The Origin of the Cosmic X-ray Background

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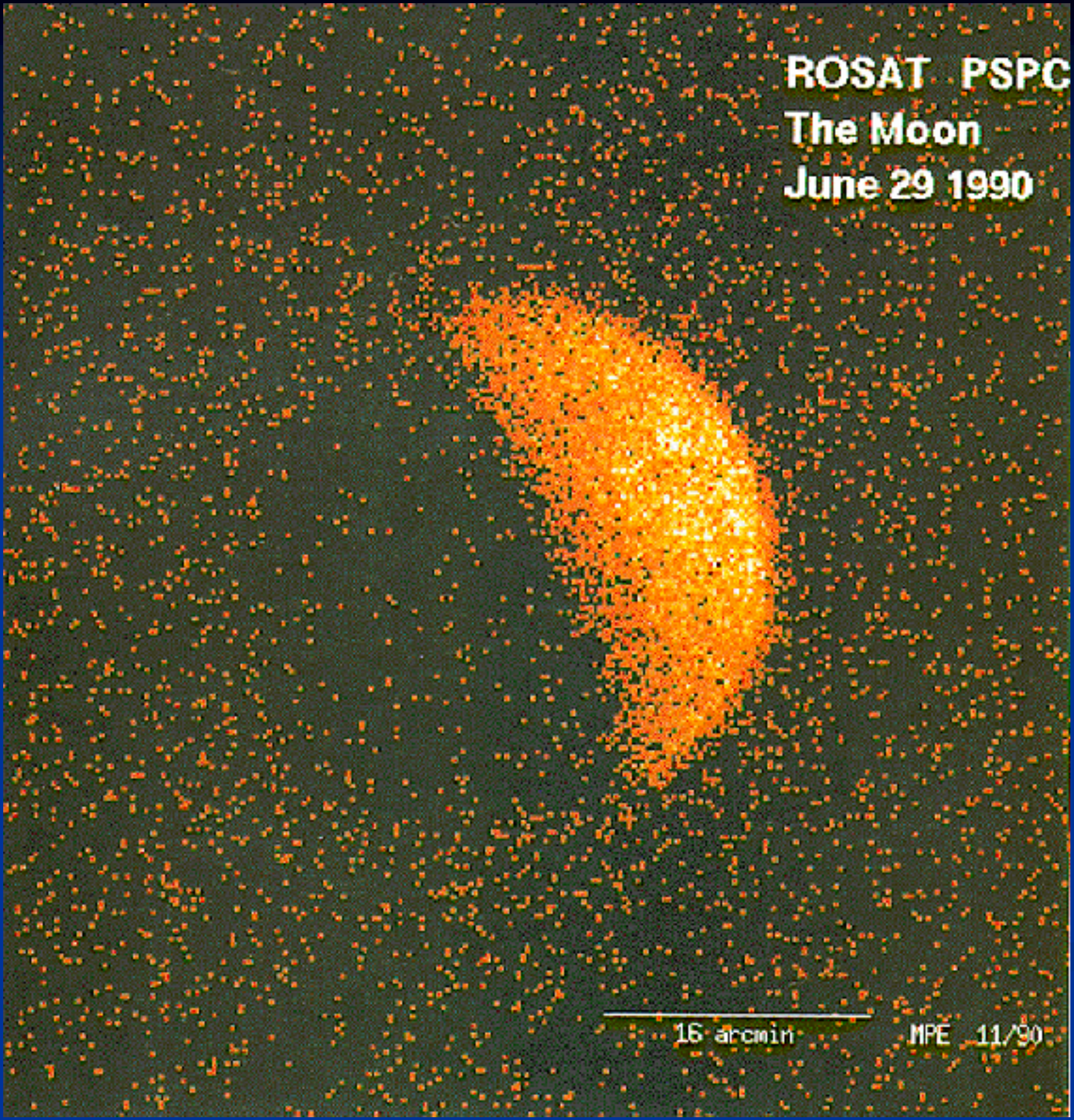
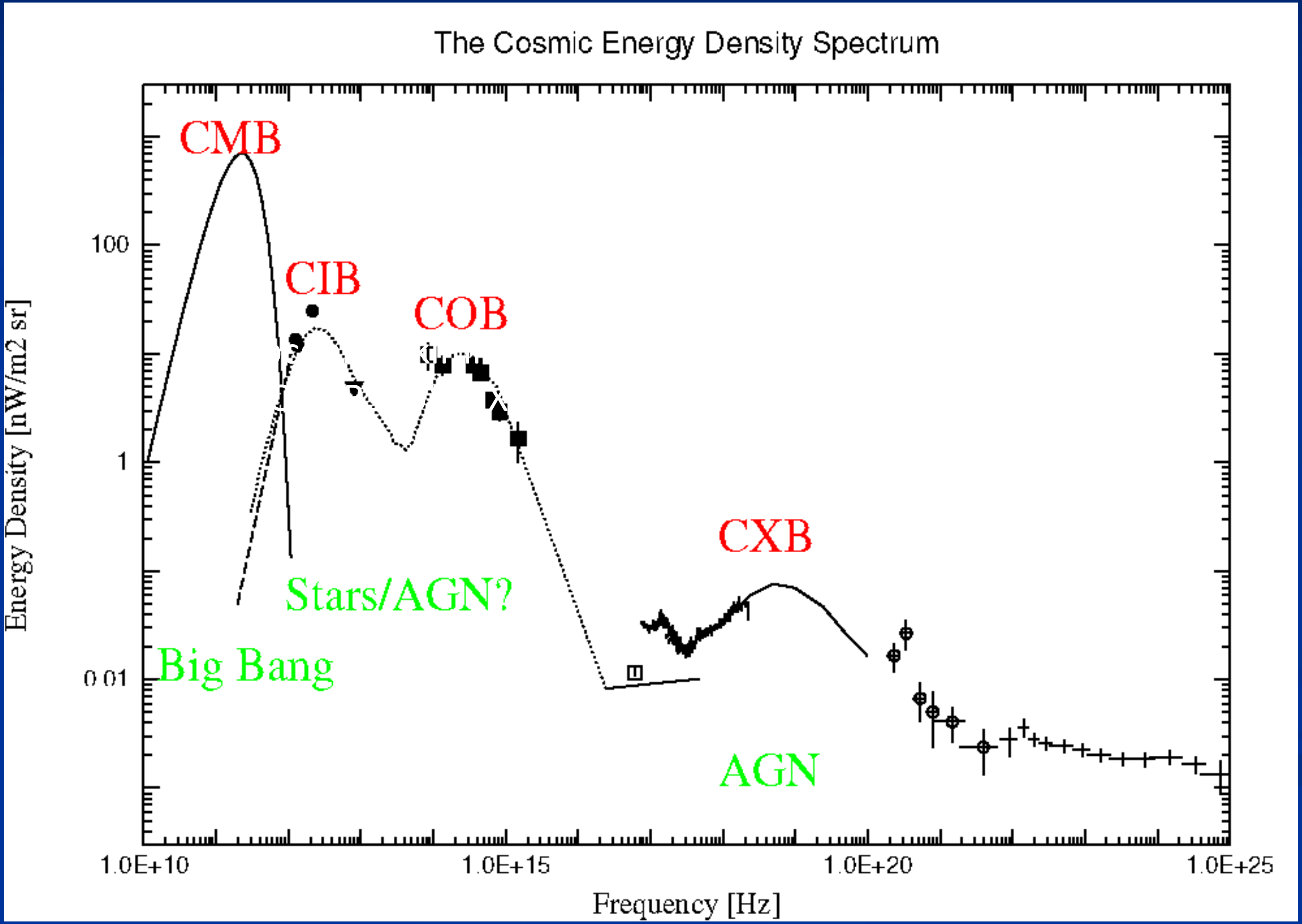


