Future SMBH Surveys

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Supermassive Black Holes: Environment and Evolution
Corfu, Hellas — June 22, 2019

Overview

- How much do AGN contribute to the accretion driven emitted power and mass budget over the cosmic history? What is their role in shaping galaxy evolution via feedback? Light up and Early growth? Duty Cycle? Accretion physics? Distributions of AGN vs L,z,SFR,M*,N_H, L_{EDD} …

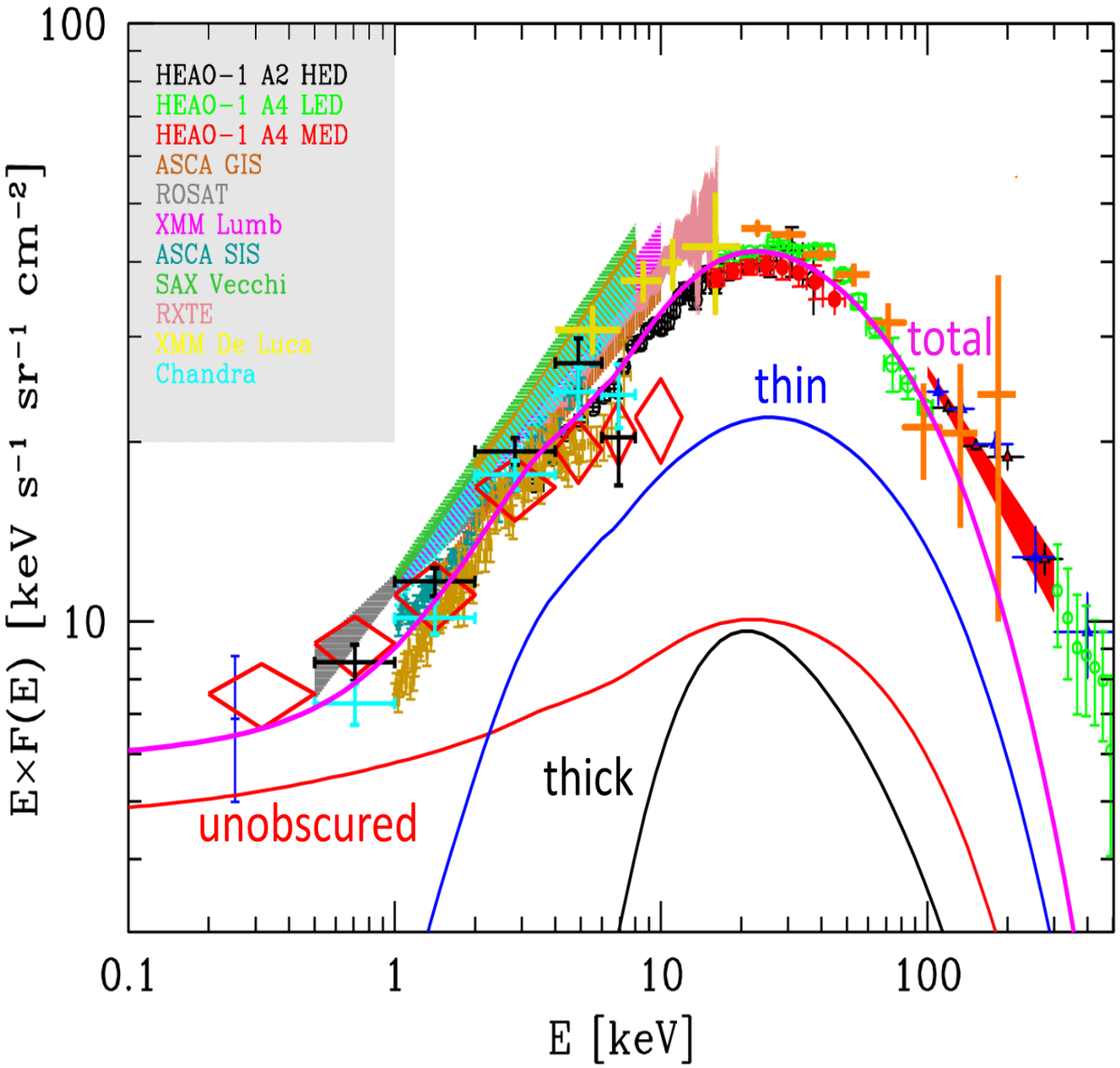
- First you need to get rid of the obscuration bias which is particularly severe for Compton thick ($\tau_T > 1$, $N_H > 1.5 \times 10^{24}$ cm^{-2}) AGN

- The X-ray Background set a constraint on the accretion history and, via the Soltan argument, on the mass density and accretion efficiency ε

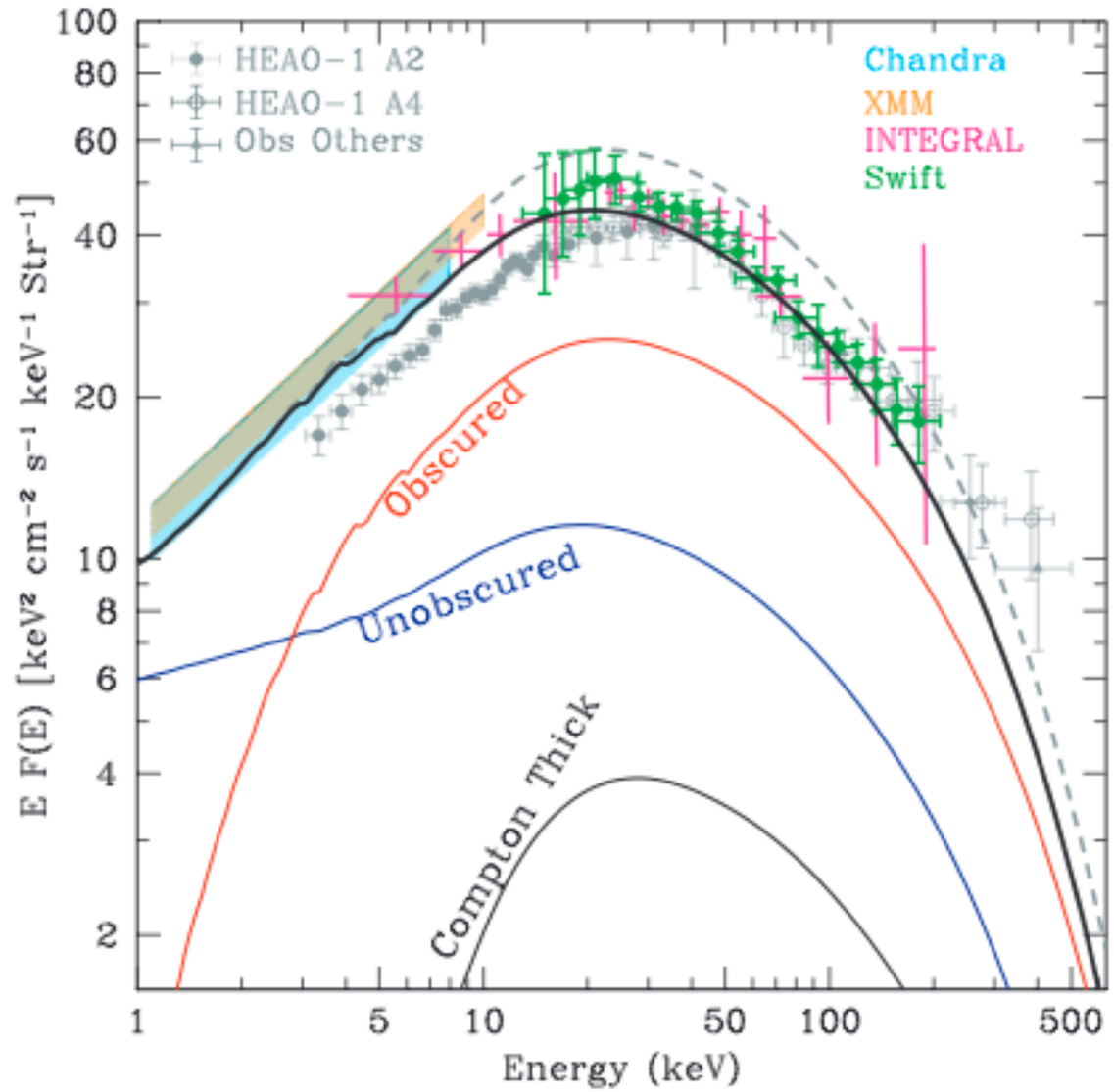
- Census needs to be performed both in terms of bolometric radiative output & accreted mass and, possibly, host properties

- (Hard) X-ray surveys are the "prime contractor" but a they need to be performed in coordination with multi-wavelength searches

Population synthesis for XRB



Gilli, AC, Hasinger 2007 GCH07

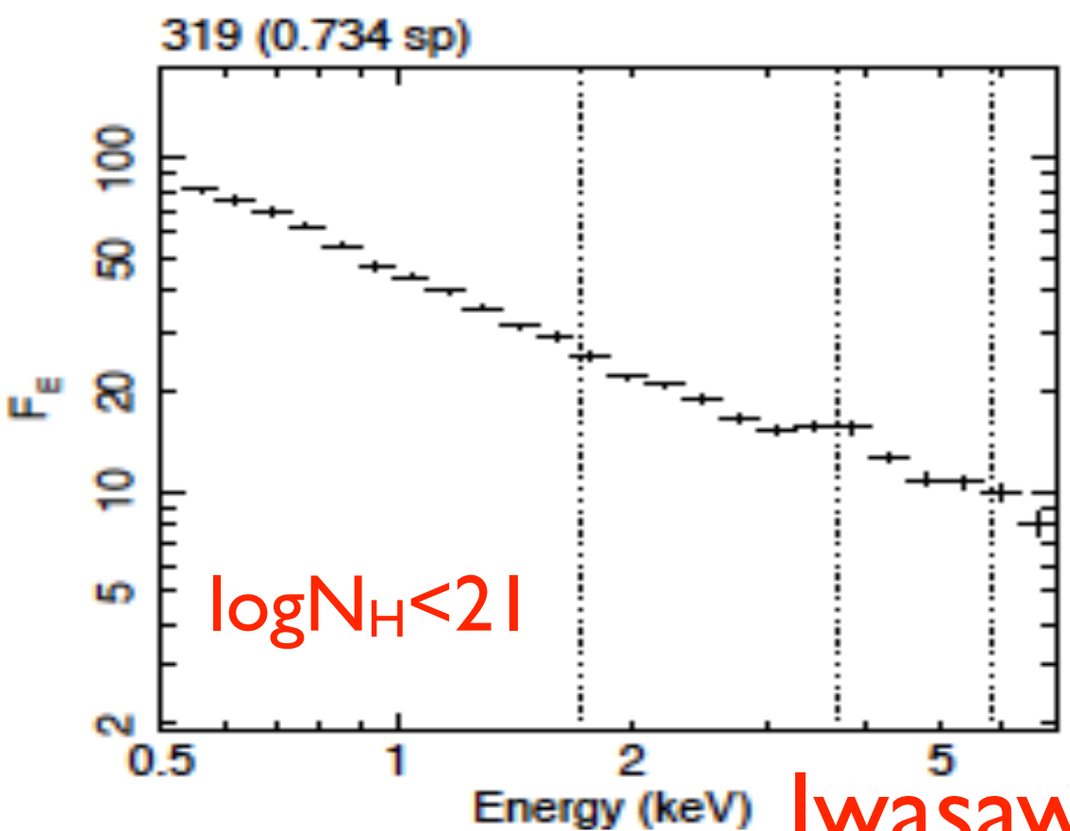


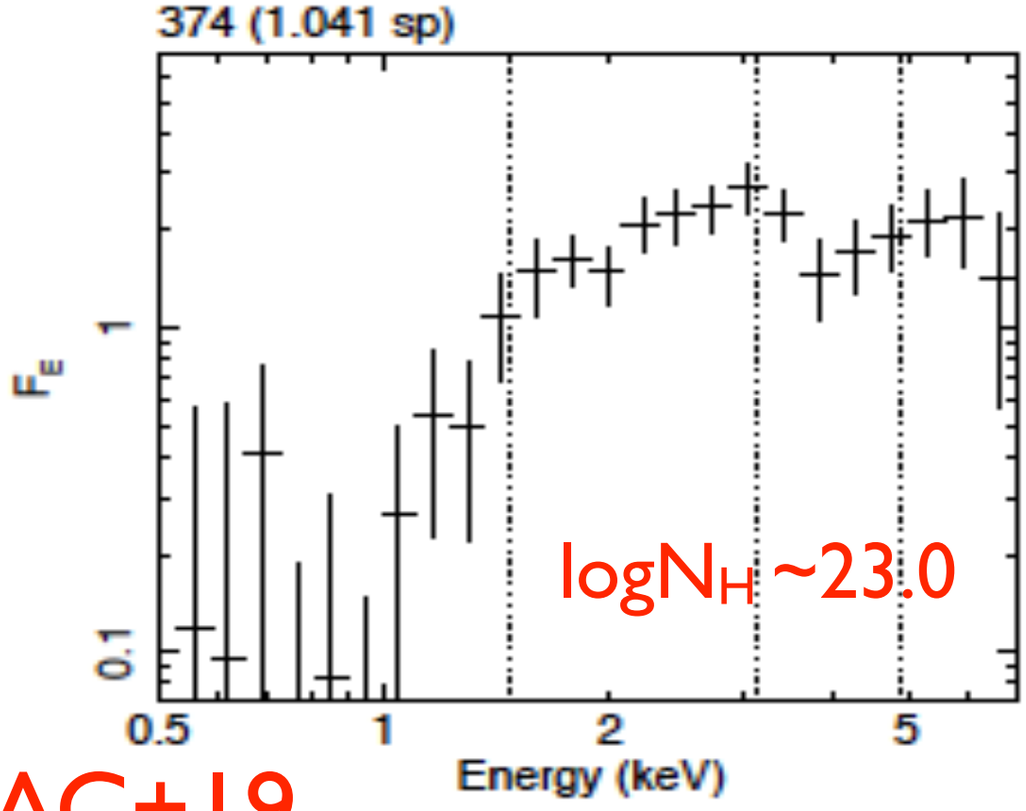
Treister, Urry, Virani 2009 TUV09

Based on luminosity dependent AGN unified scheme. Some 80% of accretion power is "mildly" obscured. About 1/4 (GCH07) or ~10% (TUV09) are Compton thick.

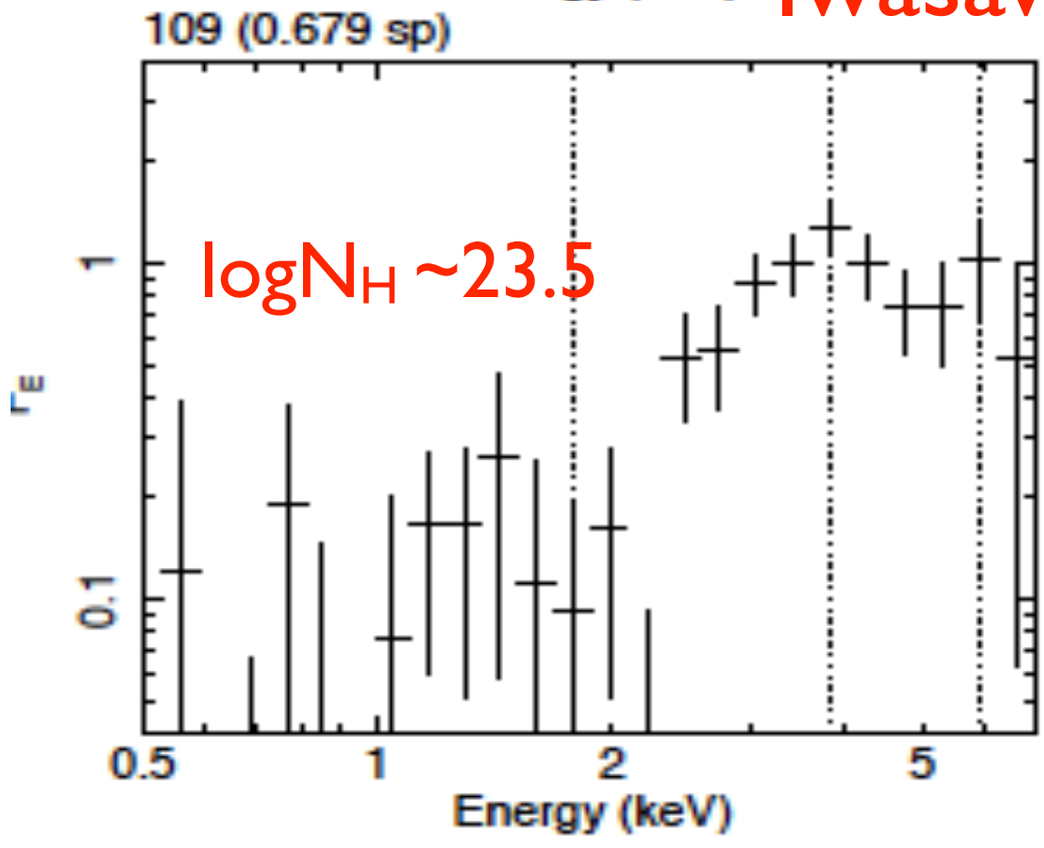
The bulk of energy output is emitted at z ~ 1.

