Distribution of Matter in Galaxies

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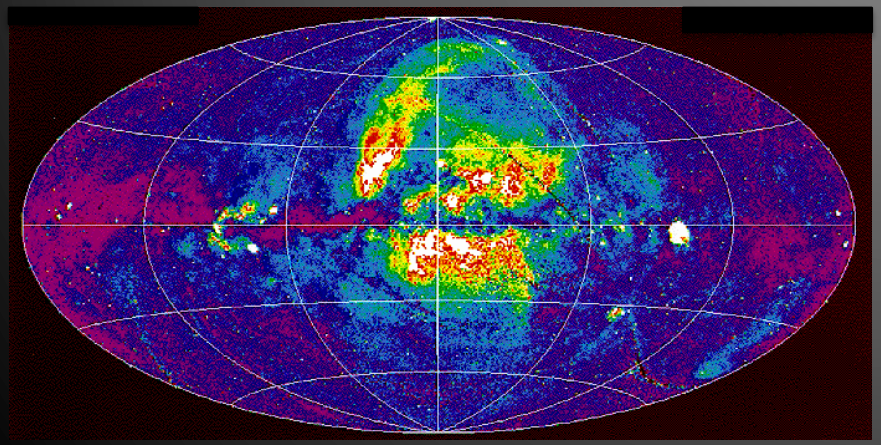
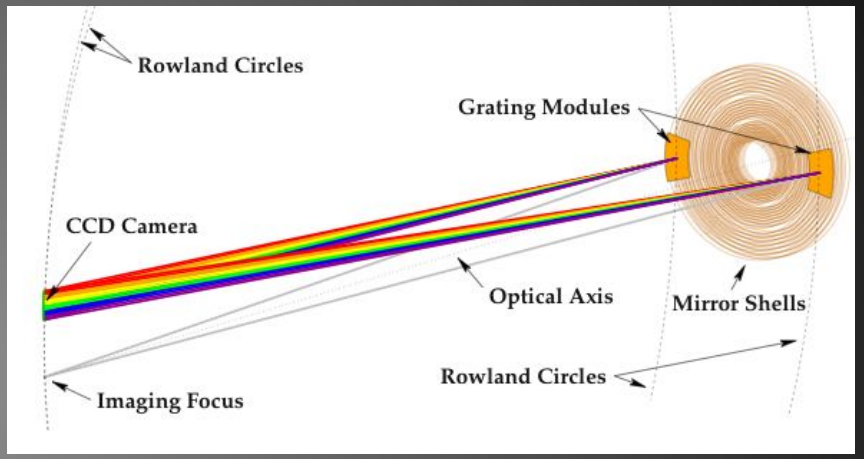
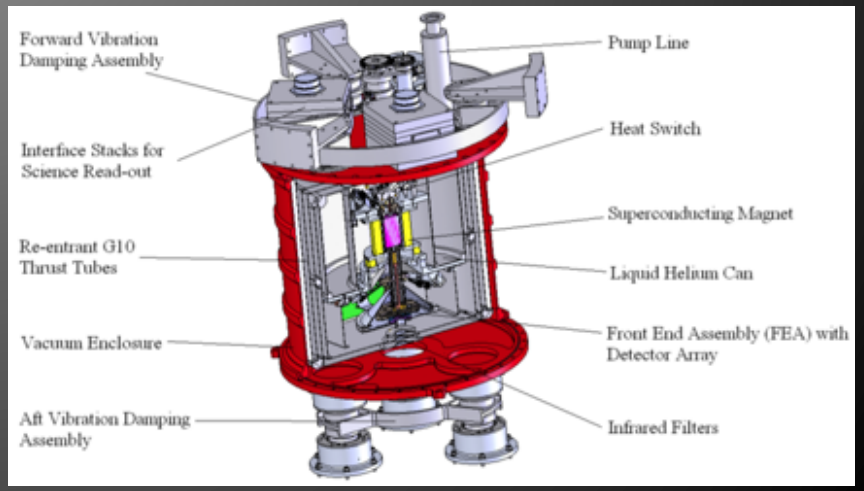


Transmission Grating Development



Micro-Calorimeter Development



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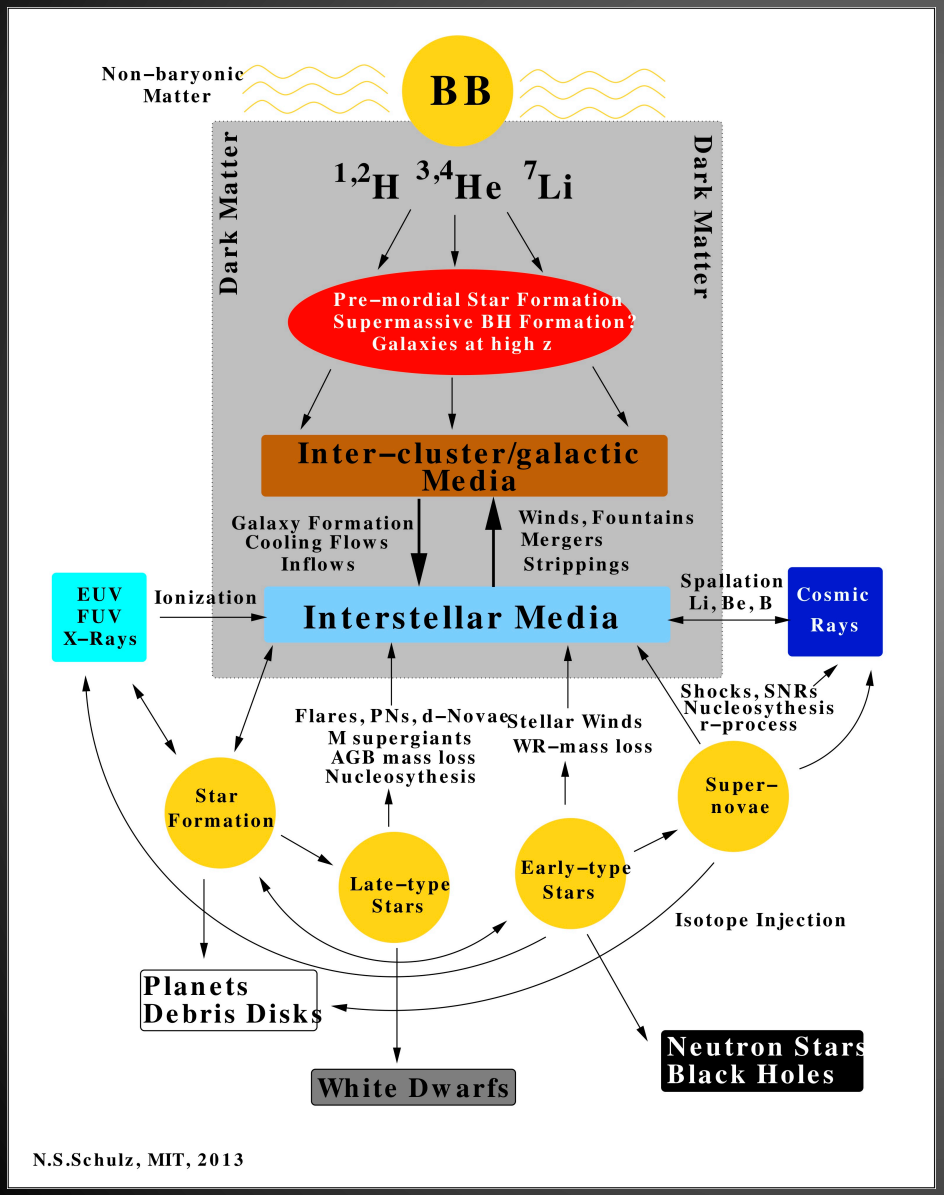
Context:



- **Chemical Abundance:**

  Elements: C, O, Ne, Mg, Si, S, Ar, Ca
  Fe, Ni

  Molecules: CO_2, CO, O_2, H_2O….
  C_sH_6O, CH_2O_2,…….