ROSAT PSPC
The Moon
June 29 1990
16 arcmin
MPE 11/90

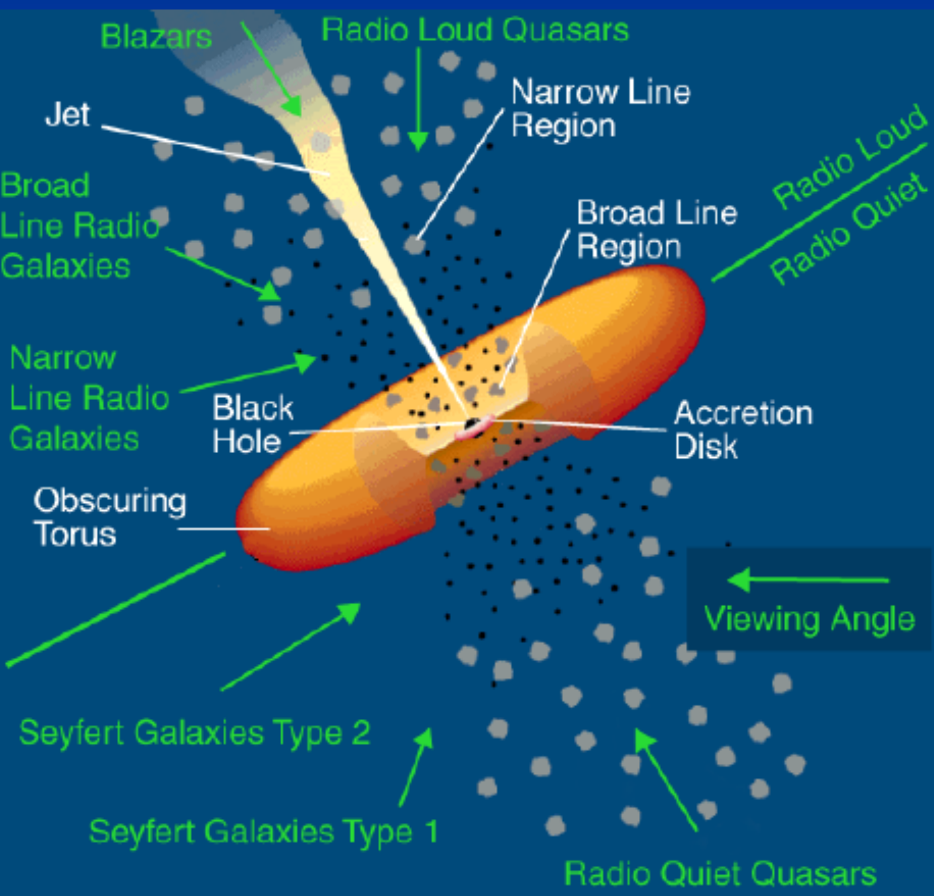
Cosmic Background Radiation

Hasinger 2000

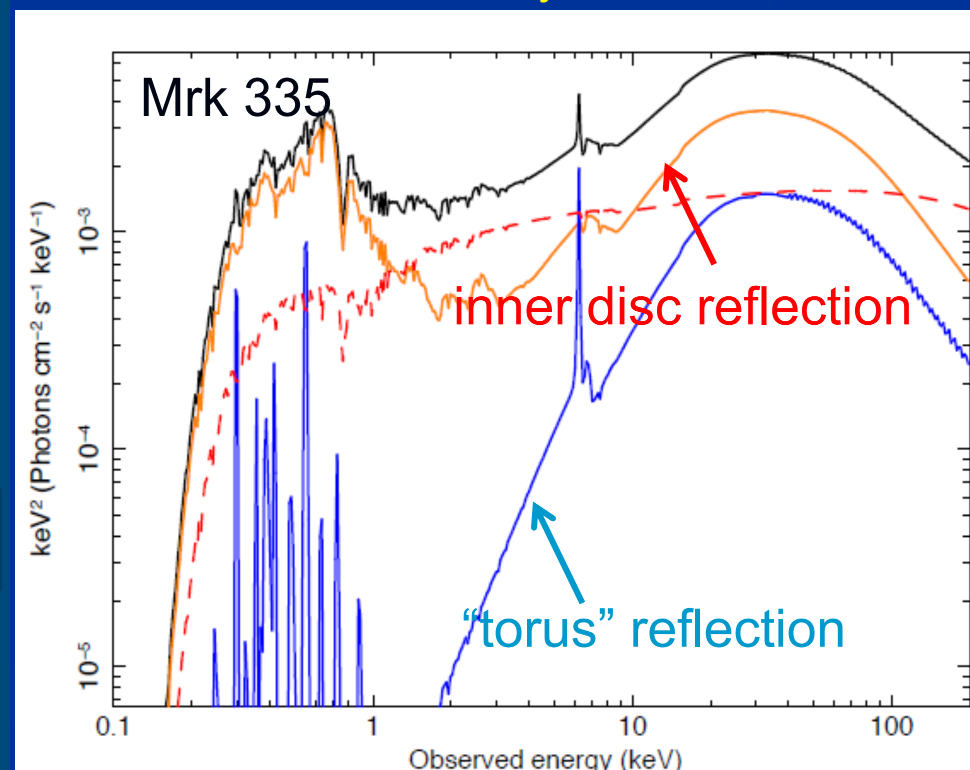


X-ray Spectrum of type-1 AGNs

- primary continuum (power law with high-E cutoff)
- absorption or emission from ionized gas
- Reflection from accretion disk/BLR/torus



Reynolds, Ueda+ 2015

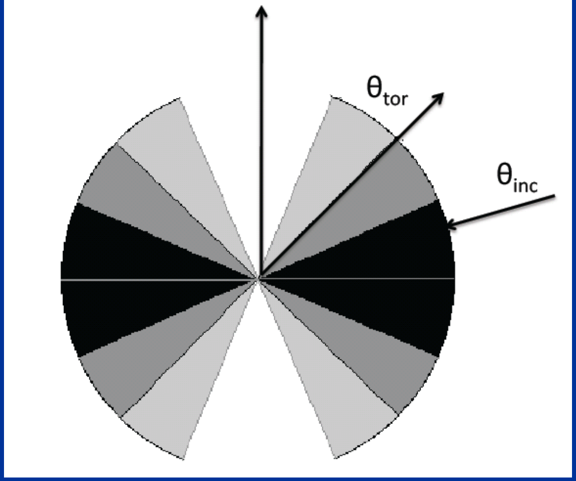


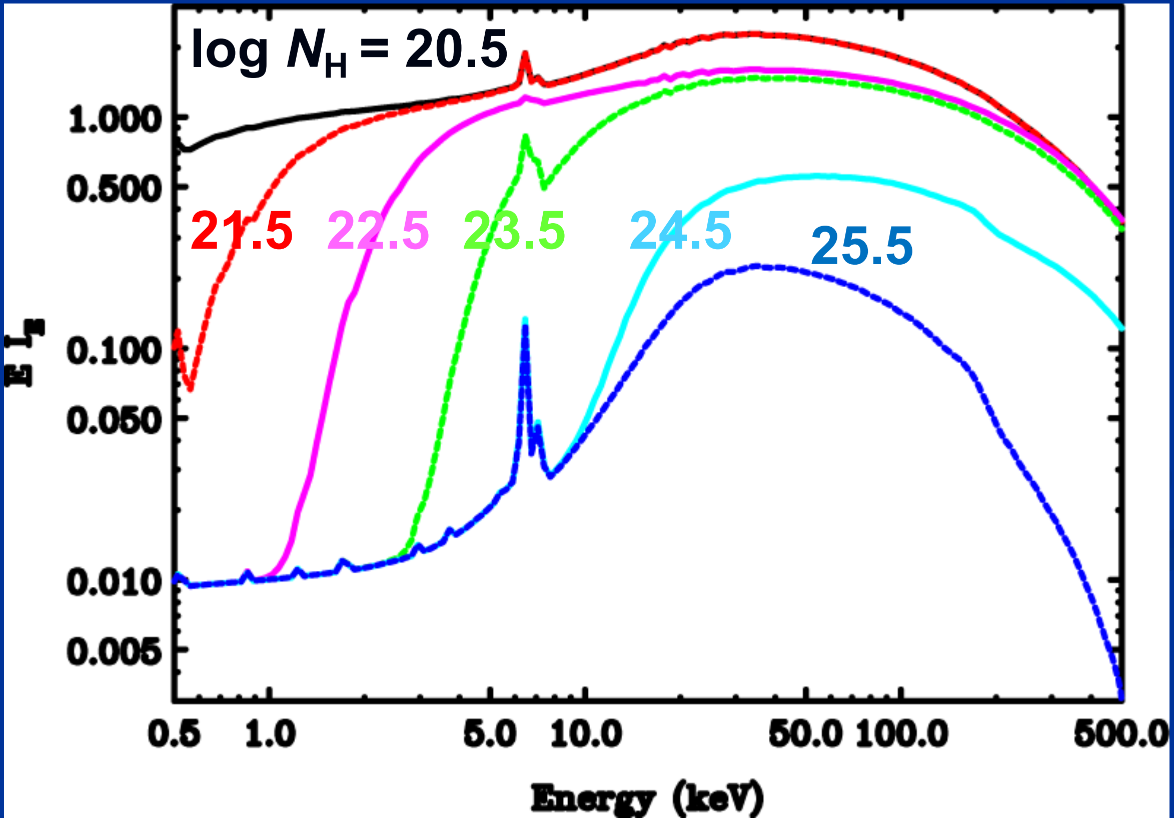
Effect of Obscuration (type 2 AGN)

