Supermassive Black Hole Growth in the Era of Extremely Big Telescopes

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Fondecyt
Fondo Nacional de Desarrollo Científico y Tecnológico

SUPERMASSIVE BLACK HOLES FORMATION & GROWTH
Anillo ACT172033

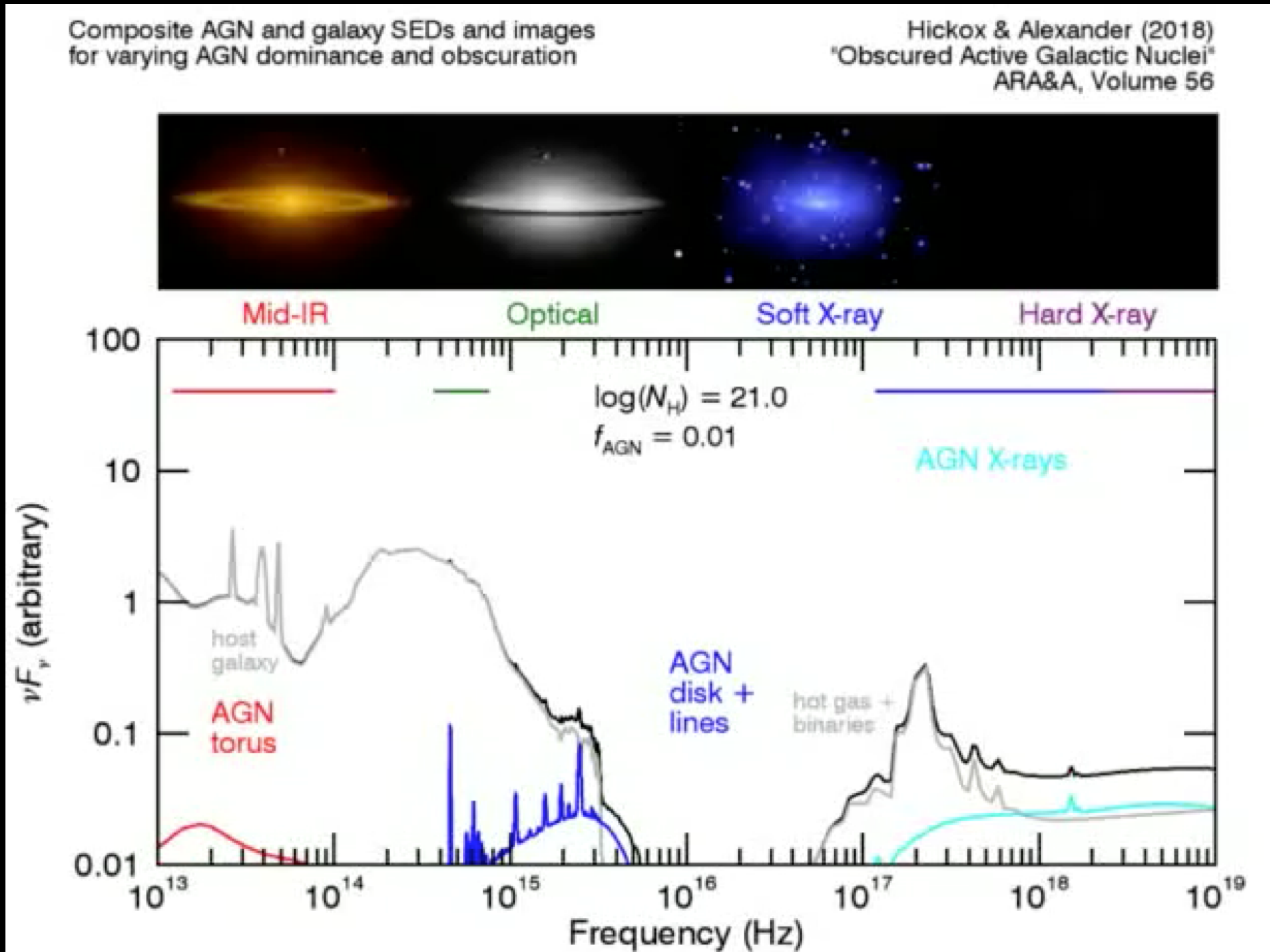
PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE

Active Galactic Nuclei (AGN)

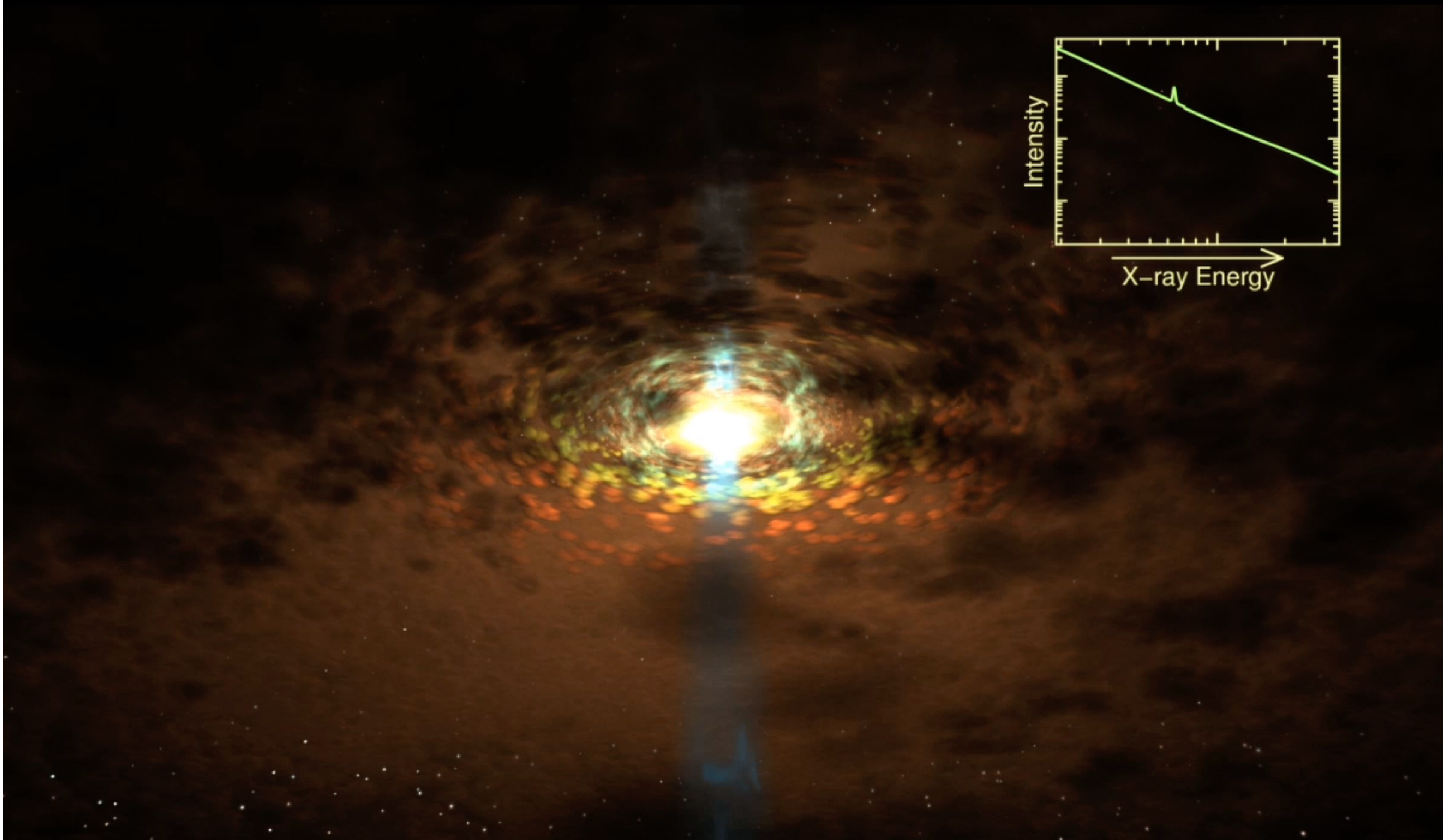
L_{bol}~$10^{42\text{-}48}$erg s^{-1} **M_{BH} ~10^6-10^9M_Θ**

Credits: NASA

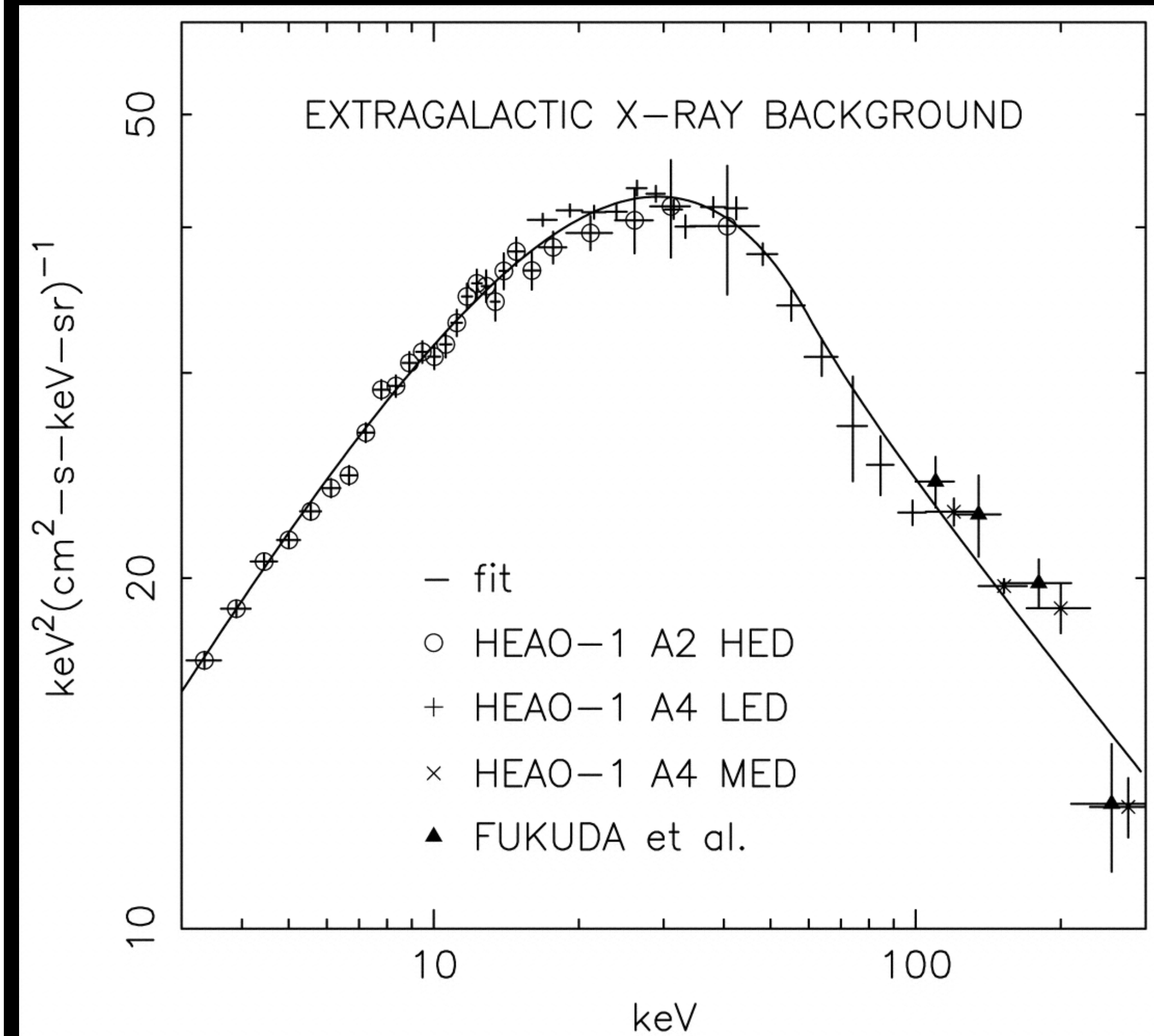
Multiwavelength AGN SEDs



AGN in X-rays



Observed X-ray Background



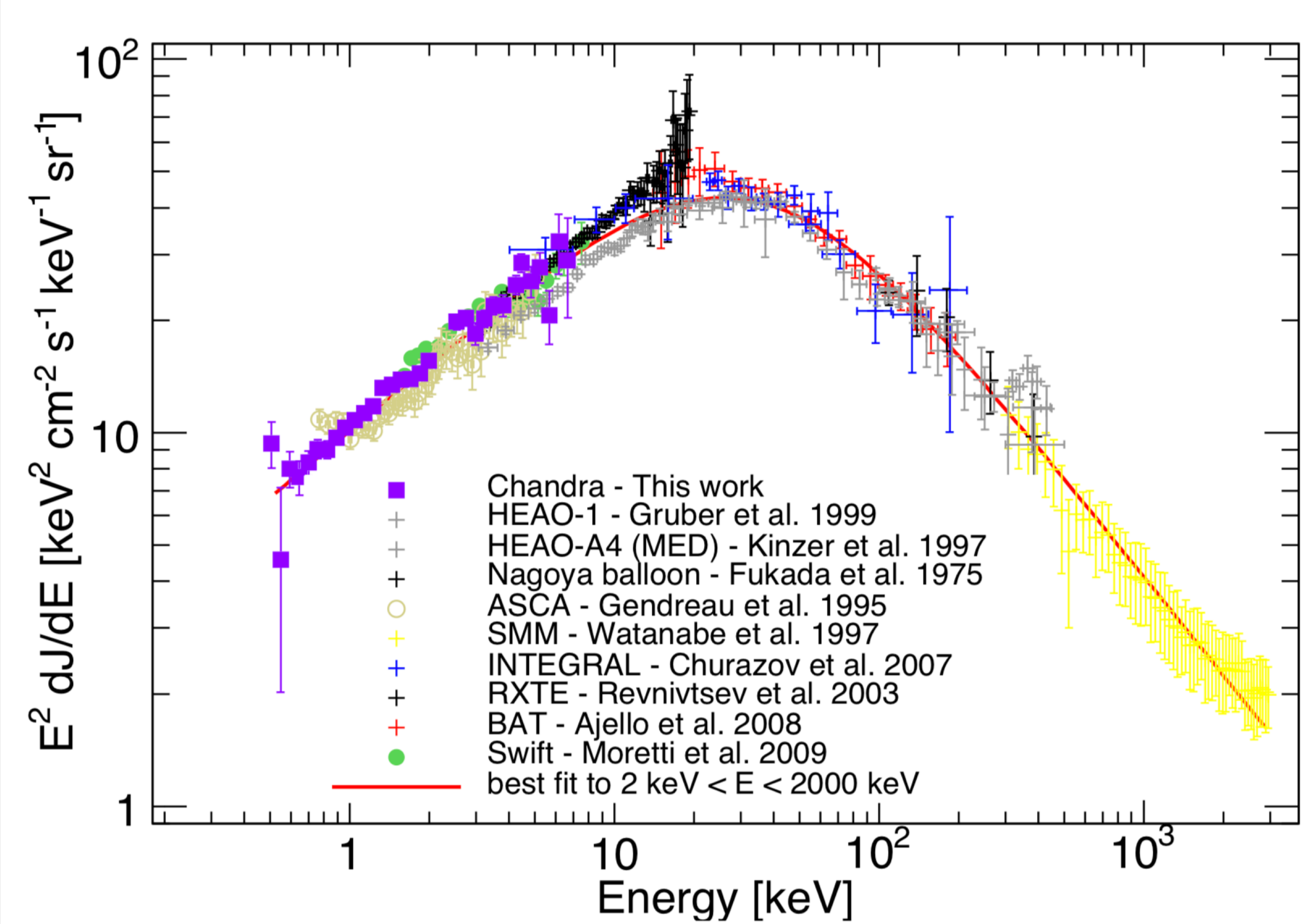
Gruber et al. 1999

X-ray background was discovered by R. Giacconi et al. in 1962, long before the CMB.