  Dust: Structure & Depletion

- **Ionization Fractions:**

  Neutral Abundances
  Ionized Abundances

  Star Formation Rates
  Missing matter (WHIM)

- **Dynamics**

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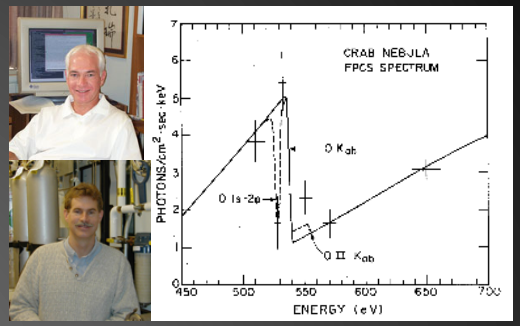
History and Context:

• EINSTEIN:

Detection of O K edge substructure: 1s-2p resonance in Crab (Schattenburg & Canizares 1986) with SPC



• ROSAT:

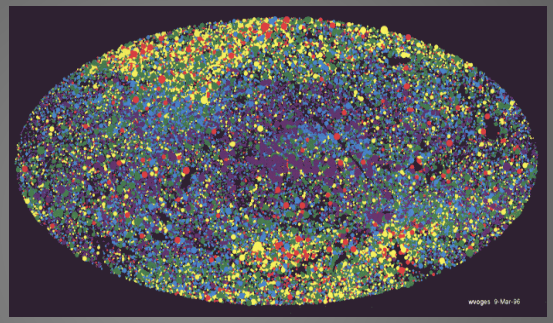
First All-Sky X-ray Survey 1990 – 1992

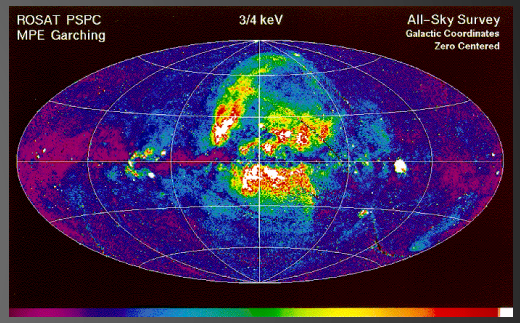
Range: 0.2 – 2.4 keV

Resolution: 2 - 5

Sensitivity: > 10^{-16} ergs/s/cm^2

Catalog: ~ 10^5 X-ray sources



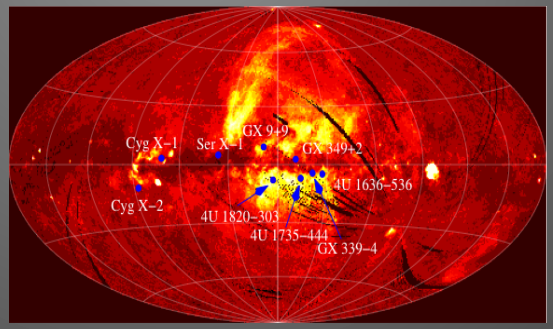


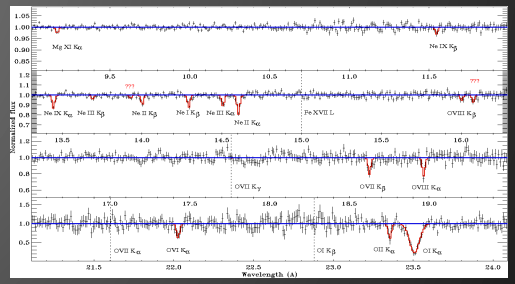
• Chandra & XMM-Newton:

Bright Galactic X-ray Sources

Range: 0.2 – 8 keV (1.5 keV RGS)

Resolution: 200 - 1200





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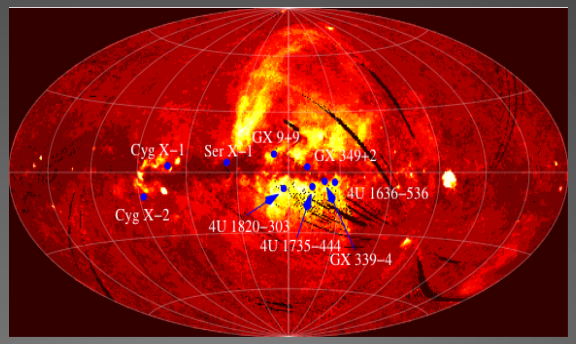
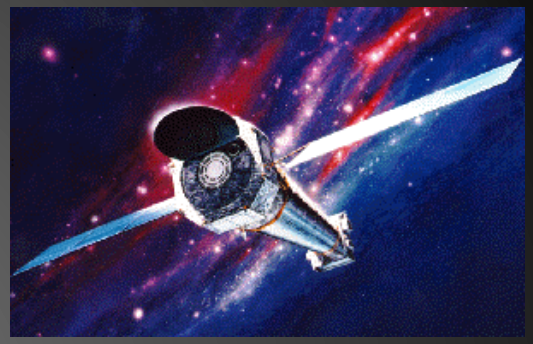
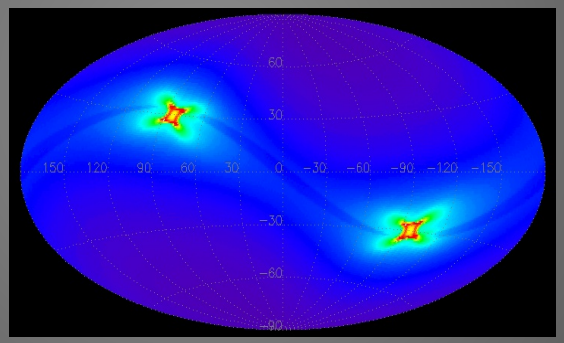
Near Future:

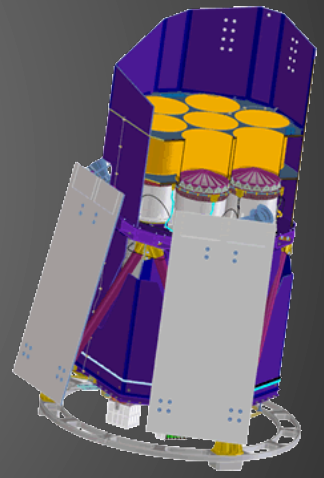
• Chandra & XMM-Newton:
Bright Galactic X-ray Sources
Range: 0.2 – 8 keV (1.5 keV RGS)
Resolution: 200 - 1200