- X-ray spectra become "hard" by photoelectric absorption in torus
- Hard X-rays (ideally *E* >10 keV) are the best band to catch the whole AGN population including heavily obscured (Compton-thick) AGNs

Ueda+14

Brightman&Nandra+11

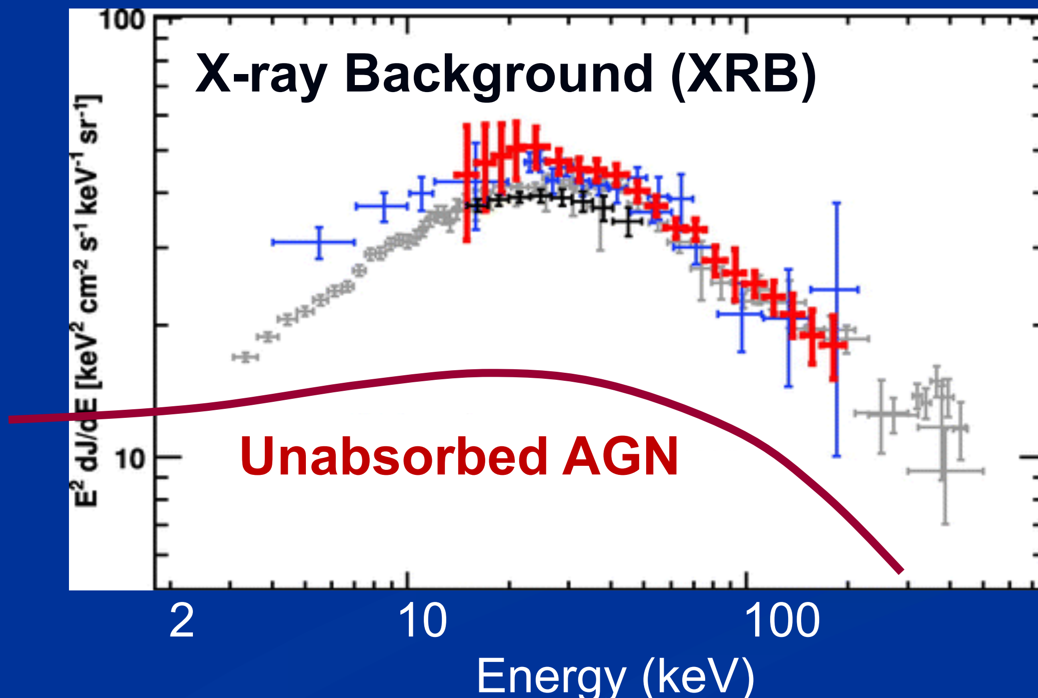




The Spectrum of the CXB

- The XRB is the integrated emission from all the AGNs in the universe, telling us the growth history of supermassive black holes.
- The energy density peaks at ~30 keV (coincidentally, it resembles a thermal bremsstrahlung of 40 keV)
- The shape of the XRB indicates that *most of the AGNs are obscured.*

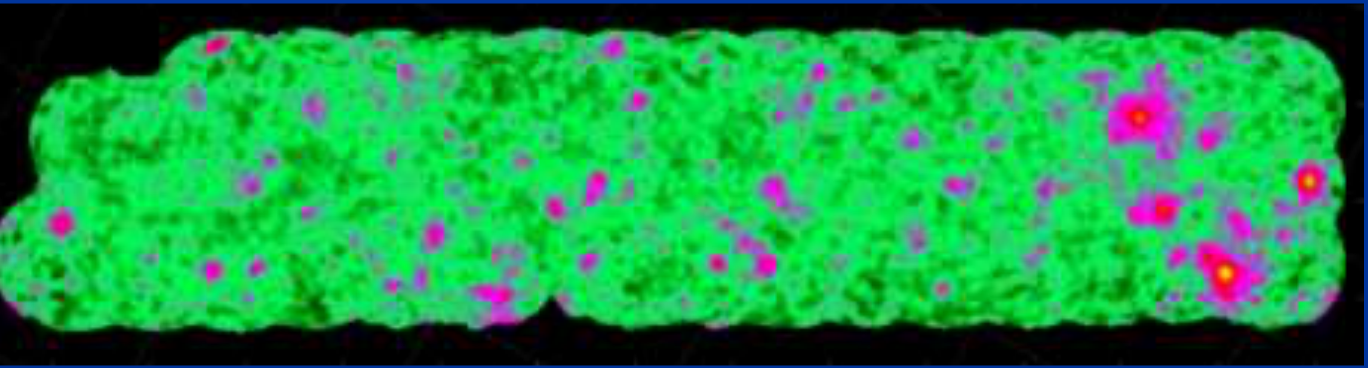
Ajello+ 08

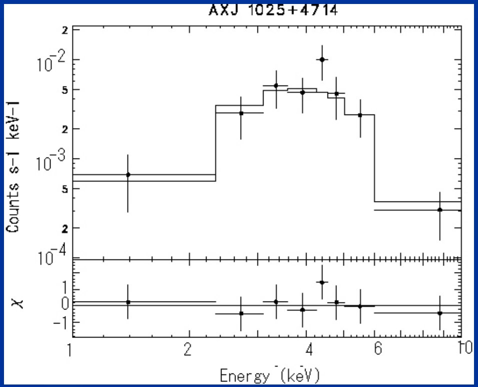


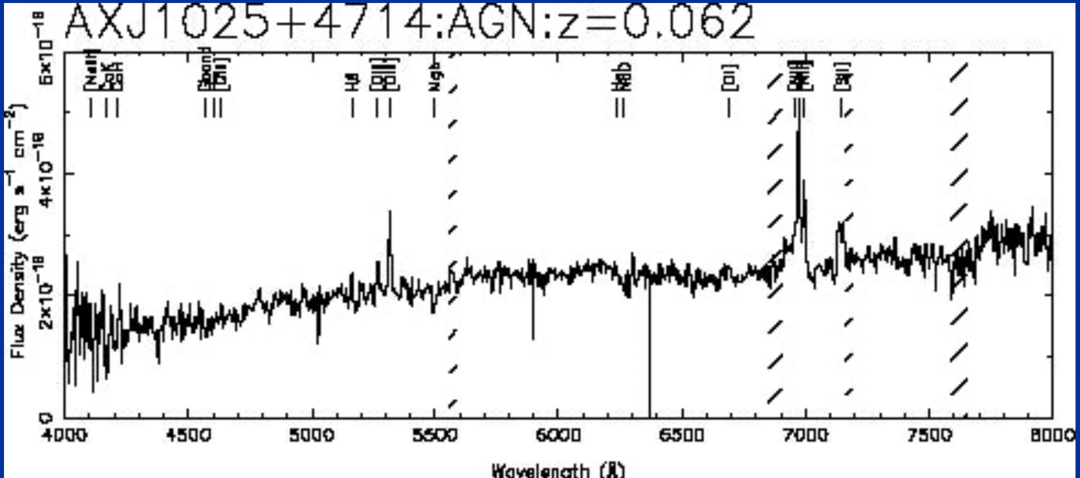
Resolving CXB

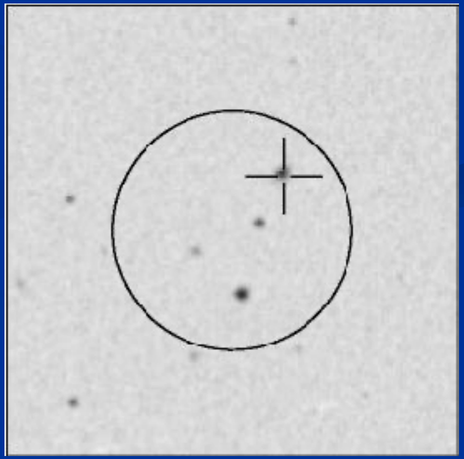
- History of X-ray Astronomy= to detect X-ray sources constituting the CXB with better sensitivities in harder band (e.g., HEAO1, ASCA, XMM-Newton/Chandra in 2-10 keV)
- Indeed 2-10 keV CXB is dominated by obscured AGNs!
- Optical identification (determination of redshift) leads to determine their luminosity function