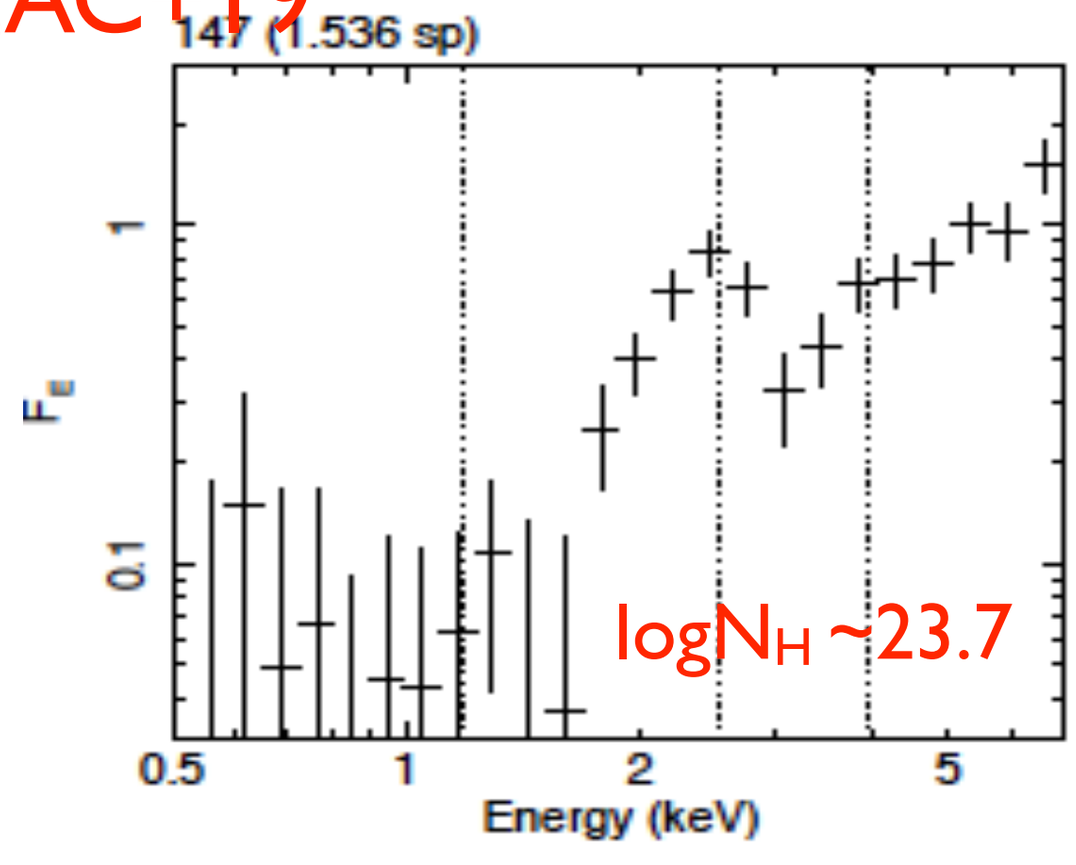
XMM-CDFS X-ray spectra





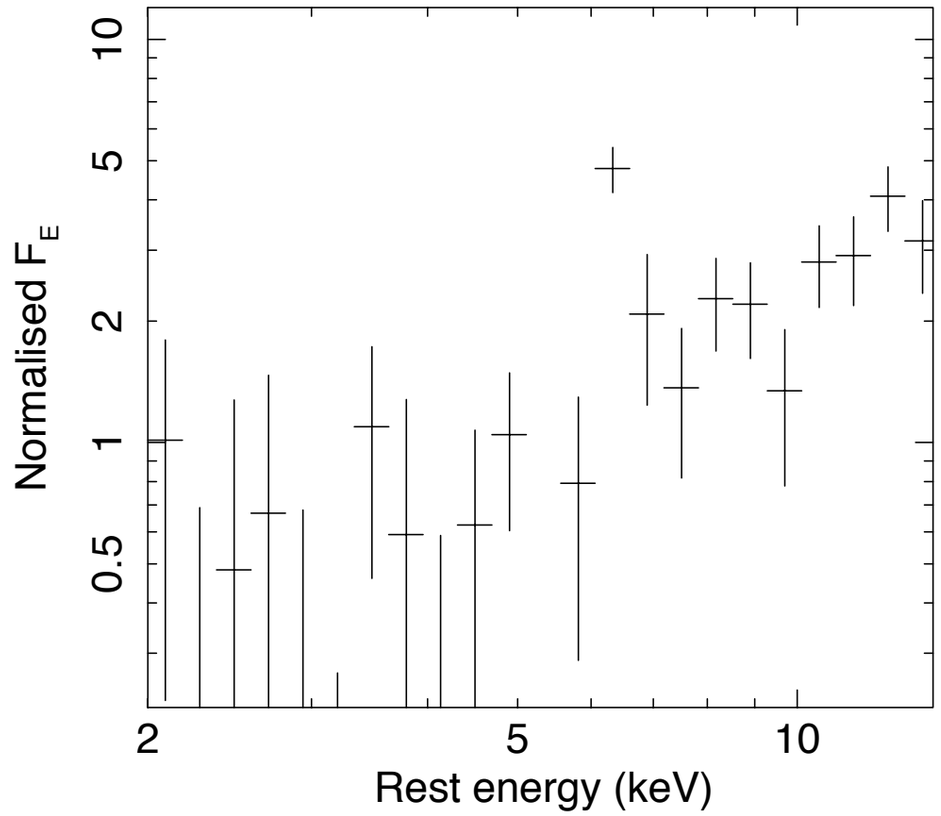
Iwasawa,AC+19





Heavily obscured AGN: Chandra/XMM & NuSTAR

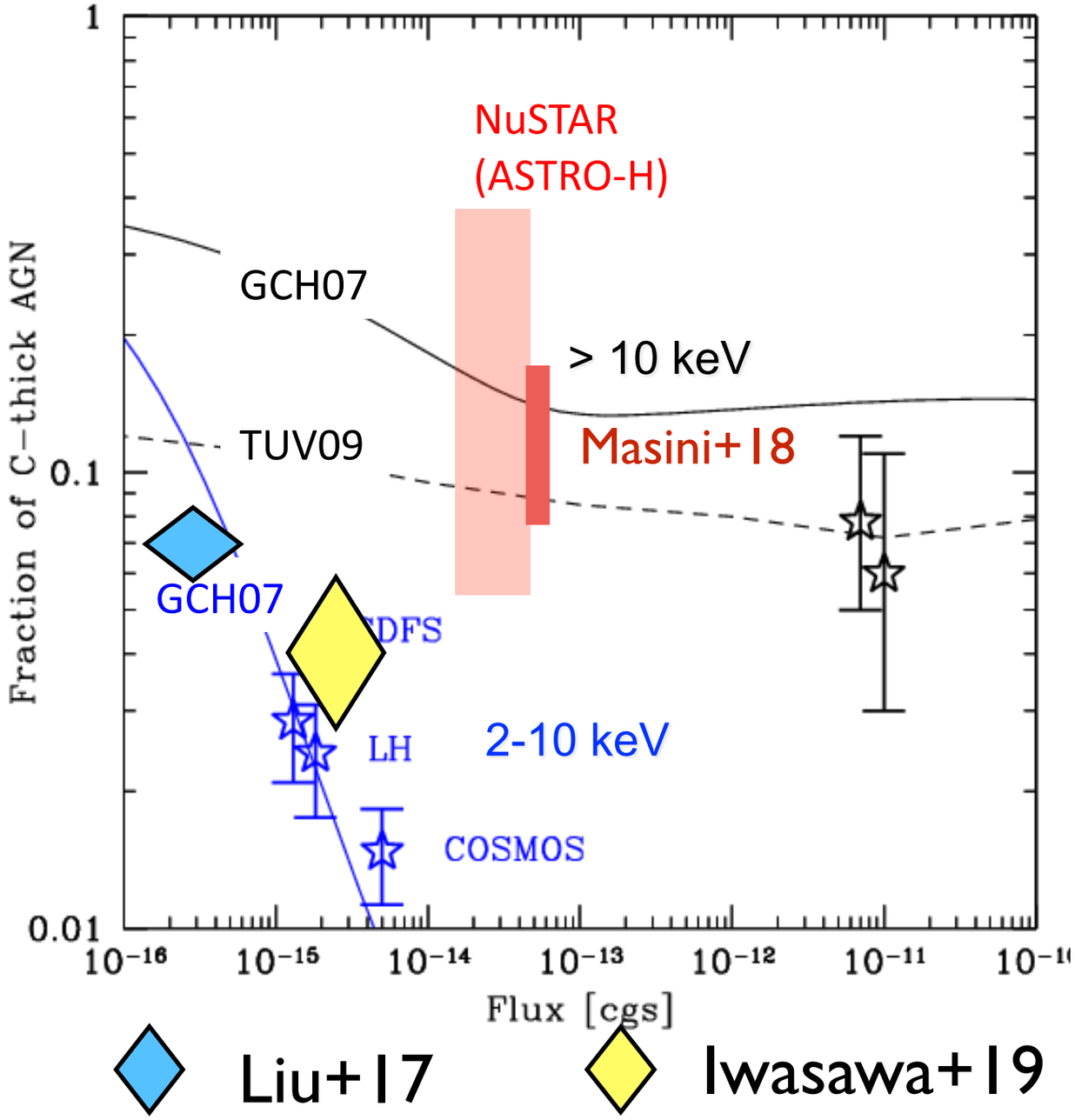
Chandra 7 Ms spectrum of a z=4.8 CT AGN Circosta+19



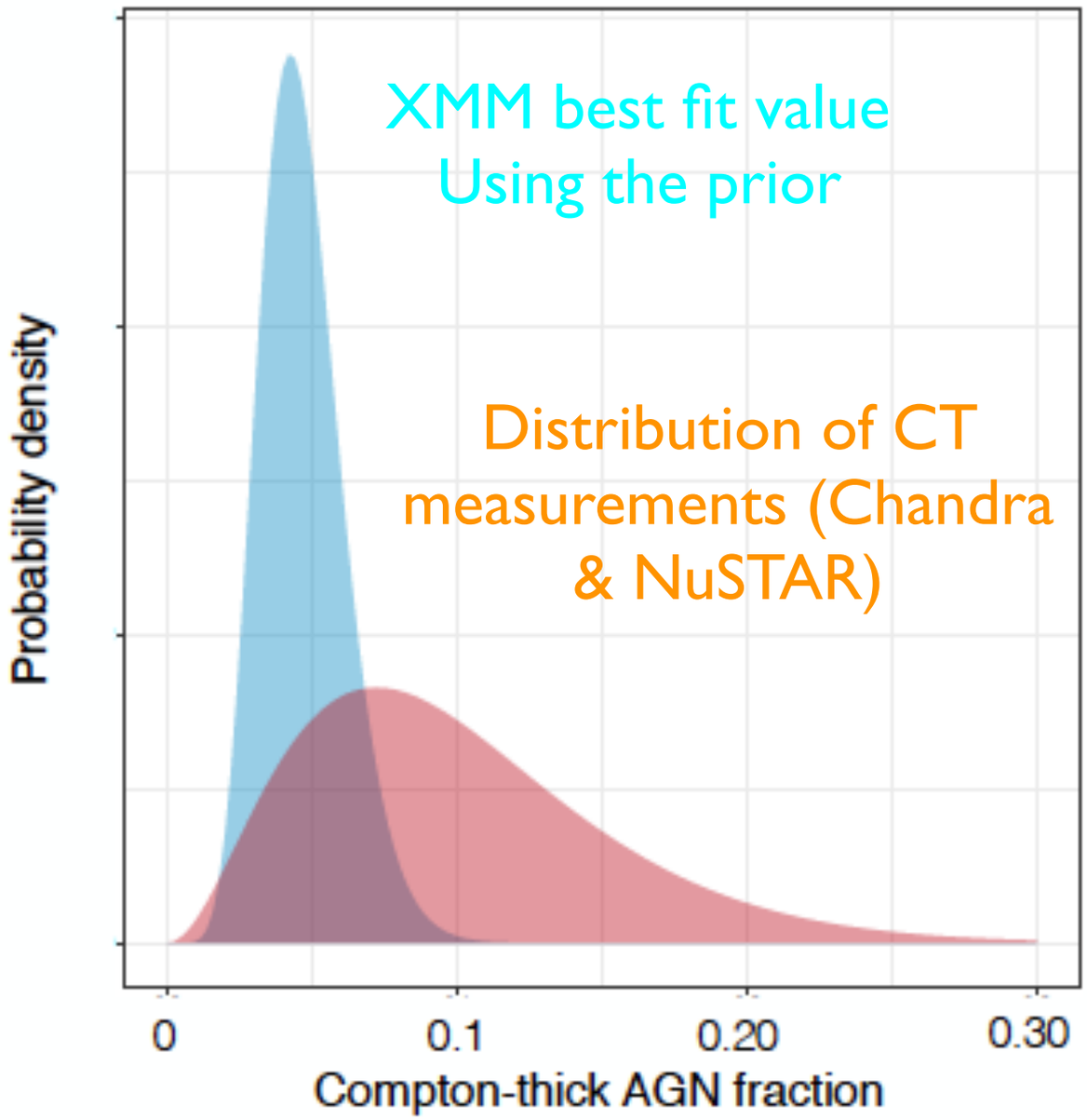
XMM Stacked Spectrum of 7 "bona fide" CT AGN at z=1.2-3.6 Iwasawa,AC+19

NuSTAR + Chandra& XMM Zappacosta+18
Alexander+13, Mullaney+15, Civano+15, …

X-ray selected Compton thick



Liu+17 Iwasawa+19



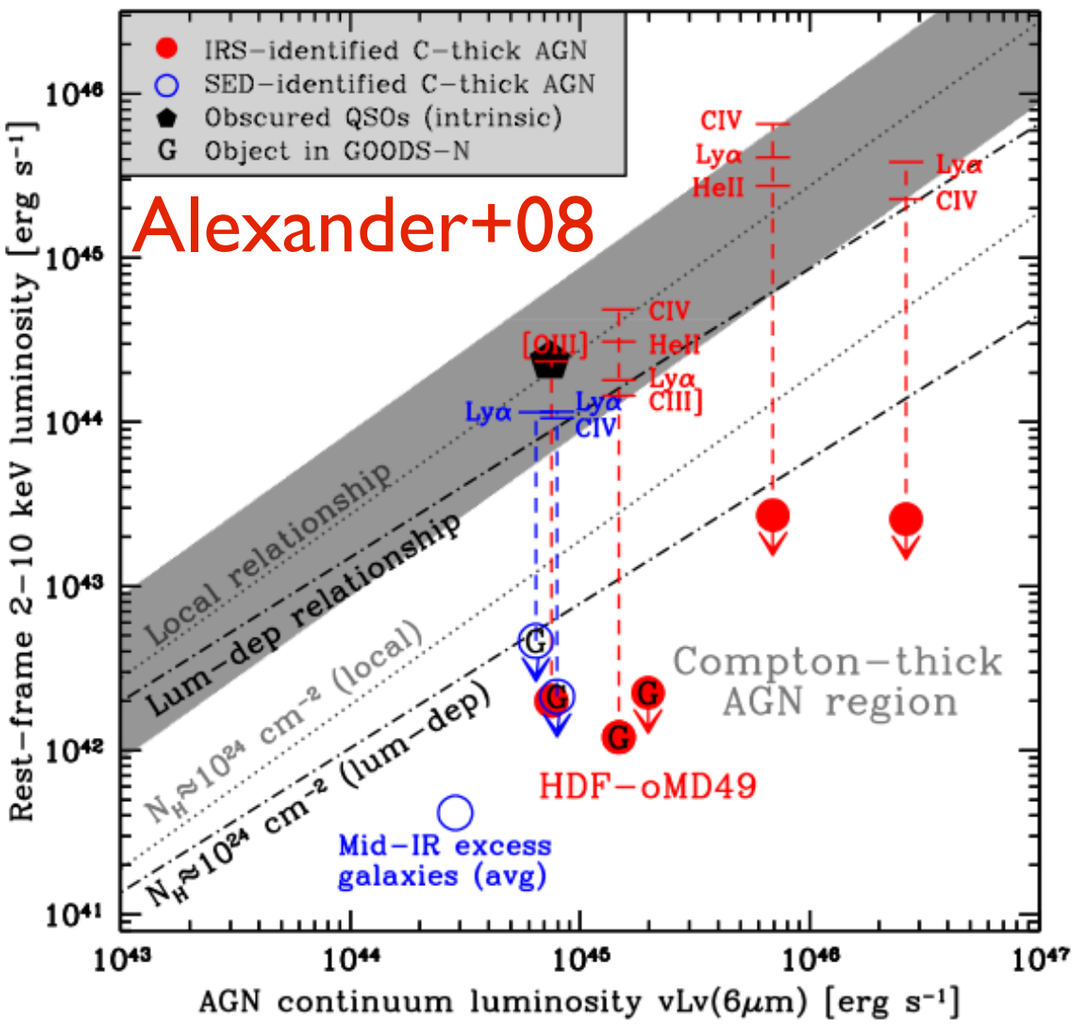
Iwasawa+19

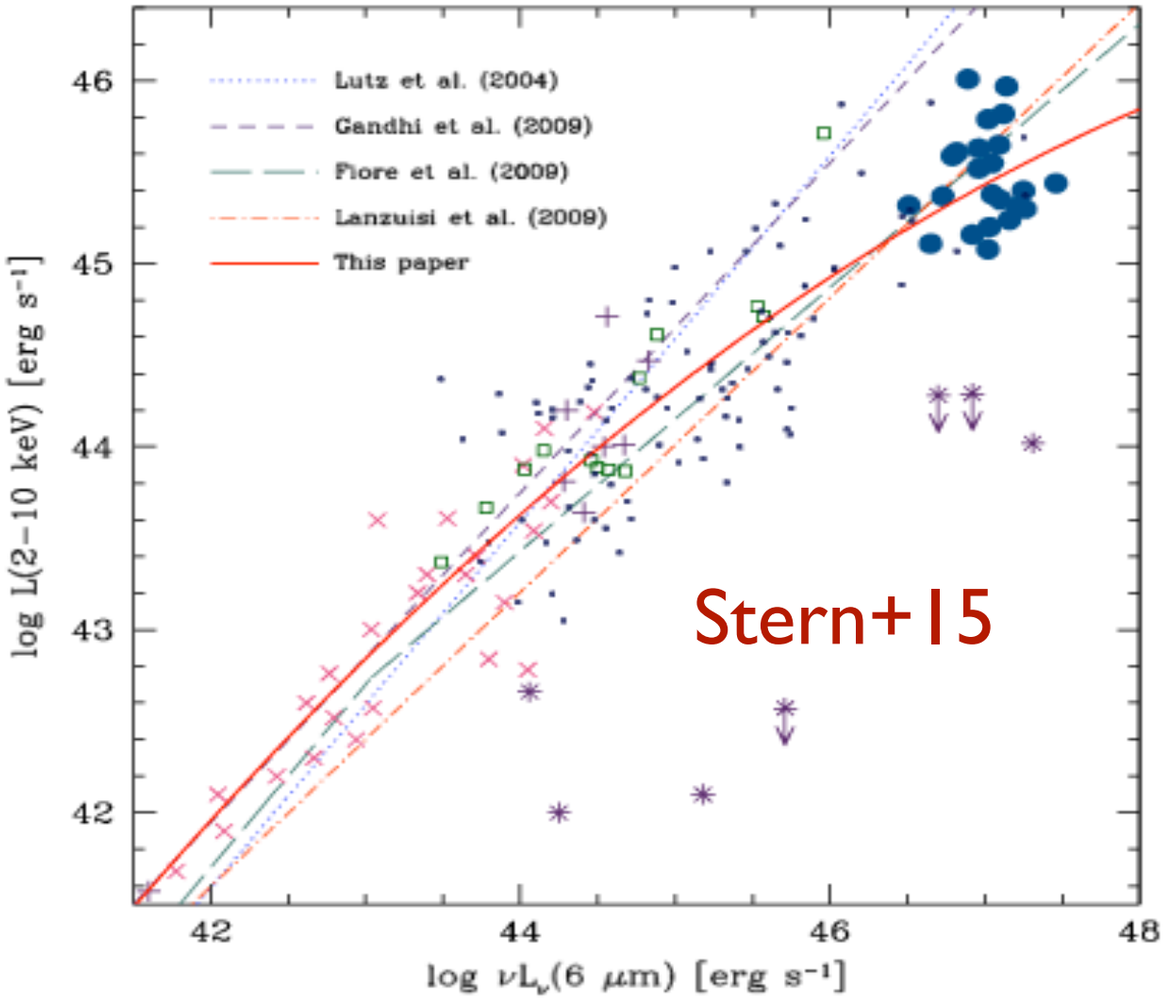
The number density of the most obscured AGN observed in the local Universe and in the deep hard X-ray surveys, are consistent with those expected/predicted by the XRB synthesis models within a factor 2