Several measurements made since then.

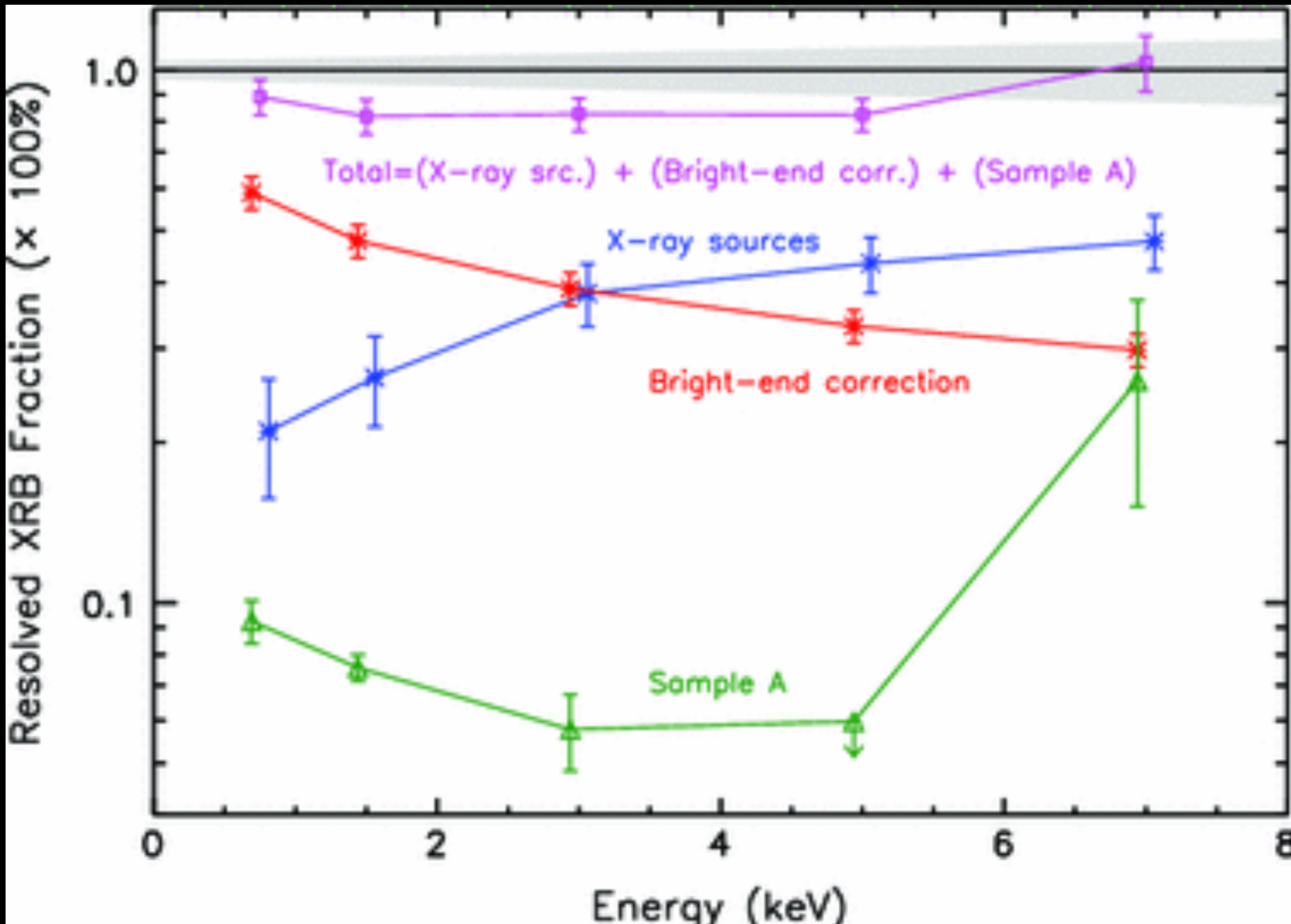
For a long time, uncertainty at the 20-30% level in total intensity.

Observed X-ray “Background”



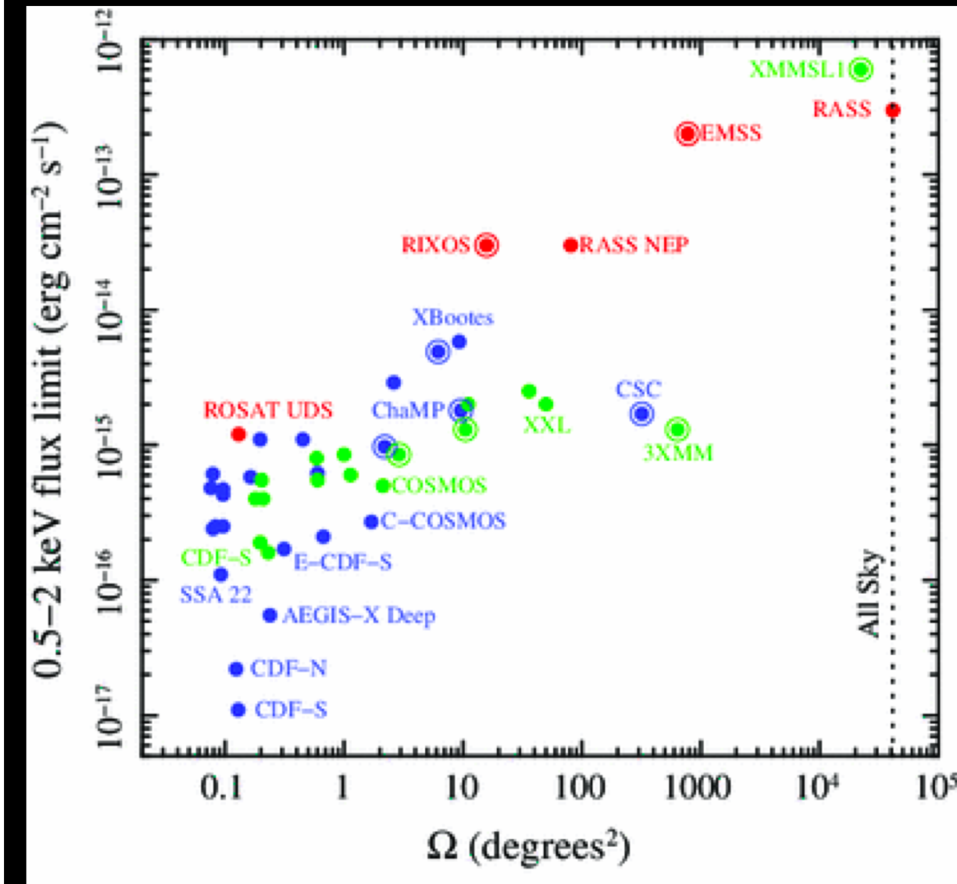
Cappelluti et al. 2017

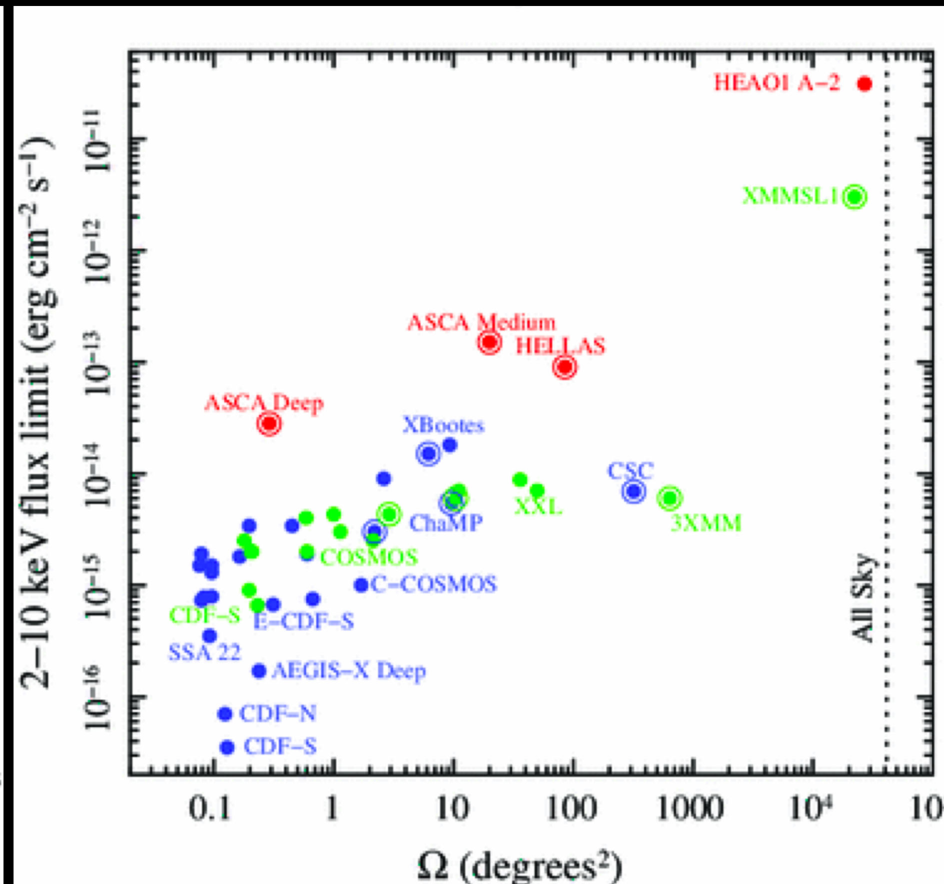
Resolved Background Fraction



Brandt & Alexander (2015)
Adapted from Xue et al. (2012)