ASCA Large Sky Survey (Ueda+98, Akiyama+00)





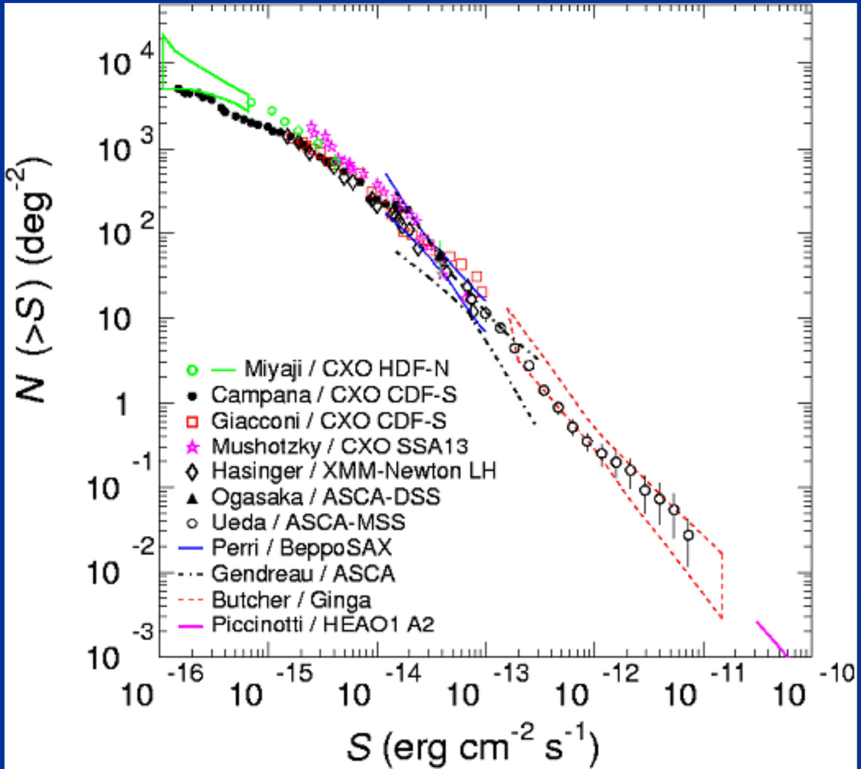




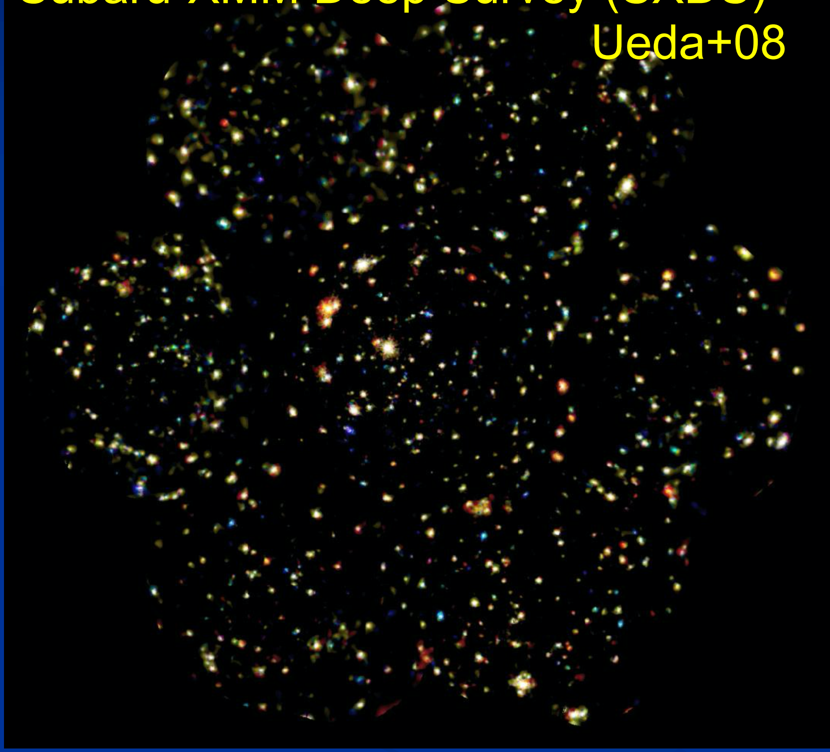
The CXB below 10 keV

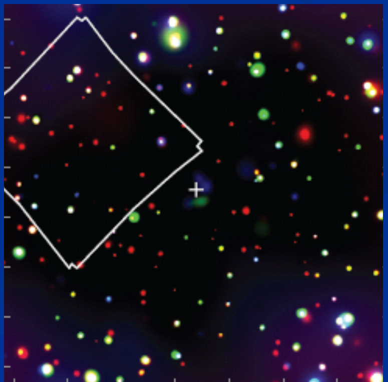
- Now almost all of the CXB below ~10 keV is resolved, mostly into Compton-thin AGNs ($N_H < 10^{24}$ cm^2) with ~10^4 deg^{-2}
- X-ray surveys are the most sensitive among those at any wavelengths