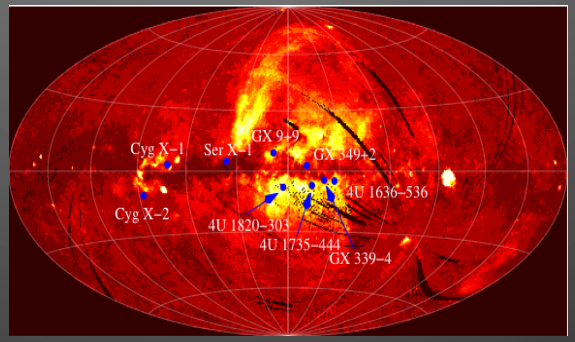


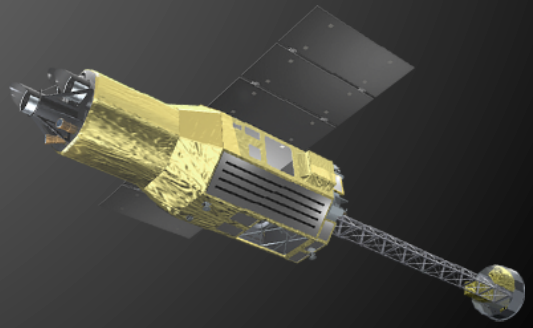
• eROSITA:
Soft & Hard All-Sky Survey 2014 – 2017
Range: 0.2 – 15 keV
Resolution: 6 – 60 (16)
Sensitivity: 25x RASS





•Astro-H:
Bright Galactic X-Ray Sources
Range: 0.3 – 12 keV
Resolution: 200 – 3000
Sensitivity: 1.5 – 3 x Chandra





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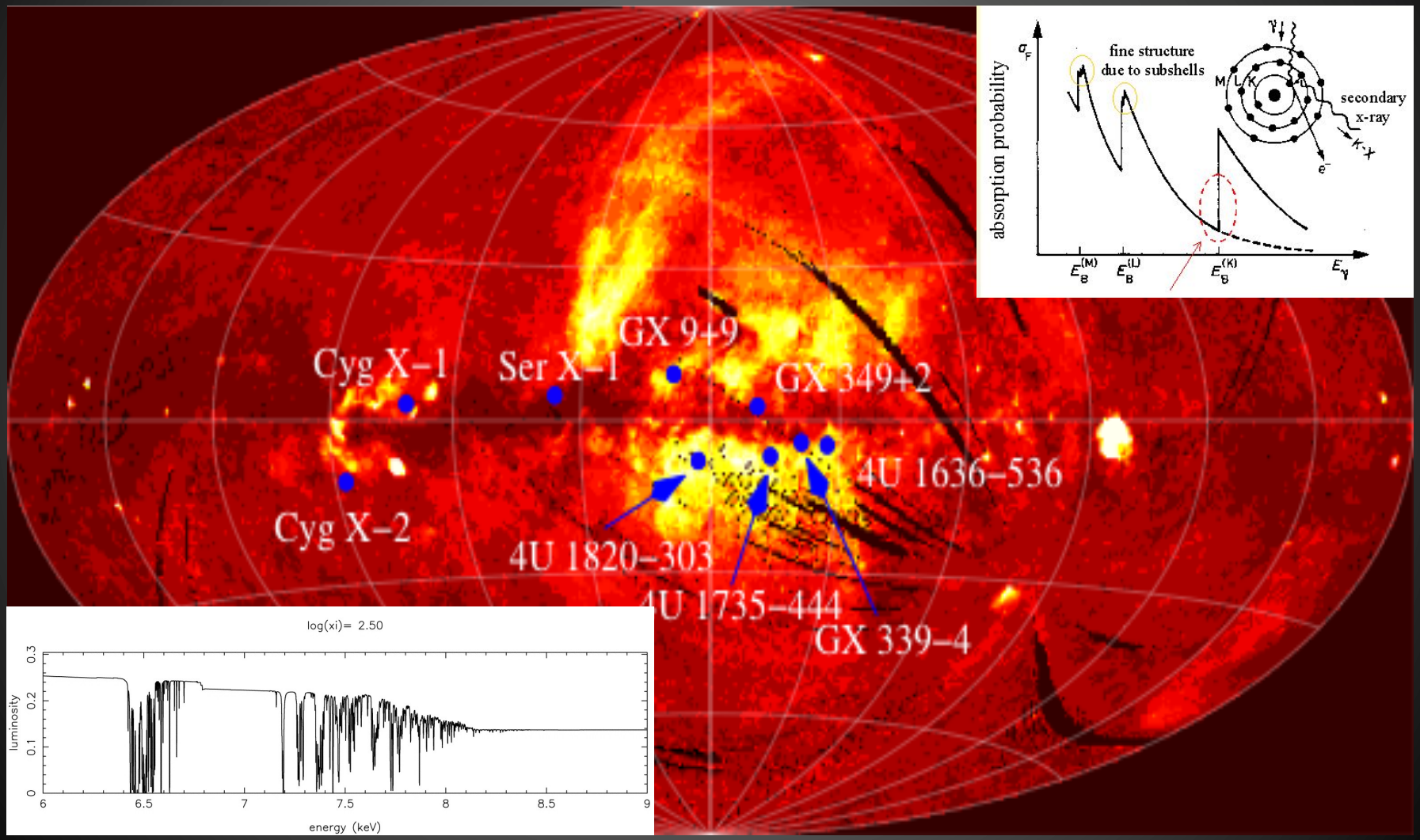
Photoelectric and Warm Absorption in Bright X-Ray Binaries:

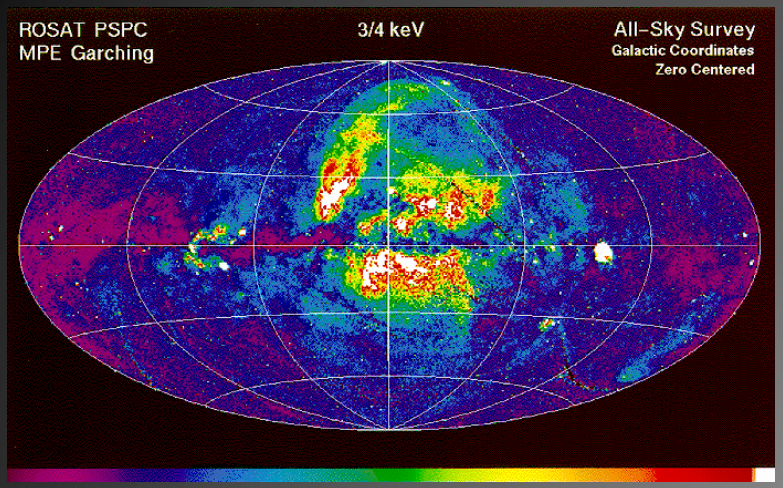


Distribution of Matter in Galaxies

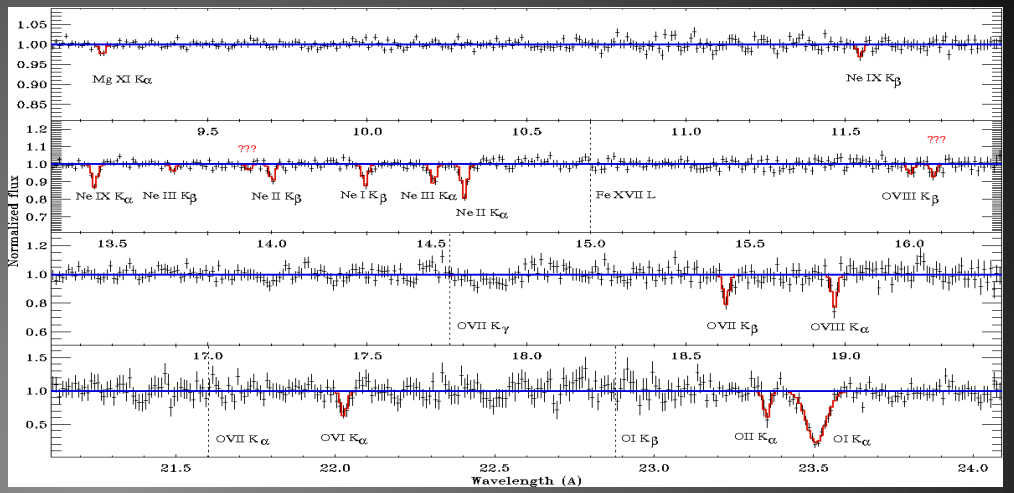
Q: What do we learn from Photoelectric and Warm X-Ray Absorption:

- State and Consistency of Atomic and Molecular Matter
- Absolute Matter Abundances: Neutral, Ionized Matter
- Cold, Warm, Hot Properties: Density, Temps, Kinematics
- Solid State Properties of Matter, Dust
- Accurate Redshifts up to z = 4
- No other waveband can offer all these simultaneously