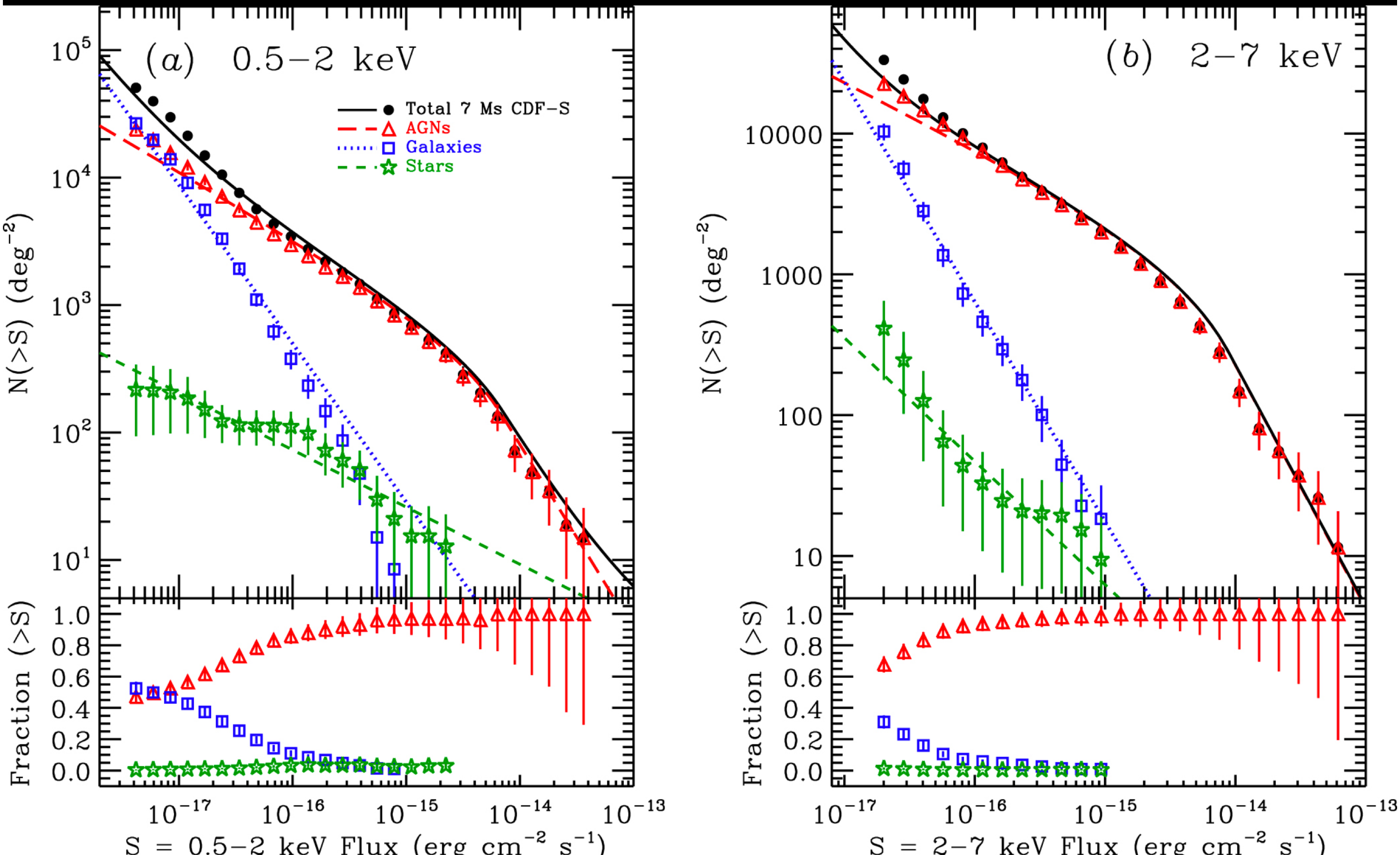
Extragalactic X-ray Surveys





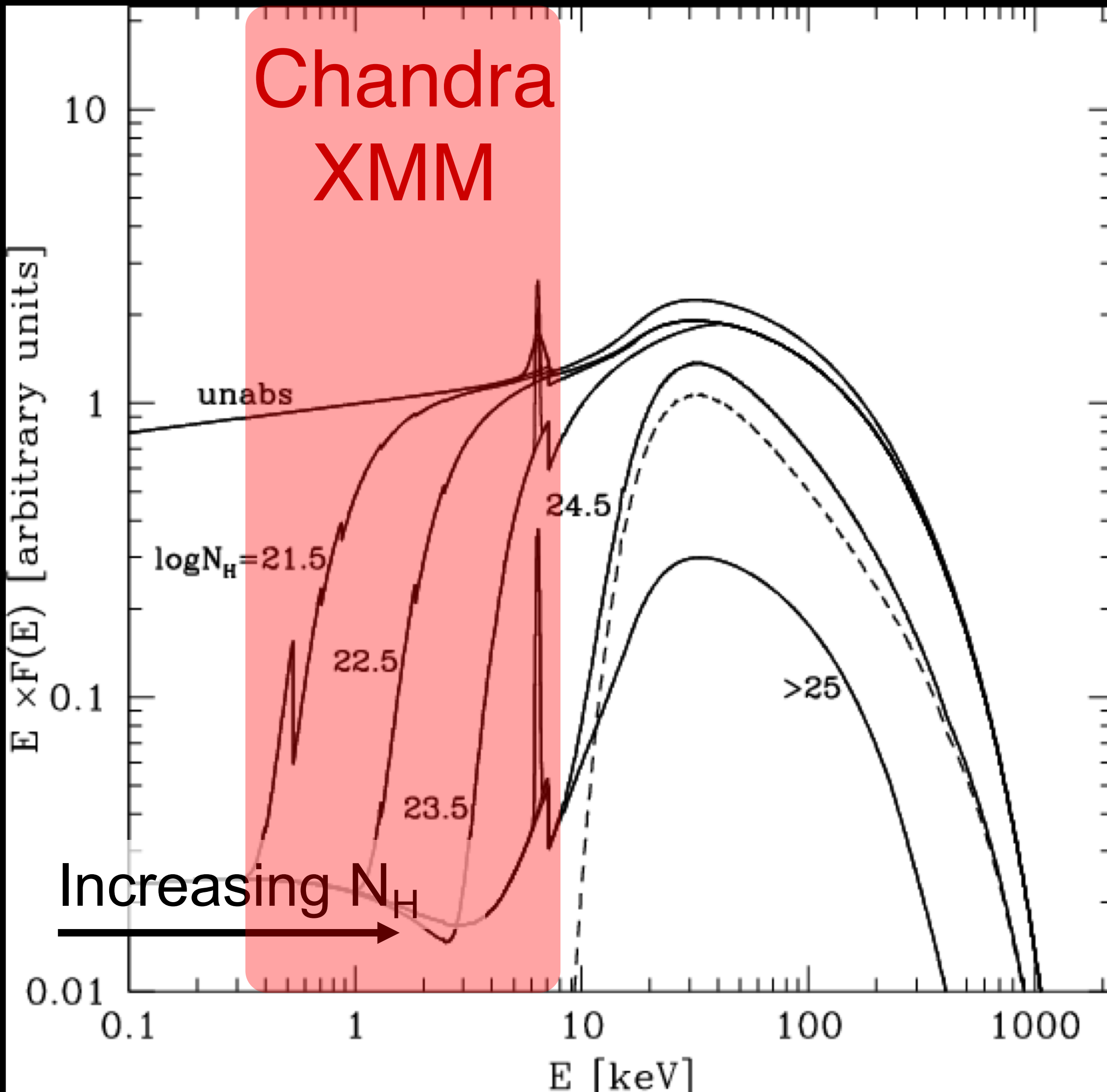
Brandt & Alexander (2015)

X-ray Number Counts



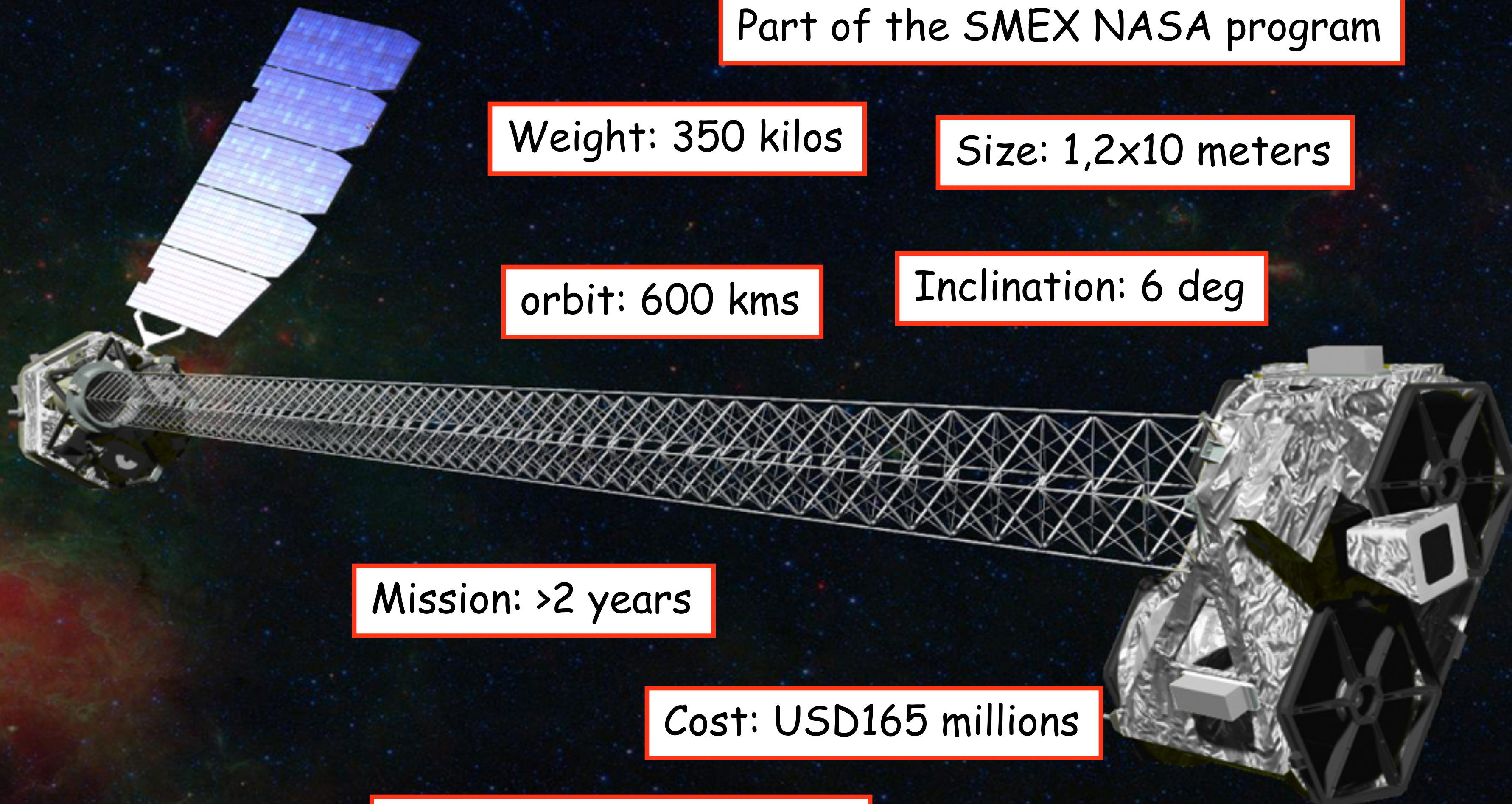
Luo et al. (2016)