Kushino+ 02



Subaru-XMM Deep Survey (SXDS)
Ueda+08



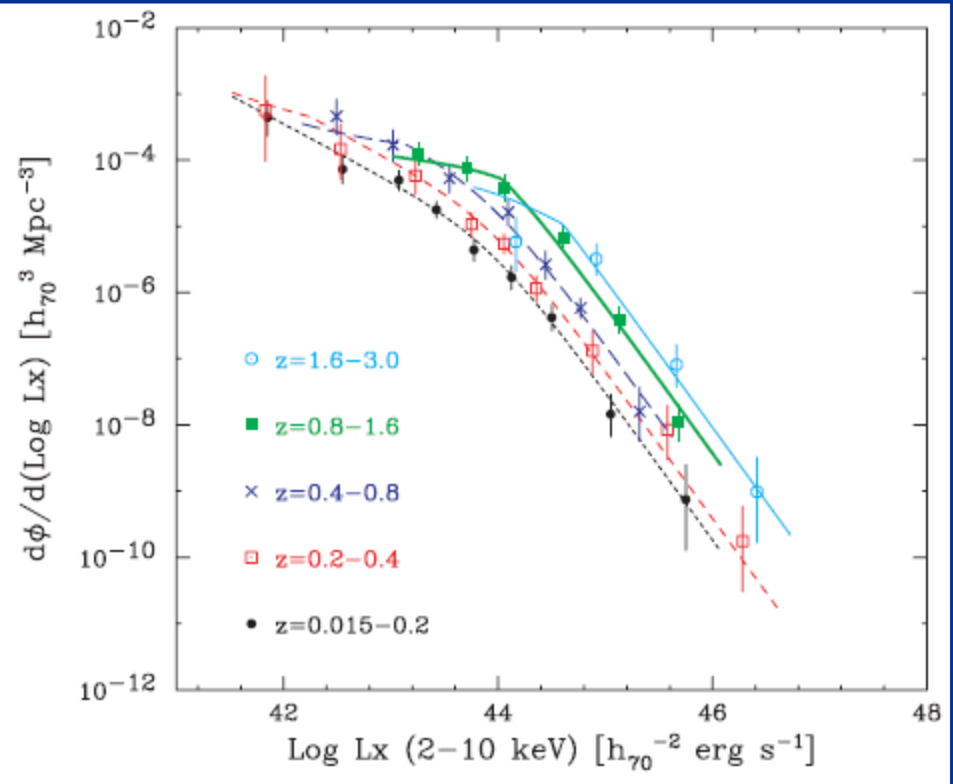


CDFS
Xue+ 11

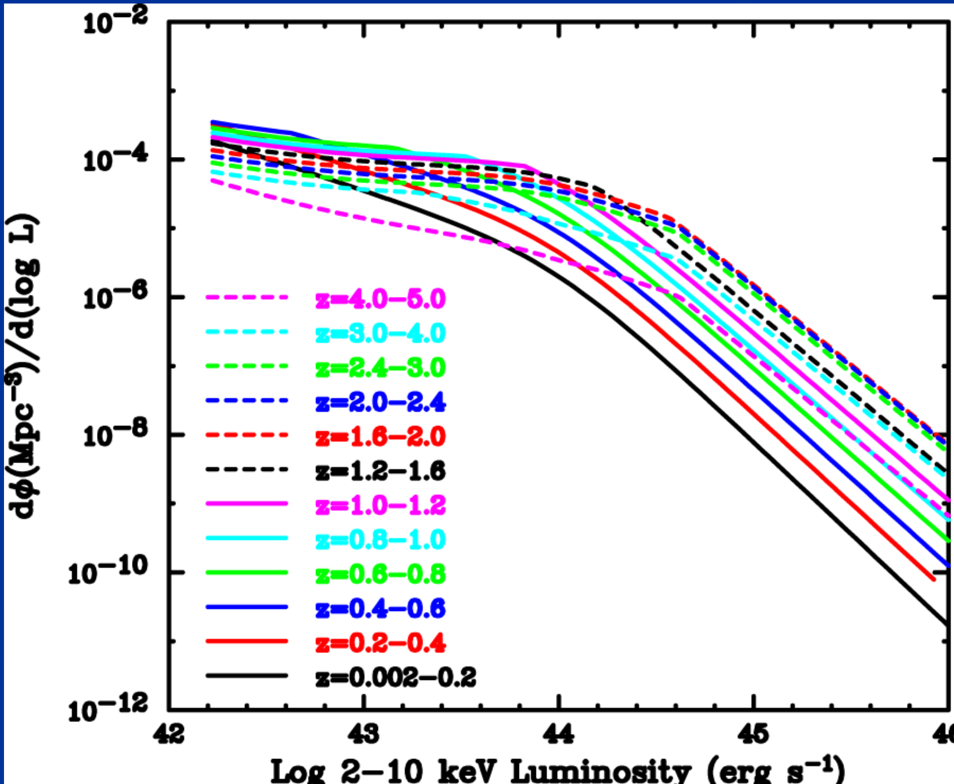
AGN X-ray Luminosity Function

- Luminosity function = comoving spatial number density as a function of luminosity and redshift
- AGN XLF is well described by Luminosity Dependent Density Evolution (LDDE)

Ueda+03



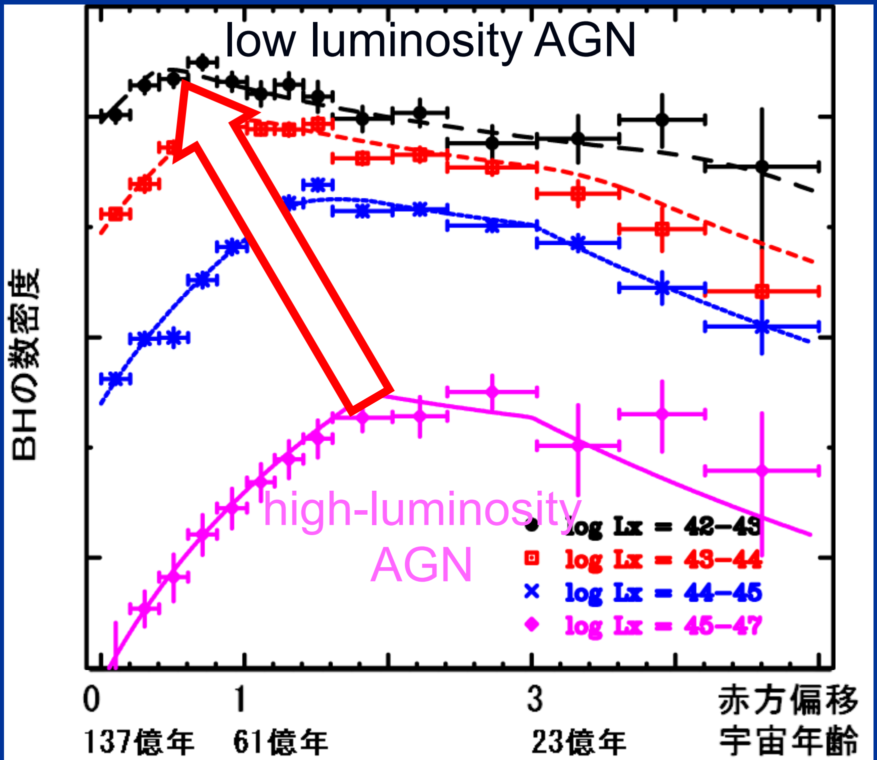
Ueda+14



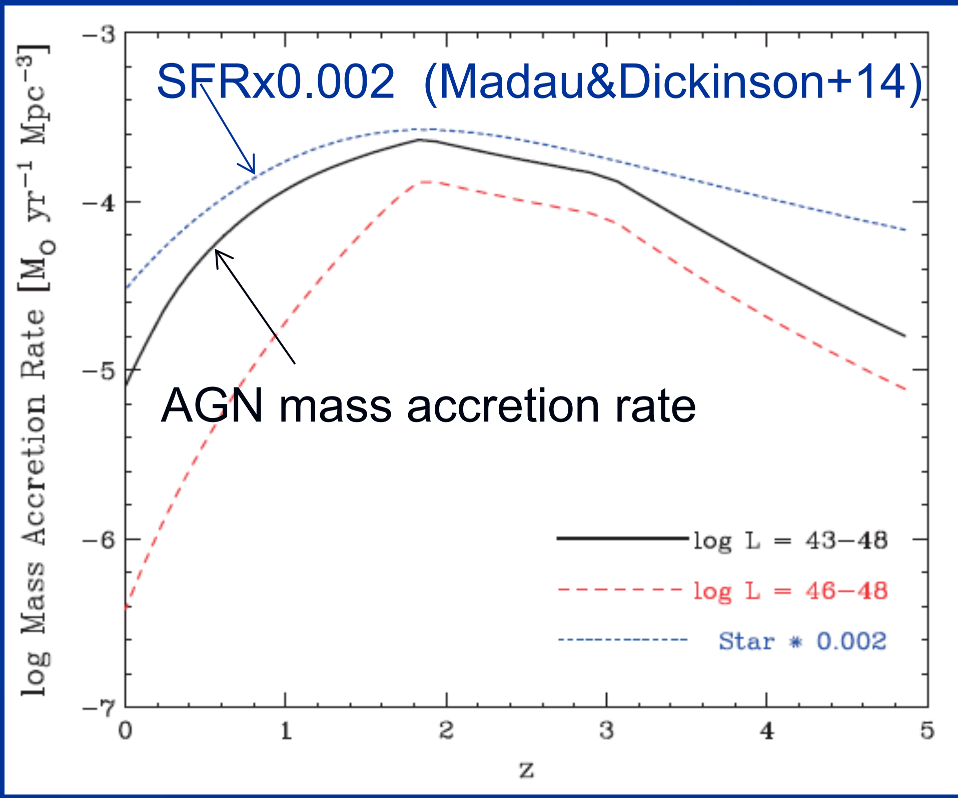
Results from AGN surveys at E<10 keV

- "Downsizing" or "anti-hierarchical evolution"
  - Apparently opposite to the bottom-up scenario predicted by CDM model
  - Large number of obscured, lower luminosity AGNs
- Overall good match between star forming rate denstity and mass-accretion rate density, supporting "co-evolution"

