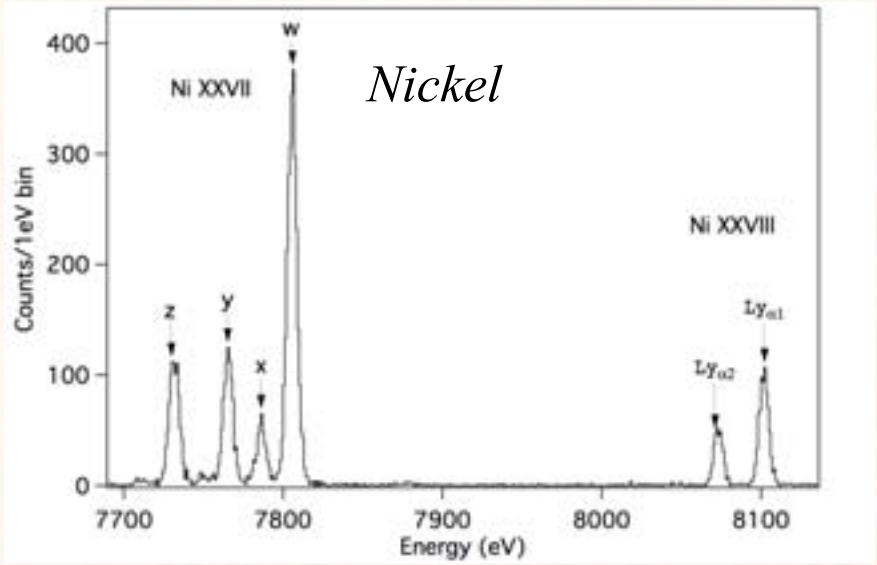
# Working examples

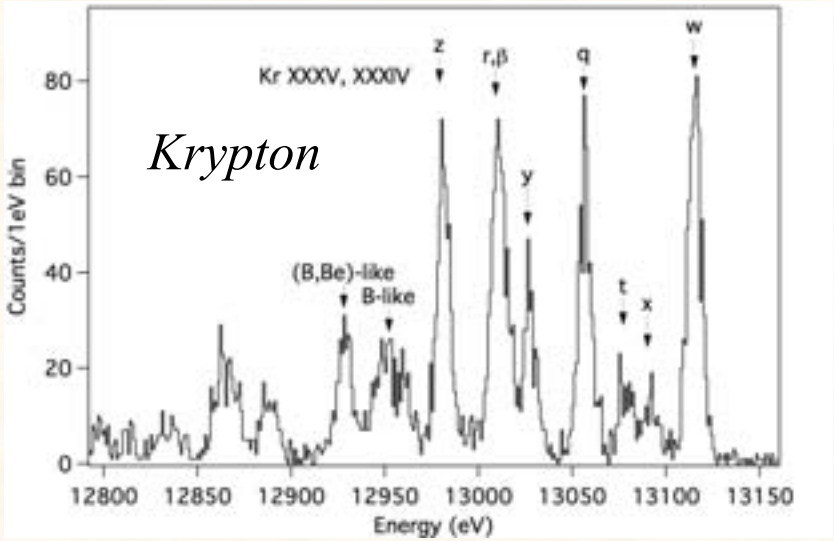


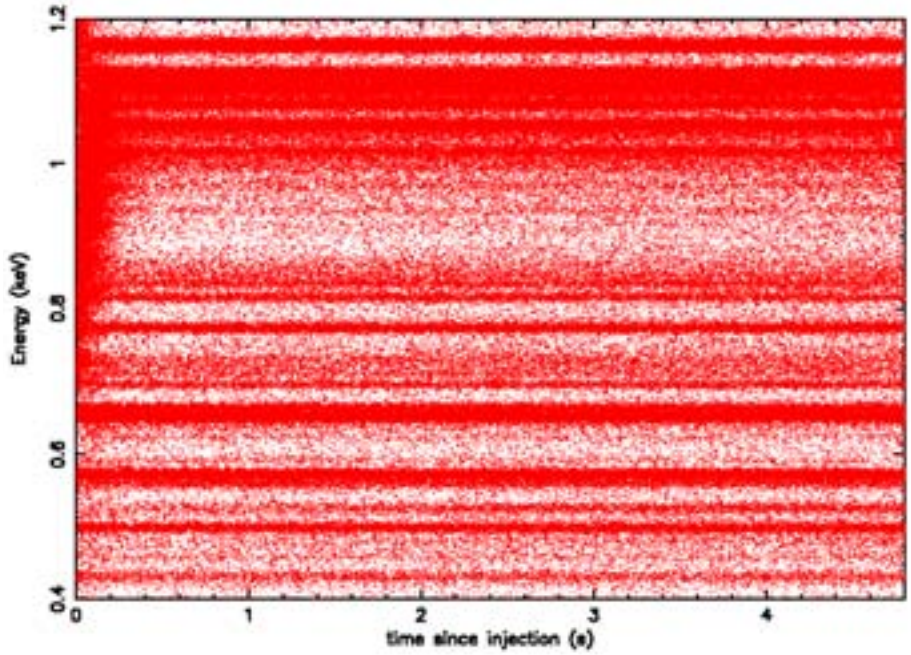
# Some Sample Spectra

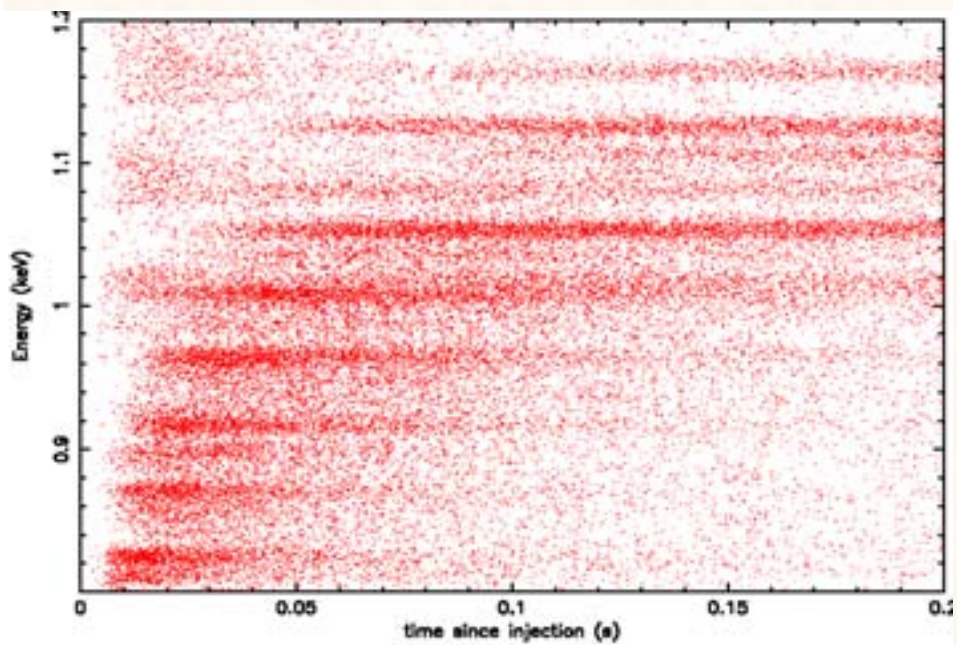


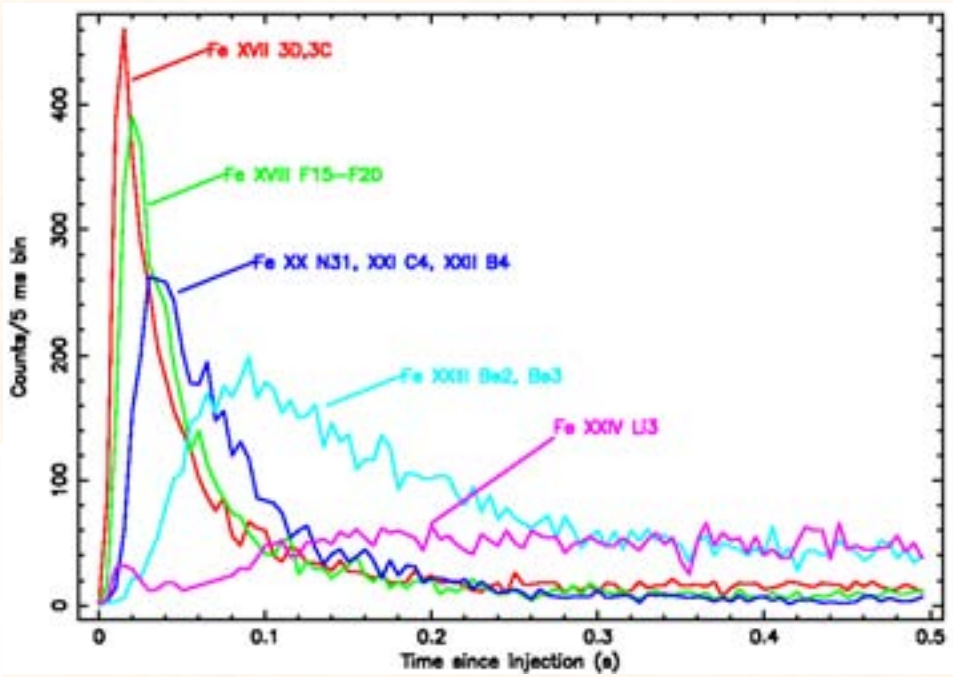



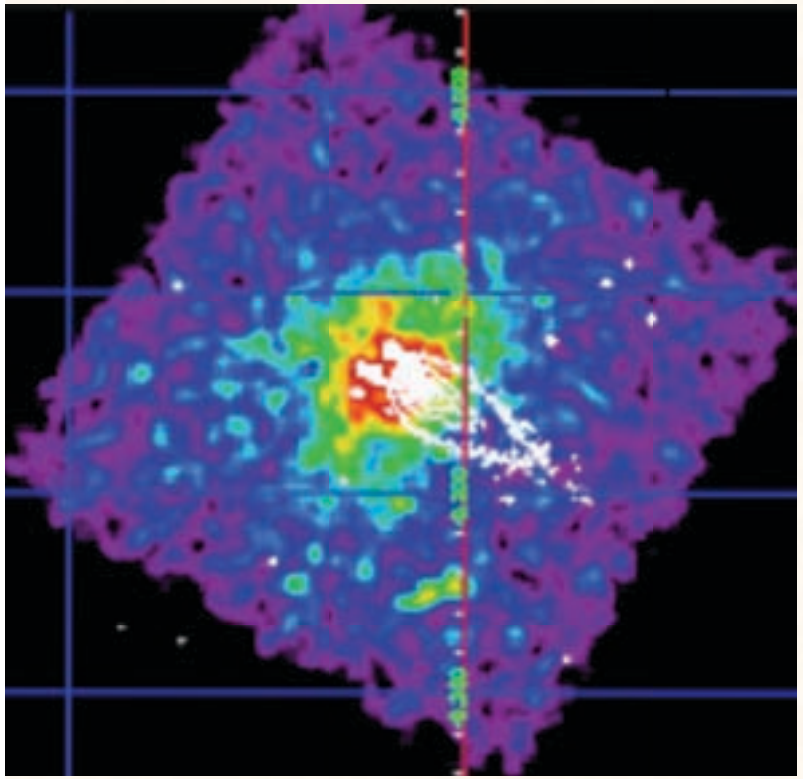