Multiwave selection of candidate Compton thick

The bottom line is to compare line and/or optical/IR continuum luminosities to X-ray observations Fiore+08,09; Gilli+10;Vignali+10;Del Moro+15;…

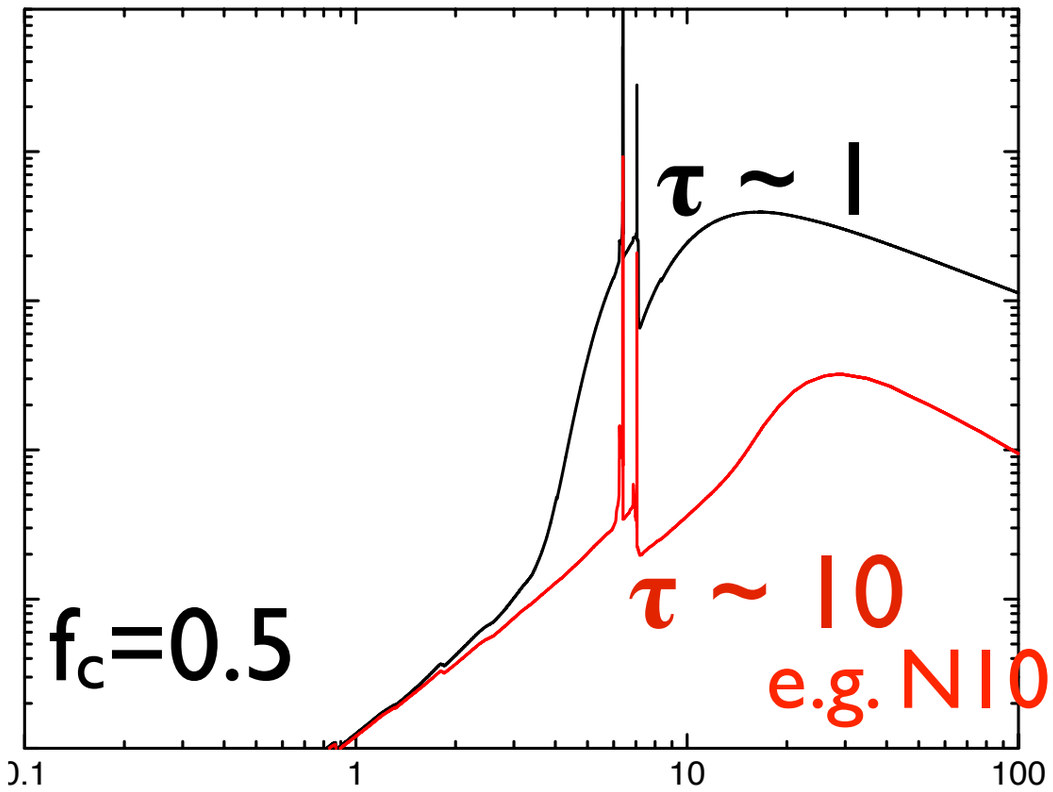
A sizeable population of highly obscured and CT AGN over a range of redshifts (say 0.5-2), is inferred from INDIRECT methods. If they are AGN they add up to the X-ray detected ones. How many of them? Too many?
Likely to be the most obscured and with the highest covering factor or both



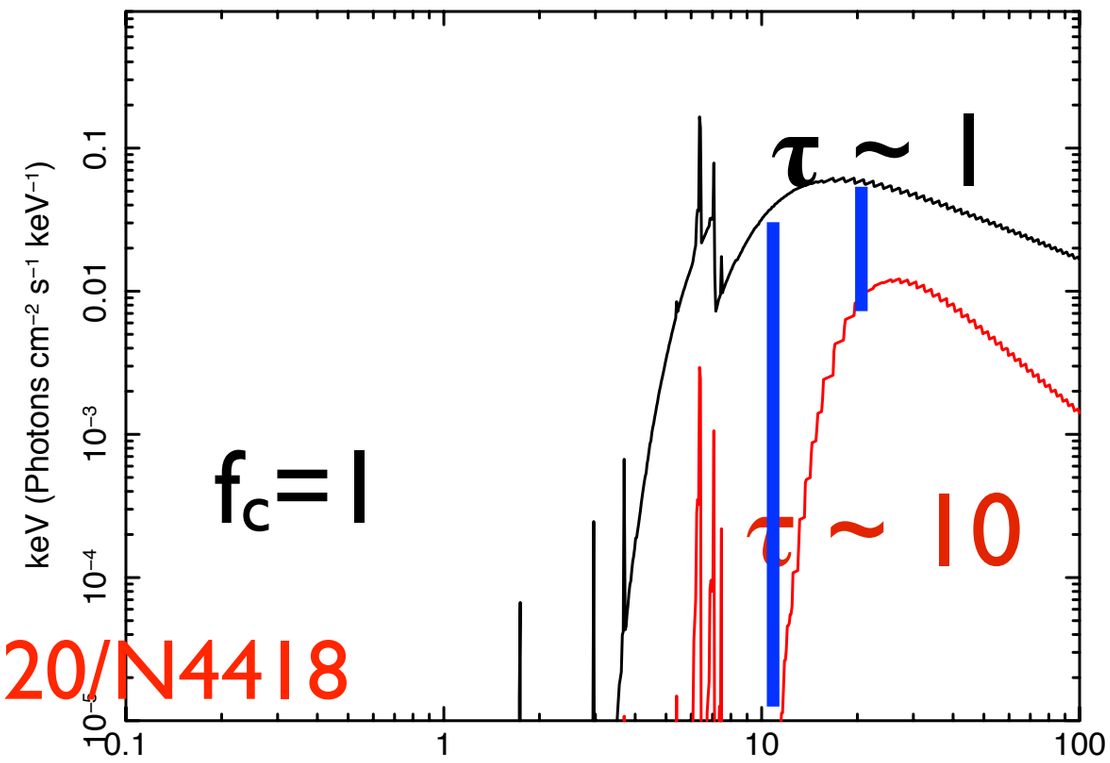


Compton thick AGN

Chandra/XMM/NuSTAR X-ray surveys are sampling the $\tau \sim 1$ population



e.g. N1068/Arp220/N4418



A small variation in the optical depth above the Compton thick threshold has a large impact on the observed X-ray flux: a factor "a few" around 20 keV corresponds to a few order of mags at 10 keV for high covering factors.

Easy to miss these objects, if they exist. The are ample margins — but not infinite — to accomodate more sources and thus luminosity and mass

Constraints from the XRB

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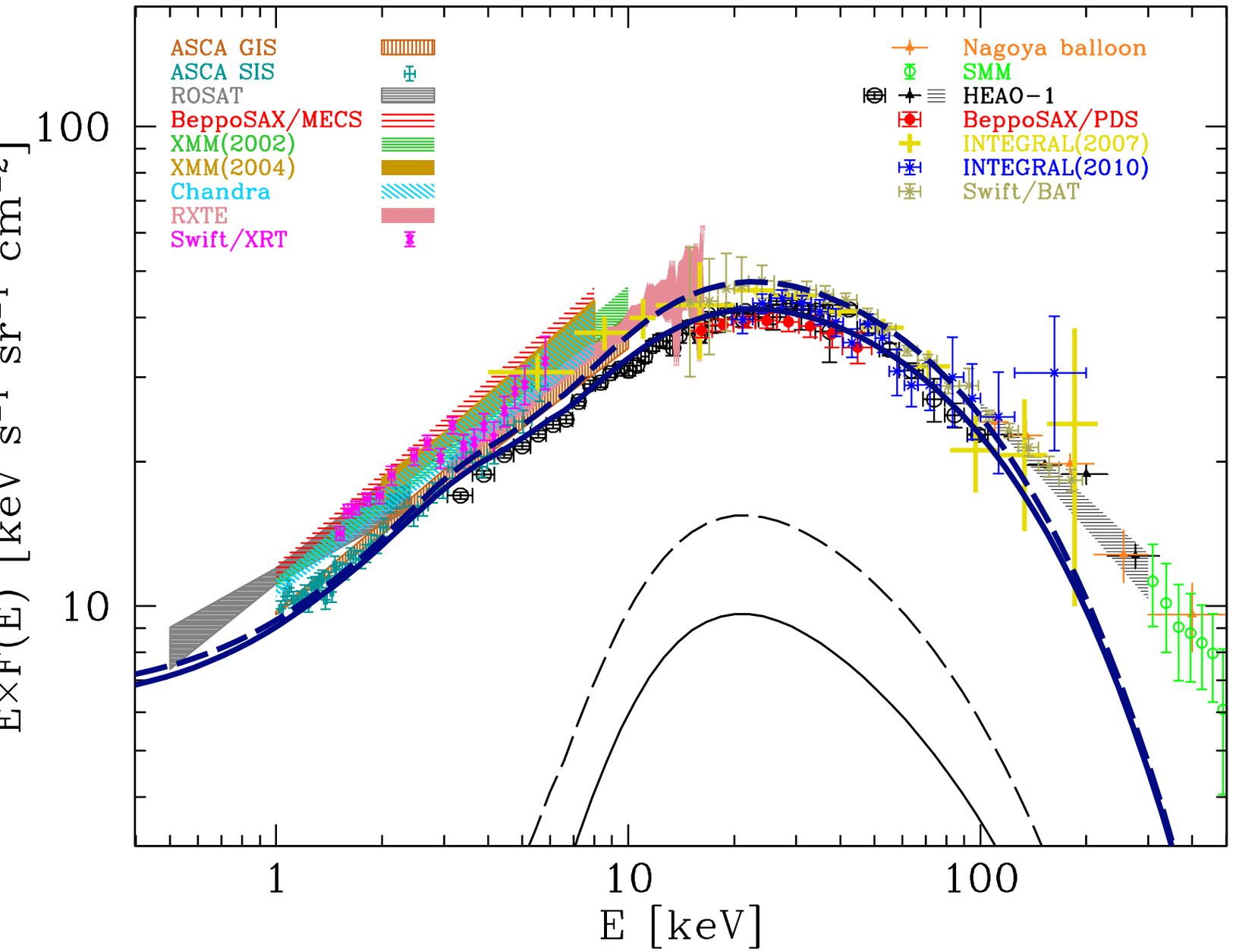

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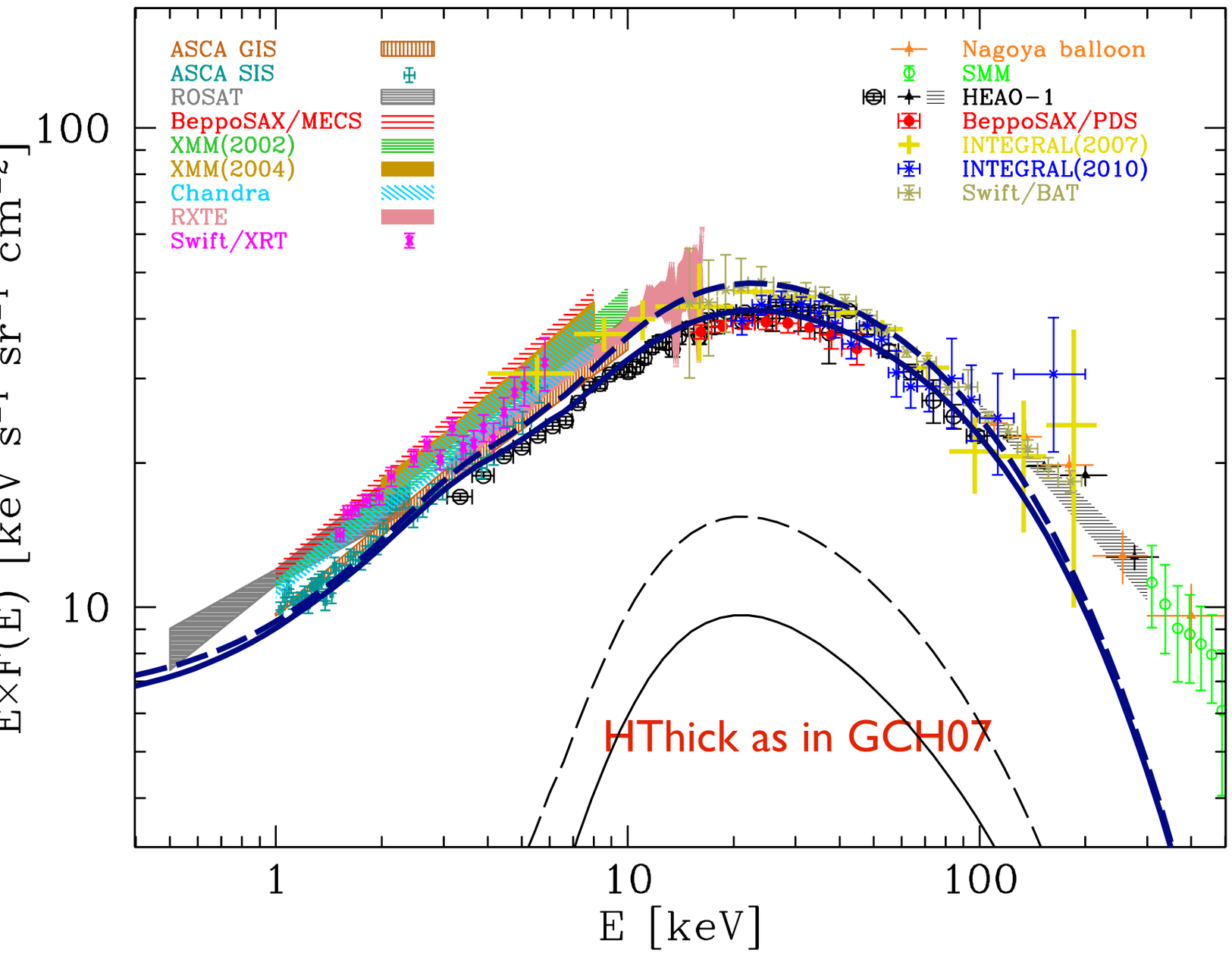

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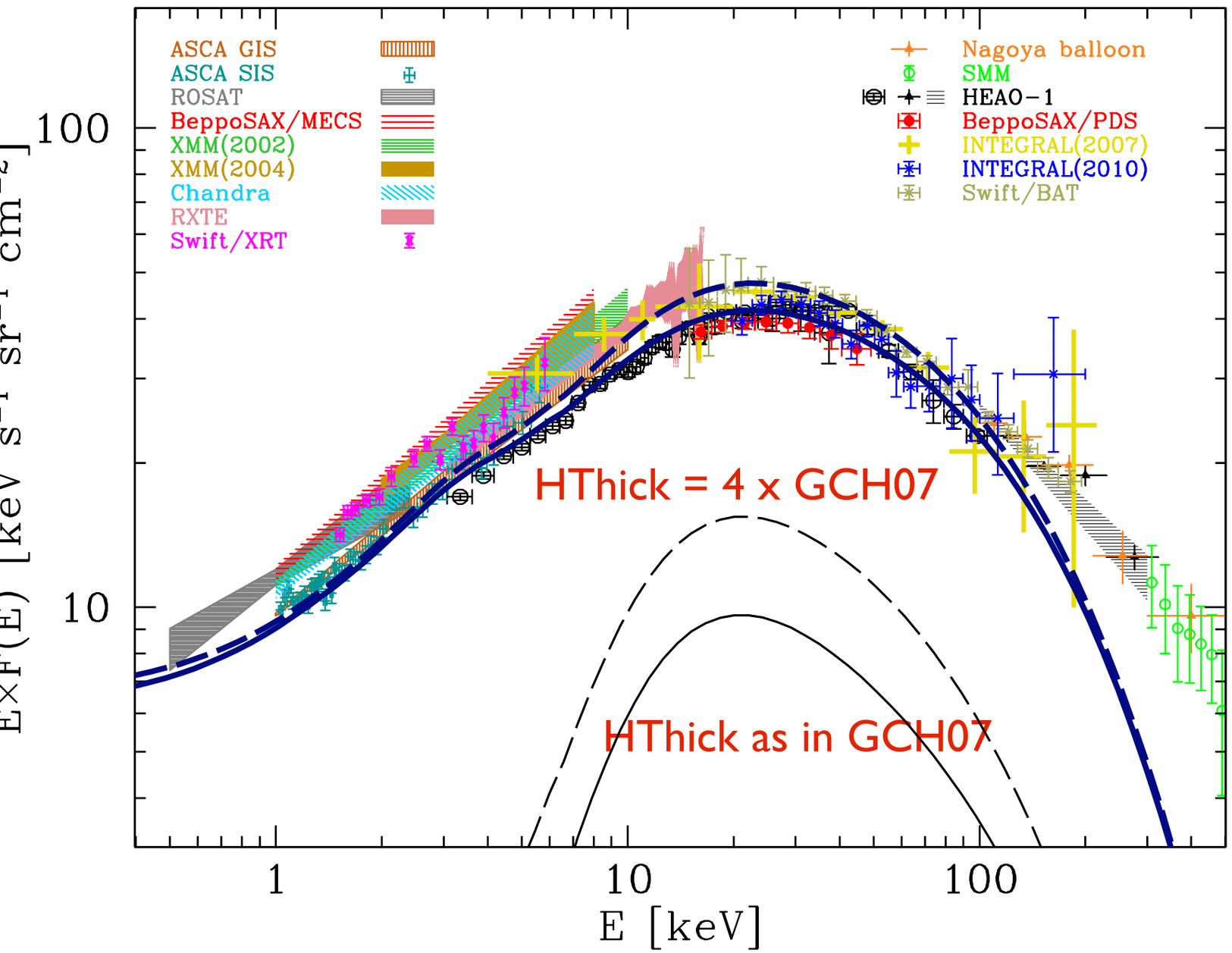