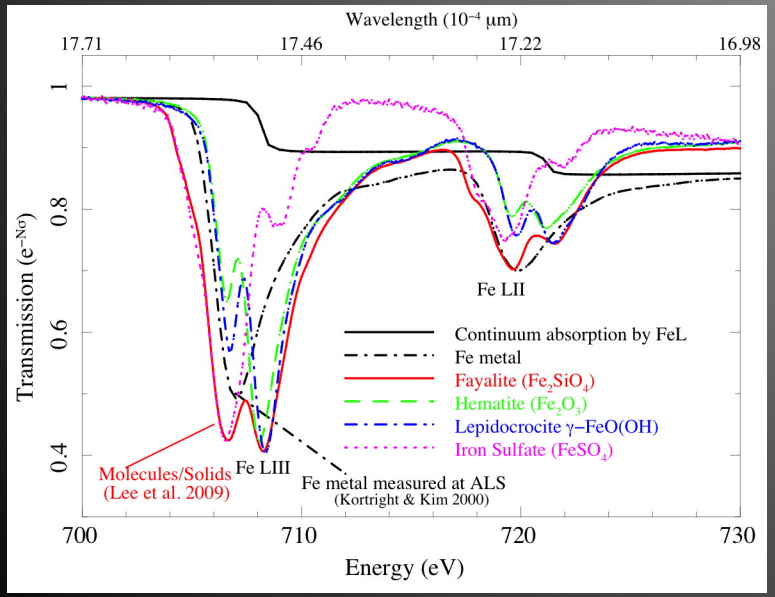
Distribution of Matter in Galaxies

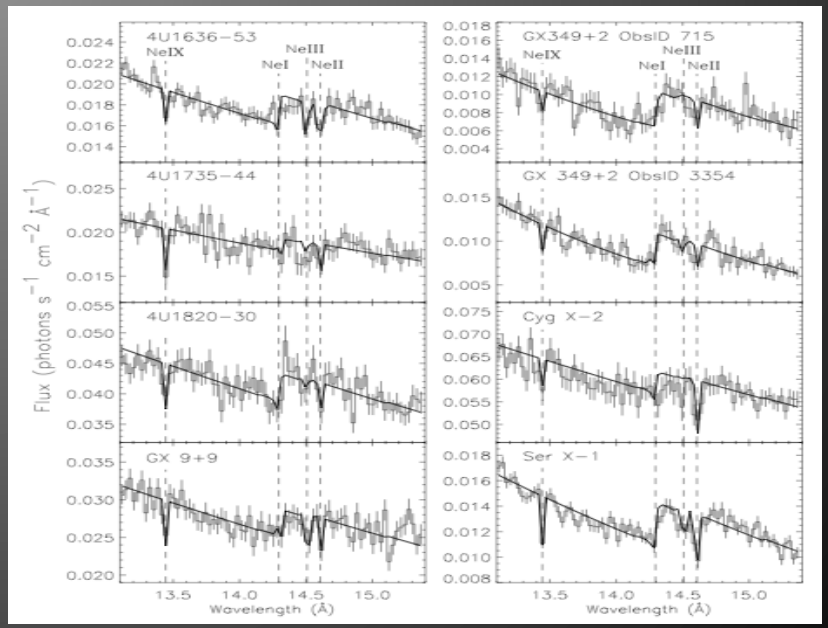


Cold, Warm, and Hot phases of ISMs: C, N, O, and Ne –K edges



Fe L edges, Mg, Si, S edges: dust





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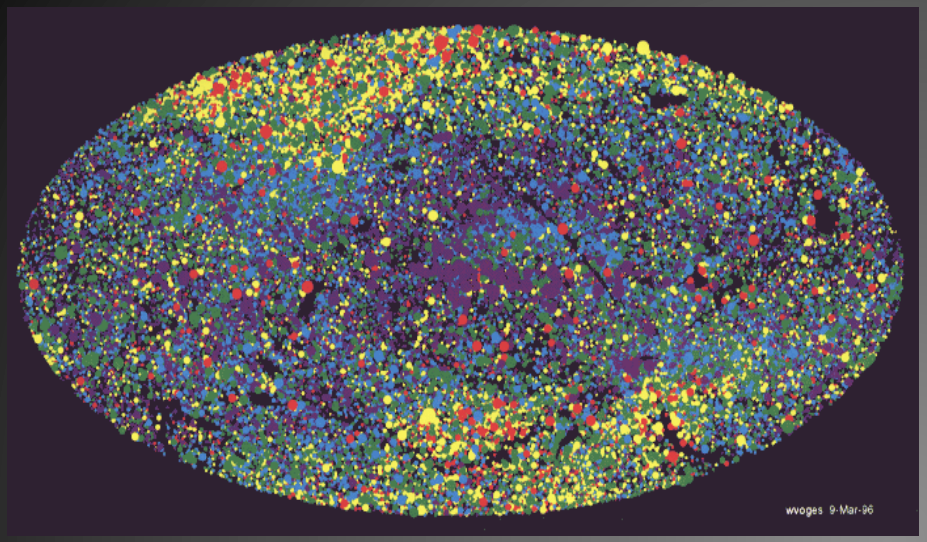
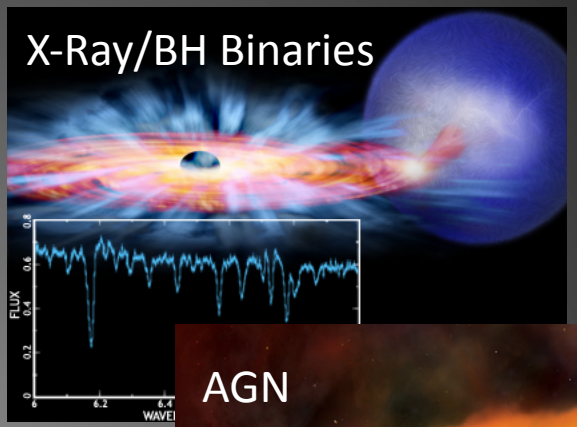
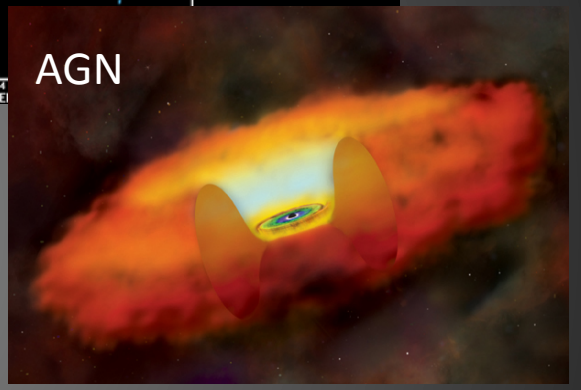
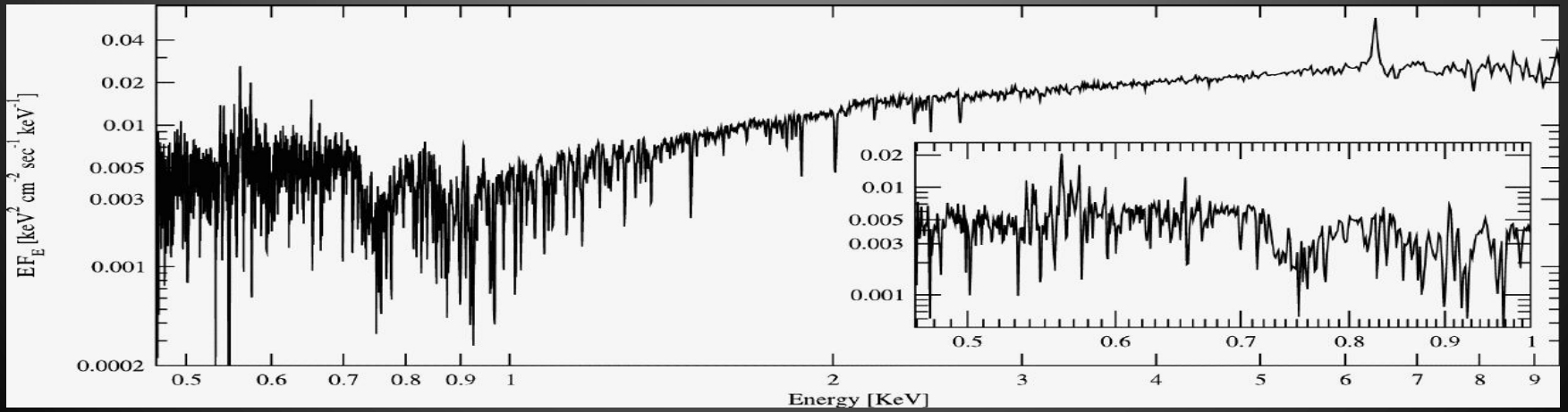






NGC 3783,
Kaspi et al. 2002



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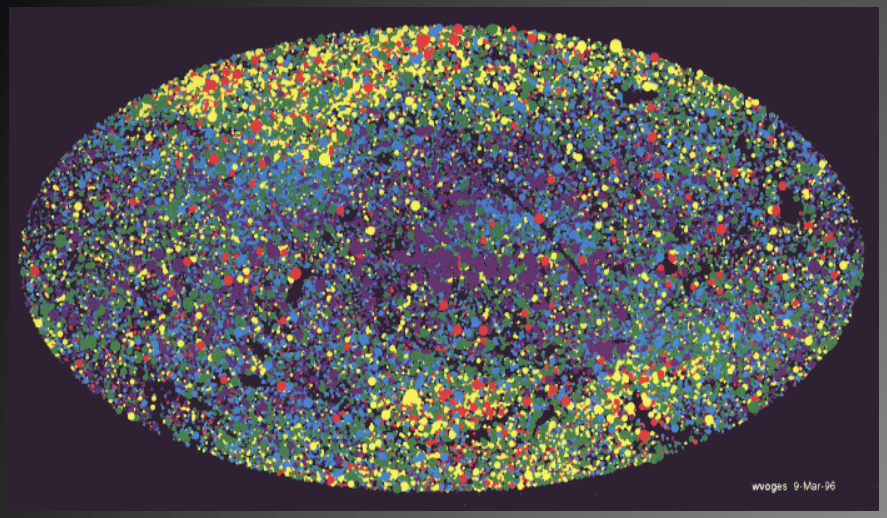
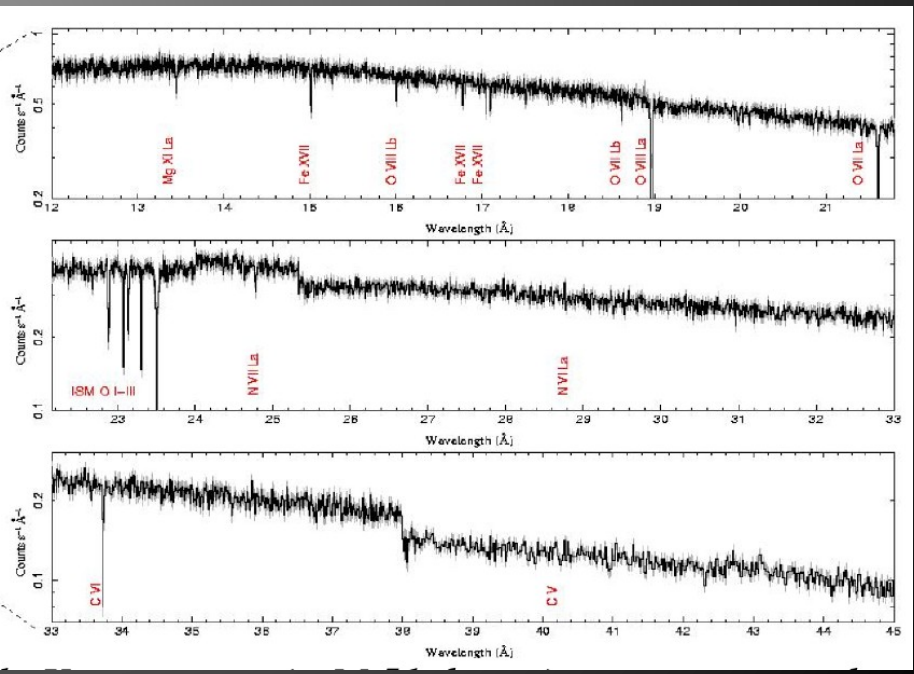