# Even Time-Resolved



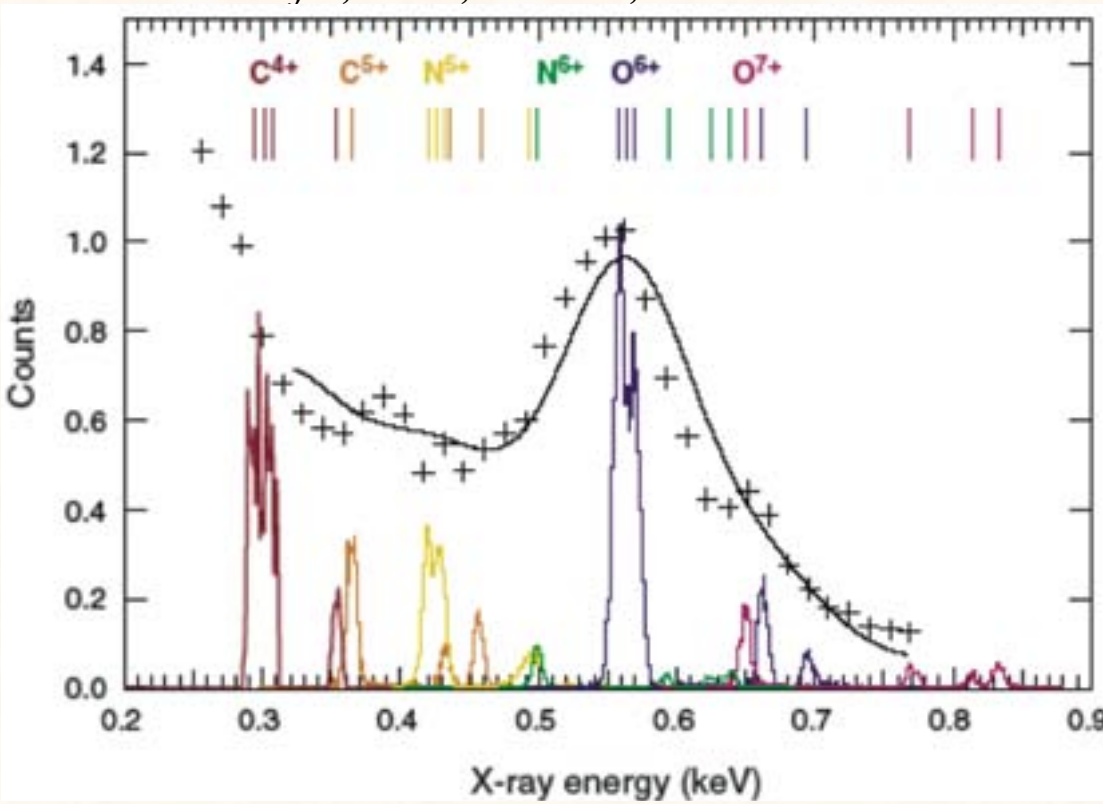



# *Charge Exchange, empirical models*



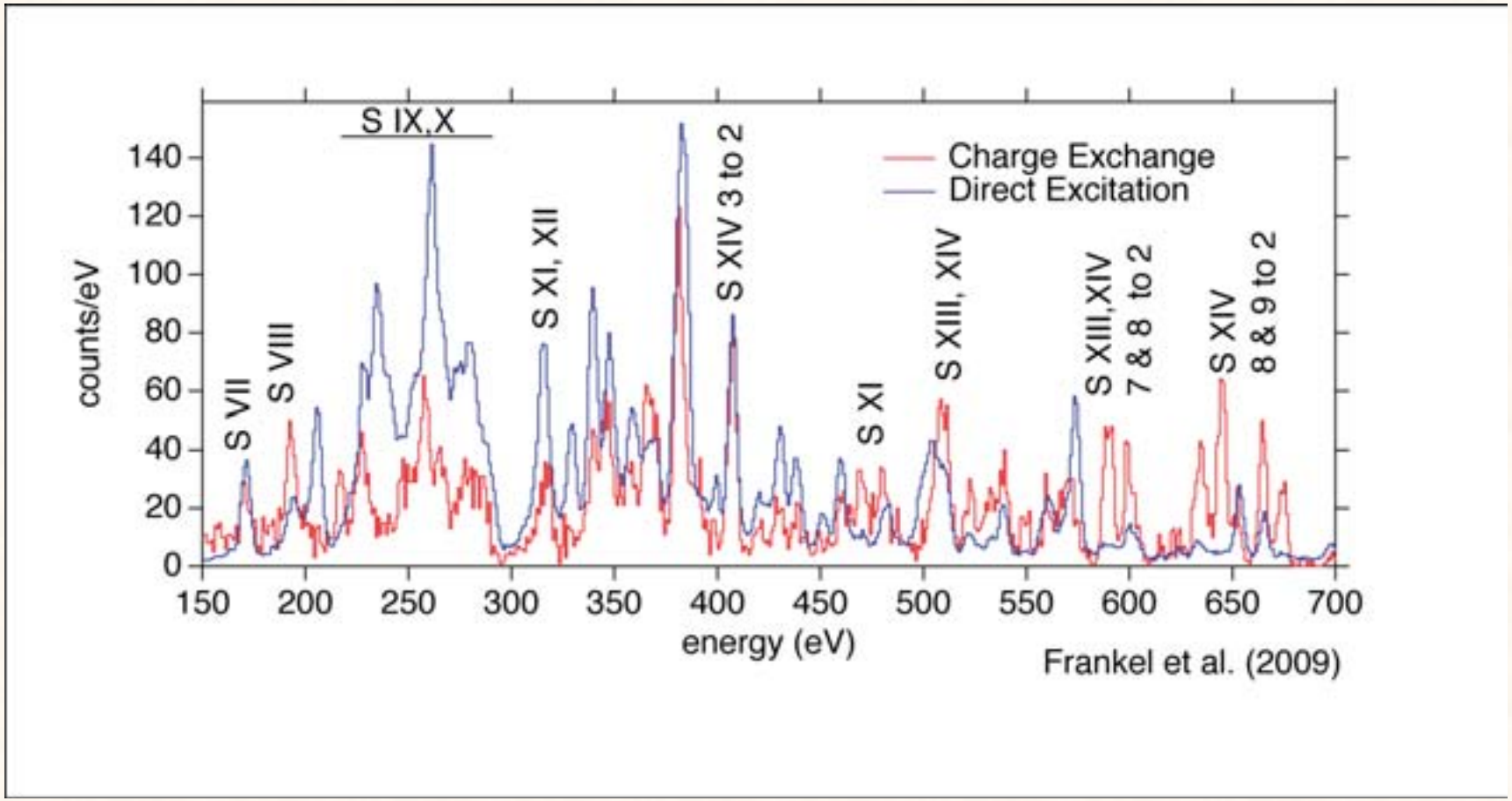
Comet 73P/SW3 fragment C with the Suzaku and Swift observatories, 6/2006

*Beiersdorfer, et al., Science, 2003:*



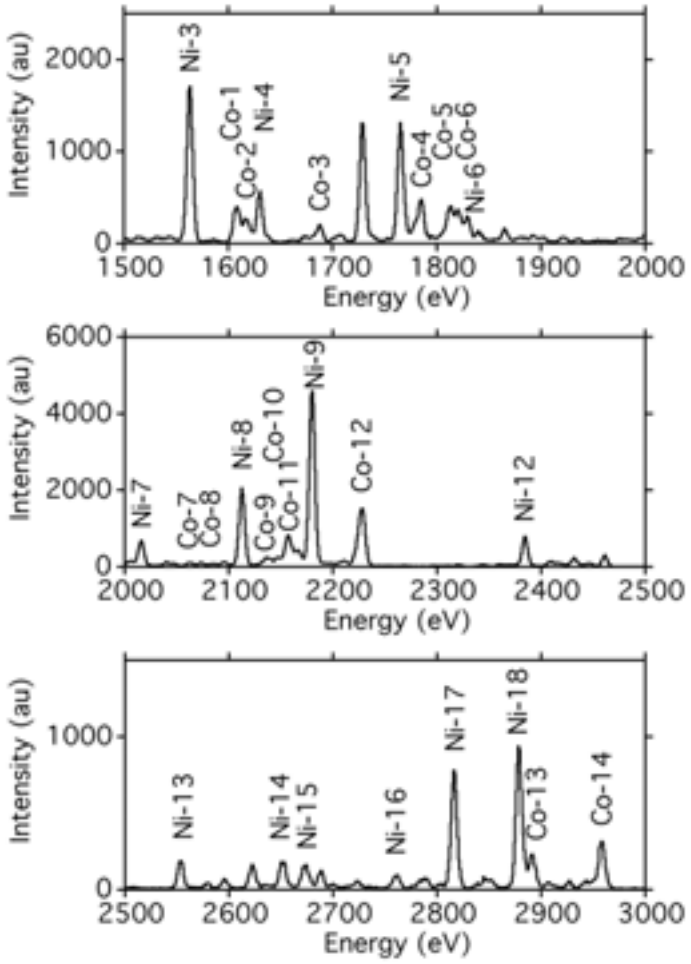

Comet Linear C/1999 S4