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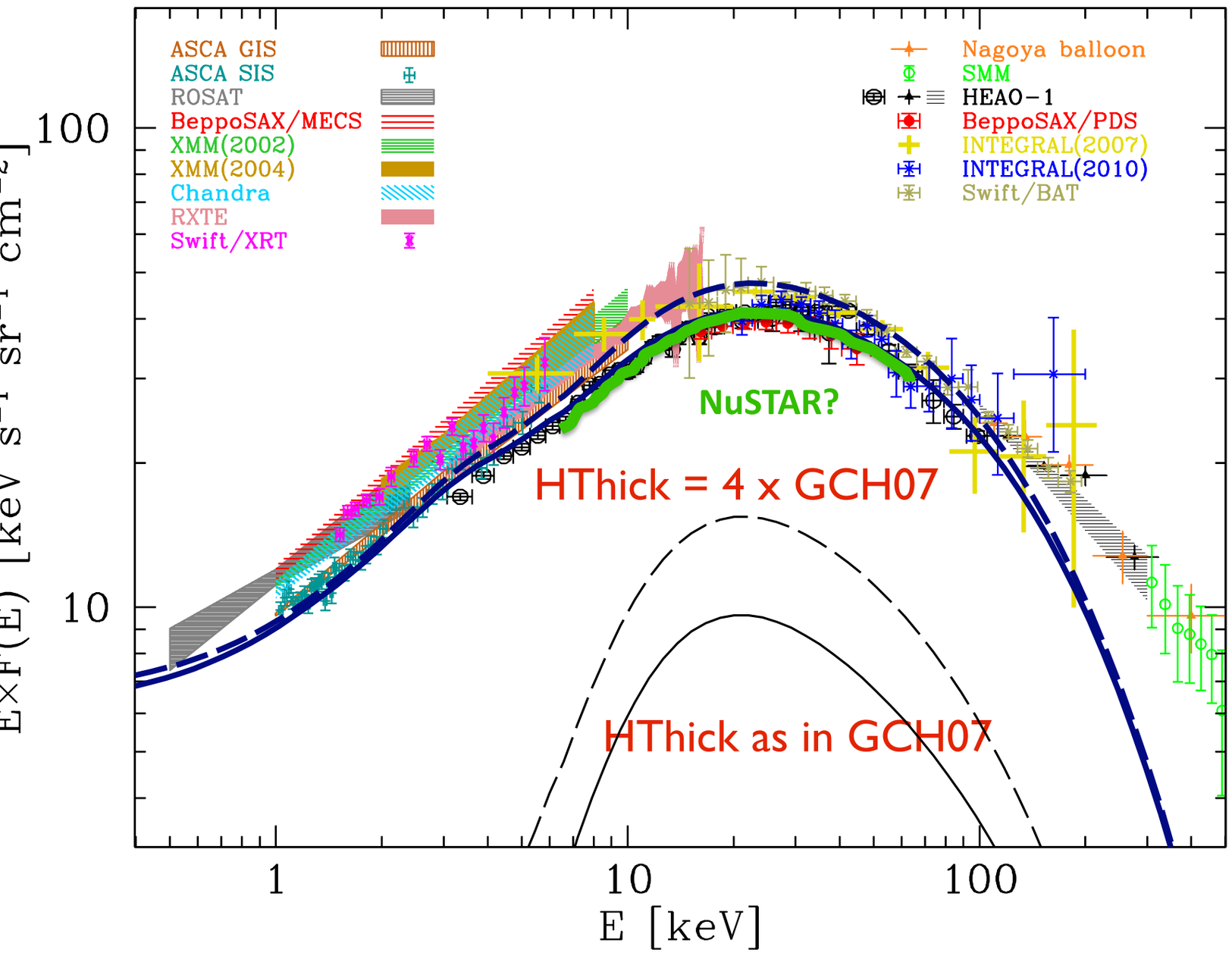

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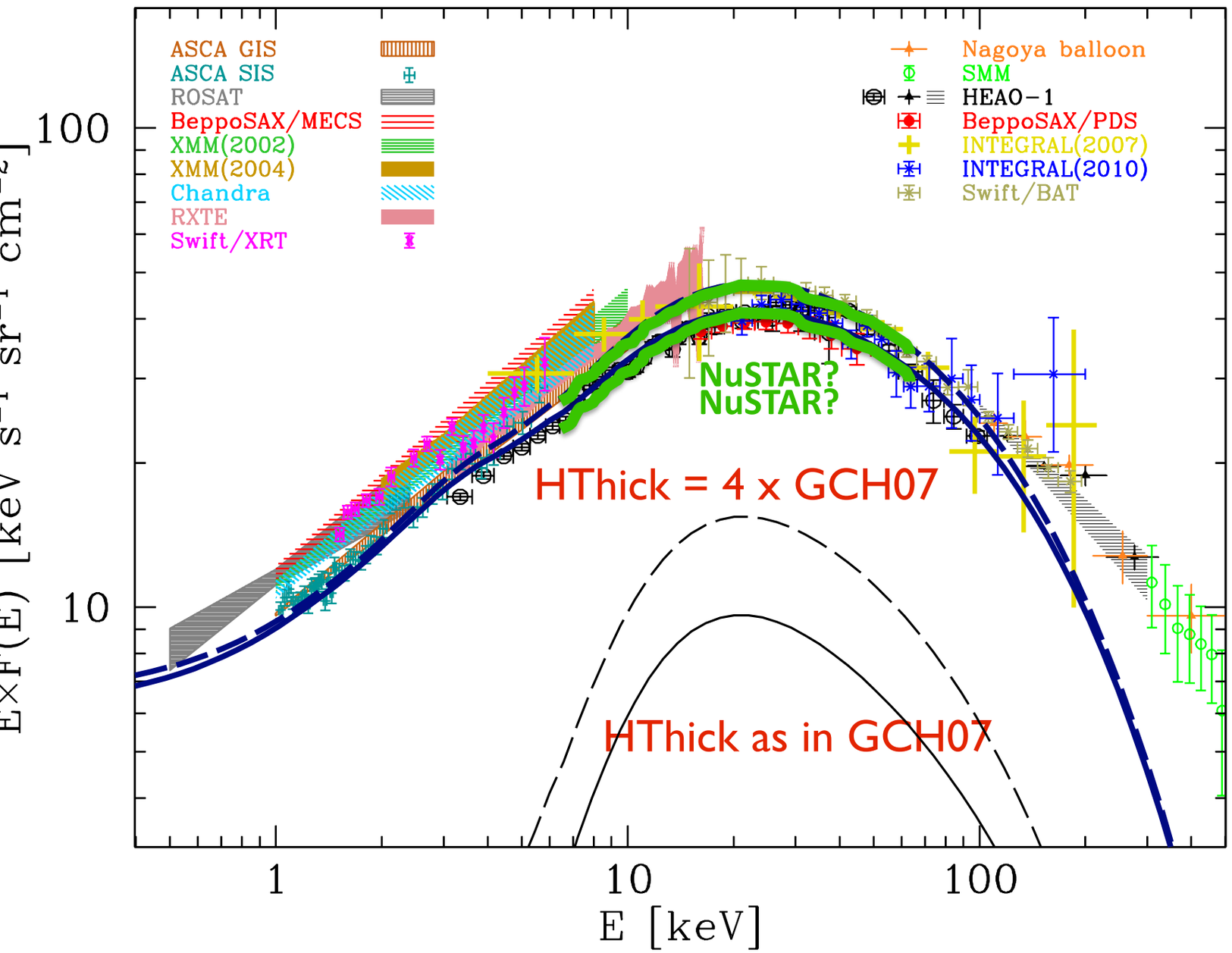

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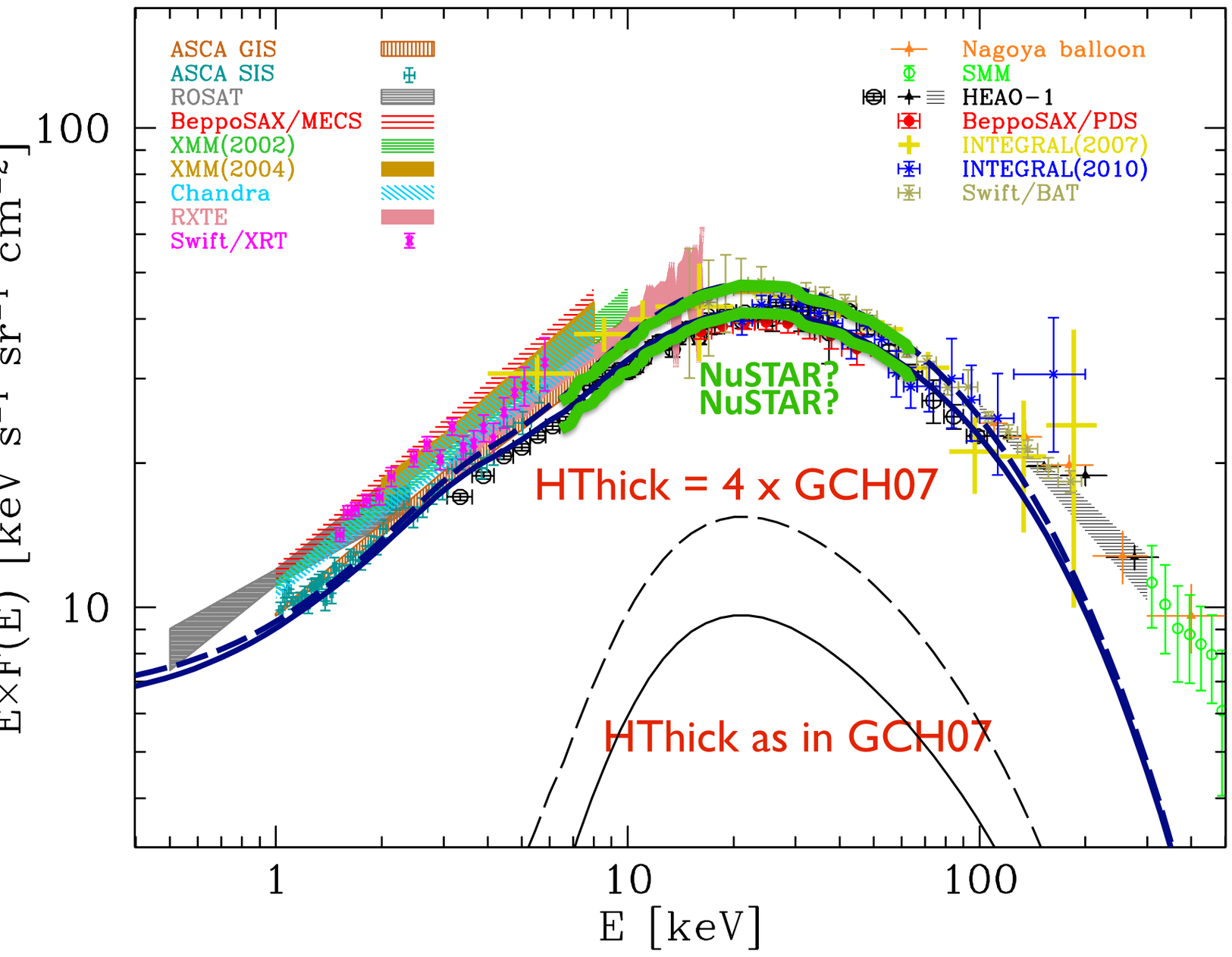

For each SMBH contributing to the XRB (unobscured, thin & thick) there could be an X—ray silent object contributing to the mass density only. You may "play" with current uncertainties on the intensity of XRB peak Still a sizeable fraction (~20%) of "all" SMBH could be X-ray silent

AC+2015

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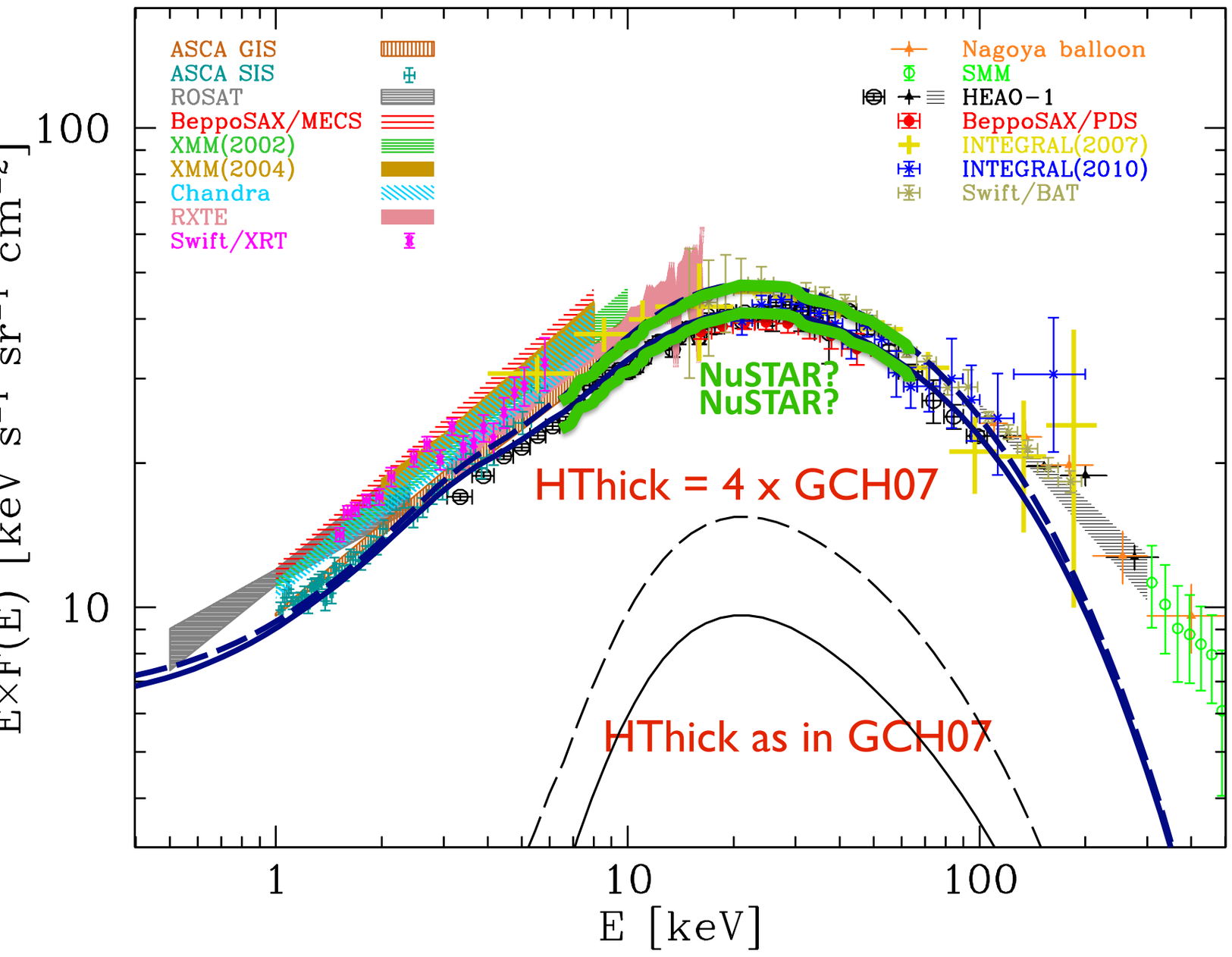