~5000 Galactic Sources:
Log f_x = [-9, -13]
<exposure> > 10 ks

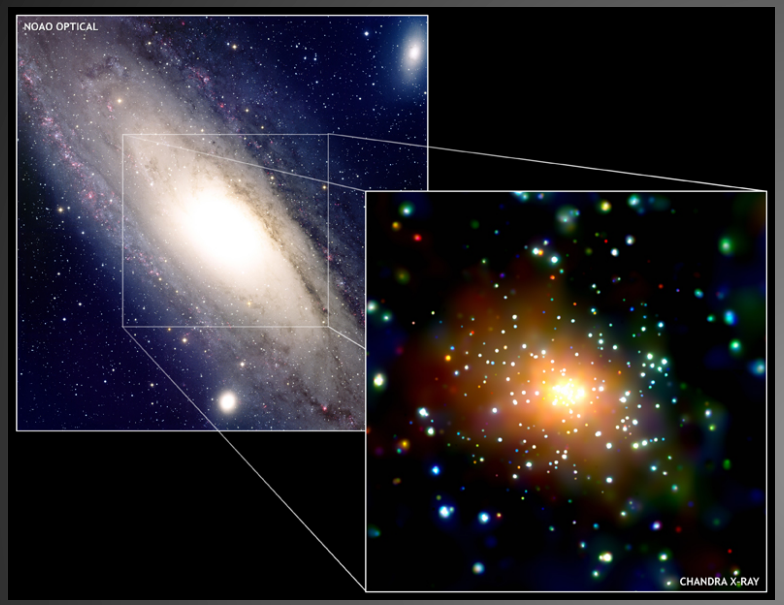
~ $10^{2.2}$ Nearby Galaxies/AGN:
Log f_x > -13]
<exposure> > 30 ks

> 10^3 Deep Survey Sources:
Log f_x = [-10 -14]
<exposure> > 100 ks

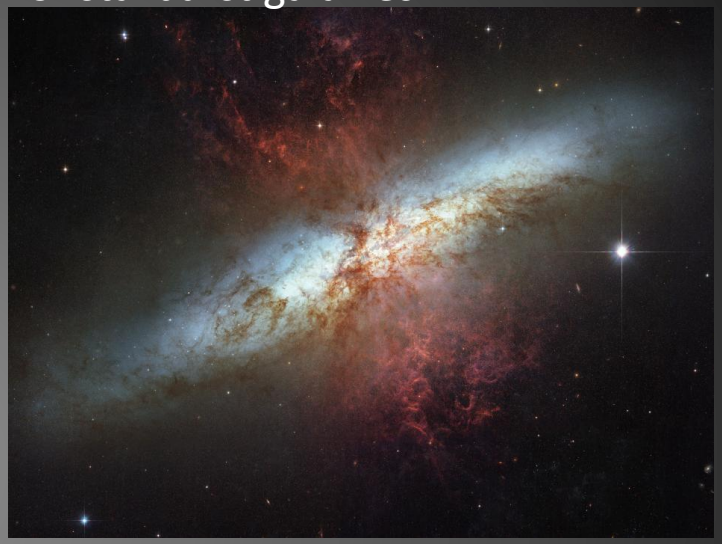


Distribution of Matter in Galaxies

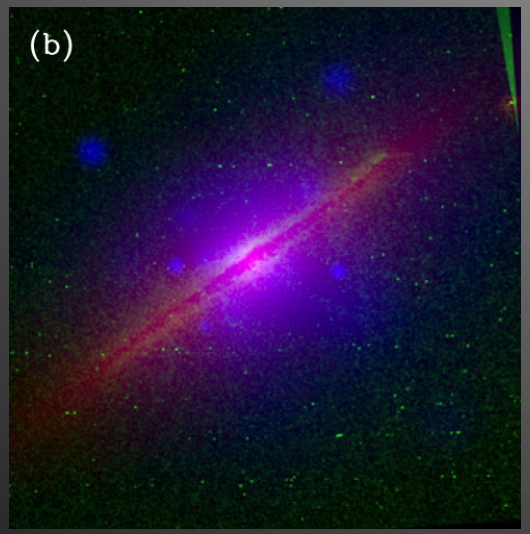
Map X-ray sources in Local group Galaxies



Kinematics and matter properties of starburst galaxies



Diagnose X-ray emissions From galactic halos:



Kinematics and matter properties of X-ray

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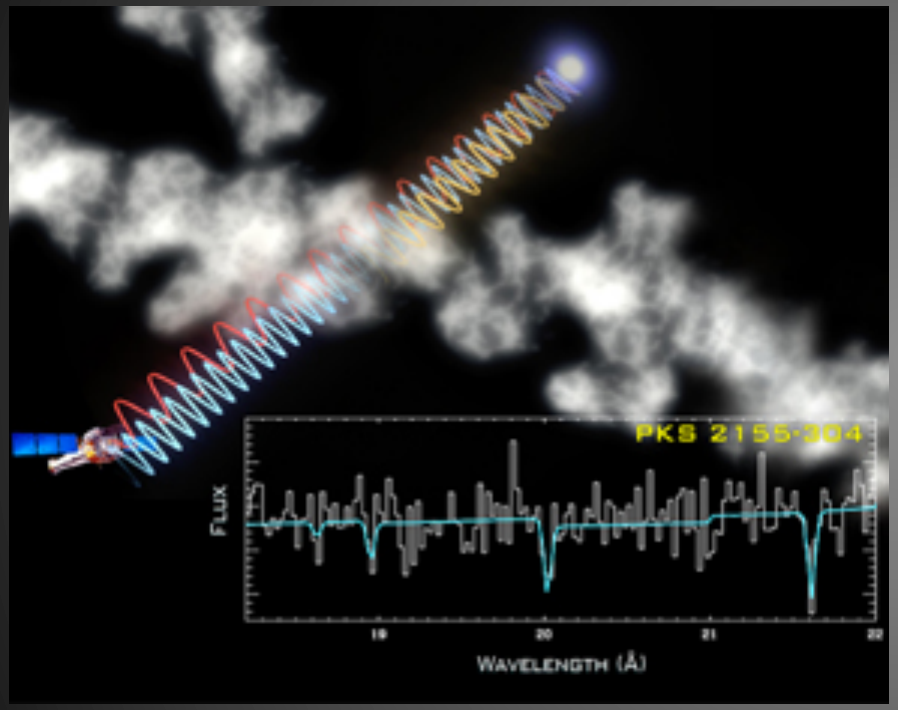
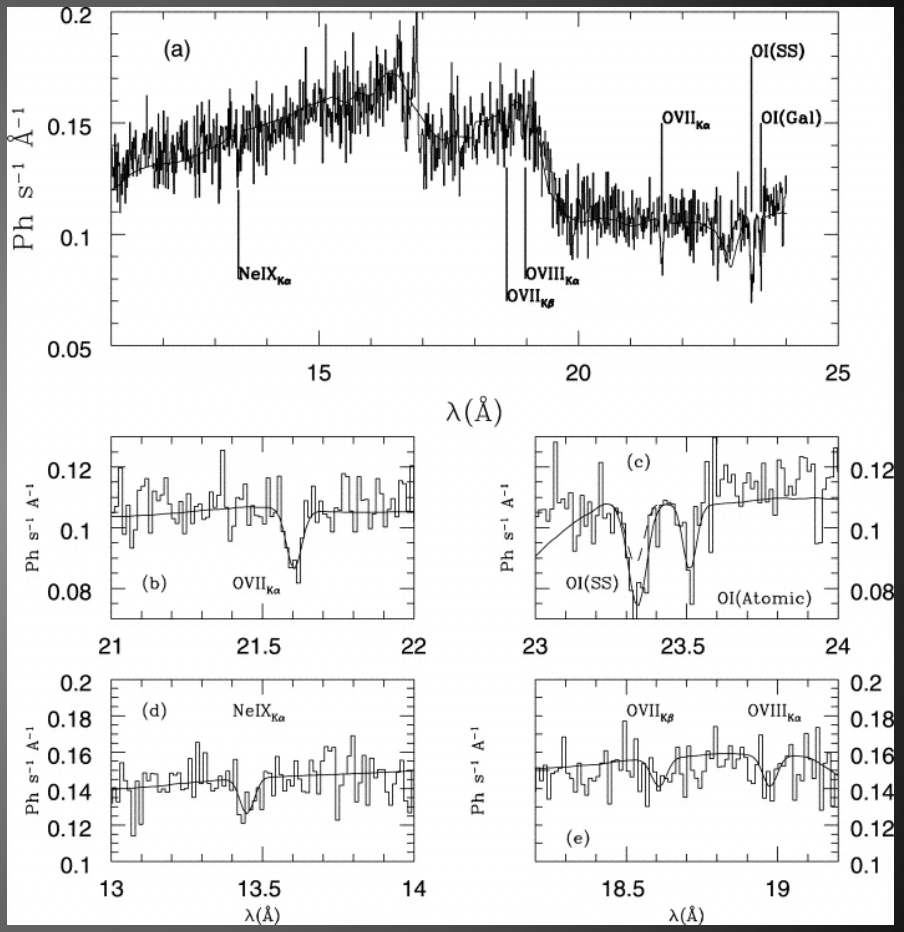
WHIM: baryonic matter absorption





Distribution of Matter in Galaxies

Q: What instrumentation do we need to realize effective X-ray absorption studies:

→high efficiency X-ray optics (segmented) with optical performance < 0.1" - 5"

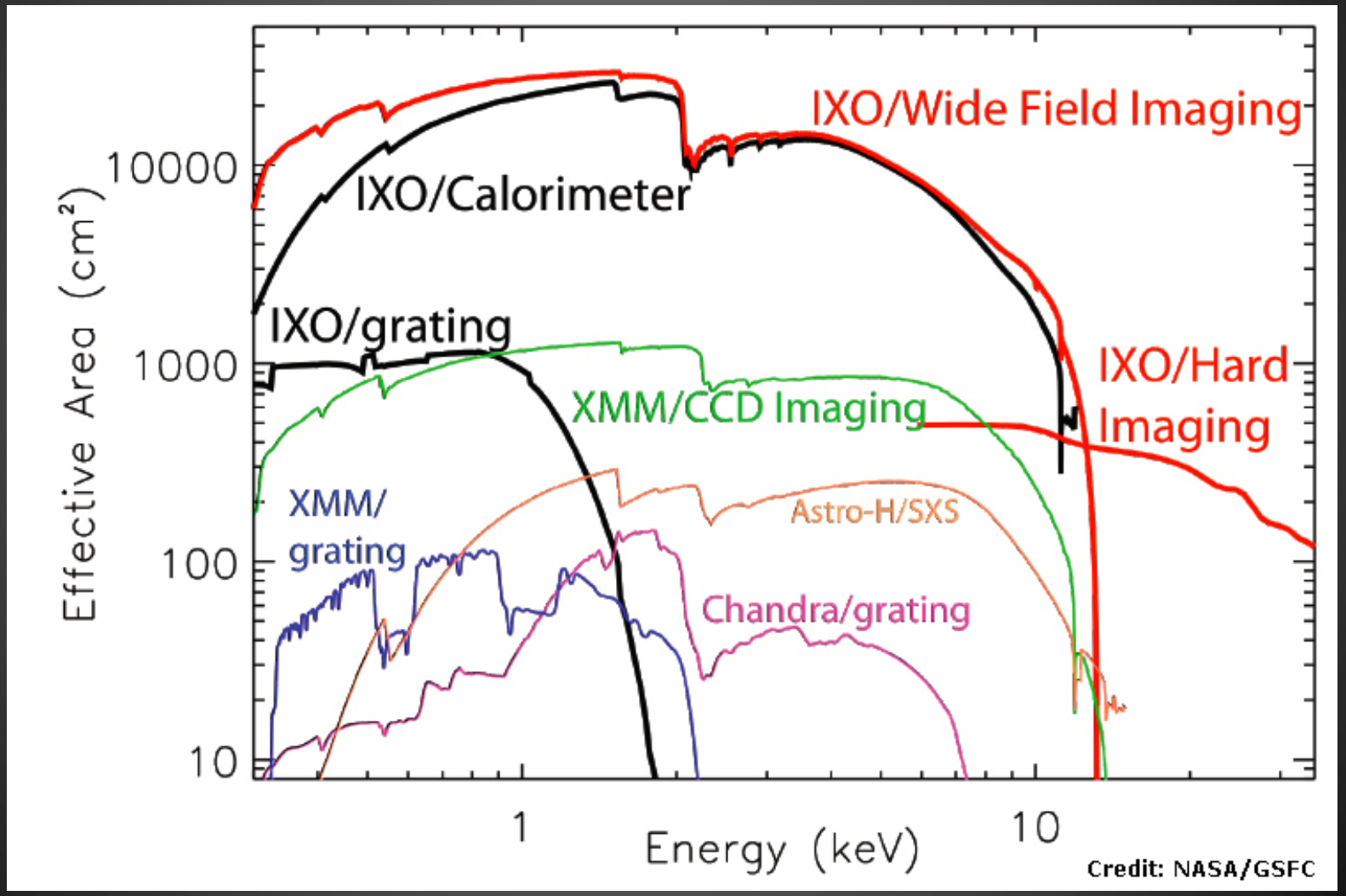
→ high resolution X-ray gratings with R > 3000 for E < 1.5 keV

→ X-ray micro-calorimeters with R > 2000 for E > 1.5 keV

→ Need R > 10000 to resolve thermal line properties

Distribution of Matter in Galaxies

→ Required Sensitivities (within the next decade):