# Soft X-rays: DE vs CX

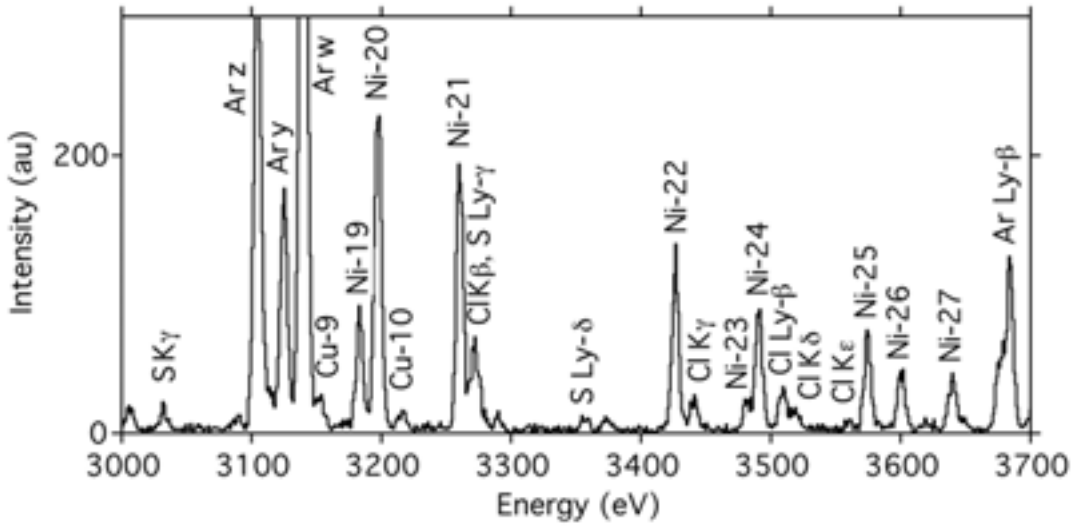



Slide courtesy Greg Brown, LLNL – LLNL-CONF-416255

# W X-ray line energy measurements




- M-shell (n to 3) transitions in highly charged W ions.
- Lines are labelled with the ion charge state, i.e., Ni-3 is nickel-like W.