AGN in X-rays



Gilli et al. 2007

NuSTAR



Part of the SMEX NASA program

Weight: 350 kilos

Size: 1,2x10 meters

orbit: 600 kms

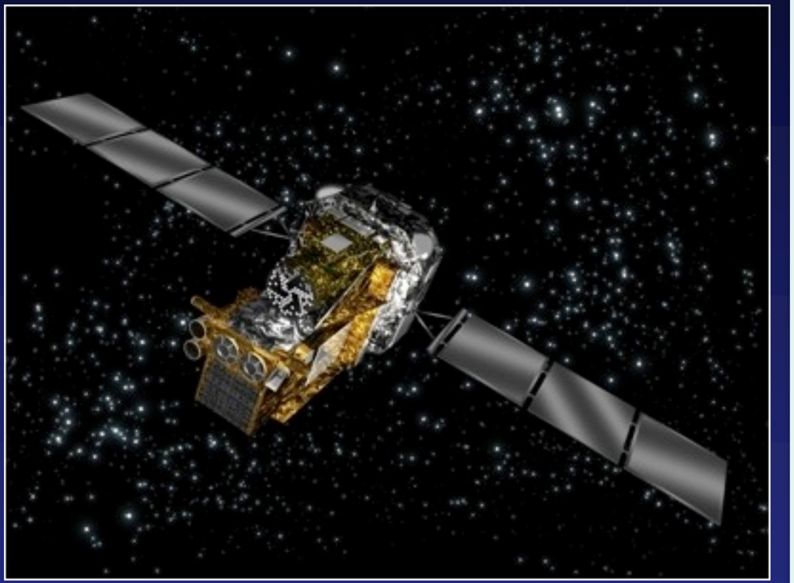
Inclination: 6 deg

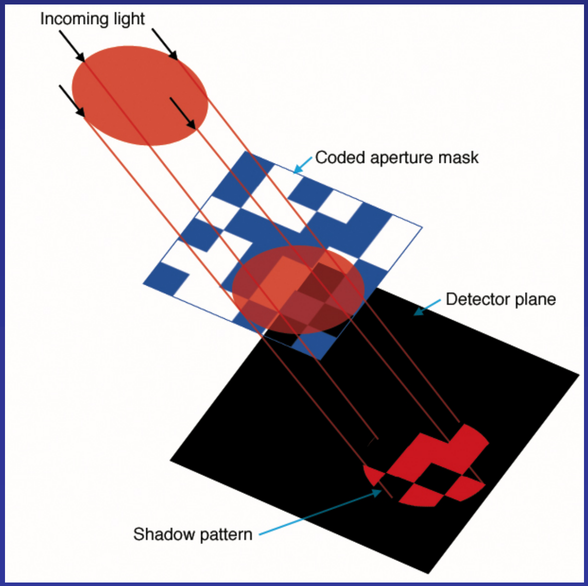
Mission: >2 years

Cost: USD165 millions

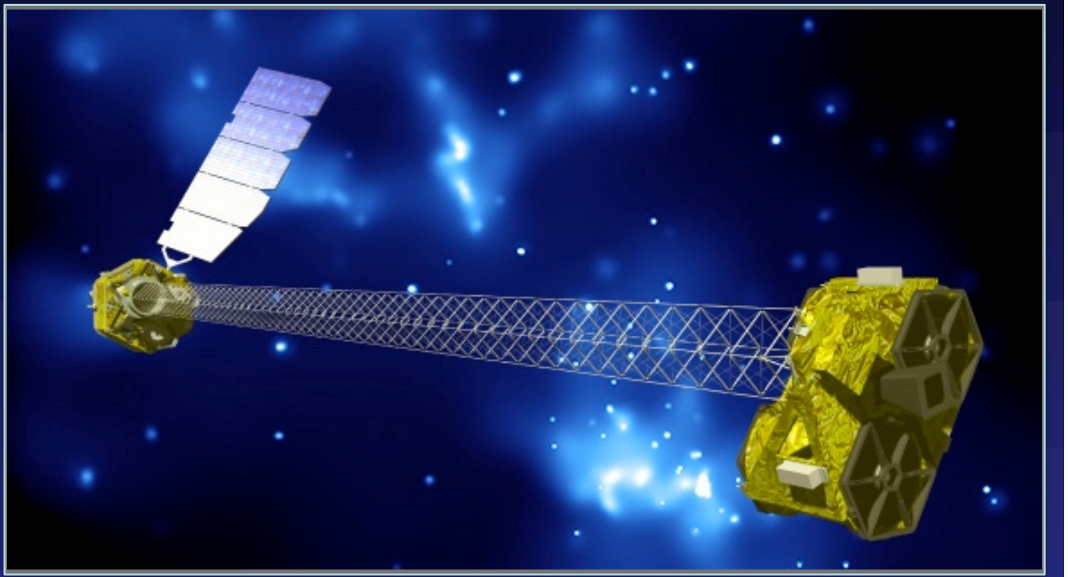
Launch: June 13th, 2012

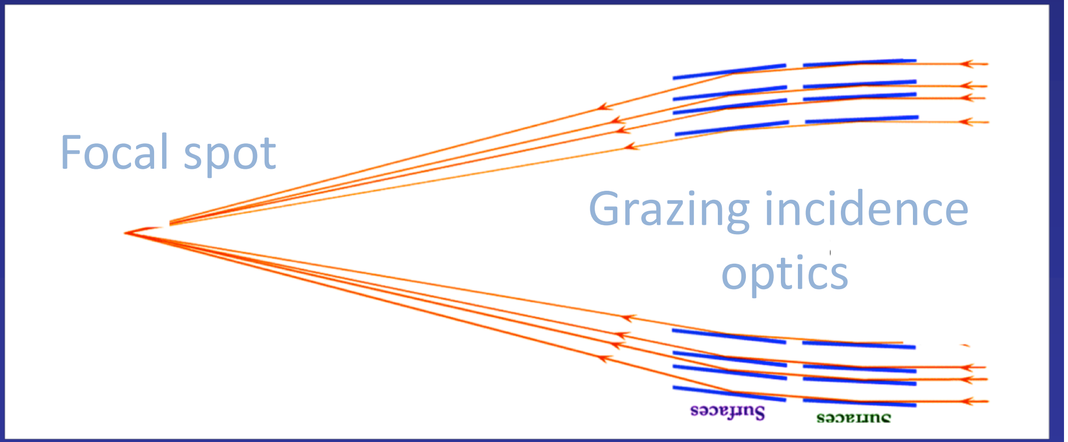
INTEGRAL, Swift BAT



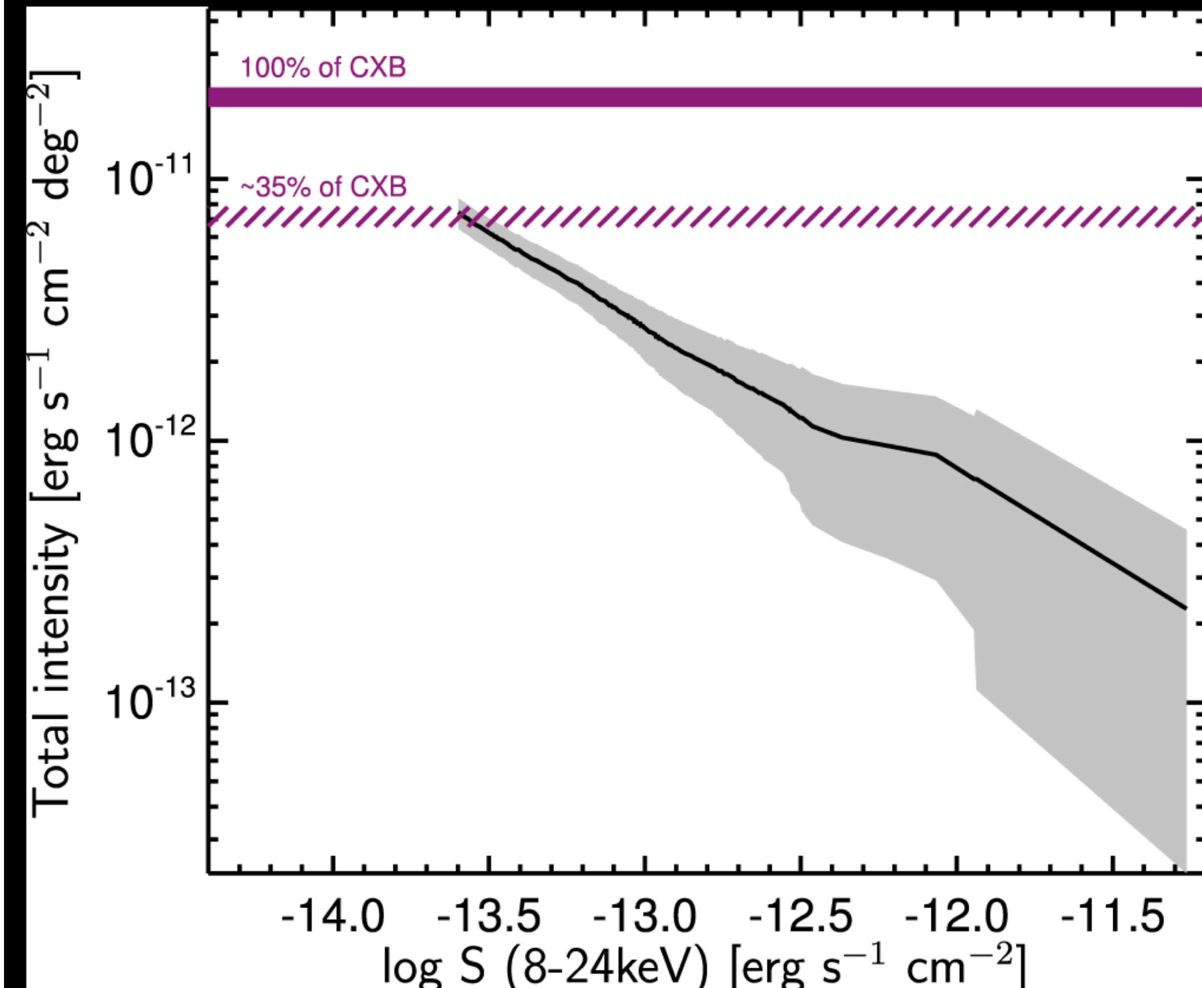


NuSTAR





NuSTAR Resolved Fraction



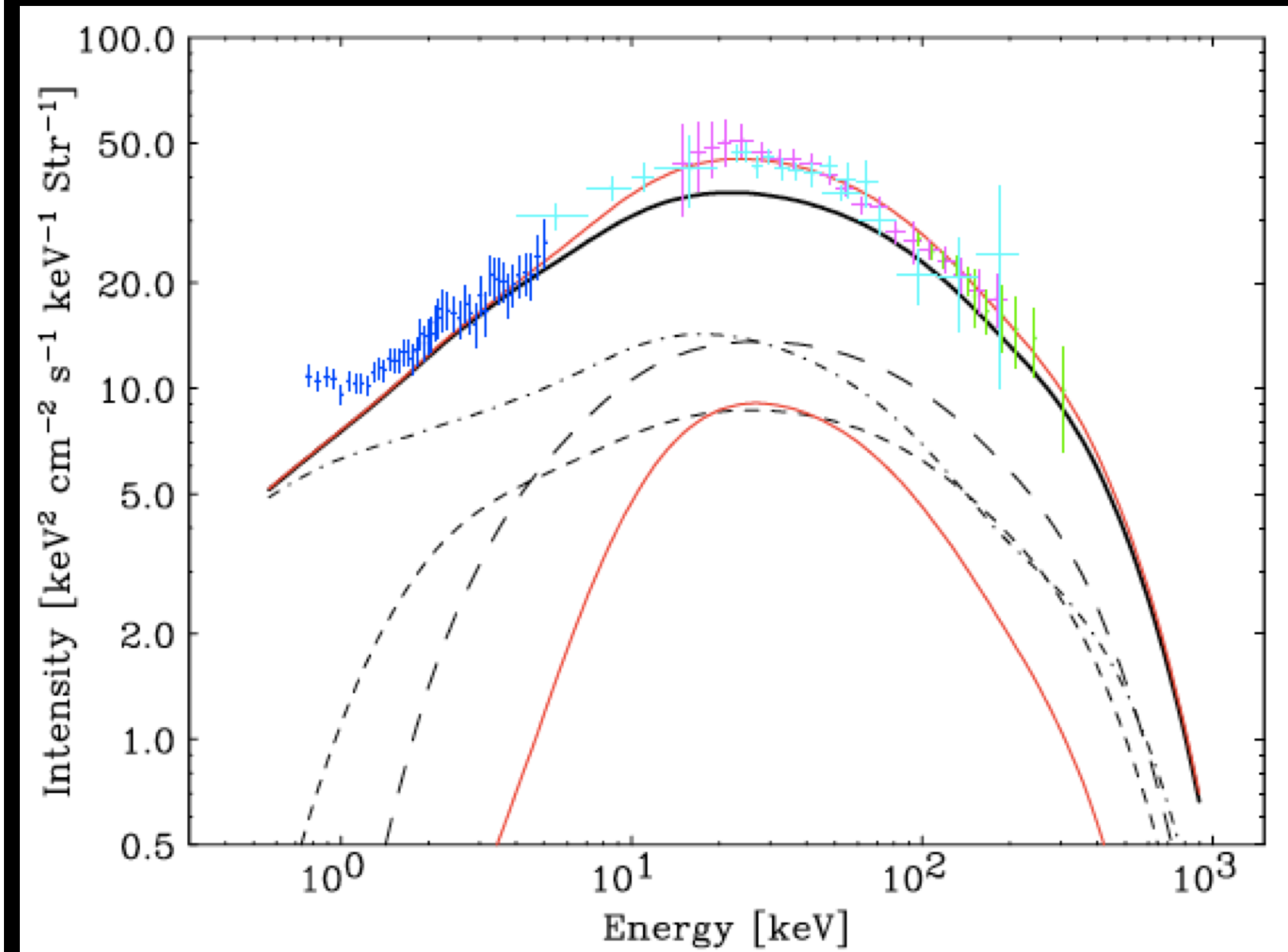
Only ~2% of the XRB resolved by Swift/BAT at E=14-195 keV

~35% of the XRB resolved directly by NuSTAR at E>10 keV

~70% resolved when stacking Chandra sources (Hickox et al., in prep.)

Harrison et al. (2016)

X-ray Background

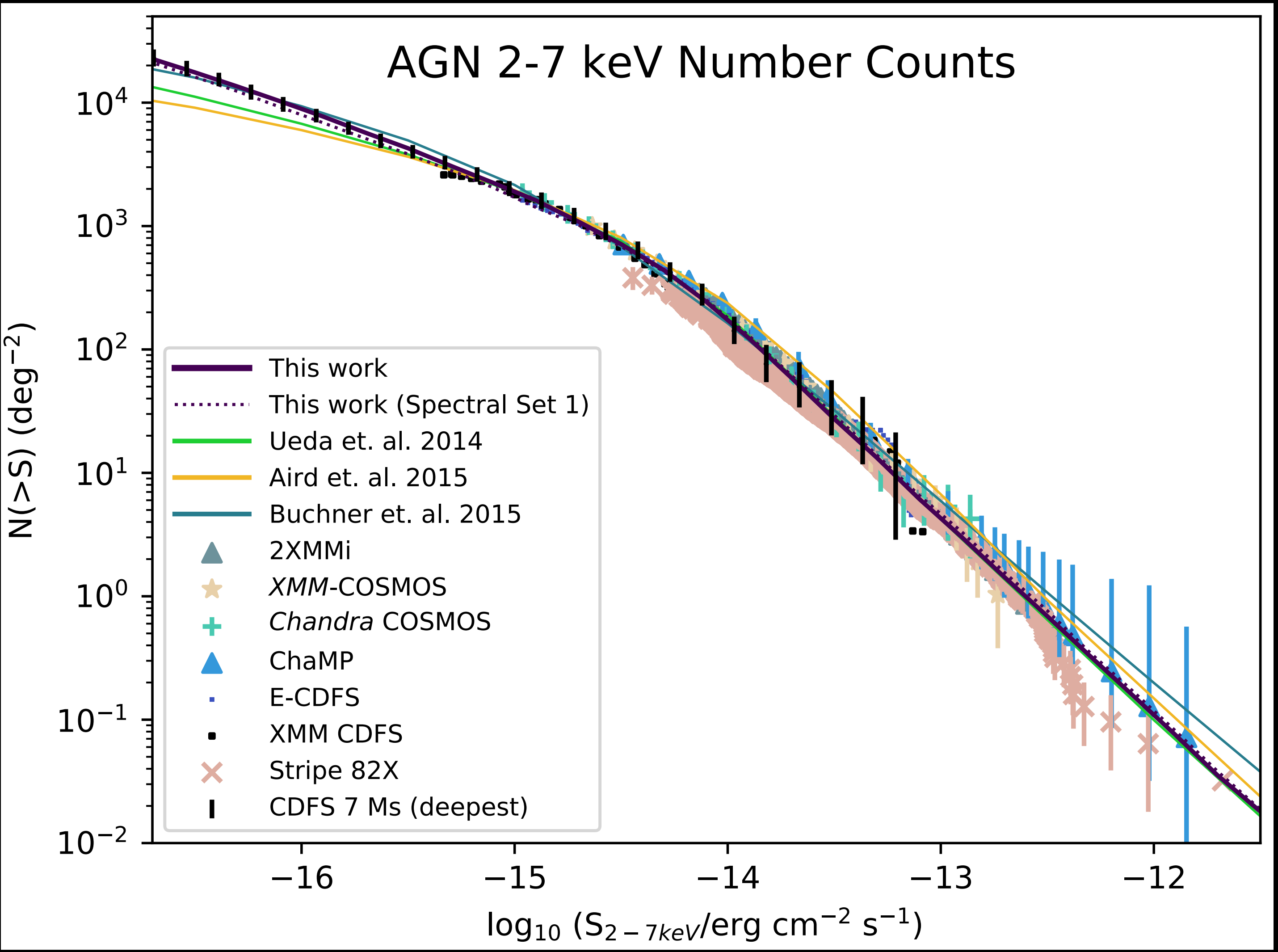


Ueda et al. 2014

XRB well explained using a combination of obscured and unobscured AGN.