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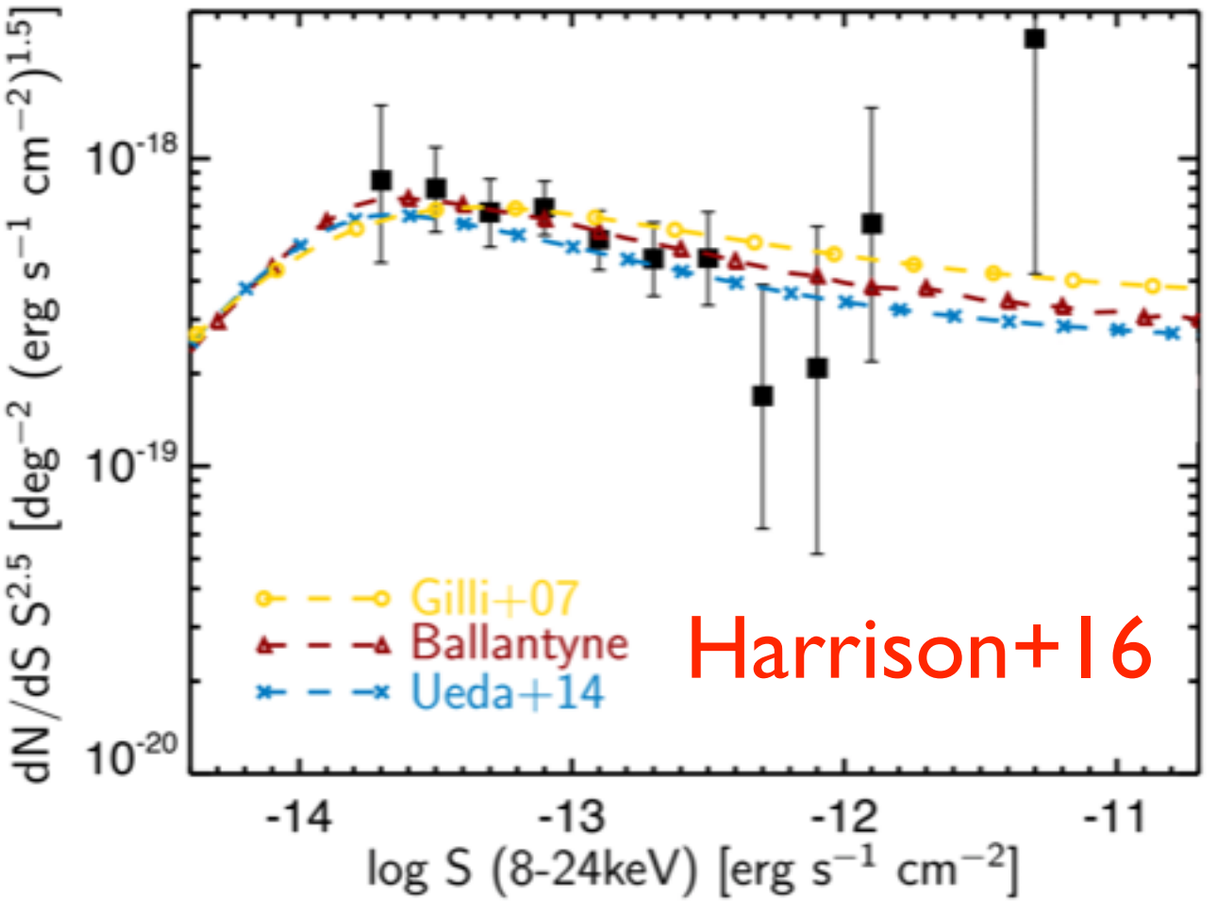
AC+2015

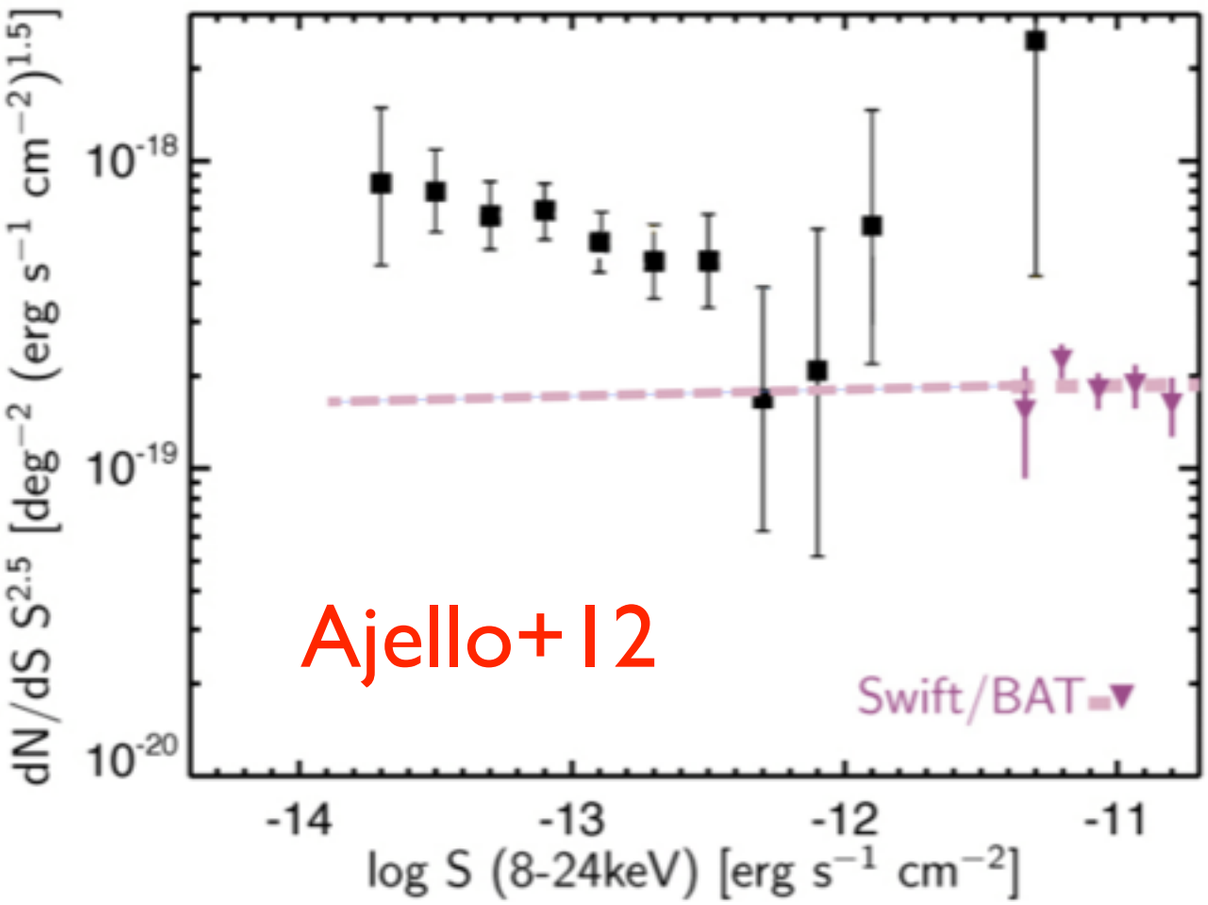
Covering factor approaching 1 (i.e. a geometrically thick torus w/ small/ zero opening angle) and/or super-thick columns (i.e. $N_H > 10^{25}$ cm^{-2})

Need sensitive hard X-rays (> 10 keV) Surveys

Number Counts in the hard X-rays: 8-24 keV



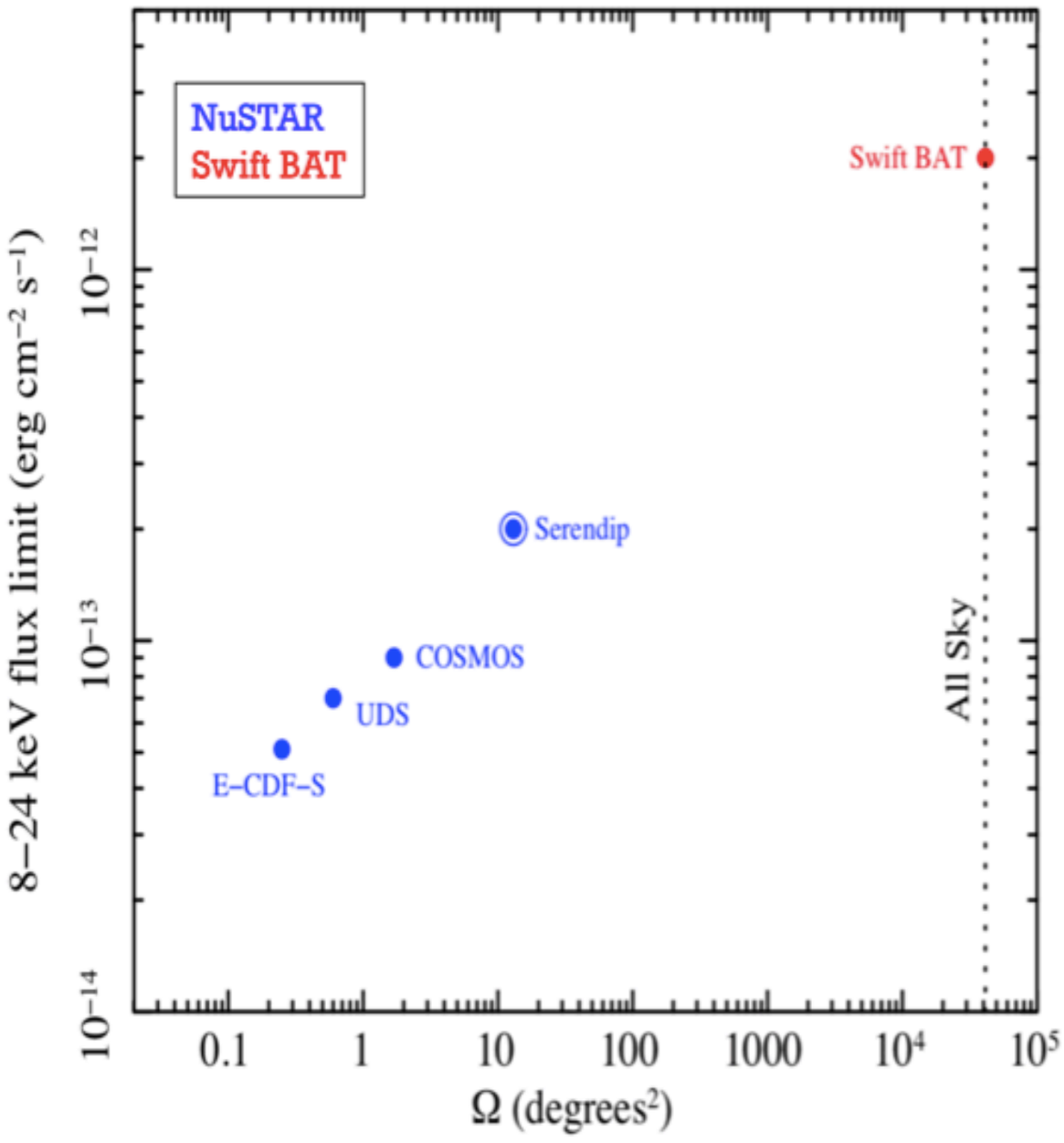
Good agreement with XRB synthesis models including heavily obscured and CT



Significant discrepancy with the extrapolation of the Swift/BAT number counts

Disagreement due to the faint end of NuSTAR logN-logS wrt BAT and Chandra (Akylas&Georgantopoulos 19). Spurious fraction/ Eddington bias? Unclear …
Evolution of the obscuration between z~0 and z~0.5-1 not accounted for in current modelling. Possibly due to a rapid increasing evolution of Reflection/Covering fraction and CT fraction Avirett-McKenzie&Ballantyne 19

What's Next?


NuSTAR
Swift BAT
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All Sky
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Ω (degrees^2)