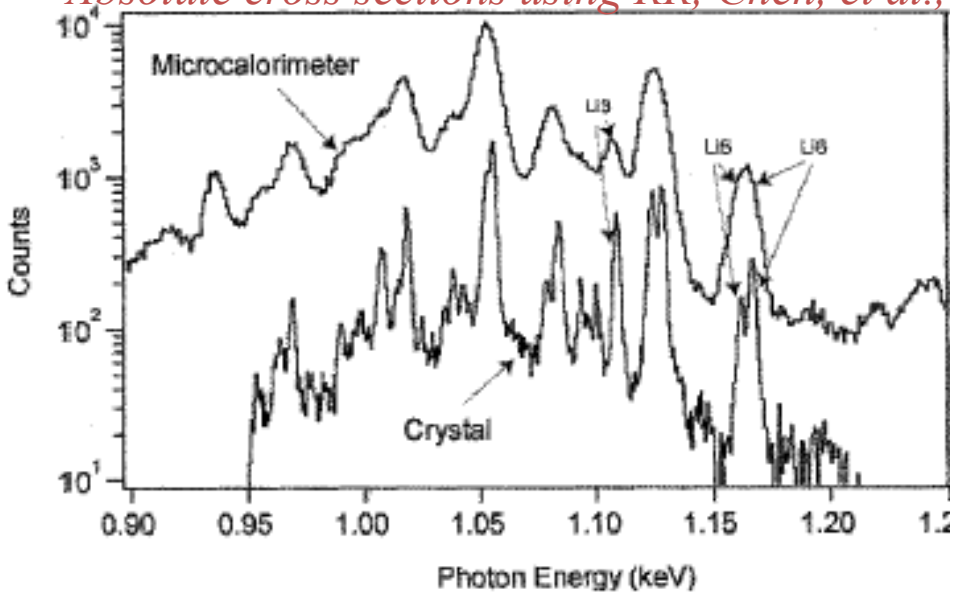

Clementson et al. (2009)

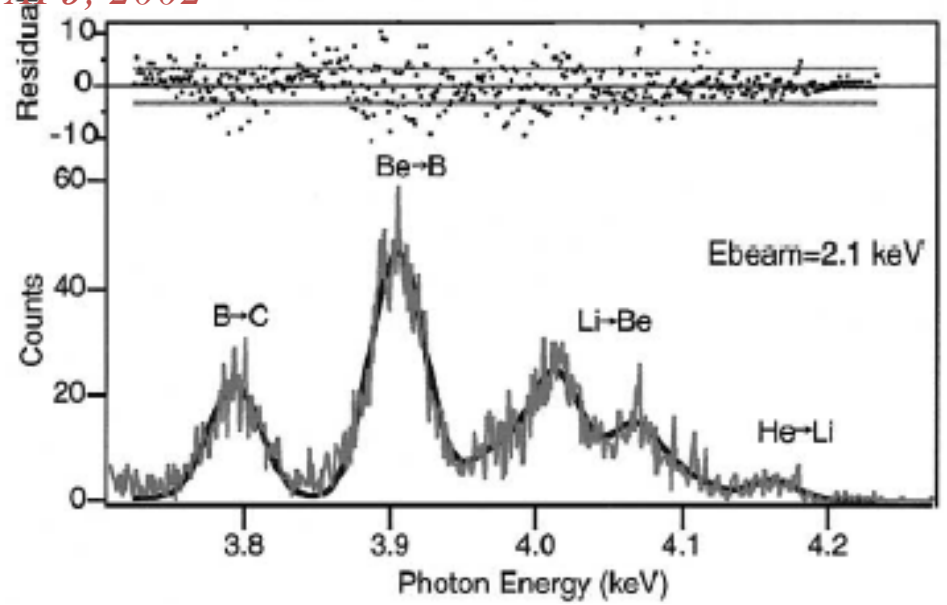
Slide courtesy Greg Brown, LLNL – LLNL-CONF-416255

# Microcalorimeter @ EBIT:

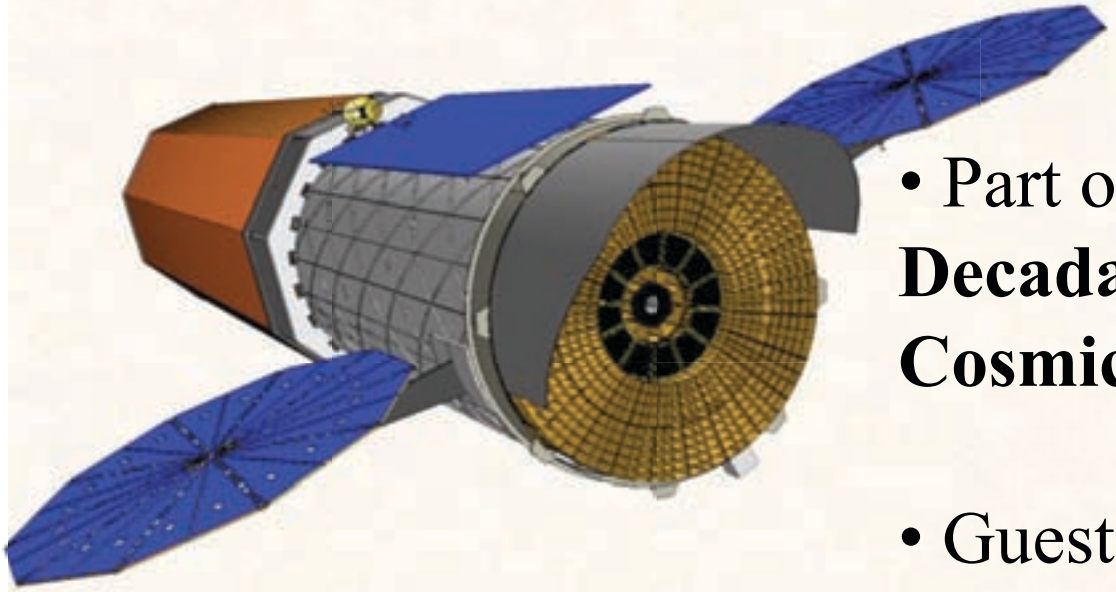
- 24 publications: Science, PRL, APJ, APJL, Phys Rev A, RSI, NIM,…
- Strengths:
  - Broadband: 0.01- 100 keV
  - (moderately) high resolution, 5.5 eV@6keV FWHM
  - Polarization insensitive, non-selective
  - Real time spectra
  - Non-dispersive, slit-less spectroscopy
  - Fast: good for experiments with poor contrast.