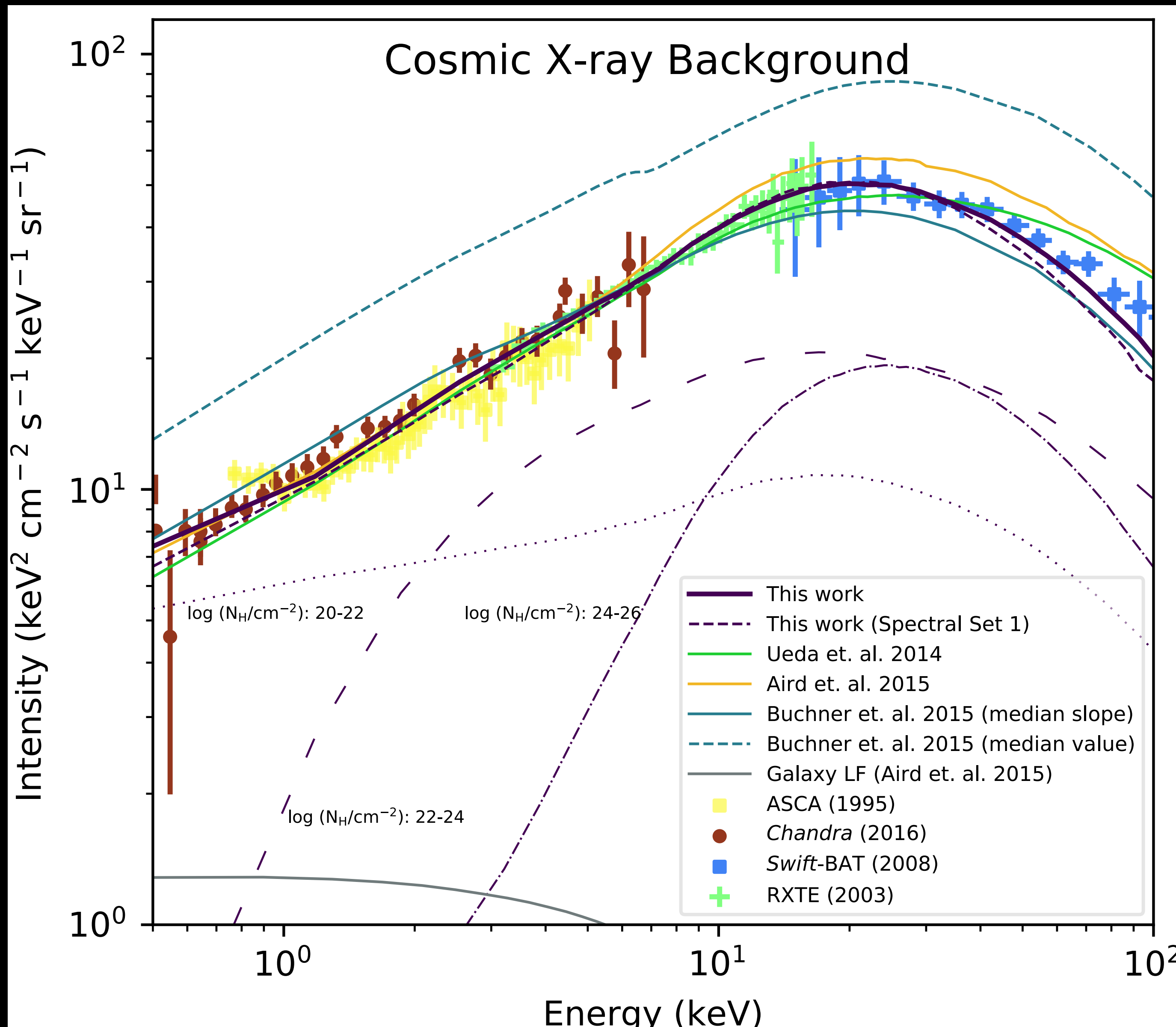
- Setti & Woltjer 1989
- Madau et al. 1994
- Comastri et al. 1995
- Gilli et al. 1999,2001
- Treister & Urry 2005
- Ballantyne et al. 2006
- Gilli et al. 2007
- Treister et al. 2009
- Akylas et al. 2012
- Ueda et al. 2014
- and others…

New XRB Model



Ananna et al. ApJ in press, arXiv:1810.02298

New XRB Model



Ananna et al. ApJ in press, arXiv:1810.02298

What do we know about Black Hole Growth?

The X-ray background tells us that most (Compton thin) black hole accretion happens in:

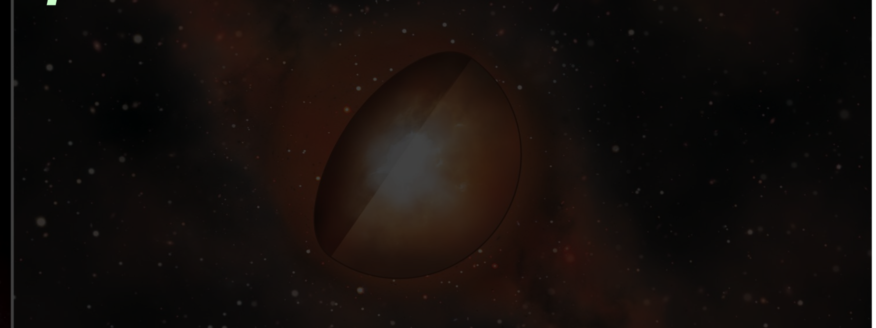
- Moderate luminosity AGN
- z~0.5-1
- Obscured but Compton-thin sources

Different XRB analyses agree: most (Compton thin) black hole accretion happens in:

- Moderate luminosity AGN
- z~0.5-1
- Obscured sources

Current uncertainty about Compton-Thick AGN:

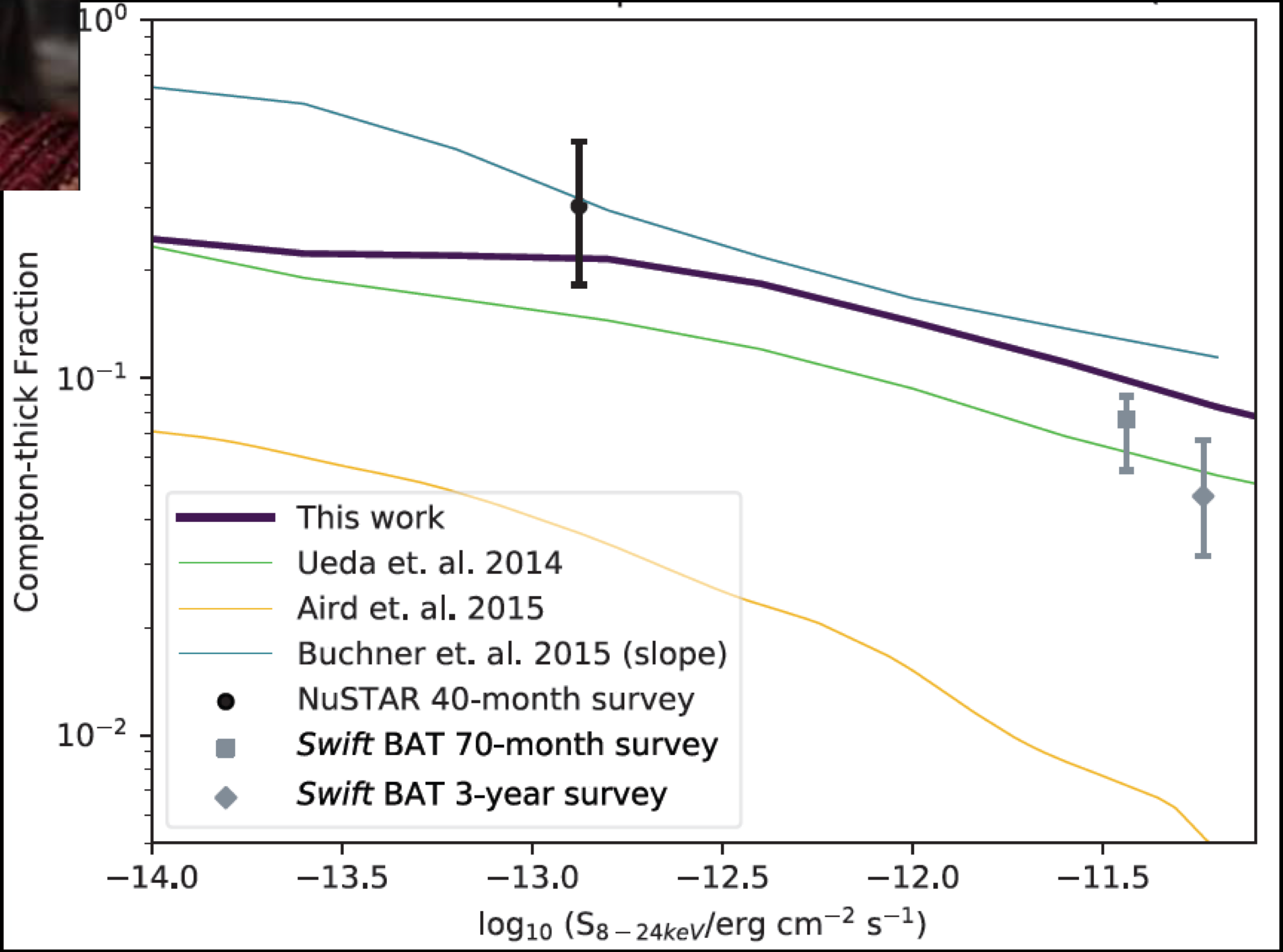
- Number density
- Evolution
- Spectral shape
- Contribution to BH mass



The XRB is not a strong constraint on CT AGN:

- Degeneracy of number & spectrum
- Flux is weighted by distance
- Affected by obscuration

Compton Thick Number Counts



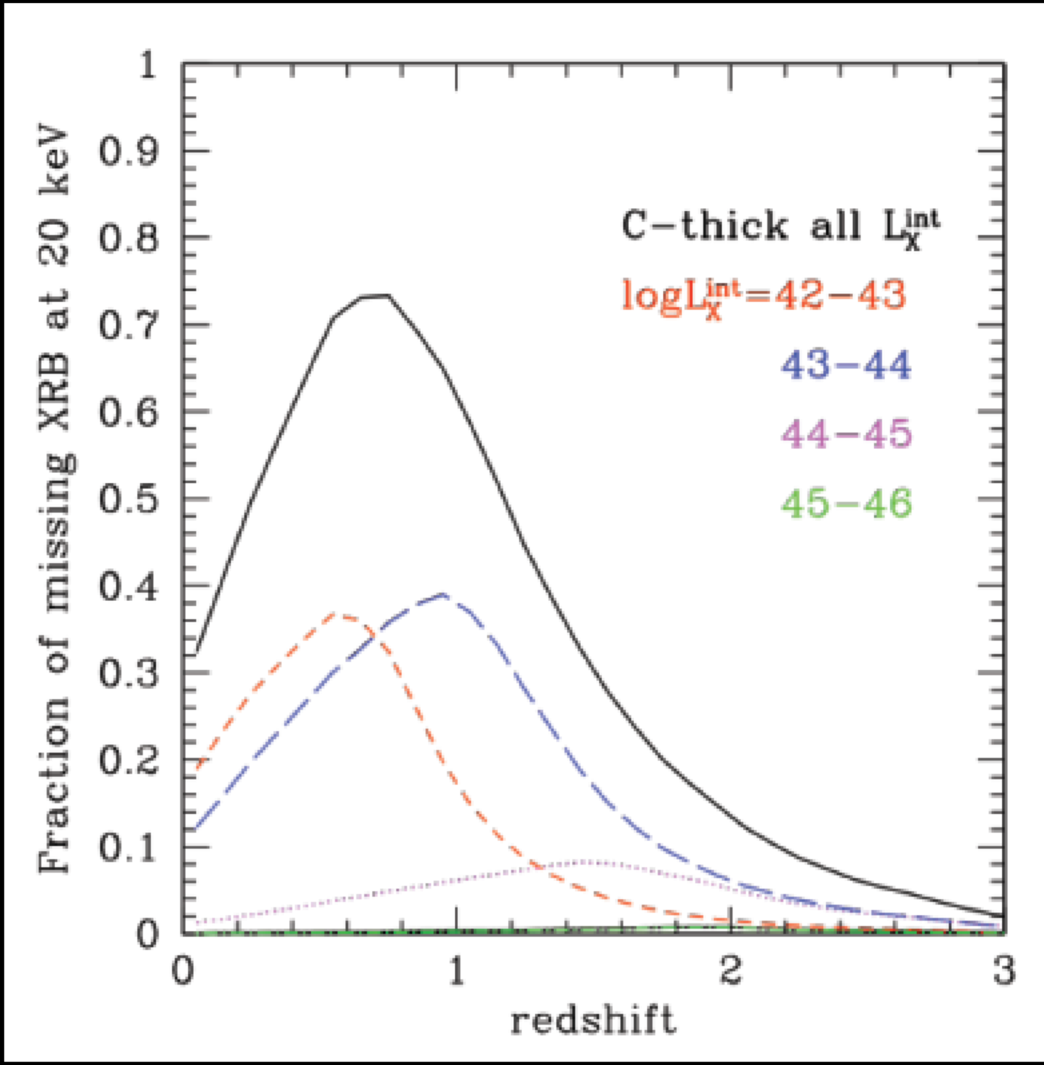
Ananna et al. ApJ in press, arXiv:1810.02298

What is Missing?

Clearly we are still missing heavily obscured (CT) accretion, at all but mostly high redshifts.

The so-called ”Soltan Argument” still allows for up to ~2x more SMBH growth currently unaccounted.

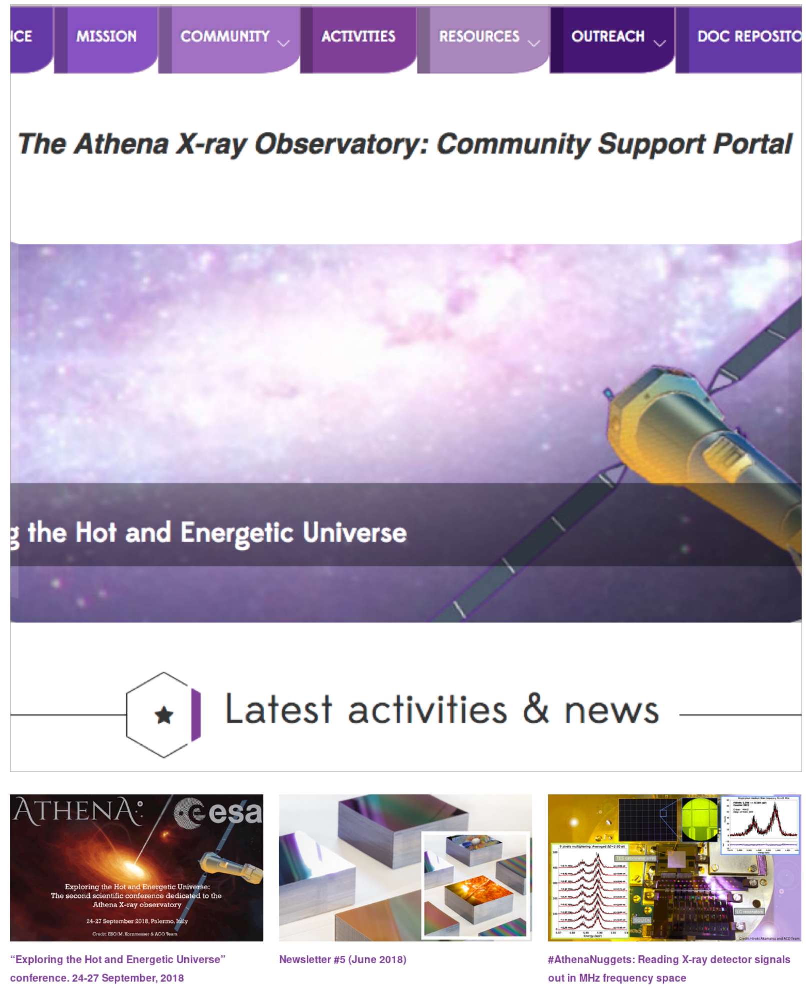
Luckily in the next ~15-20 years we will have the tools to identify and study this missing accretion.