Ueda+ 14



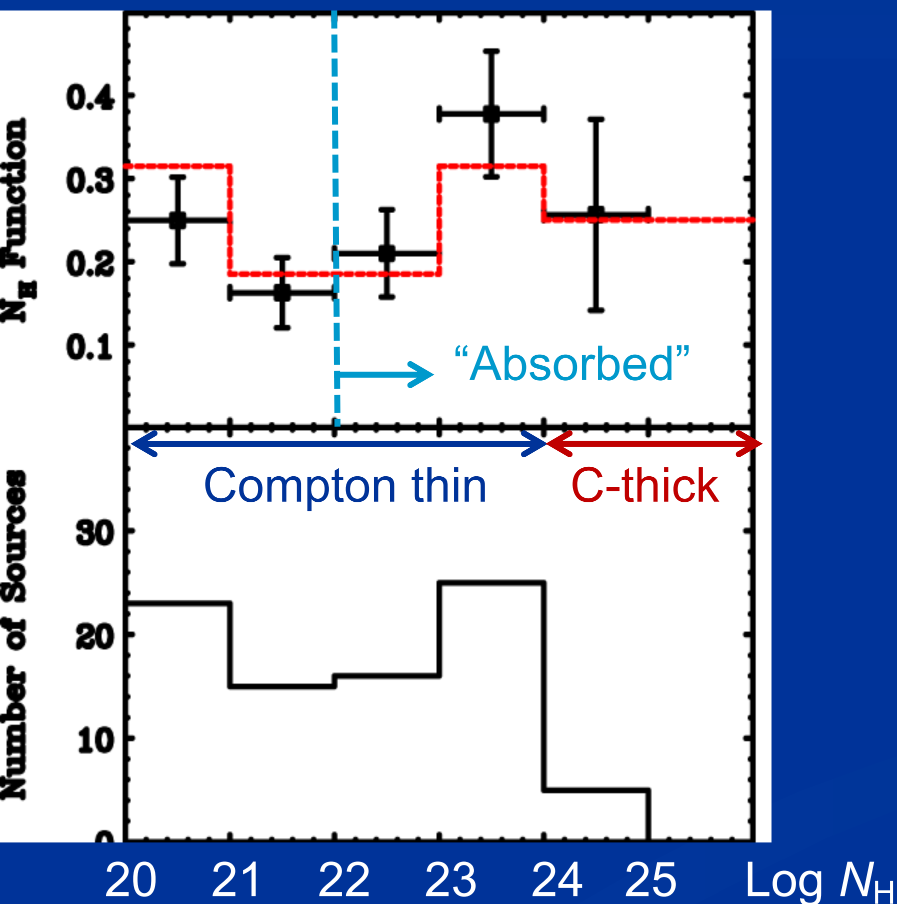
Ueda 15, Aird+15a



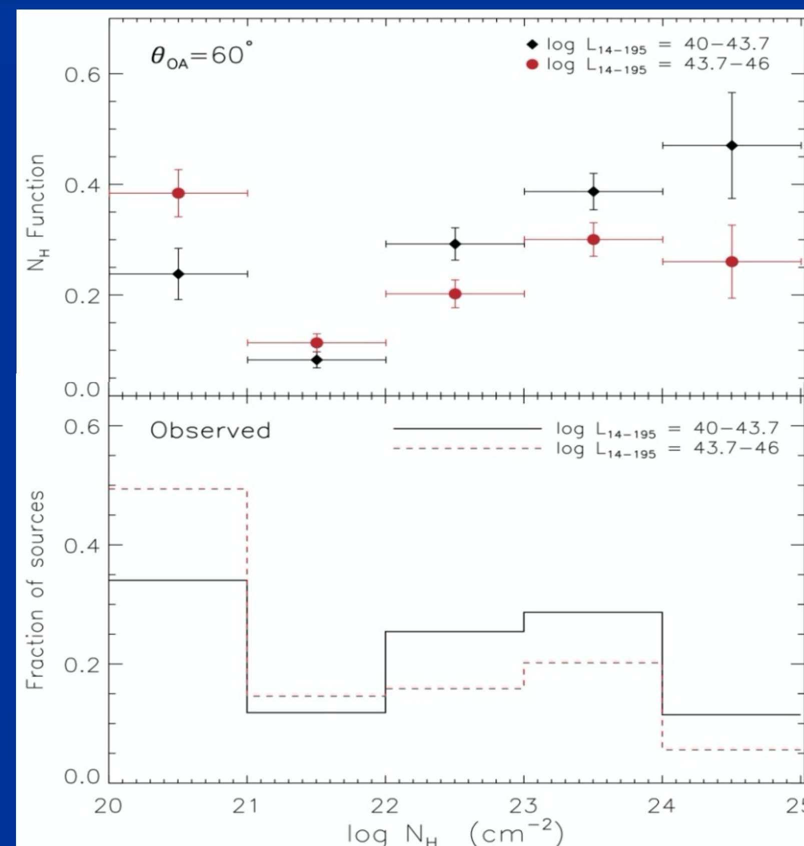
Absorption Distribution

- In the local universe, Swift/BAT (14-195 keV) survey gives tightest constraint on the column density distribution
- It depends on luminosity (or Eddington ratio) and redshift

Swift/BAT 9-month (Ueda+ 14)

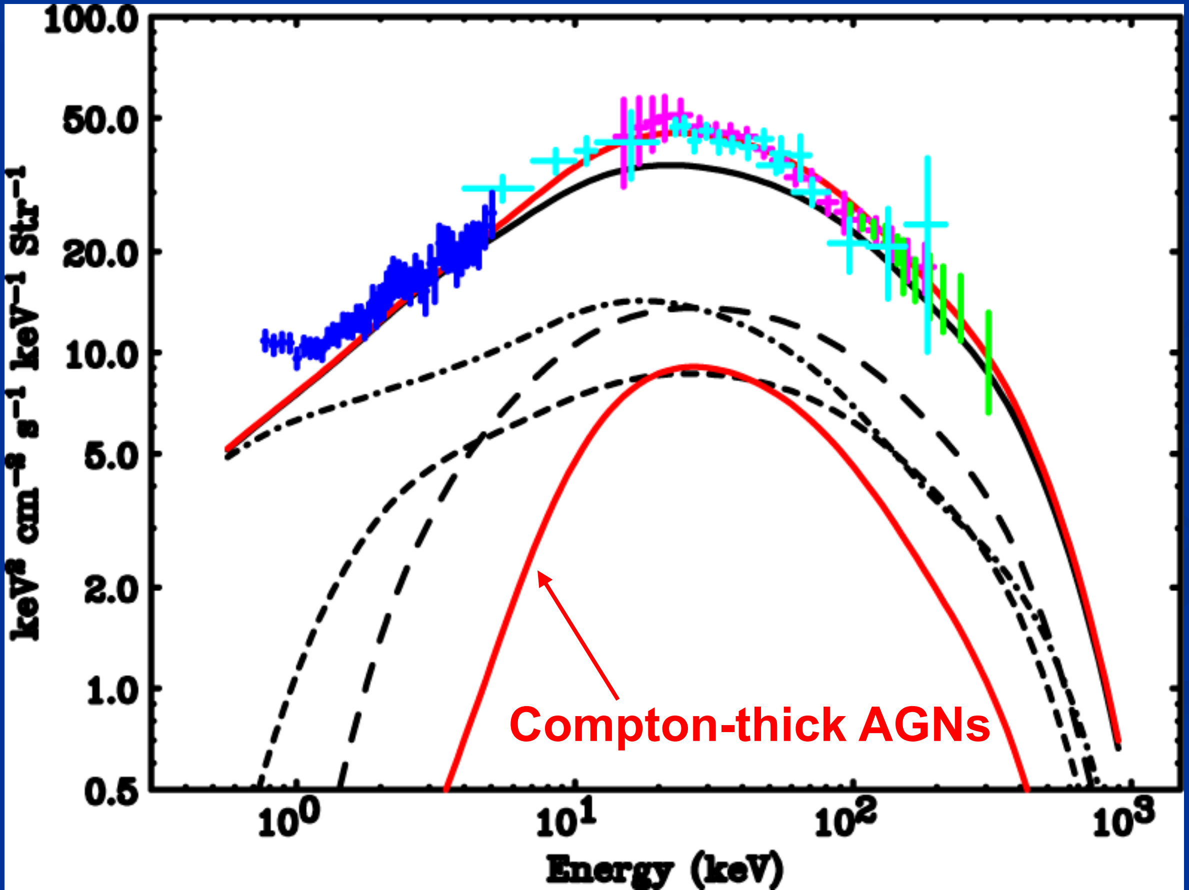


Swift/BAT 70-month (Ricci+ 15)