*Absolute cross sections using RR, Chen, et al., APJ, 2002*



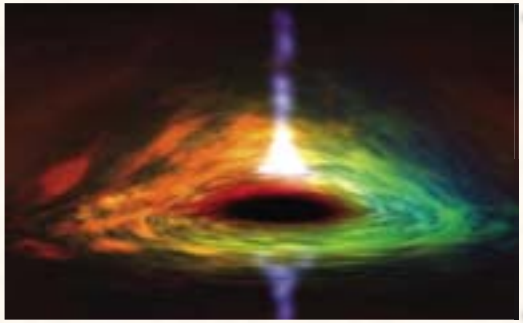
# Just the facts..



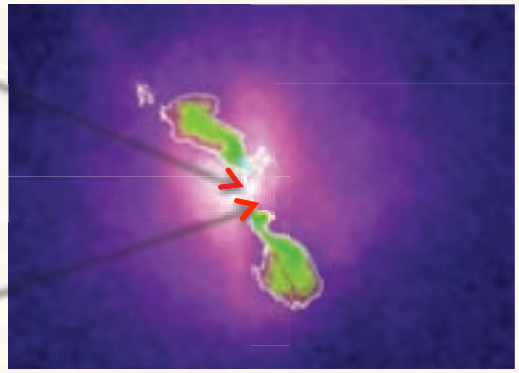
- Merger of ESA/JAXA XEUS and NASA's Constellation-X missions
- Part of US Astro2010 **Decadal Review** and ESA **Cosmic Visions**
- Guest Observatory, with time allocation done as with Hubble, Chandra, Spitzer
- Launch planned ~2021

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

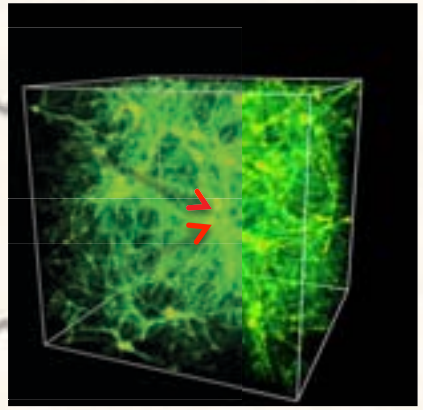
- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?