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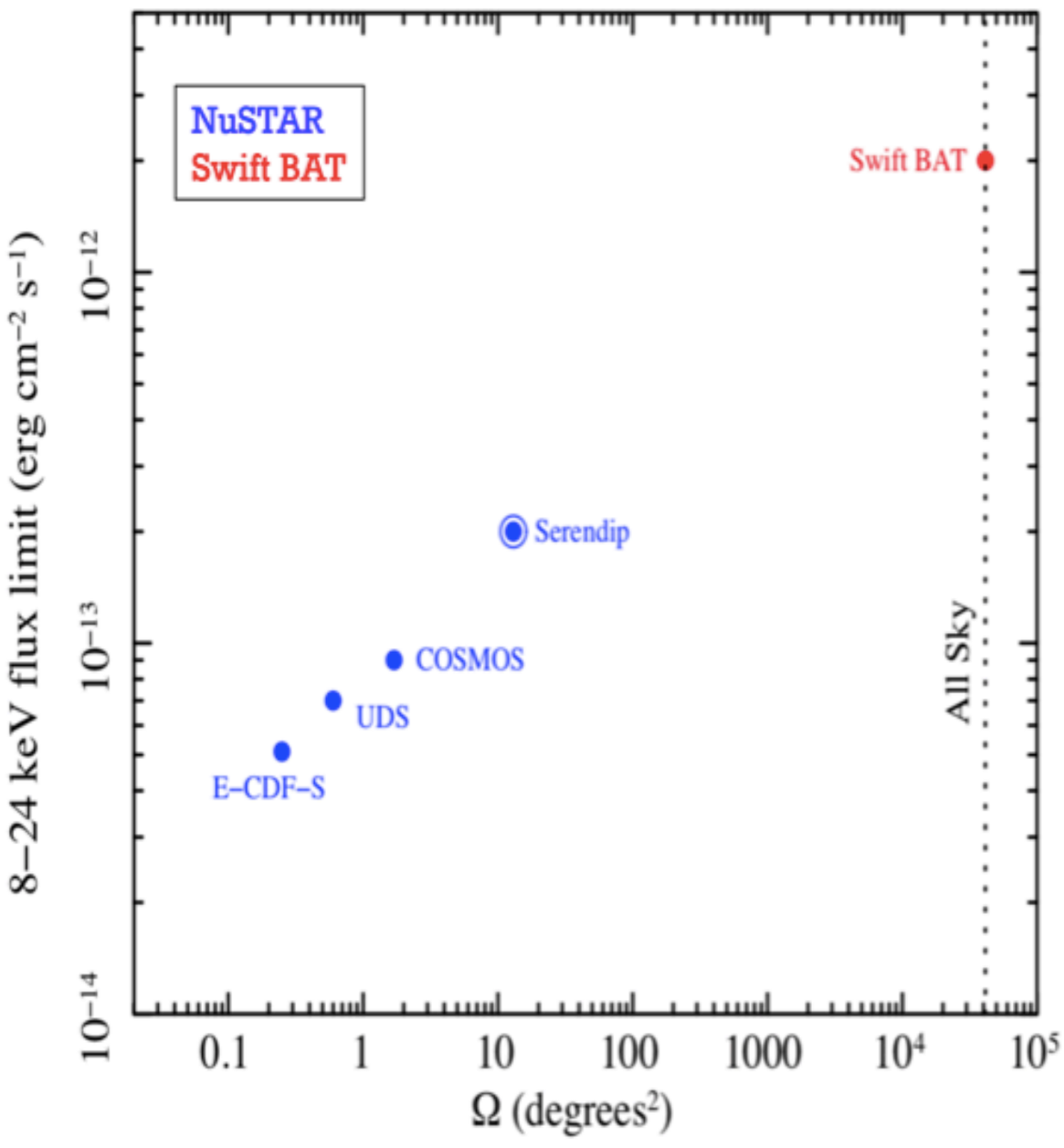
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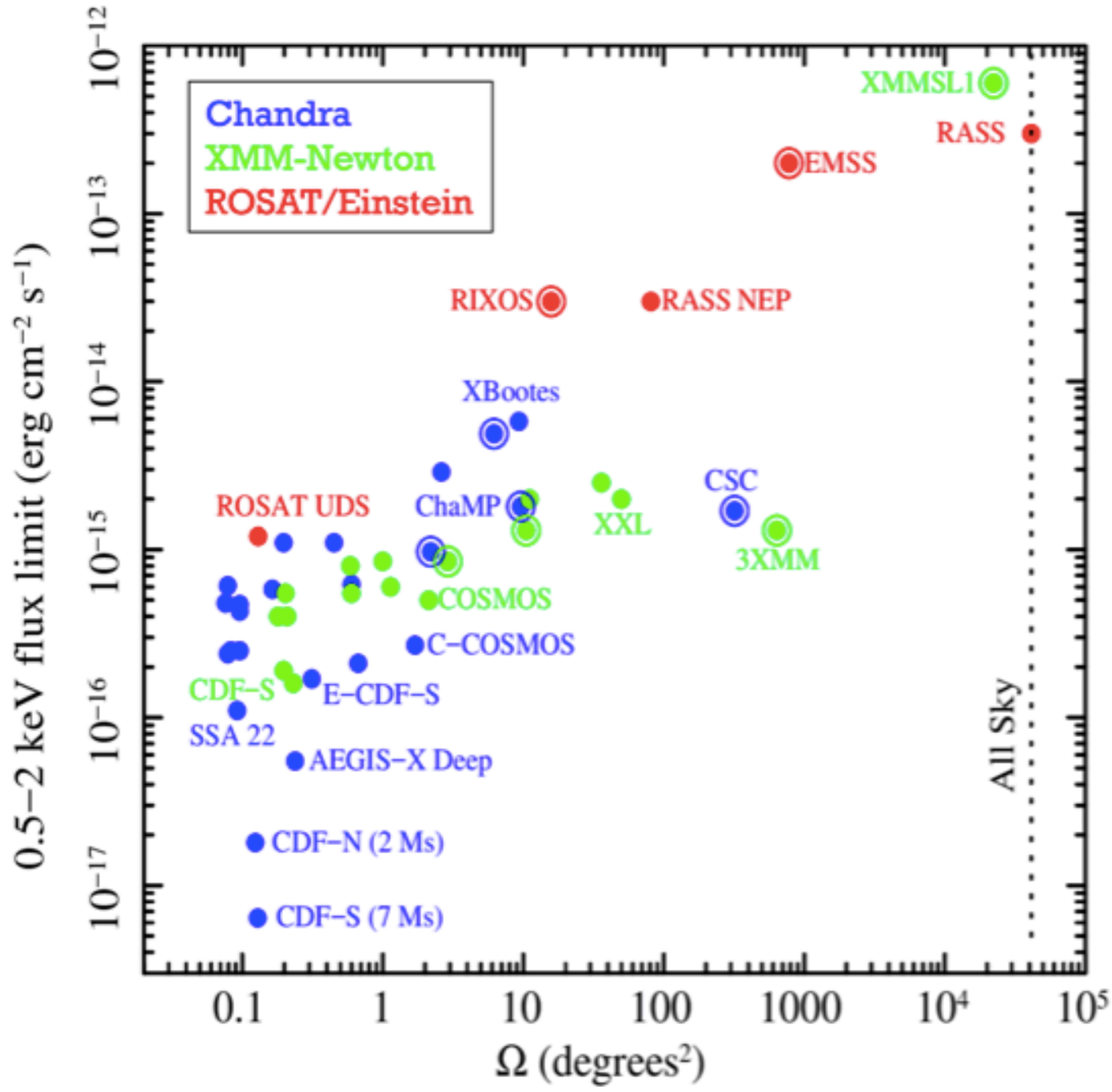
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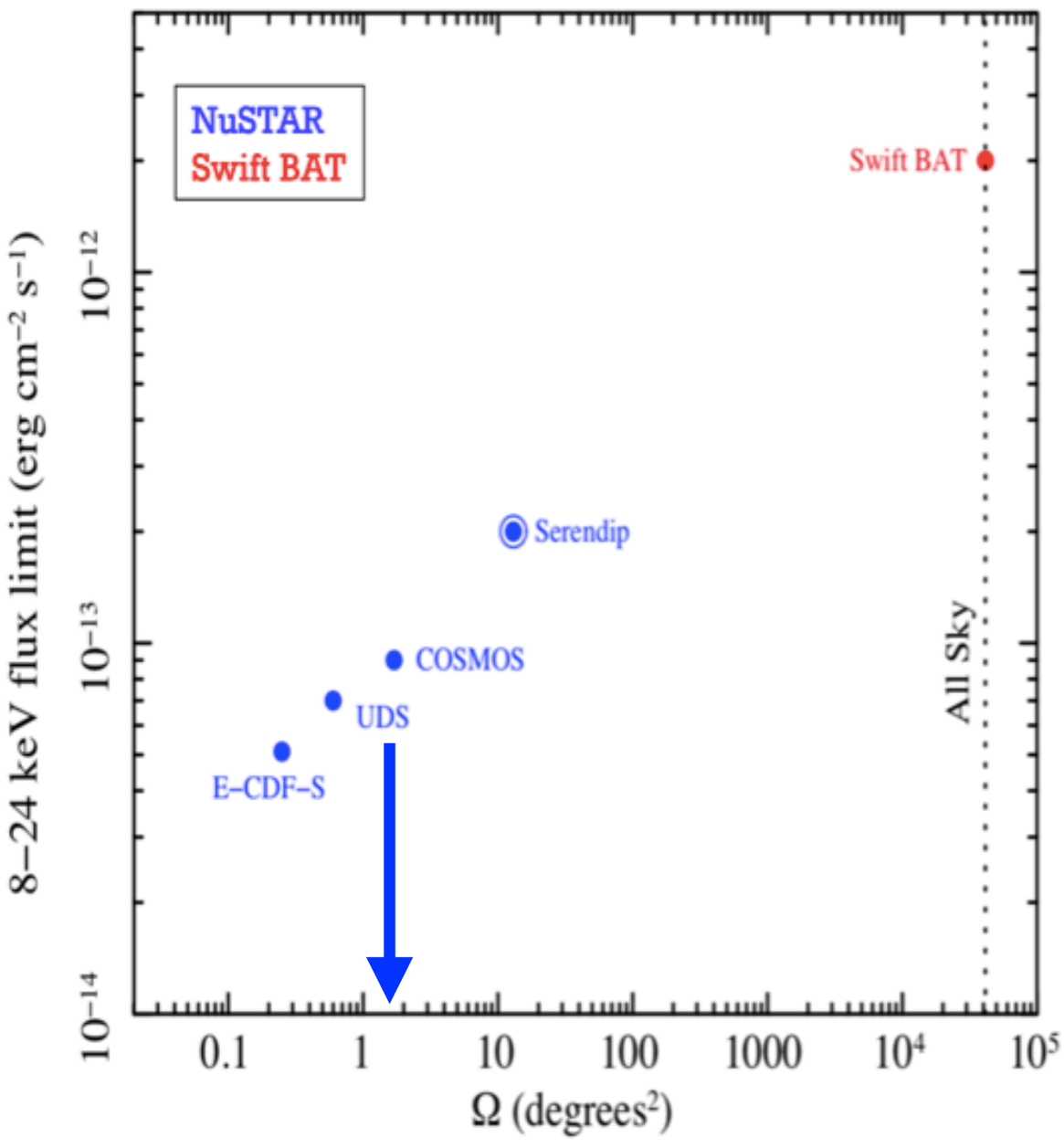
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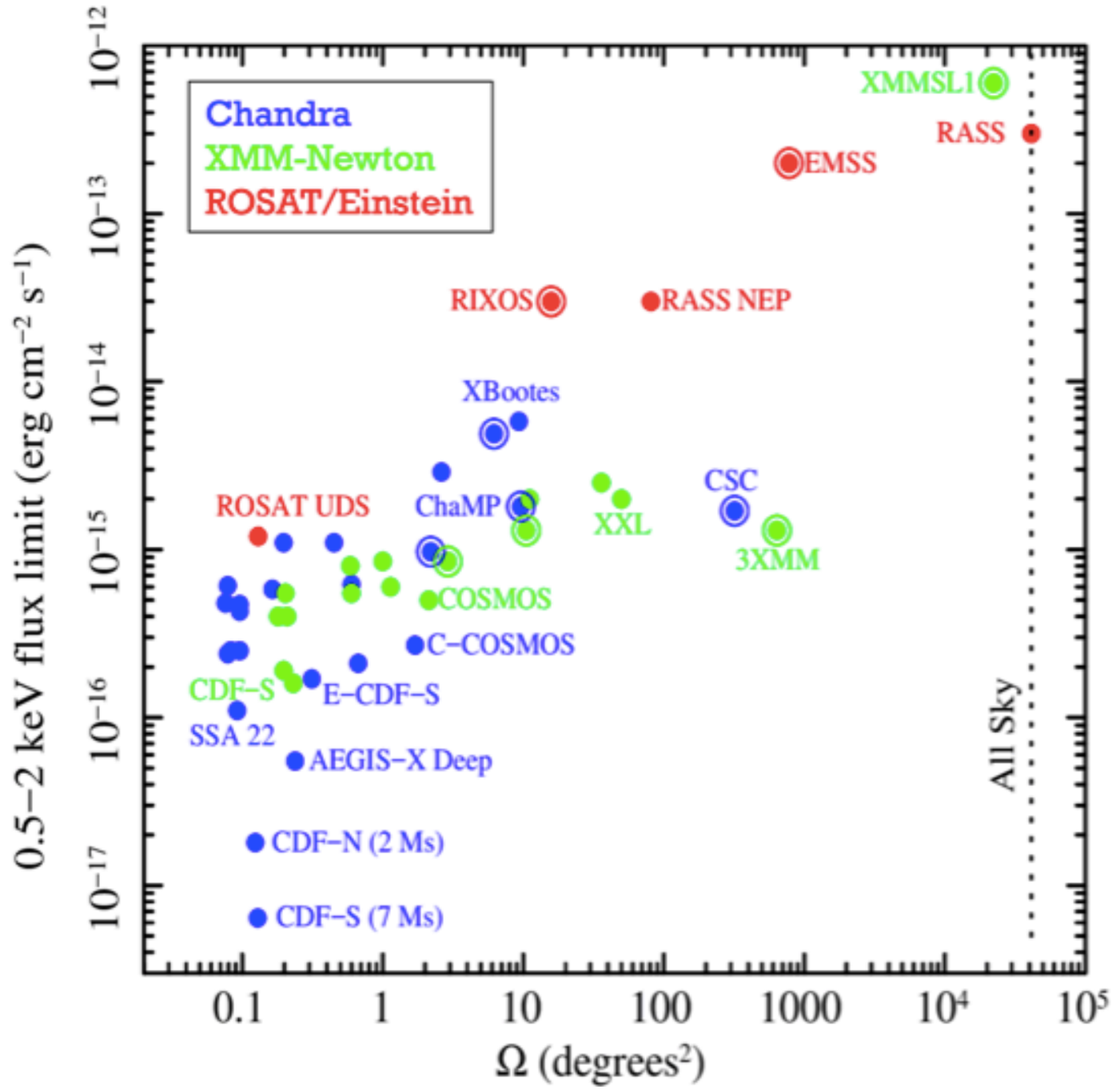
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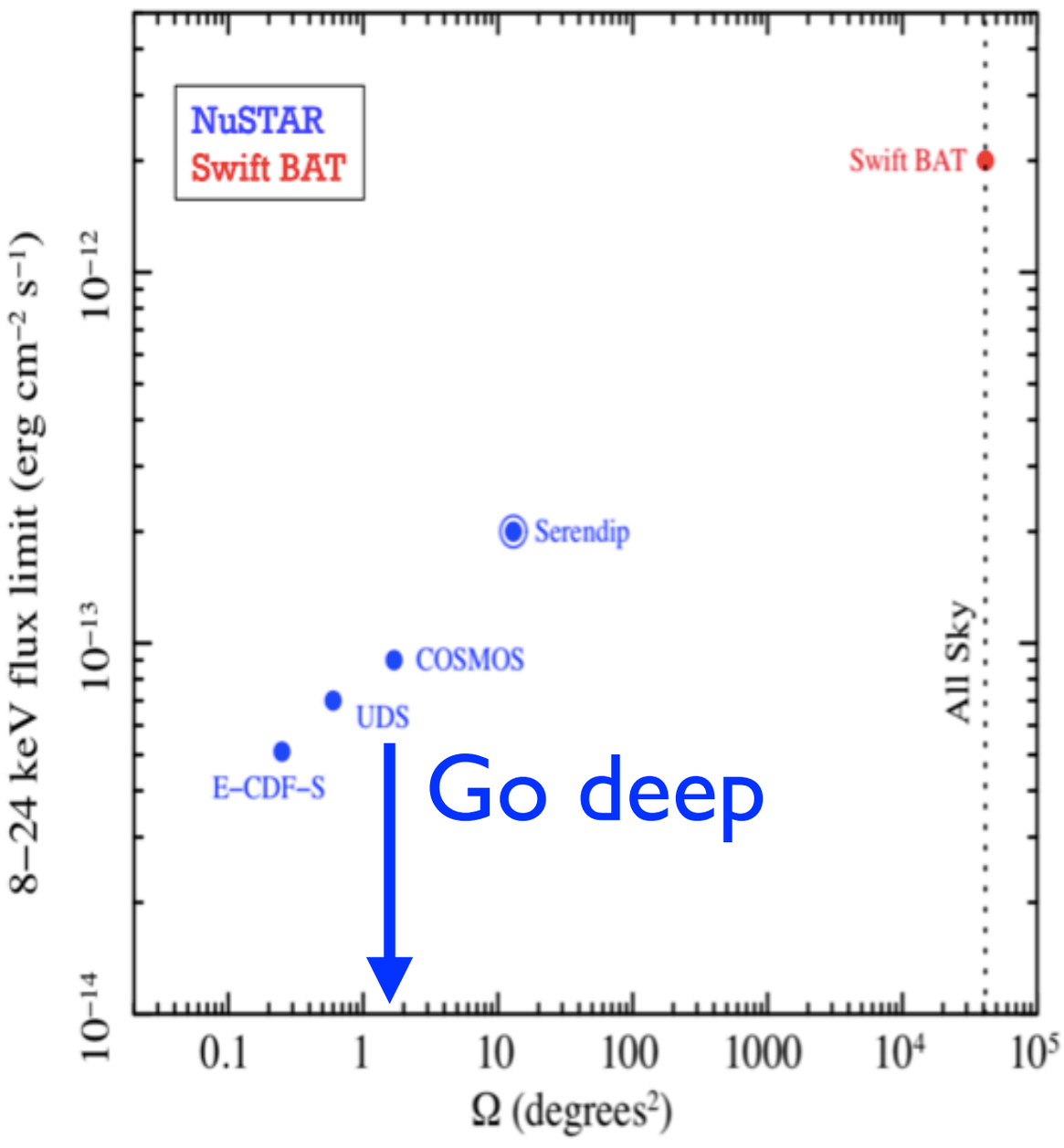
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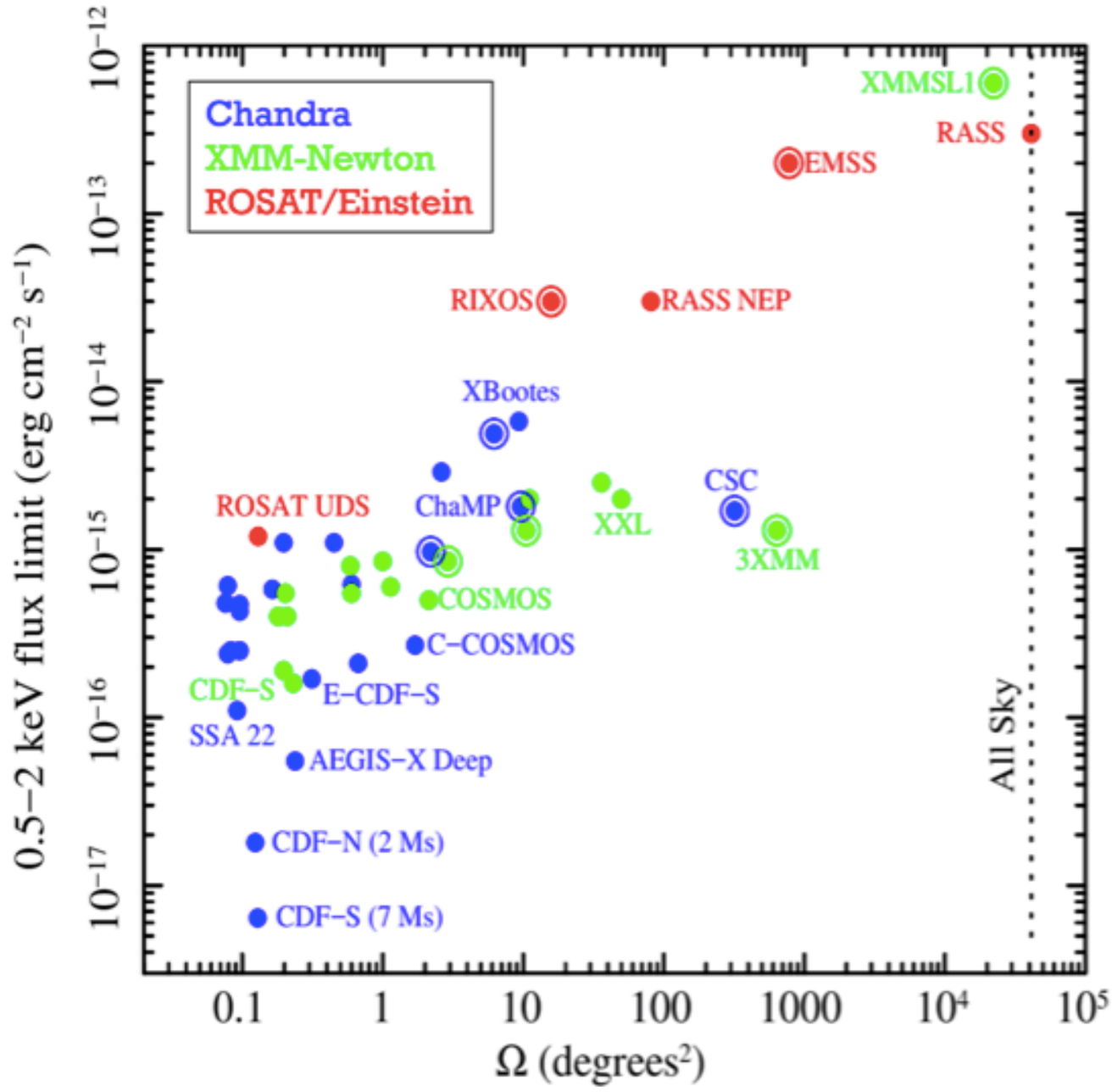
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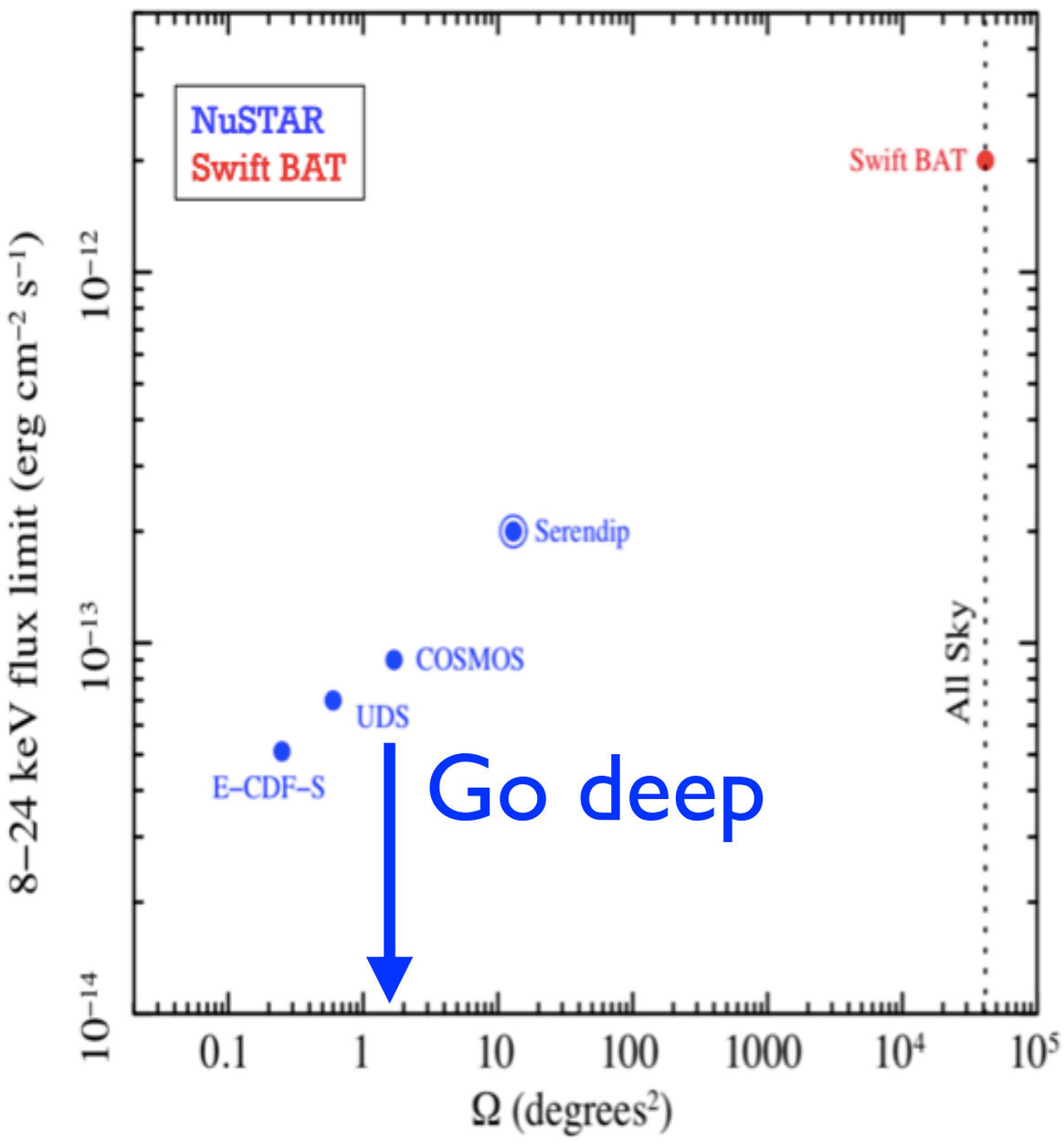