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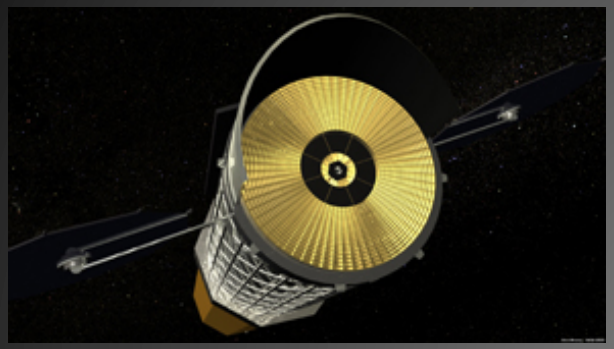
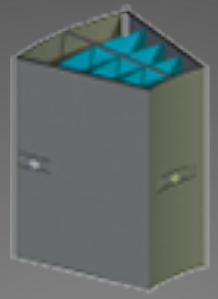
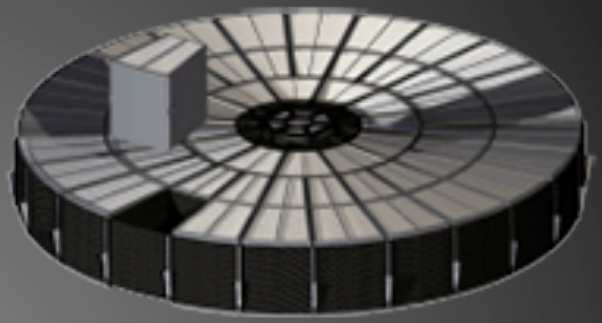
→ Technology development is well under way:



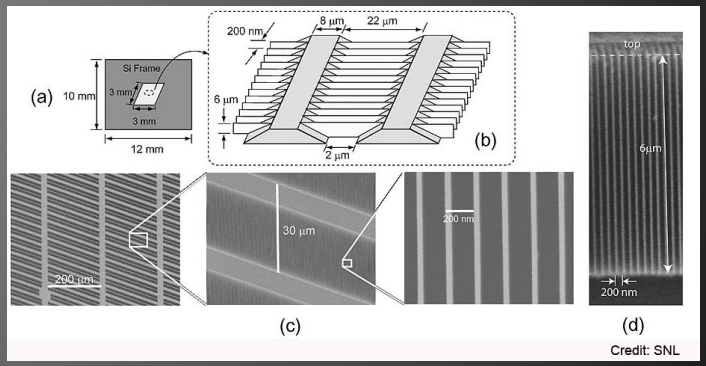
Large segmented slumped glass optics (IXO-type)

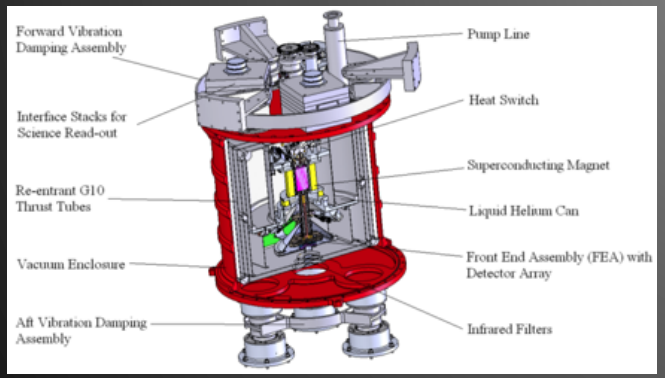




Large (piezo) adaptive optics (Smart-X-type)

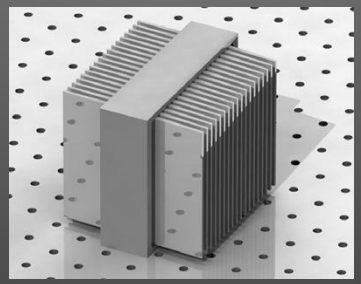
Critical angle





Micro-calorimeter developments

Off-plane



X-Ray grating developments

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Q: What can we do in the coming years/decades:

→Within the next 5 – 7 years we might utilize sub-orbital rockets to pursue specific science goals in the above categories and obtain sufficient technology readiness but should have at least some small explorer opportunities (i.e. Micro-X type)

→Within the next 12 -15 years medium explorer mission opportunities should be realized to pursue some limited surveys

→ Beyond 15 years we should be able to perform proper and deep surveys with the power of a Generation-X-type X-ray observatory

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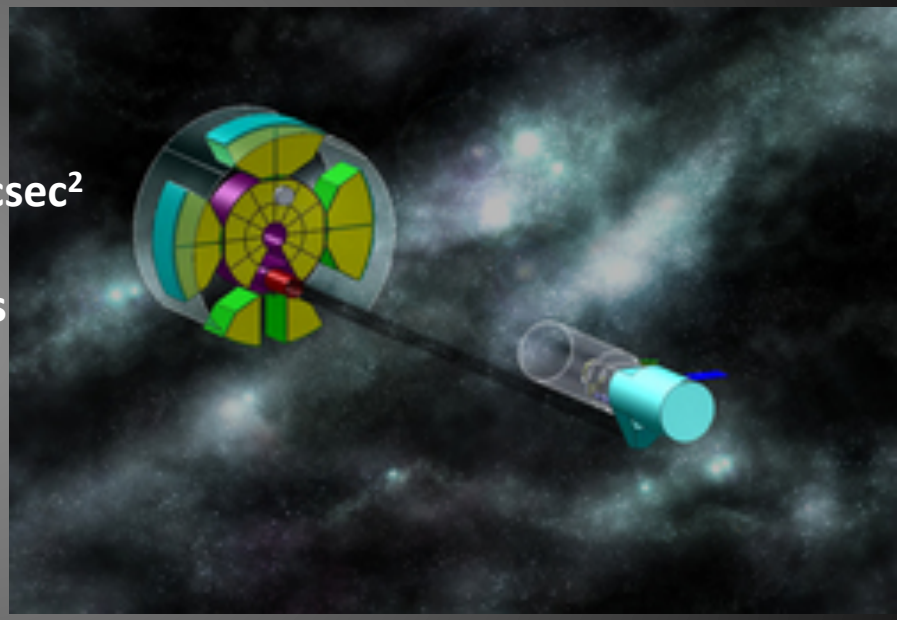
→ Generation X-type Observatory (beyond the next decade):

BaselineEffective Area (@1 keV)	50 m^2
Angular Resolution	0.1" HPD
Energy Resolution (@1 keV)	E/dE=10,000
Background (< 2.0 keV)	0.004 cts/ks/$arcsec^2$
Energy Range	0.1 - 10 keV
Field of View	5 arcmin radius
Time Resolution	50 ms
Sky Availability	90%
Calibration	3% absolute
Launch Vehicle and Orbit	Ares V to Sun-Earth L2
Launch Date	2030+



Concluding Remark:

X-ray absorption spectroscopy is a powerful tool to study existing forms of matter in our Universe. The roadmap for the next 30 years needs to lead to means and strategies which allows us to perform such absorption surveys as effectively as surveys are now or in very near future quite common in astronomy pursued in other wavelength bands such as optical, IR, and sub-mm.