R. Gilli (int. comm.)

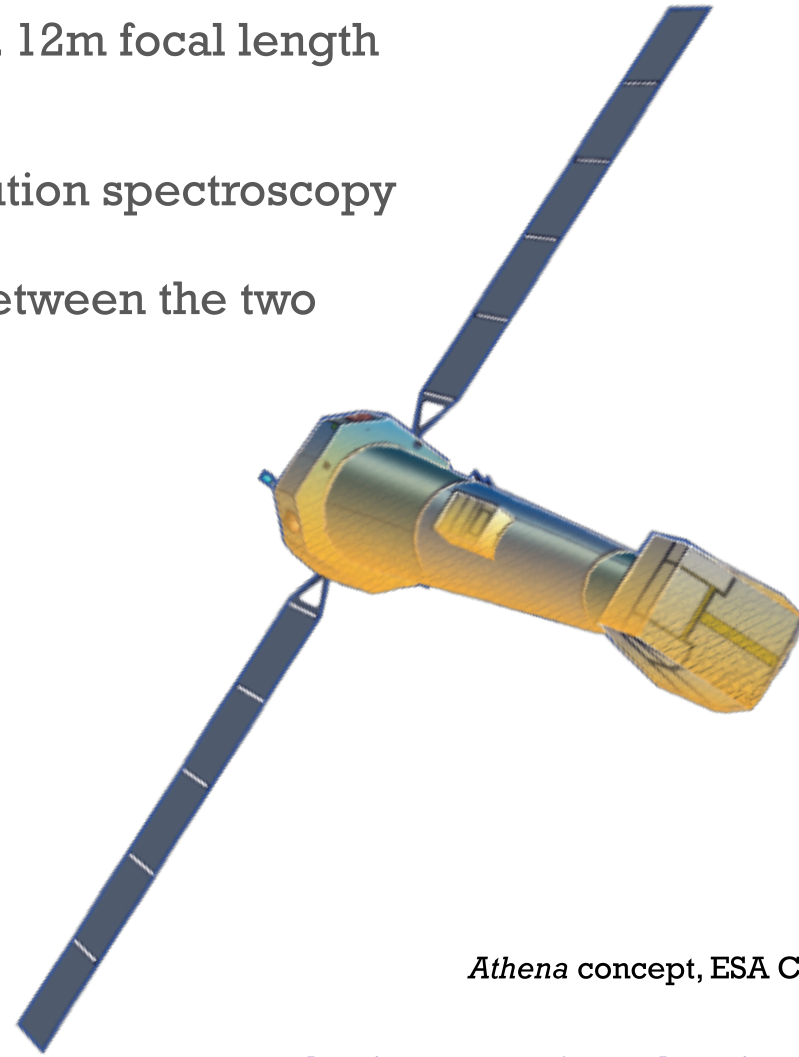
Advanced Telescope for High-Energy Astrophysics

- Second Large (L2) mission of ESA Cosmic Vision
- Science theme: The Hot and Energetic Universe:
  - How does ordinary matter assemble into the large-scale structure we see today?
  - How do black holes grow and shape the Universe?
- Next generation X-ray observatory designed to address science theme
- Broad impact across many areas of astrophysics
- More info at www.the-athena-x-ray-observatory.eu



Athena mission concept

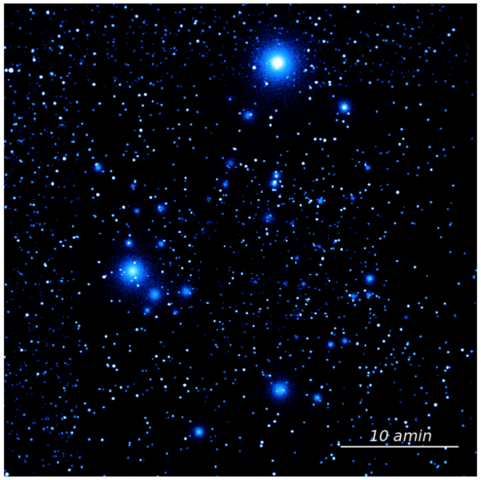
- Single telescope, using Si pore optics. 12m focal length
  - WFI sensitive imaging & timing
  - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch early 2030s, Ariane 6.4
- L2 halo orbit (TBC)
- Lifetime: 4 yr +Possible extensions

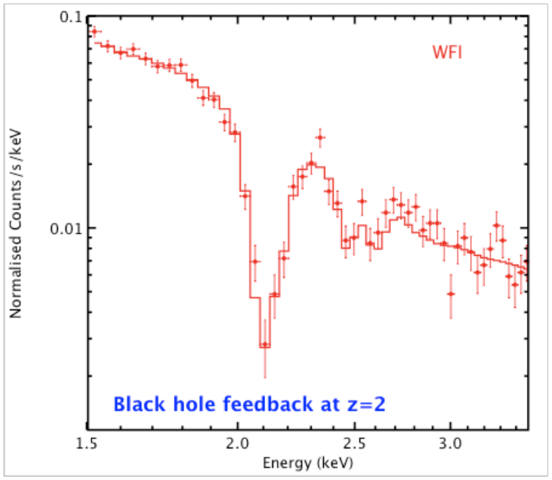


Athena concept, ESA CDF

Wide Field Imager (WFI)

- Silicon Active Pixel Detector based on DEPFET technology
- Key performances:
  - 50-150 eV spectral resolution @ 6 keV
  - 2.2´´ pixel size (PSF oversample)
  - Field of view: 40´×40´ square
  - Separate chip for fast readout of brightest sources
  - Readout speed up to ~30 MHz
- Consortium led by MPE, with other European partners (DE, AT, DK, FR, IT, PL, UK, CH, P & GR) and NASA
- Optimized for sensitive wide-field imaging and intermediate resolution spectroscopy, up to very bright sources

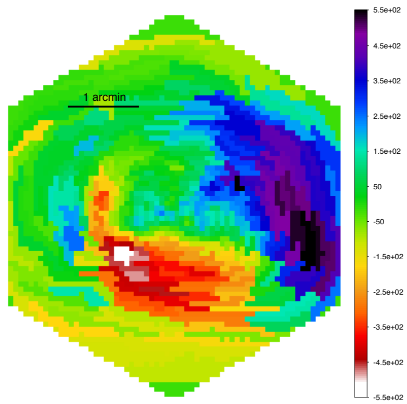




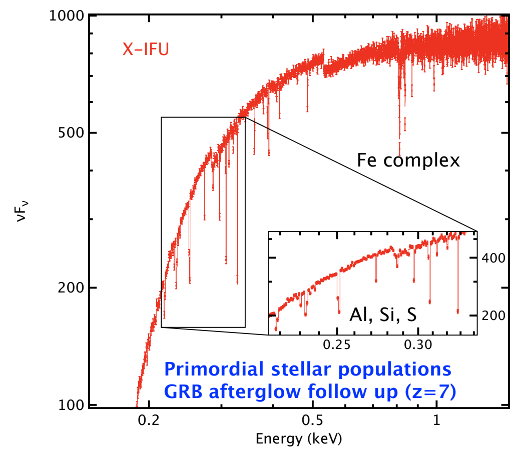
Rau et al. 2013, arXiV: 1308.6785
http://www.mpe.mpg.de/*ATHENA*-WFI/

X-ray Integral Field Unit (X-IFU)

- Cryogenic imaging spectrometer, based on Transition Edge Sensors, operated at 50 mK featuring an active cryogenic background rejection subsystem
- Key performance parameters:
  - 2.5 eV energy resolution <7 keV
  - FoV 5´ diameter
  - Pixel size <5´´
- Consortium led by IRAP/CNES-F, by IRAP/CNES-F, with Netherlands and Italy and further ESA member state contributions from Belgium, Czech Republic, Finland, Germany, Ireland, Poland, Spain, Switzerland and contributions from Japan and the United States
- Proving both spatially-resolved high spectral resolution and high count rate capability



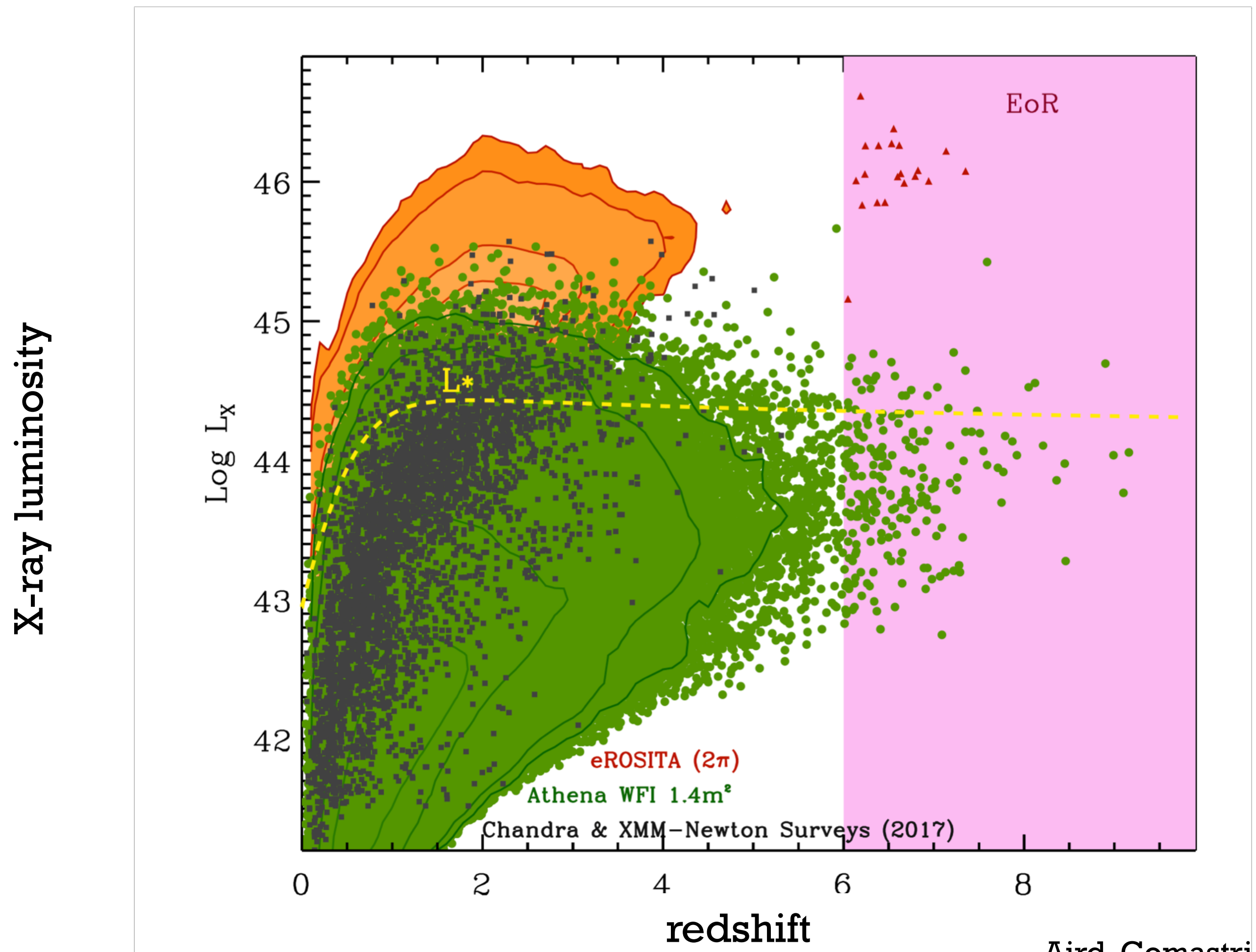
E. Pointecouteau, P. Peille, E. Rasia, V.Biffi, S. Borgani, K. Dolag, J. Wilms



Barret et al. 2013, arXiV: 1308.6784
http://x-ifu.irap.omp.eu/

The history of SMBH growth

AGN L_X versus z plane



Only most luminous /massive QSOs expected in opt/IR surveys

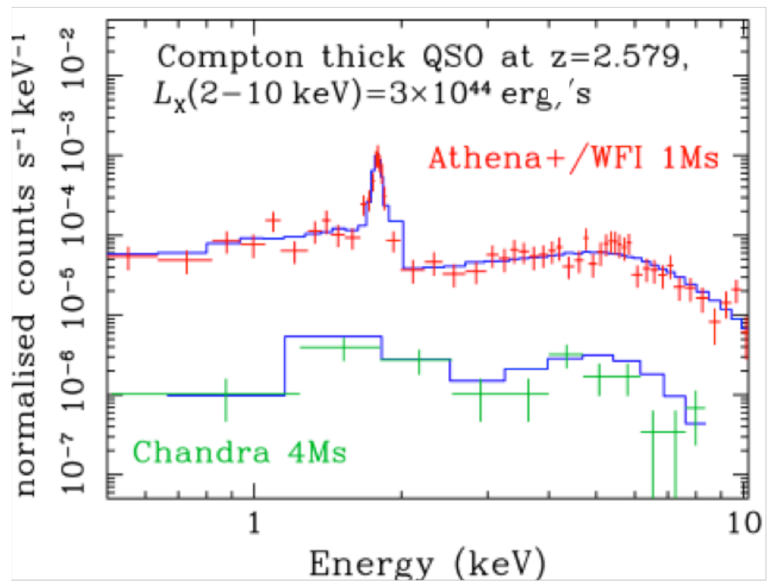
X-rays needed to signpost typical and obscured AGN

Aird, Comastri et al. 2013 arXiv1306.232
Updated by Andrea Merloni (MPE) (2017)

Obscured AGN census @ z~1-3

- What is the relation between obscured growth of SMBH through cosmic history and how does it relate to galaxy formation?