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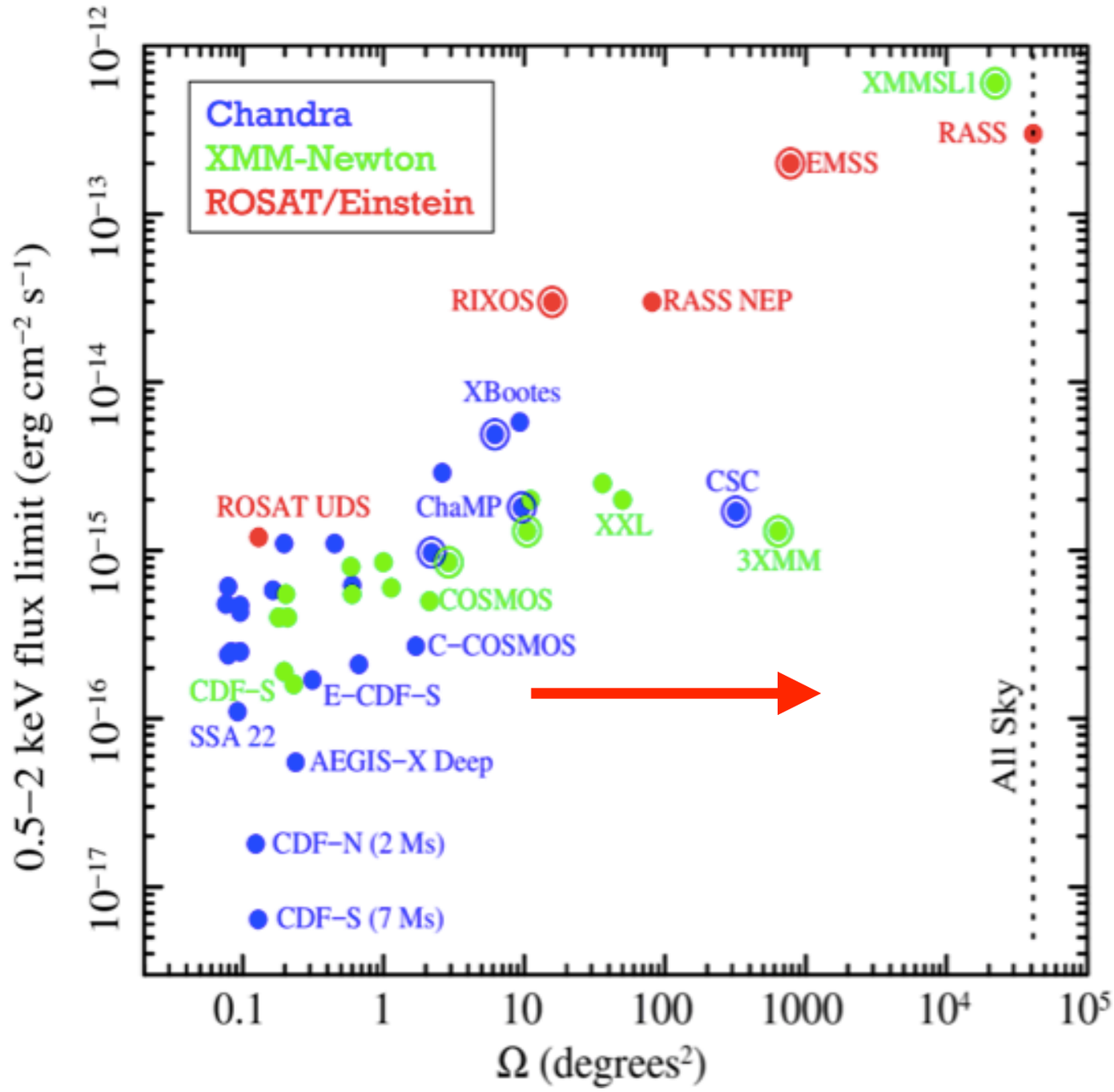
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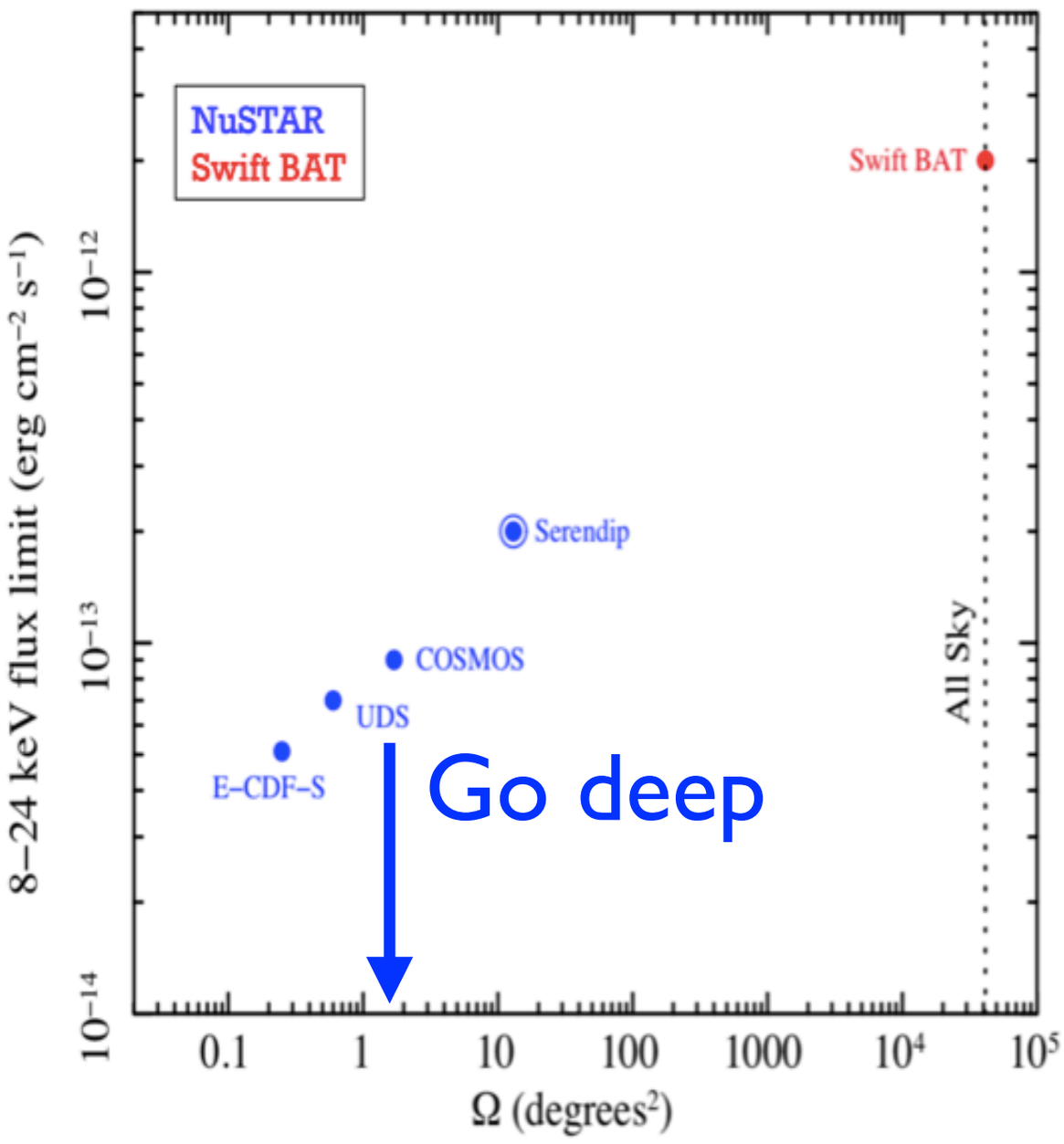
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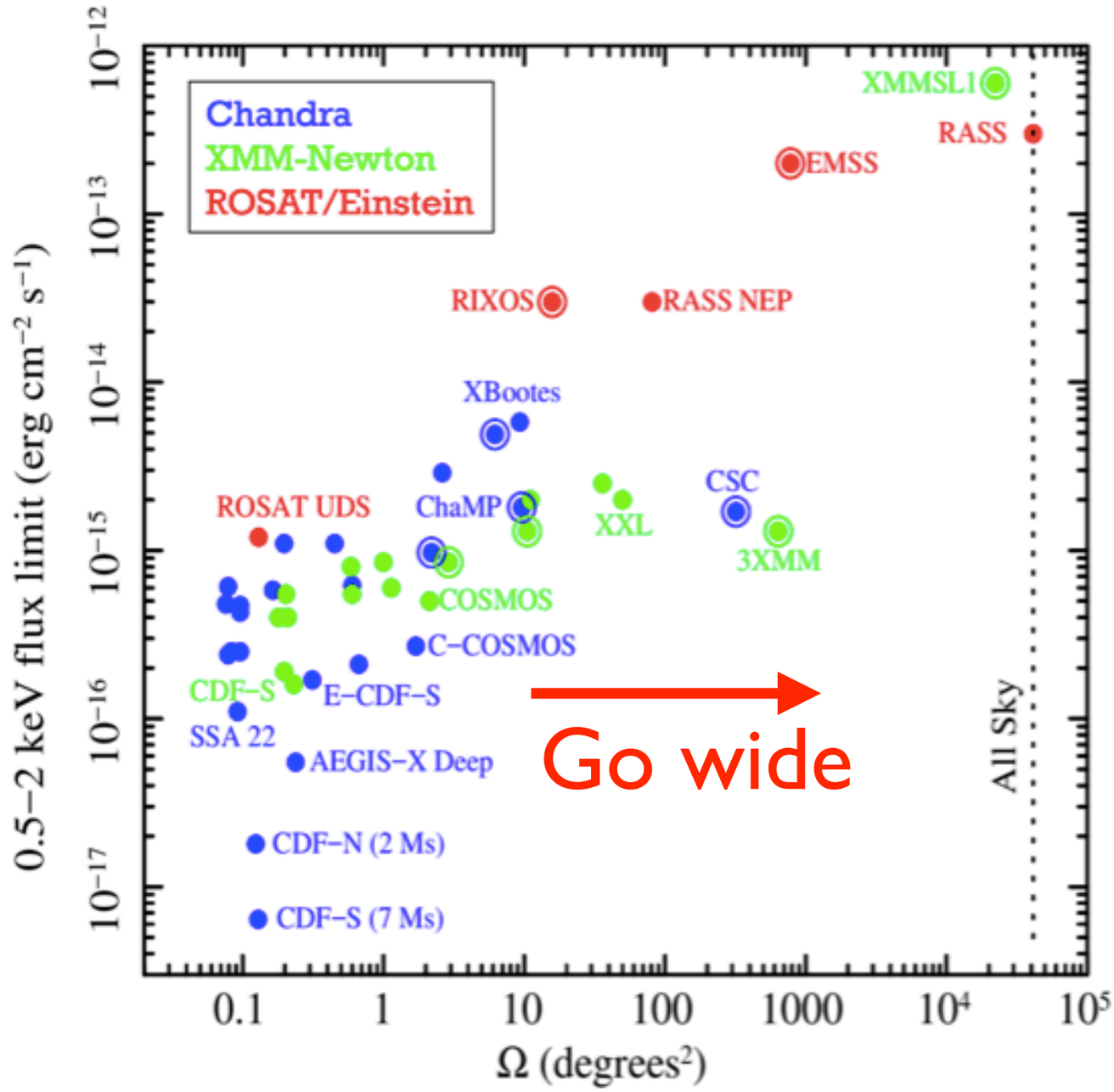
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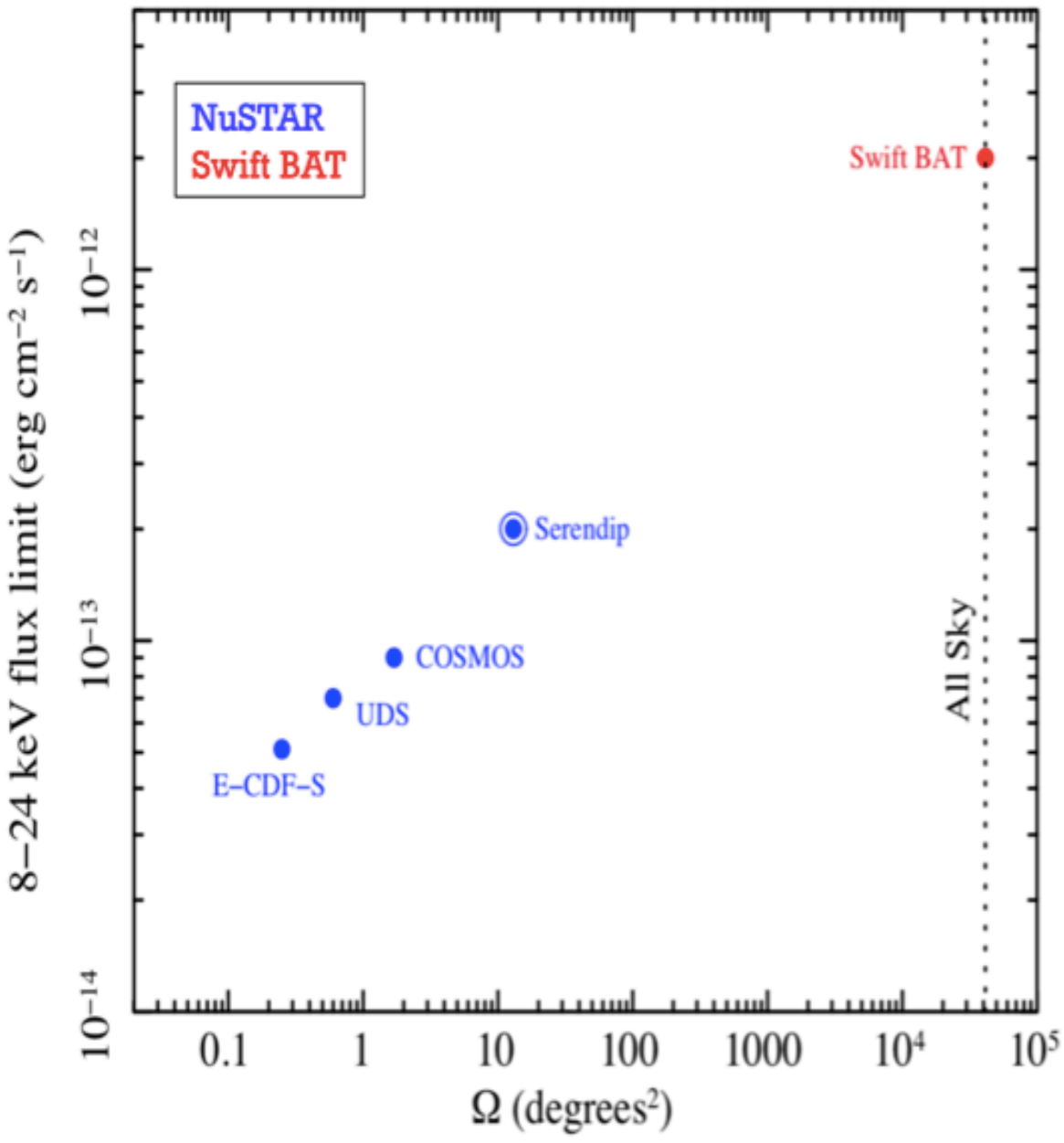
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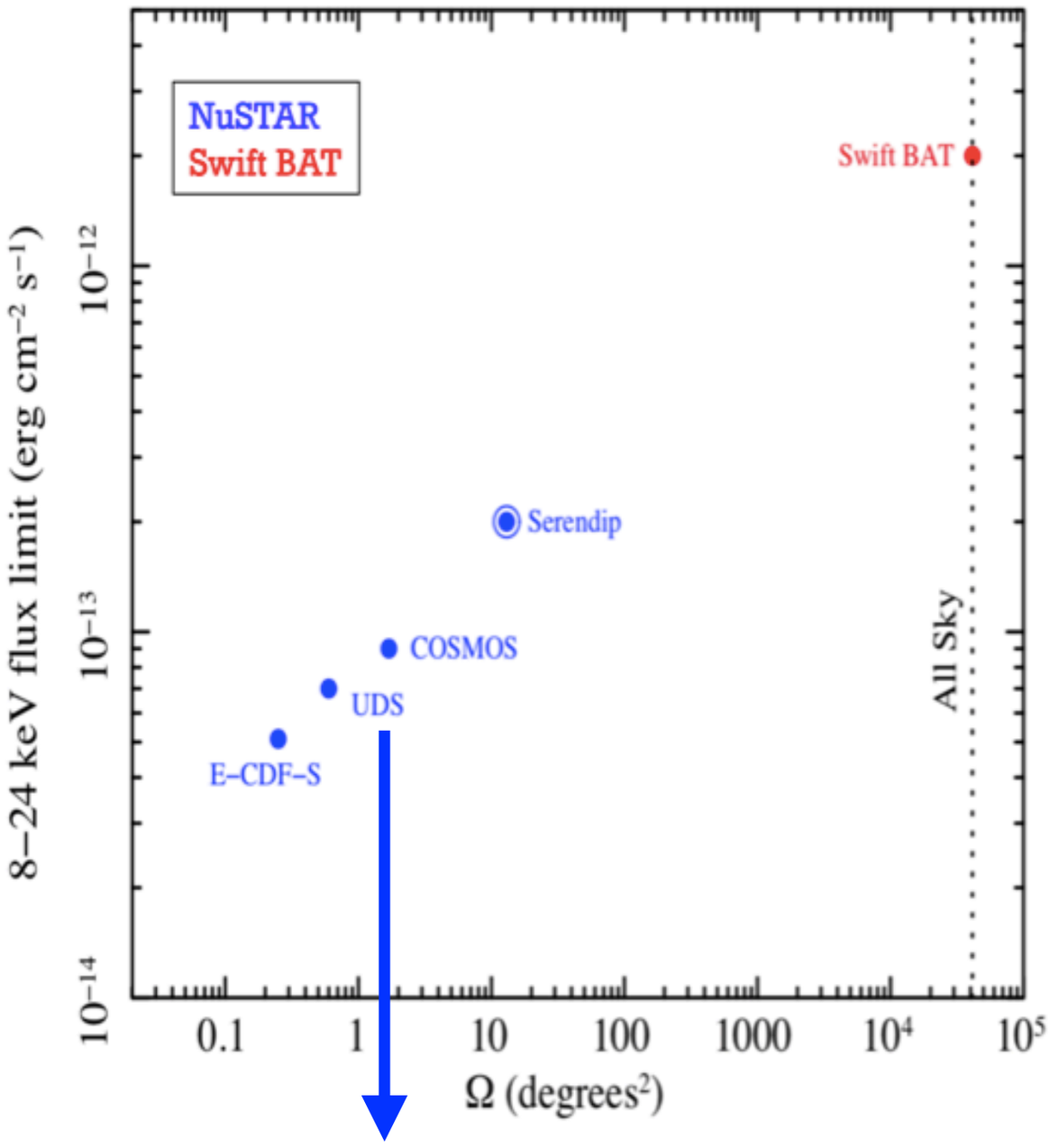
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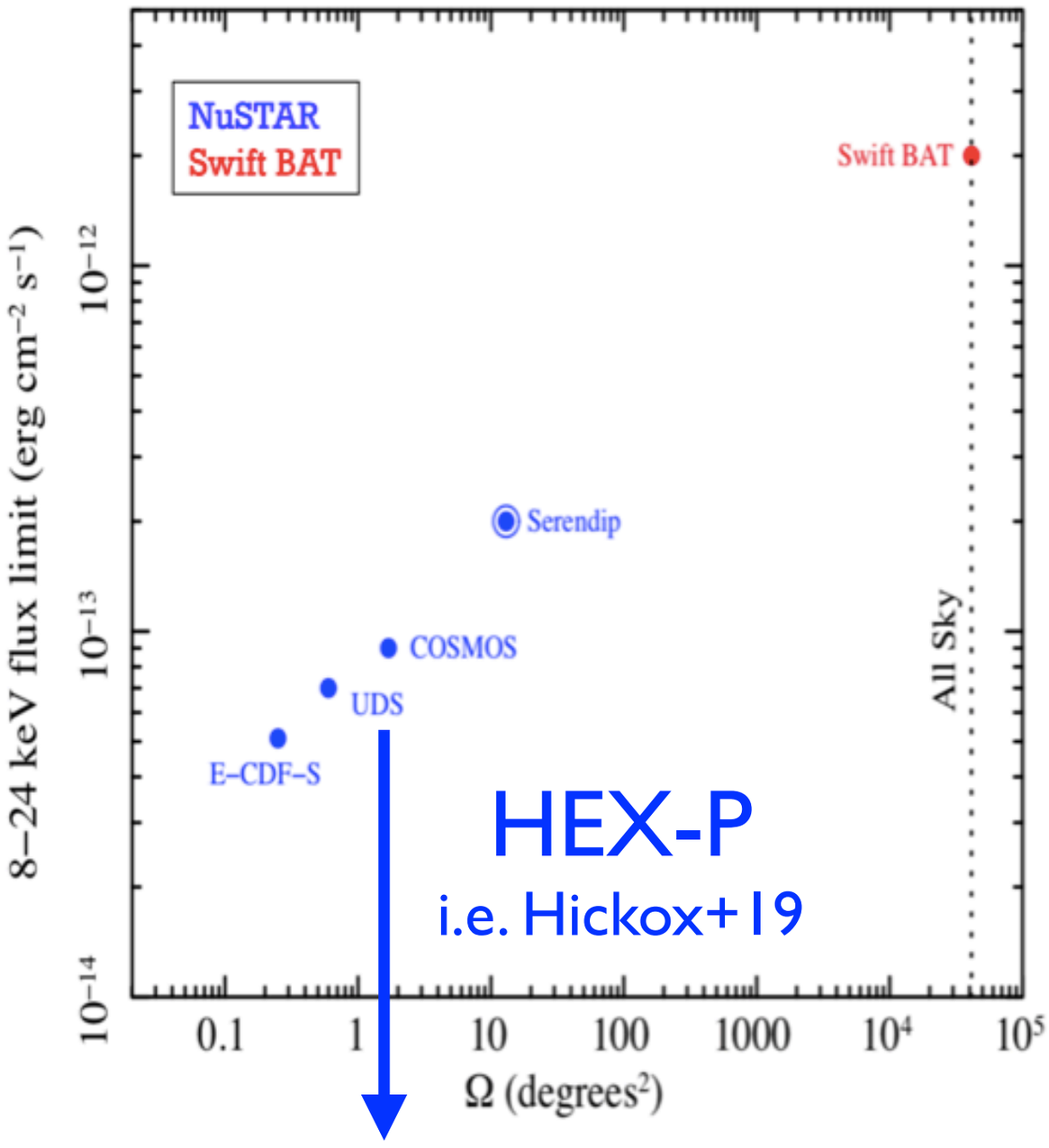
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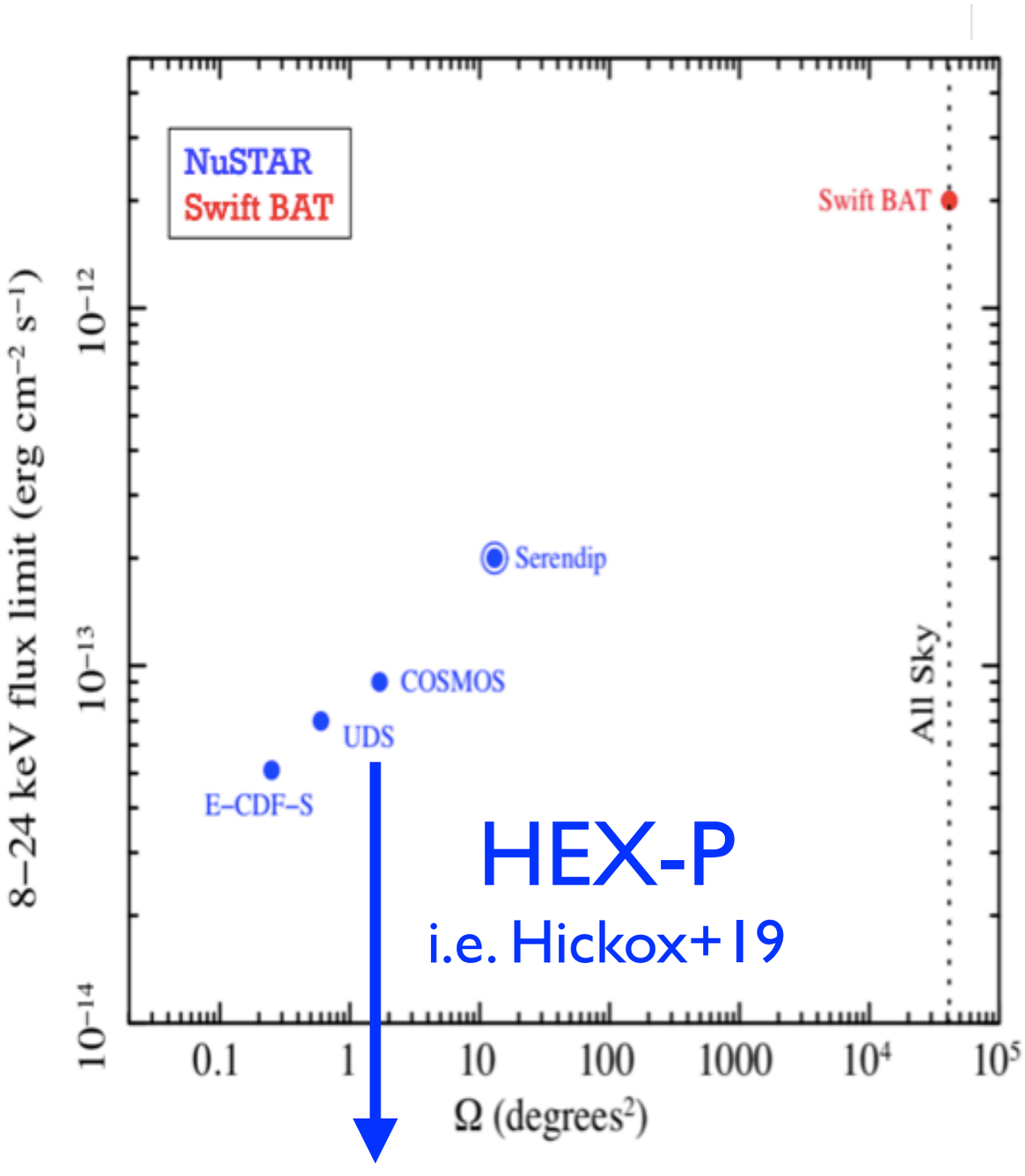
What's Next?