Population Synthesis Model of the CXB (Ueda+14)

- CXB = (luminosity function) × (absorption distribution)
- Assumptions
  - Broadband spectra (1-1000 keV)
  - *Compton thick AGNs* follow the same evolution as Compton thin AGNs



Remaining Issues on the CXB

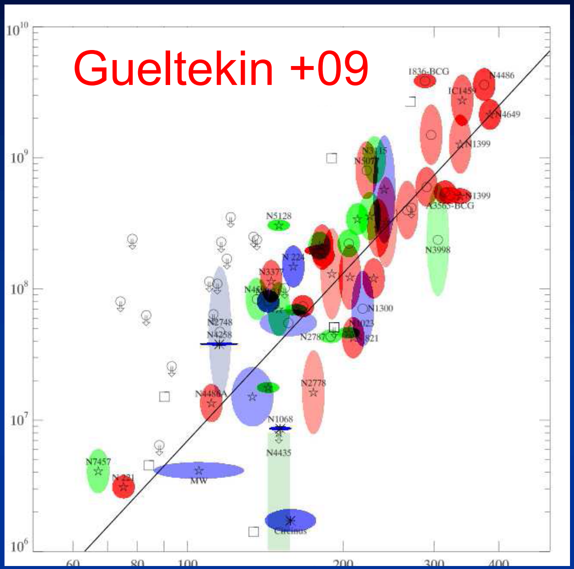
- Origin of the CXB above 10 keV
  - Contribution of Compton thick AGNs
- AGN evolution
  - Do they “co-evolve” with galaxies? Why/how?
  - Physical origin of cosmic downsizing

Coevolution of SMBHs and Galaxies

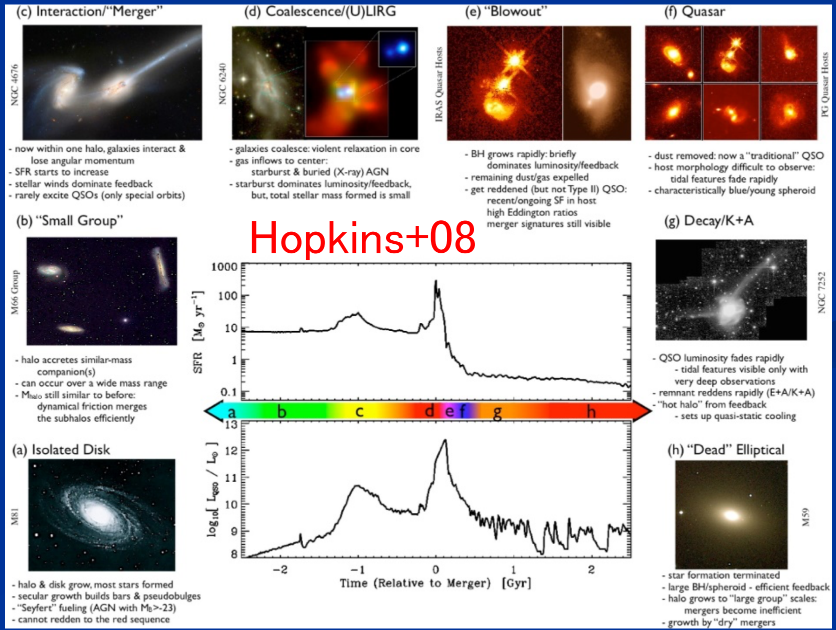
- Black holes: key players of cosmic evolution
  - Galaxies are shaped by tight interaction with central SMBHs
  - High energy astronomy is crucial to observe and characterize SMBHs

- Buried (or Compton thick) Active Galactic Nuclei (AGN)
  - Key population to understand "co-evolution"
  - Expected in rapid growth phase of BHs in intensively star-forming galaxies triggered by galactic mergers (unique tracers of mergers)
  - Hard to be found in optical
  - Their cosmological evolution is currently unknown

mass of SMBH

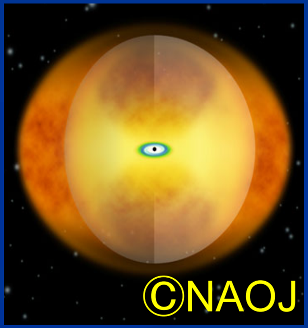


σ or bulge stellar mass

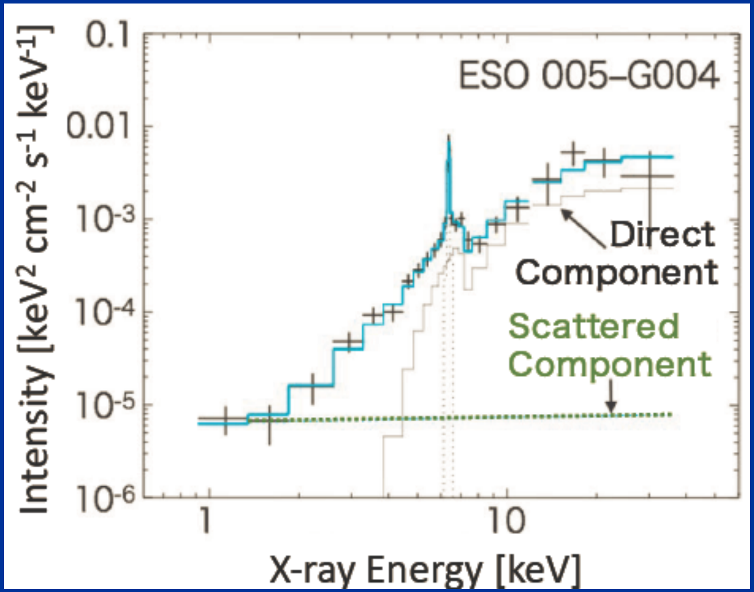


Key Population: Buried AGN

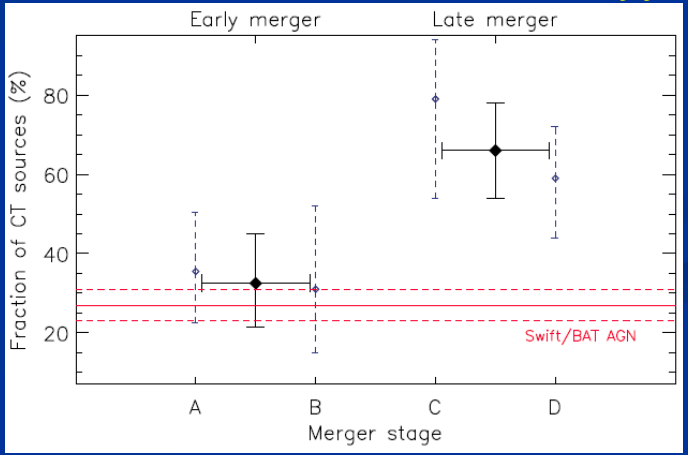
- Covered by Compton thick material with large solid angle
  - Narrow line regions are little developed because UV lights do not leak
  - Sometimes AGN can be identified only by using X-rays (ex. NGC 4945)
- Hard X-rays are the best band to catch such AGNs, thanks to
  - Strong penetrating power against obscuration
  - Little contamination from stars (cf. infrared band)