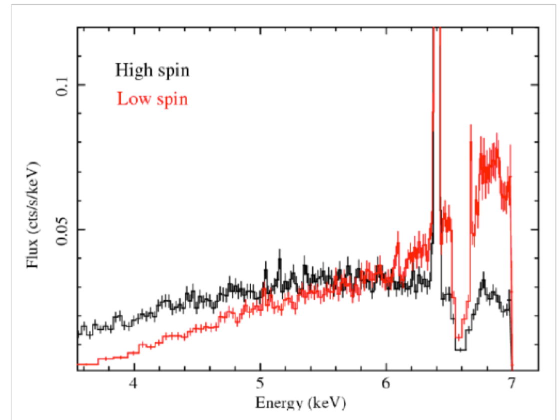
  - Most SMBH growth expected in heavily obscured (including Compton-Thick) environment
  - Best X-ray signature of typical Compton-thick AGN is the Fe emission line, EW ~0.5-1 keV
  - *Athena*/WFI observations can uncover Compton-Thick average AGN at z~3
  - MIR observations can also uncover heavily obscured AGN, but **only** when the AGN is very powerful

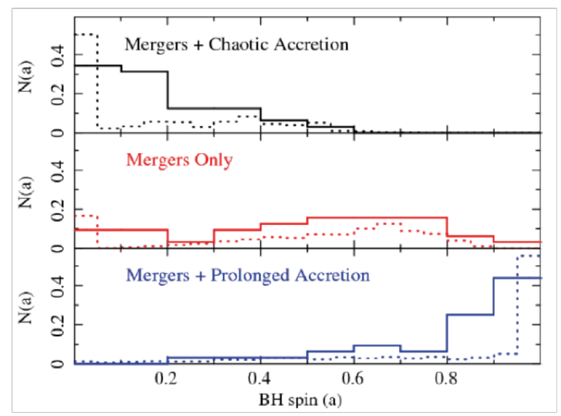


Georgakakis, Carrera et al. 2013 arXiv1306.2328

SMBH growth: accretion vs mergers

- SMBH spin distribution is highly sensitive to SMBH growth history
  - Accretion spins up SMBH
  - Mergers & chaotic accretion spin down SMBH
- A SMBH spin survey with *Athena* will reveal dominant SMBH growth mode
  - Partly doable with XMM-*Newton*, but for removal narrow features

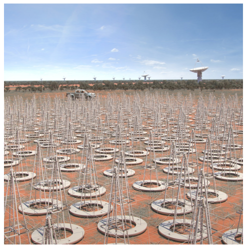




Dovciak, Matt et al. 2013: arXiv 1306.2331
simulations by G. Miniutti

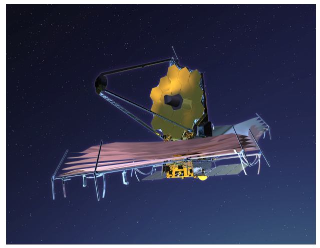
Athena in the framework of the late 2020s

SKA

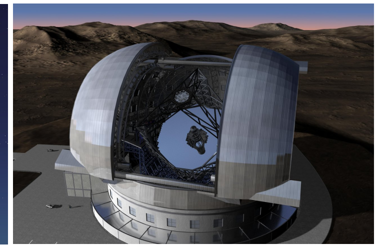


ALMA

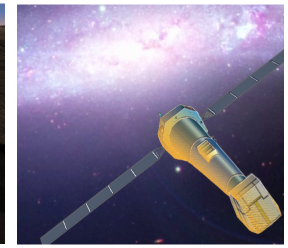
JWST



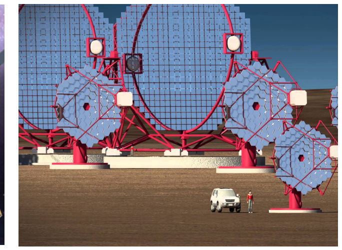
ELTs

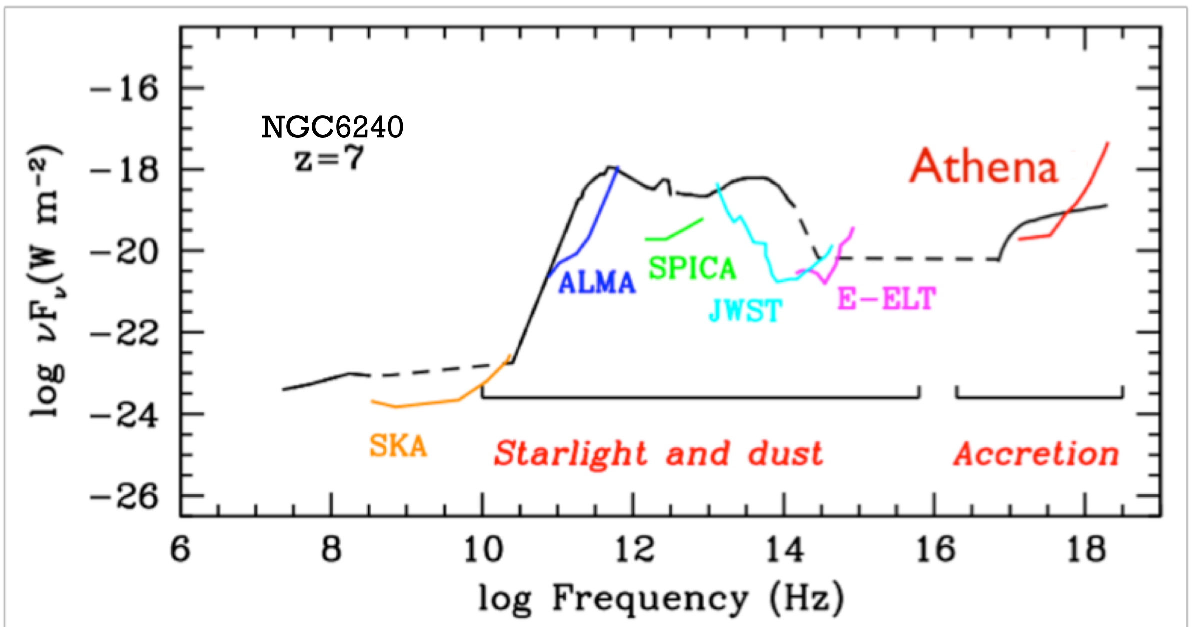


Athena



CTA

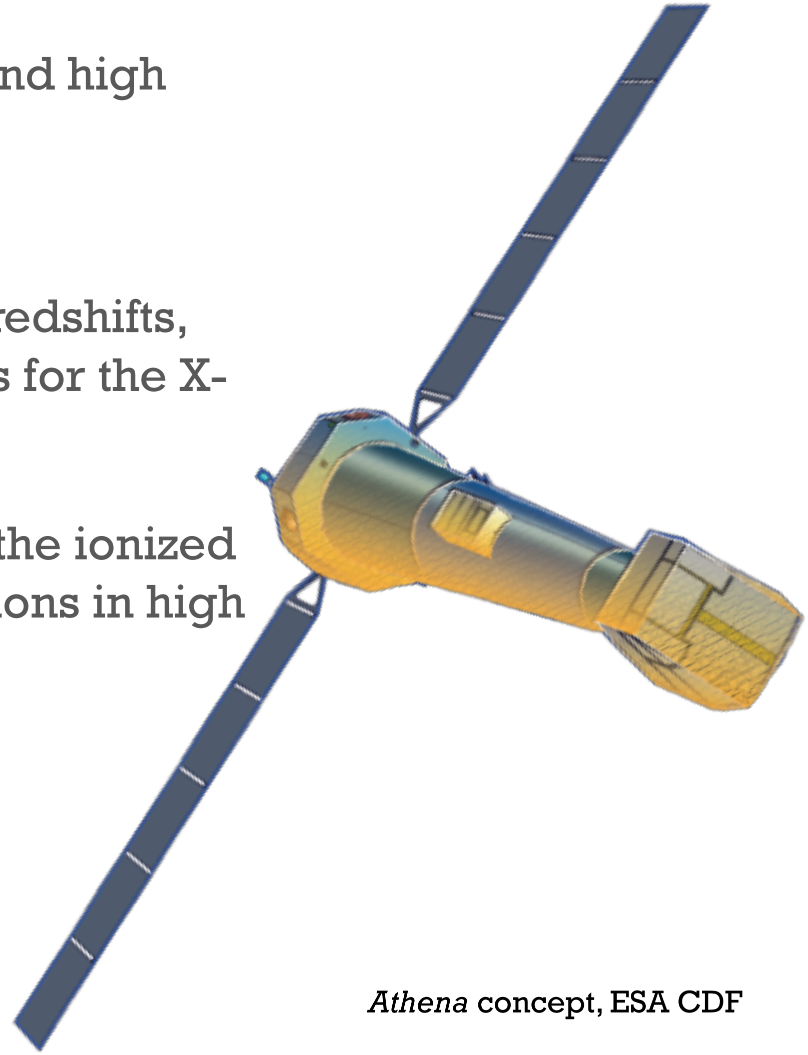




Credit: M. Türler & Athena team

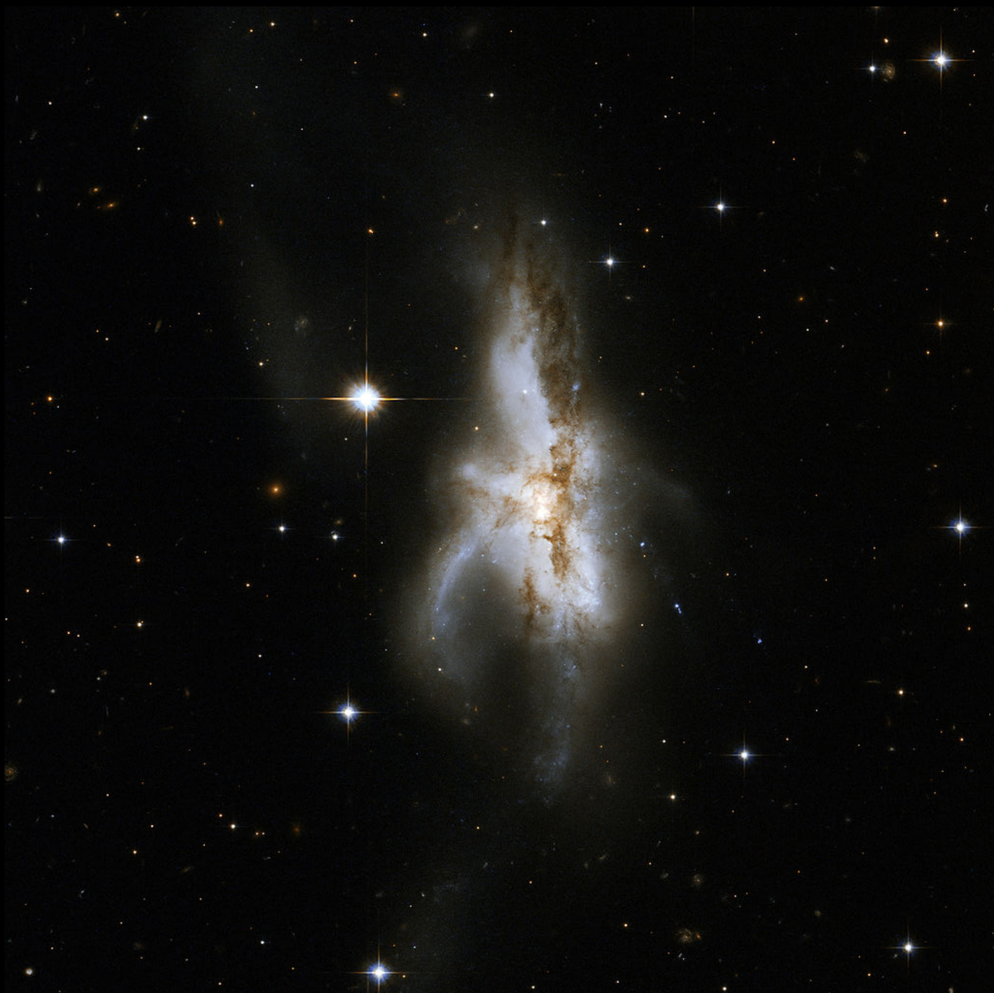
Athena-ELTs Synergies

- ELTs will provide critical high sensitivity and high resolution optical and near-IR imaging
  - Host galaxy morphologies
- ELTs Deep Spectroscopy will allow to get redshifts, and hence luminosities and accretion rates for the X-ray selected AGN up to z~8
- IFUs in ELTs will allow to spatially resolve the ionized gas and stellar populations at high resolutions in high redshift AGN host galaxies
- More information in Padovani et al. (2017, arxiv:1705.06064)



Athena concept, ESA CDF

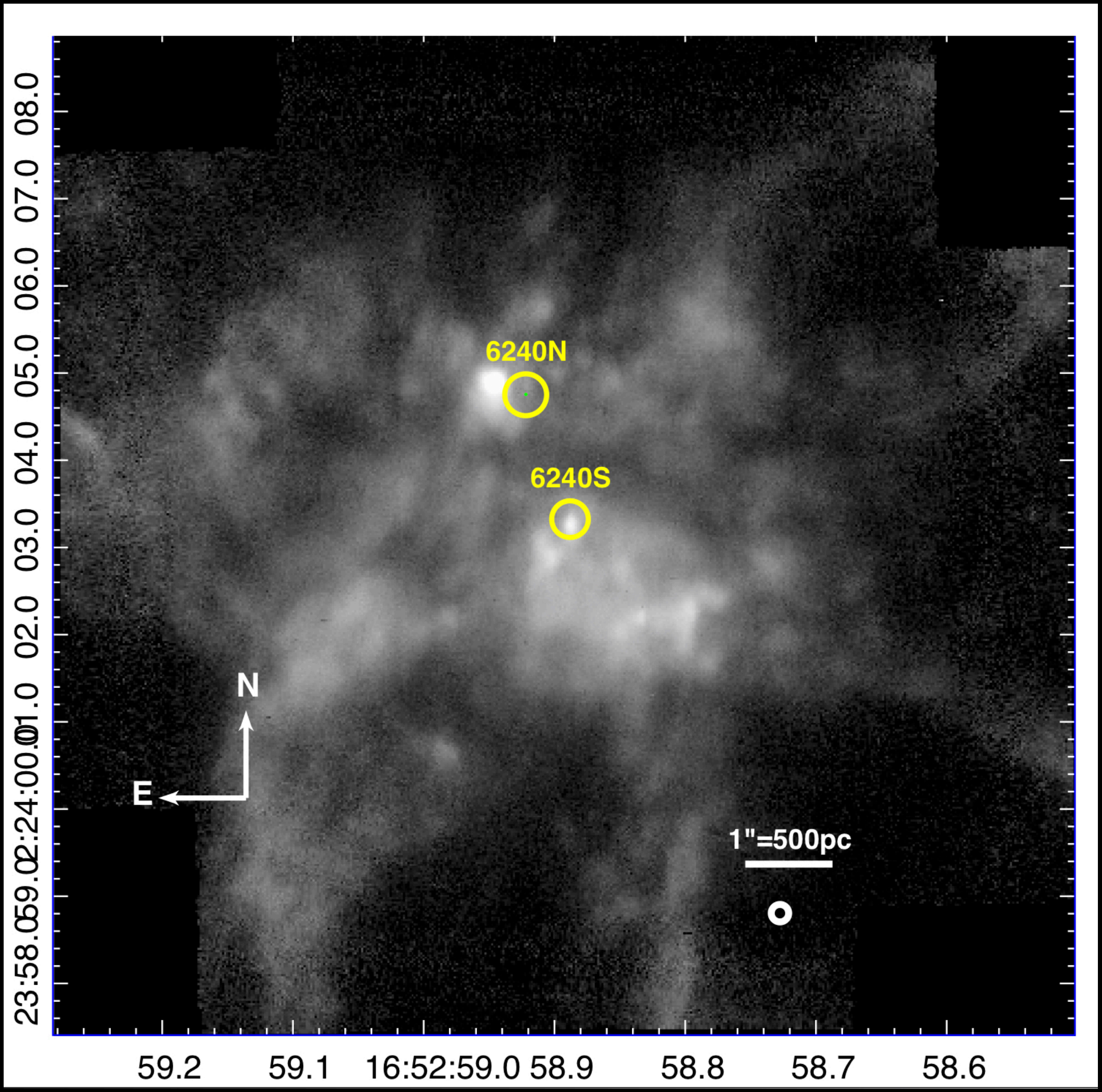
NGC6240



- L_{IR}=8.5x$10^{11}L_o$
- SFR≤150 $M_o yr^{-1}$
- Dual AGN
- Each SMBH $M \approx 10^9 M_o$