Black Hole Accretion



Hydra A Galaxy Cluster



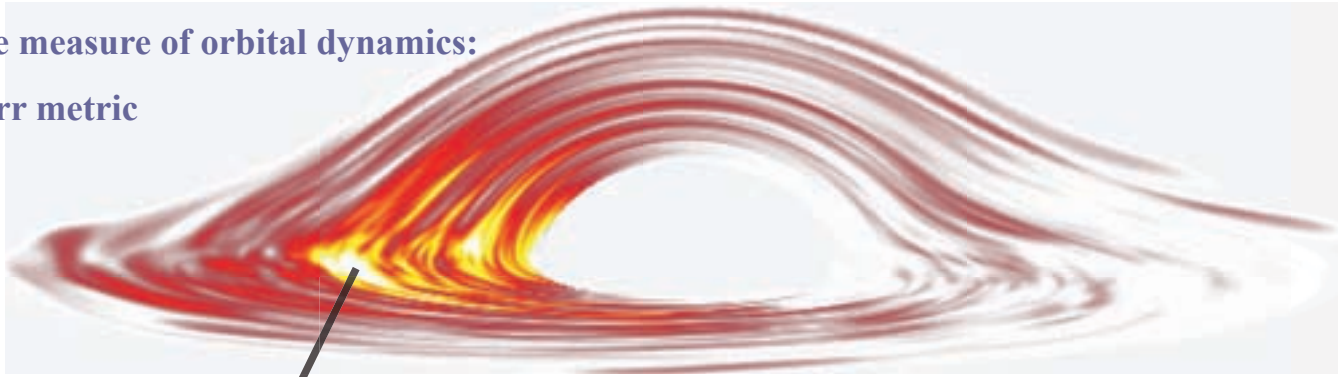
Cosmic Web

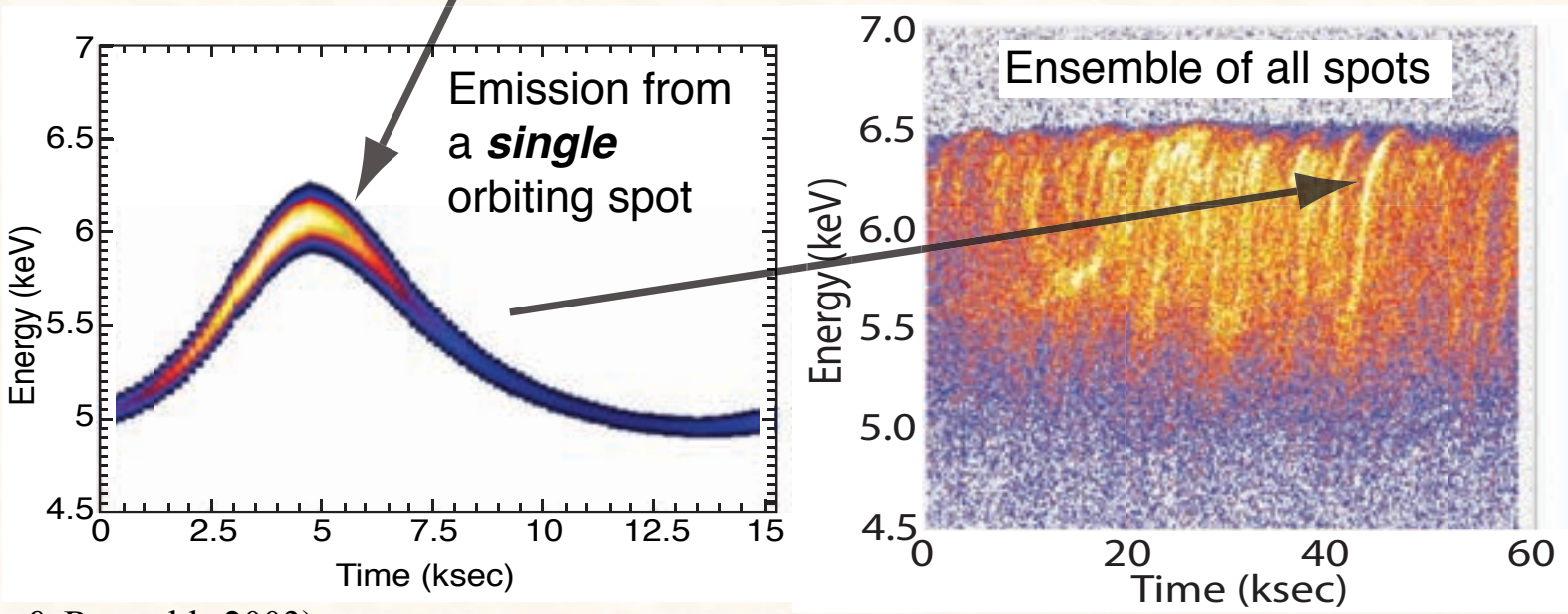
# Testing GR: Black Hole Spin

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**





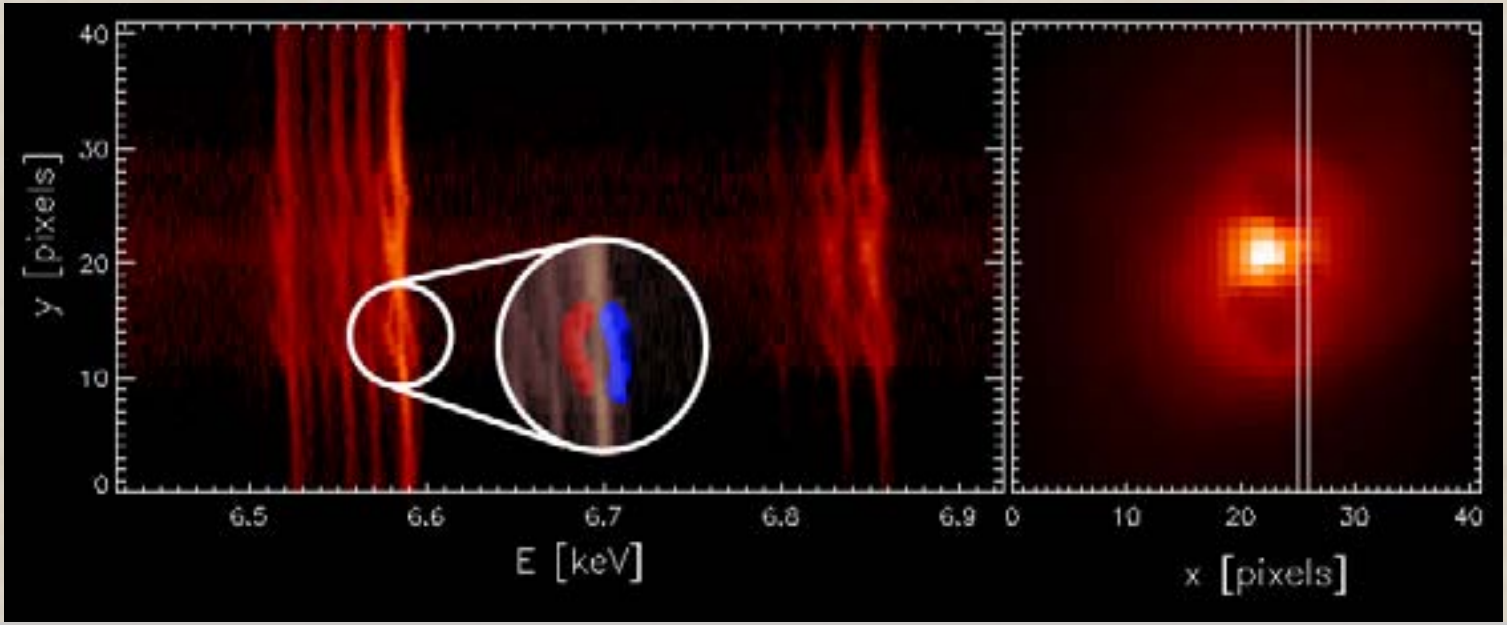

(Armitage & Reynolds 2003)

# Cosmic Feedback

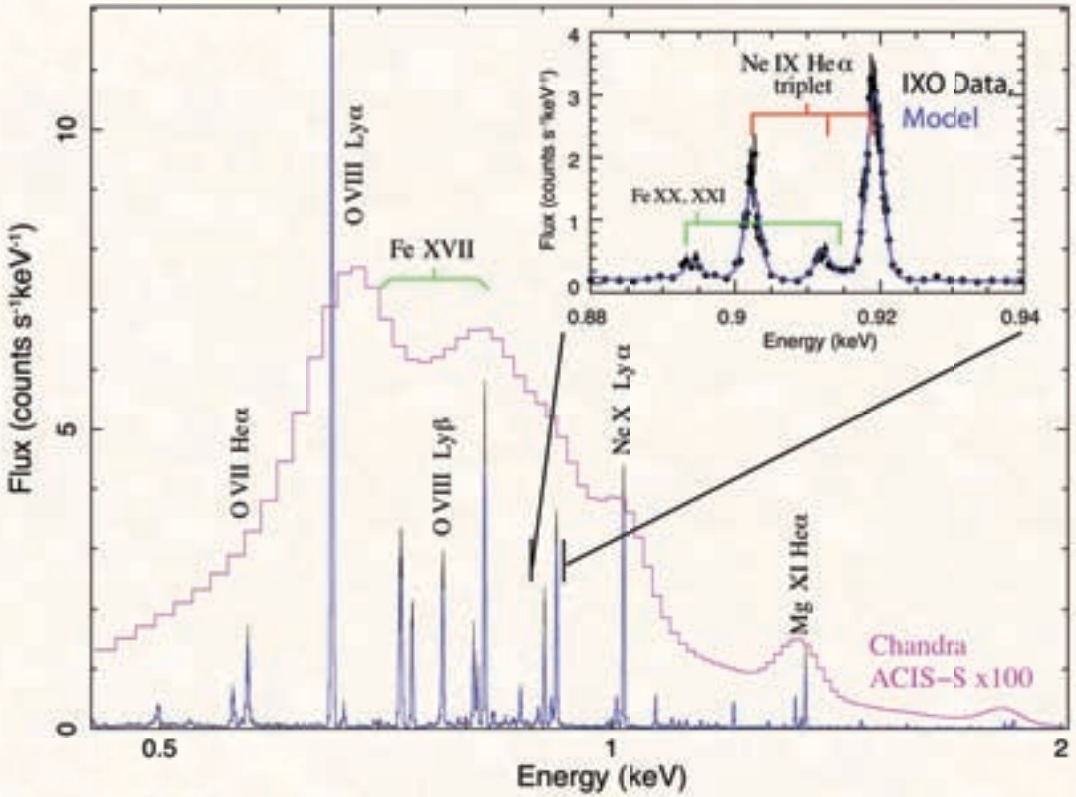
Supermassive black hole feedback regulates the growth of galaxies and clusters of galaxies

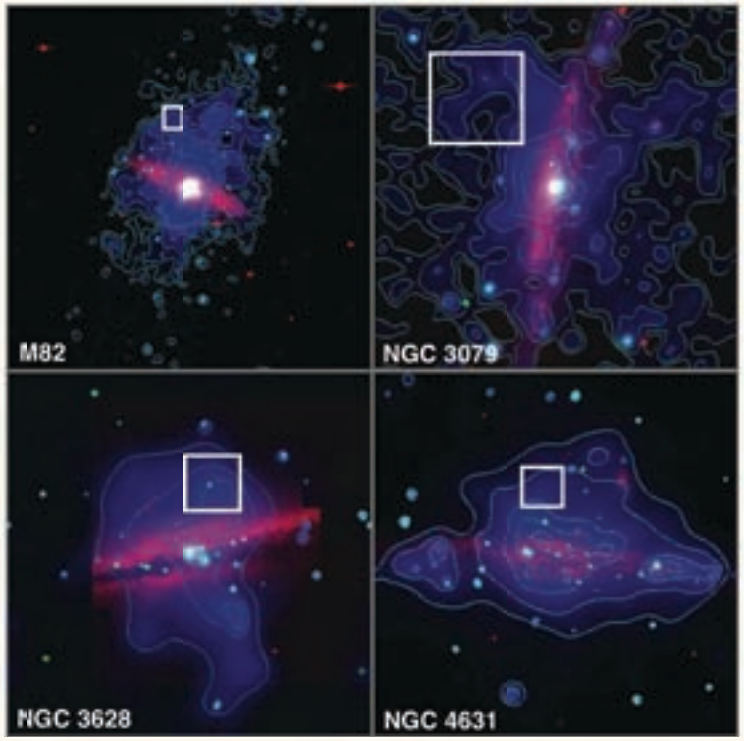
Velocity measurements crucial to determine heating and state of hot gas found within clusters of galaxies