Ueda+ 07



Ricci+ 17

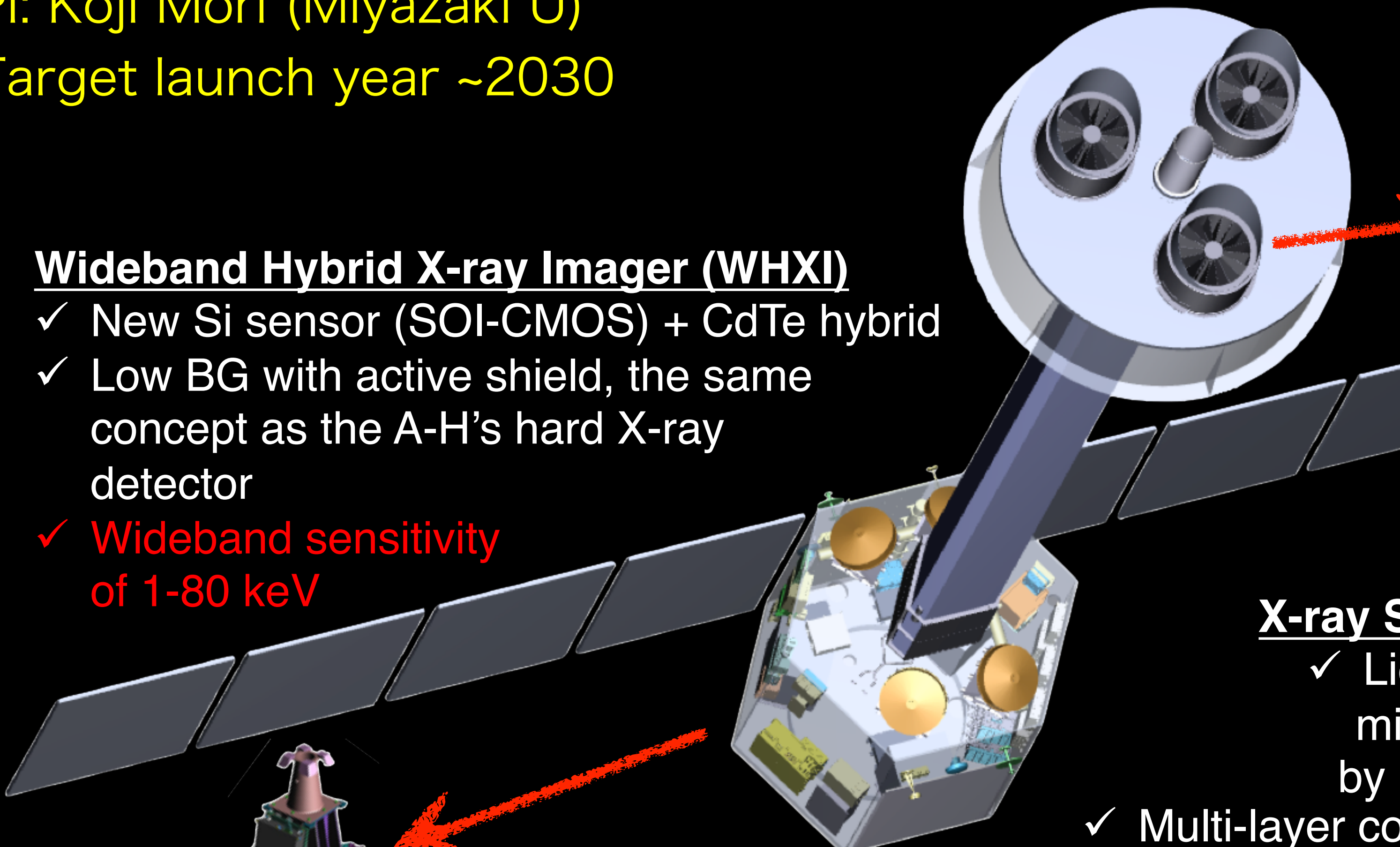


FORCE mission

Focusing On Relativistic universe and Cosmic Evolution

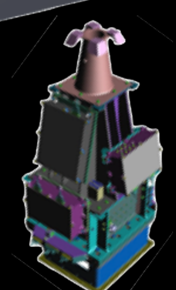
PI: Koji Mori (Miyazaki U)

Target launch year ~2030



<u>Wideband Hybrid X-ray Imager (WHXI)</u>

- ✓ New Si sensor (SOI-CMOS) + CdTe hybrid
- ✓ Low BG with active shield, the same concept as the A-H's hard X-ray detector
- ✓ Wideband sensitivity of 1-80 keV



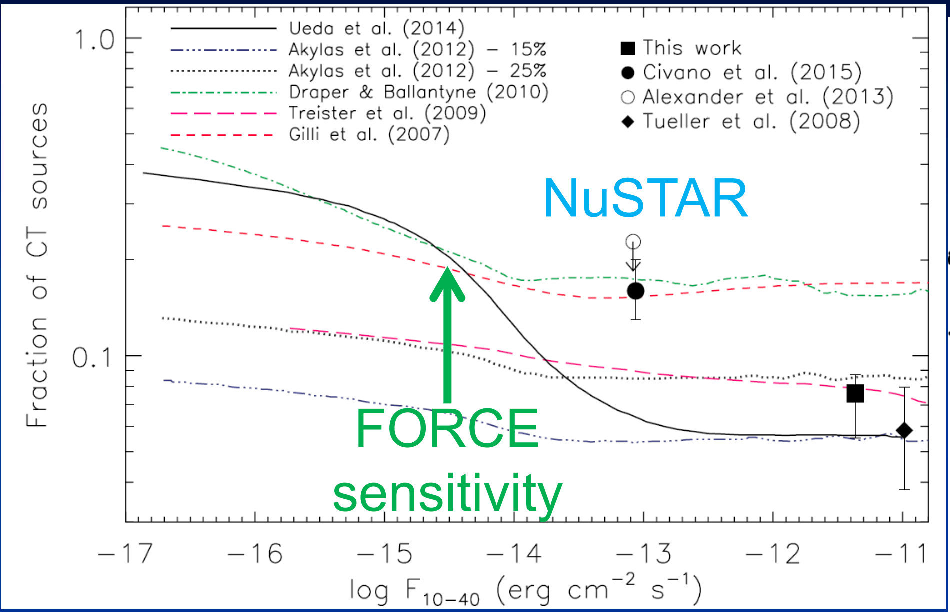
<u>X-ray Super-mirror</u>

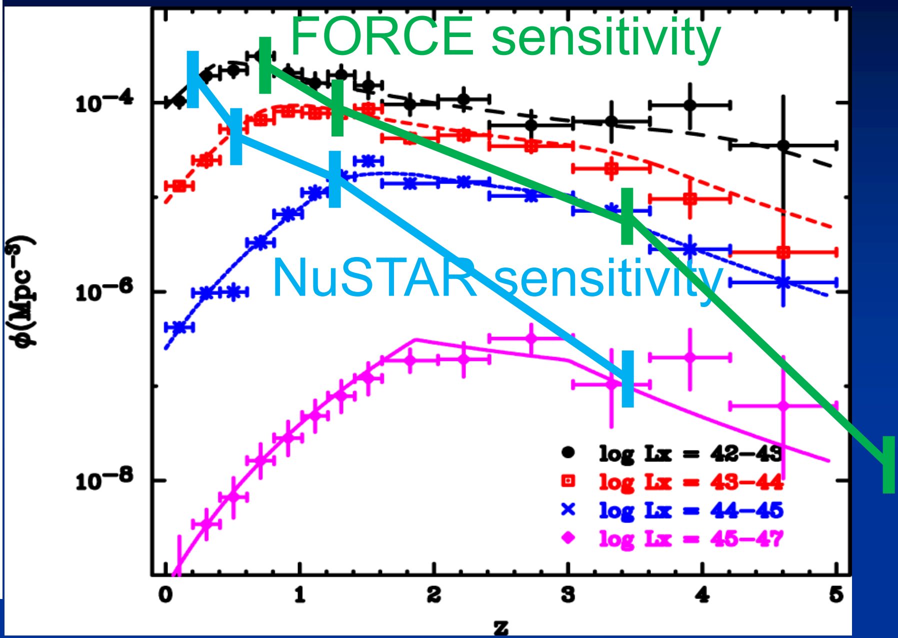
- ✓ Light-weight Si mirror provided by NASA/GSFC
- ✓ Multi-layer coating directly on the Si mirror surface

angular resolution of <15” in hard X-ray

C: K.. Mori

Cosmological Evolution of CTAGNs





- CTAGNs rapidly increases at fluxes below the NuSTAR limit
  - Fraction of CTAGN predicted from a standard CXB model (black line)
  - NuSTAR results suggest a few times more CT AGNs than in the prediction
- Requirements to FORCE
  - Flux limit: to cover redshifts where the space number density peaks, 3×10^{-15} erg cm^{-2} s^{-1} (10-40 keV)

Outlook

- What is your targeted physics in next decades?
  - Origin of SMBH-galaxy coevolution
  - Role of heavily obscured AGNs in cosmic history
  - Origin of SMBH "cosmic downsizing"

- What do we need to accomplish?
  - Build XRISM and FORCE (!)
  - Systematic multiwavelength study of AGN
  - Comparison with theories