(Heckman+1987, Komossa+2003, Armus+2009, Medling+2011, Feruglio+2013ab)

The Importance of High Resolution IFUs



Hα MUSE NFM map of central region of NGC6240

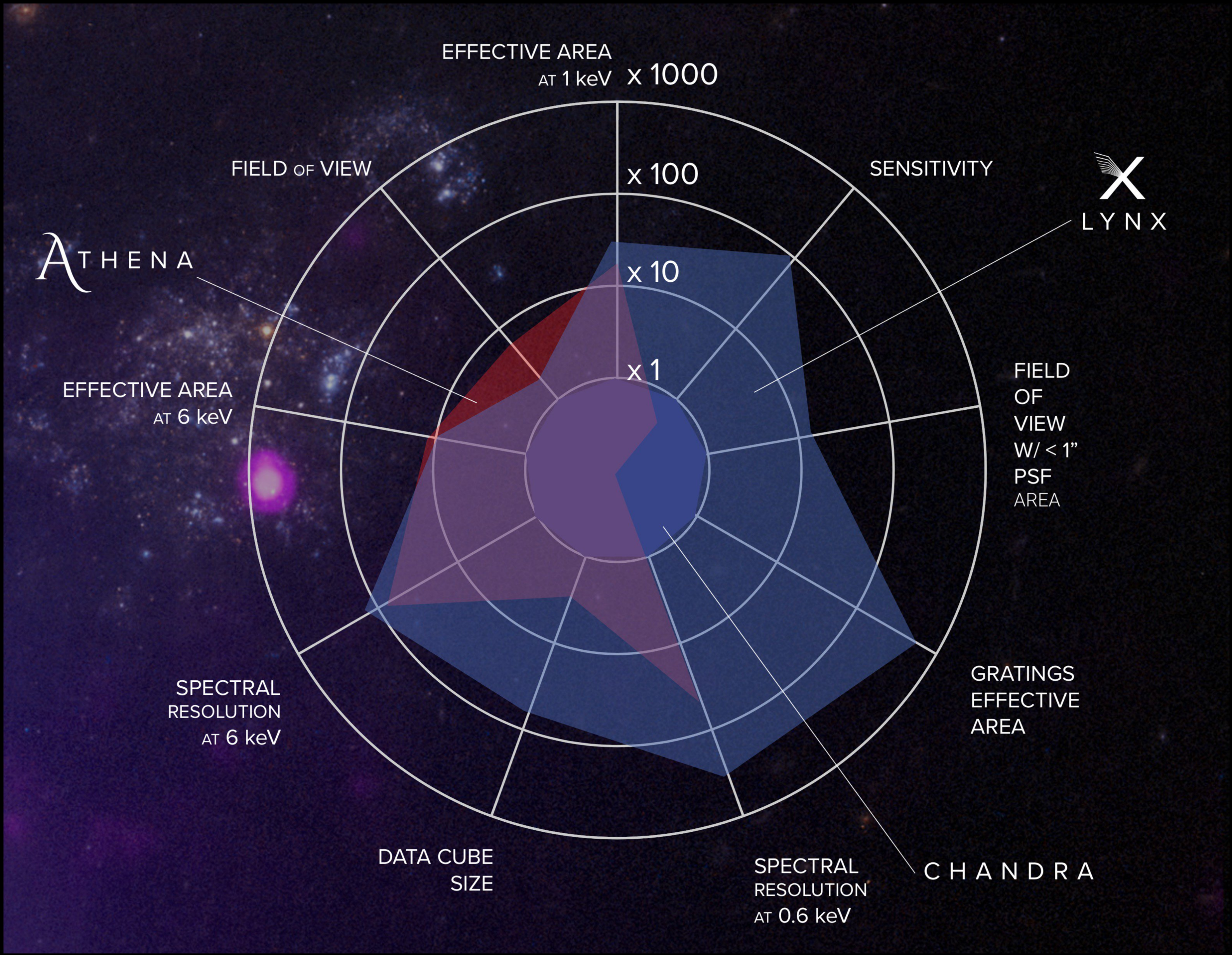
Resolution ~0.1”, ~50pc at 100Mpc

For IFUs at ELTs, resolution ~50-100pc at all redshifts

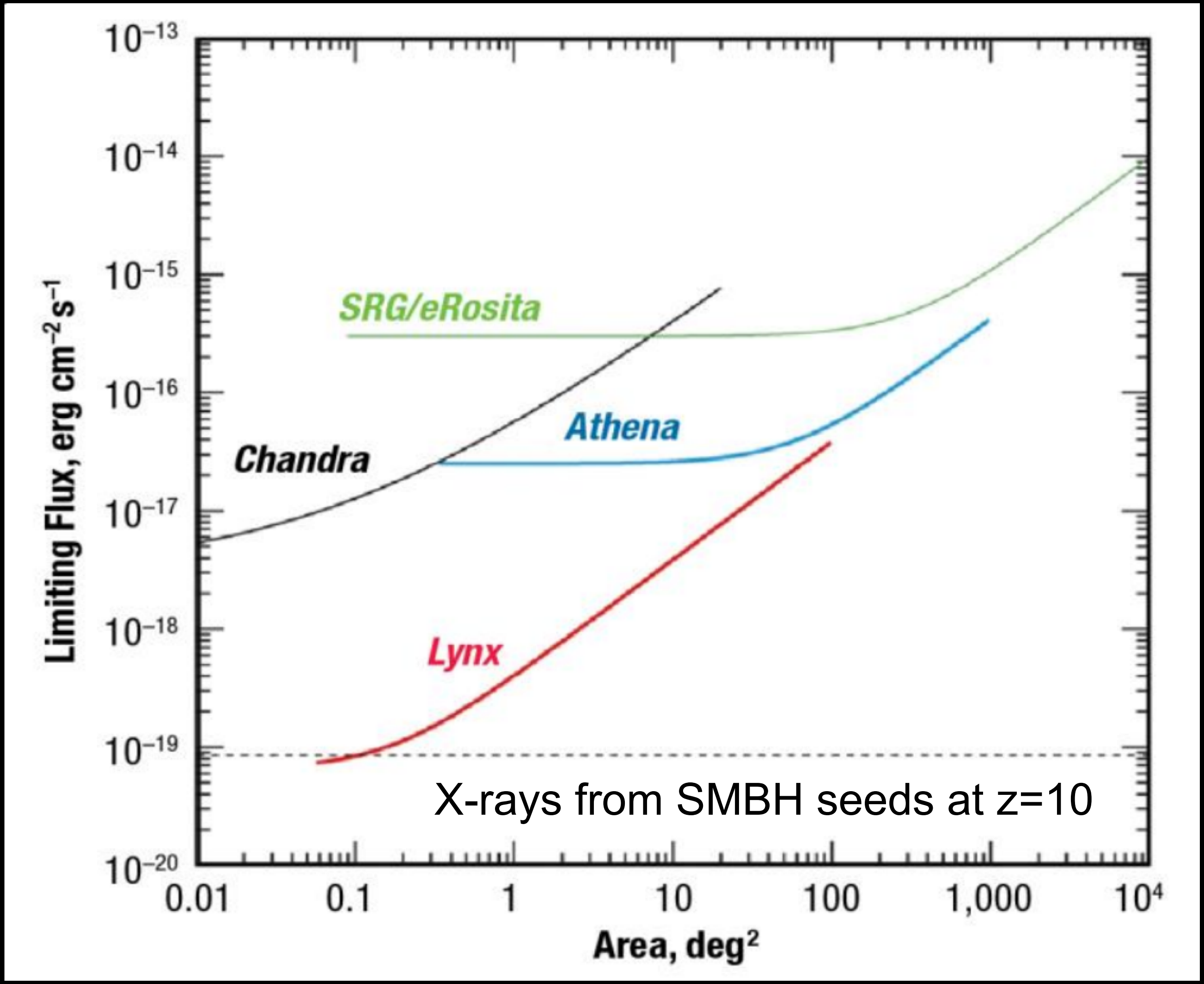
MUSE NFM Science Verification

LYNX X-RAY OBSERVATORY

LYNX


EFFECTIVE AREA
AT 1 keV
x 1000
x 100
x 10
x 1
SENSITIVITY
LYNX
FIELD OF VIEW W/ < 1" PSF AREA
GRATINGS EFFECTIVE AREA
CHANDRA
SPECTRAL RESOLUTION AT 0.6 keV
DATA CUBE SIZE
SPECTRAL RESOLUTION AT 6 keV
EFFECTIVE AREA AT 6 keV
ATHENA
FIELD OF VIEW

LYNX



From Lynx interim report

Summary

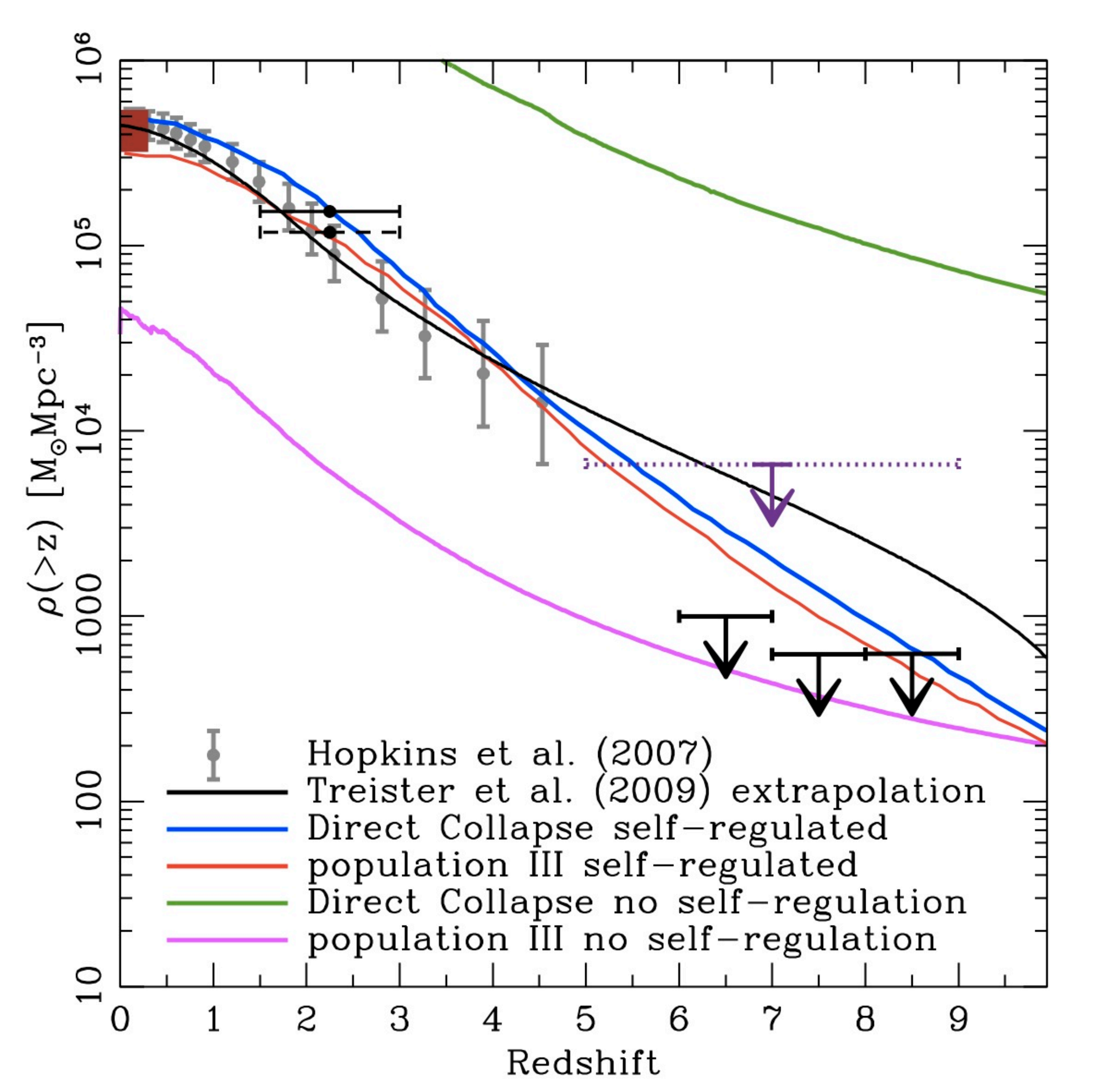
Thanks to **heroic** efforts carrying out and interpreting the results from X-ray surveys and fitting the spectral shape and intensity of the CXB we now know that most SMBH growth happens in:

- Moderate luminosity AGN
- At z~0.5-1
- In obscured but Compton-thin sources

Still room for up to ~2x more SMBH growth in heavily obscured systems, mostly at high redshift. Athena and Lynx will find them and the ELTs will characterize them.

High resolution IFU observations with ELTs will allow to study them in detail at all redshifts.

Accreted BH Mass Density



Treister et al., 2013