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

# Strong Winds from Galaxies



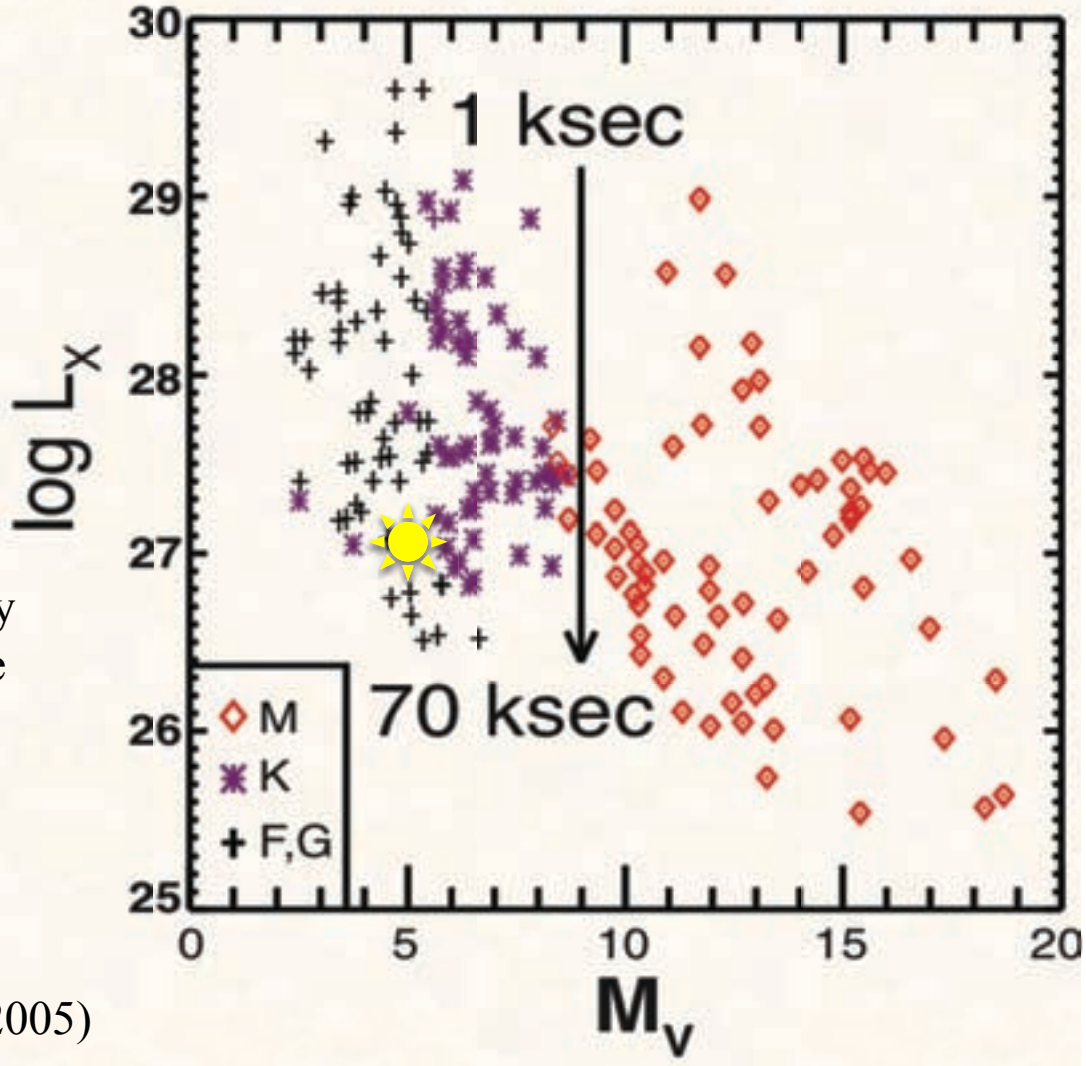




100 ksec observation of a small region in a typical superwind. Direct measurements of the velocity, abundances, and ionization state of the outflowing gas will allow mass, metal and energy ejection rates to the IGM to be measured.

# 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)

# Summary

*X-ray microcalorimeters have great potential to measure time- and energy-resolved X-ray spectra over a wide band*

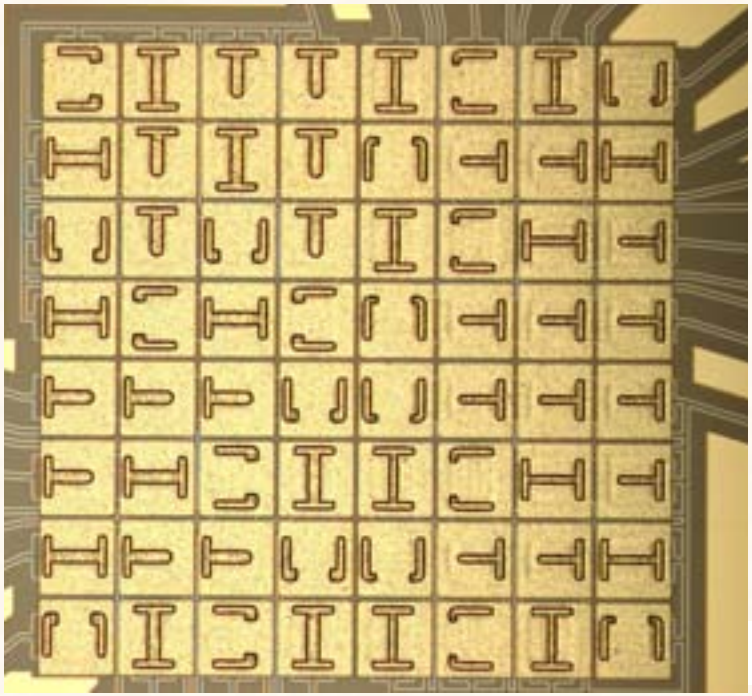
*IXO will bring a factor of ten gain in telescope aperture combined with next generation instrument technology to realize a quantum leap in capability*

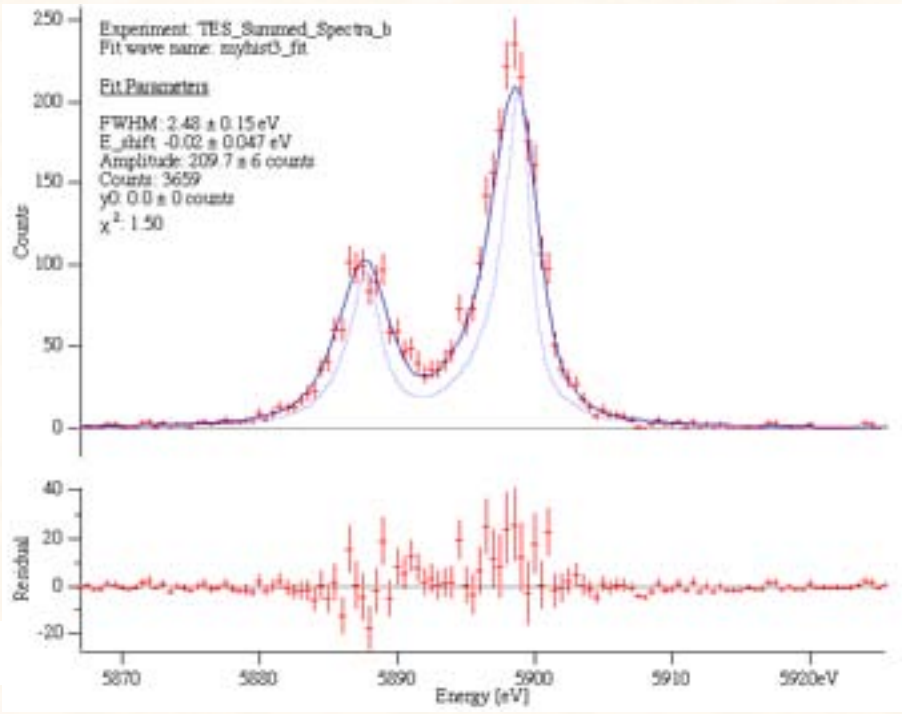
*Separate studies by ESA and NASA demonstrate that the mission implementation for a 2021 launch is feasible with no major show stoppers*

# Backup

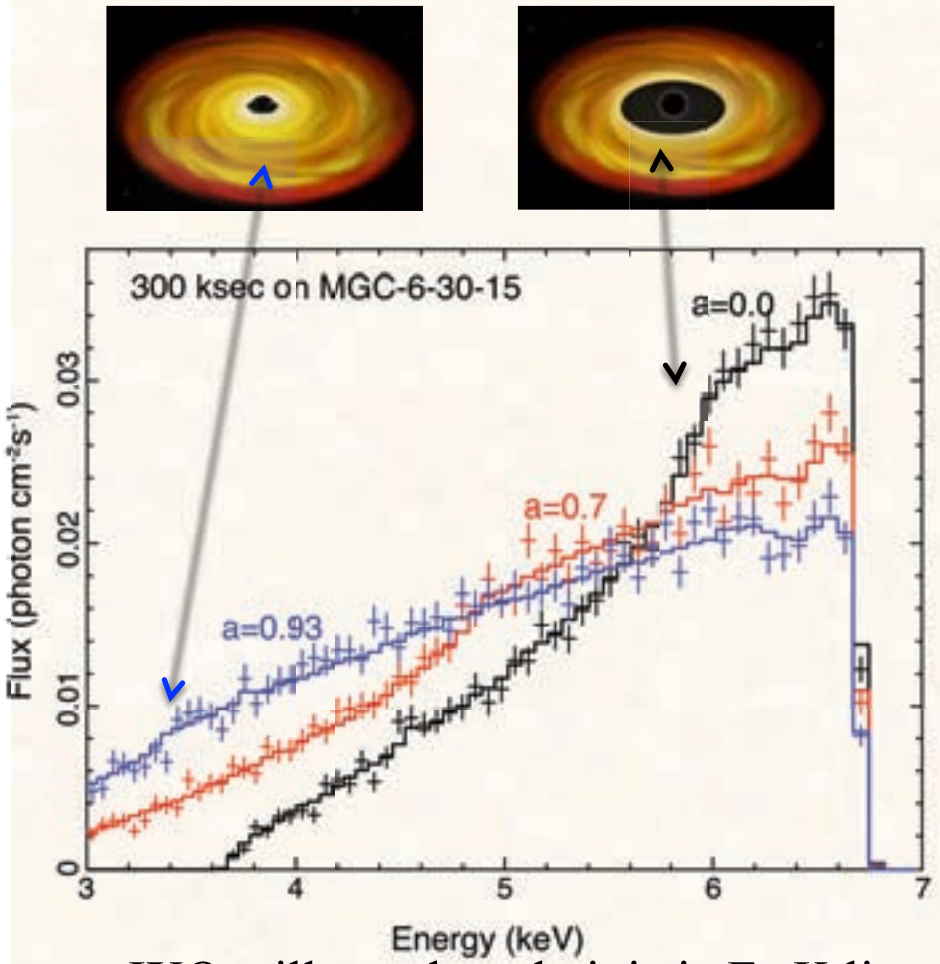
# The International X-ray Observatory XMS

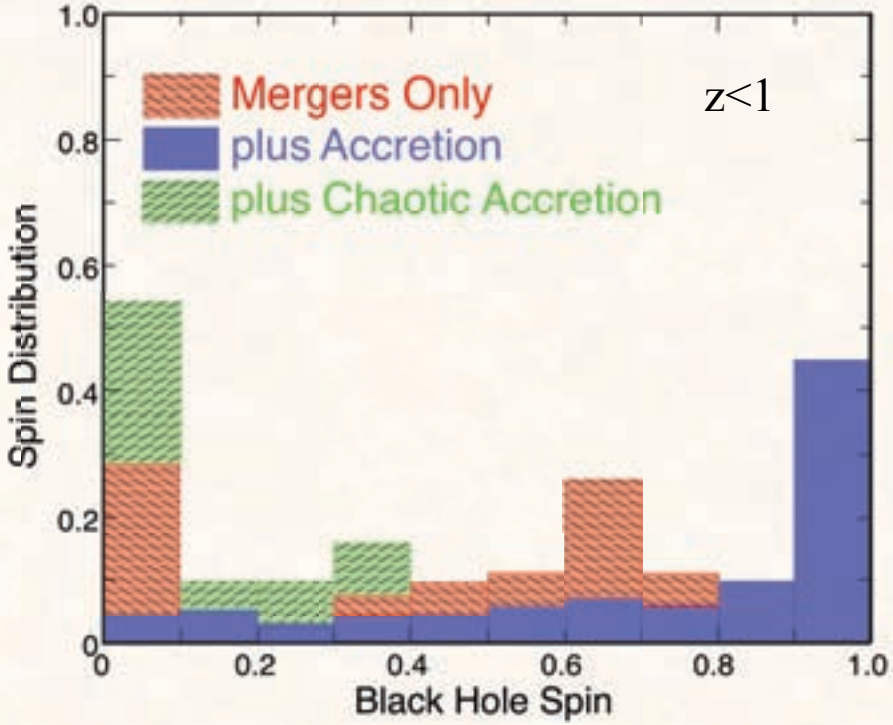
- Higher resolution:
  - 2eV at 6 keV with a 0.01-10 keV bandpass
  - ~0.5 eV with a  0.01-1.0 keV bandpass
  - 10 eV with a 0.1-100 keV bandpass
- Much higher throughput: ~100-1000 cps/per pixel
- Much higher pixel count through multiplexing, 100s-1000s pixels





# 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

# Focal Plane Layout (Aft View)