NuSTAR
Swift BAT
Swift BAT
Serendip
COSMOS
UDS
E-CDF-S
All Sky
HEX-P
i.e. Hickox+19
8–24 keV flux limit (erg cm^{-2} s^{-1})
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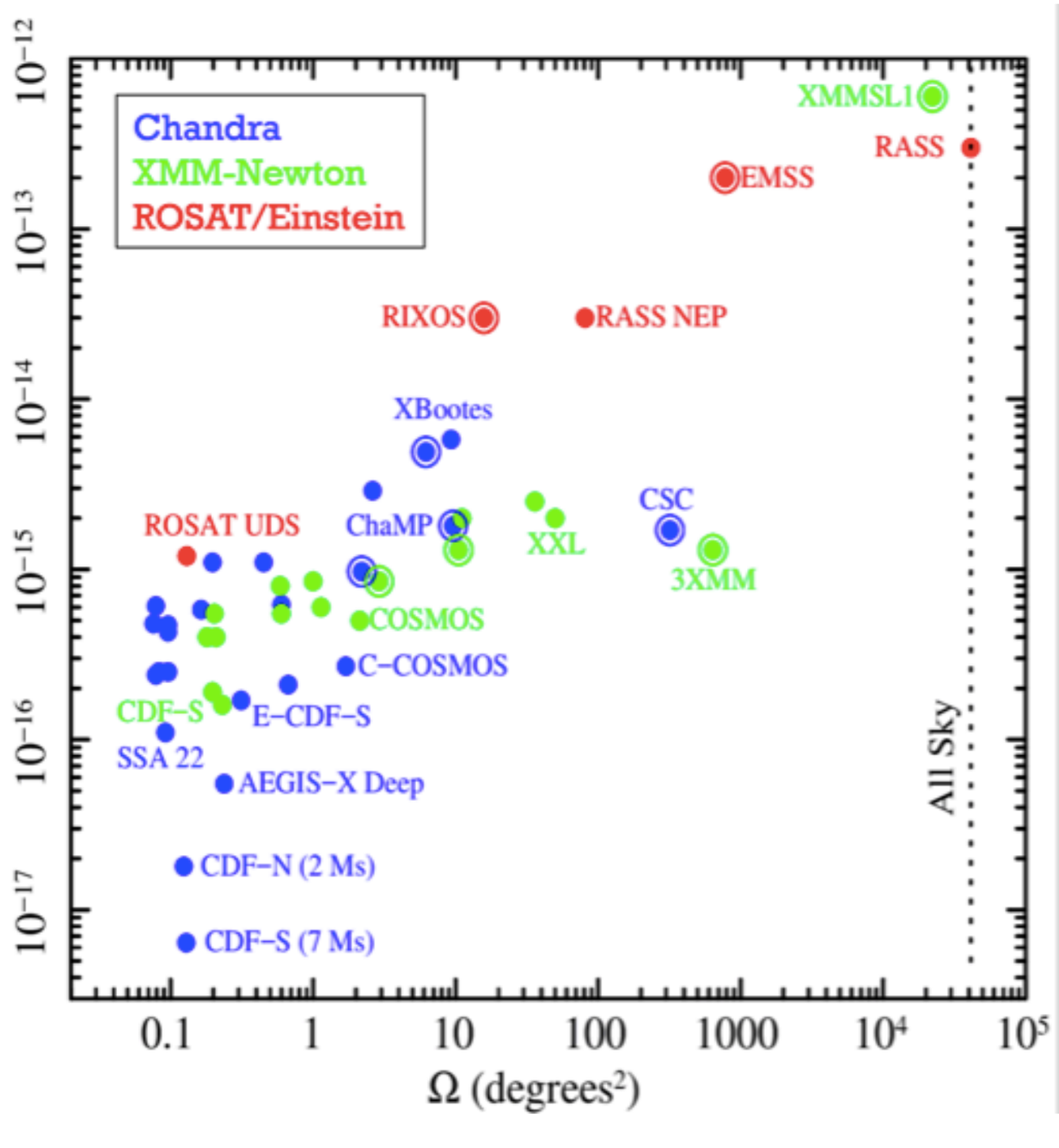
Ω (degrees^2)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XMM-Newton
ROSAT/Einstein
XMMSL1
RASS
EMSS
RIXOS
RASS NEP
XBootes
ROSAT UDS
ChaMP
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CSC
3XMM
COSMOS
C-COSMOS
CDF-S
E-CDF-S
SSA 22
AEGIS-X Deep
CDF-N (2 Ms)
CDF-S (7 Ms)
All Sky
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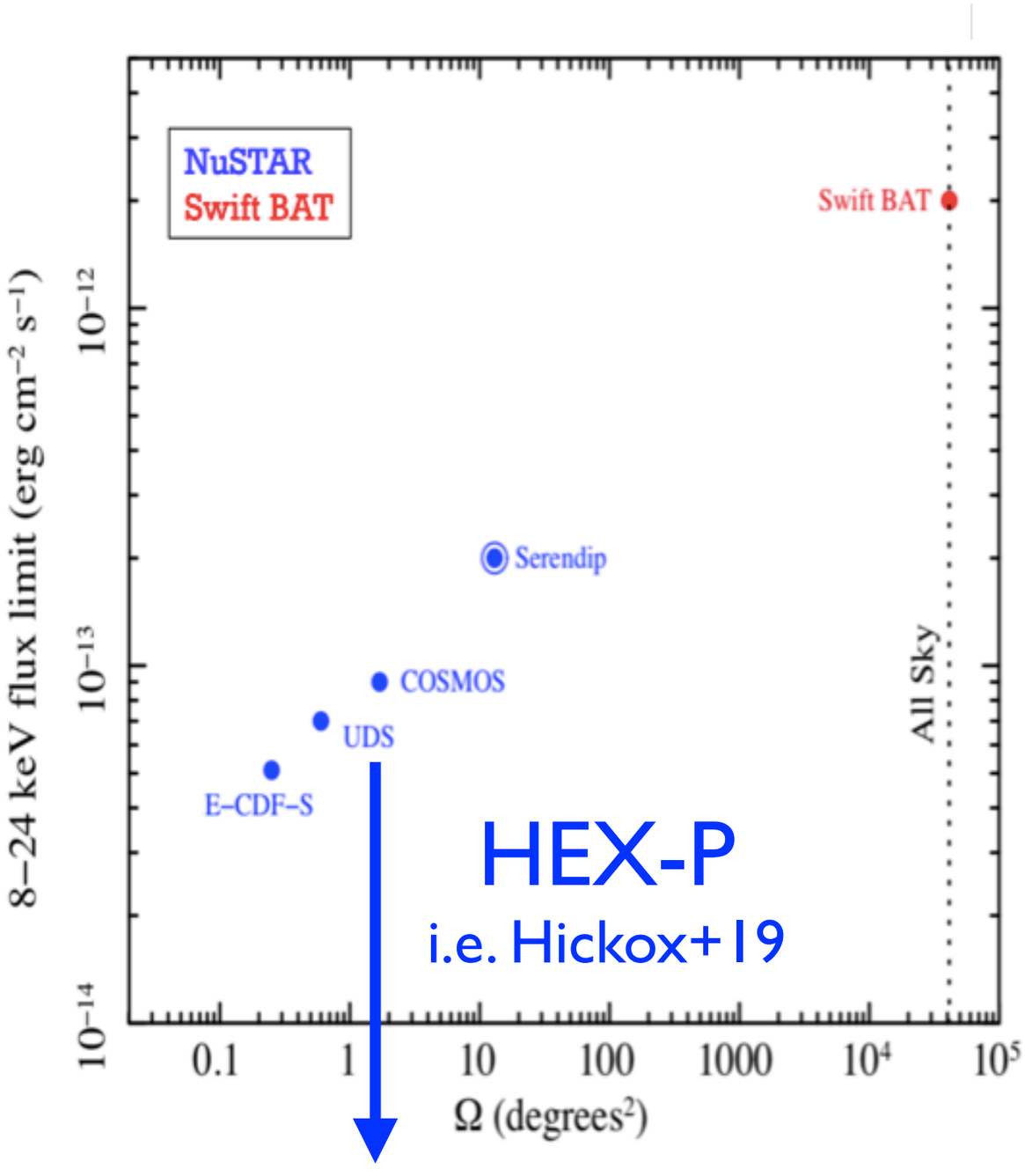
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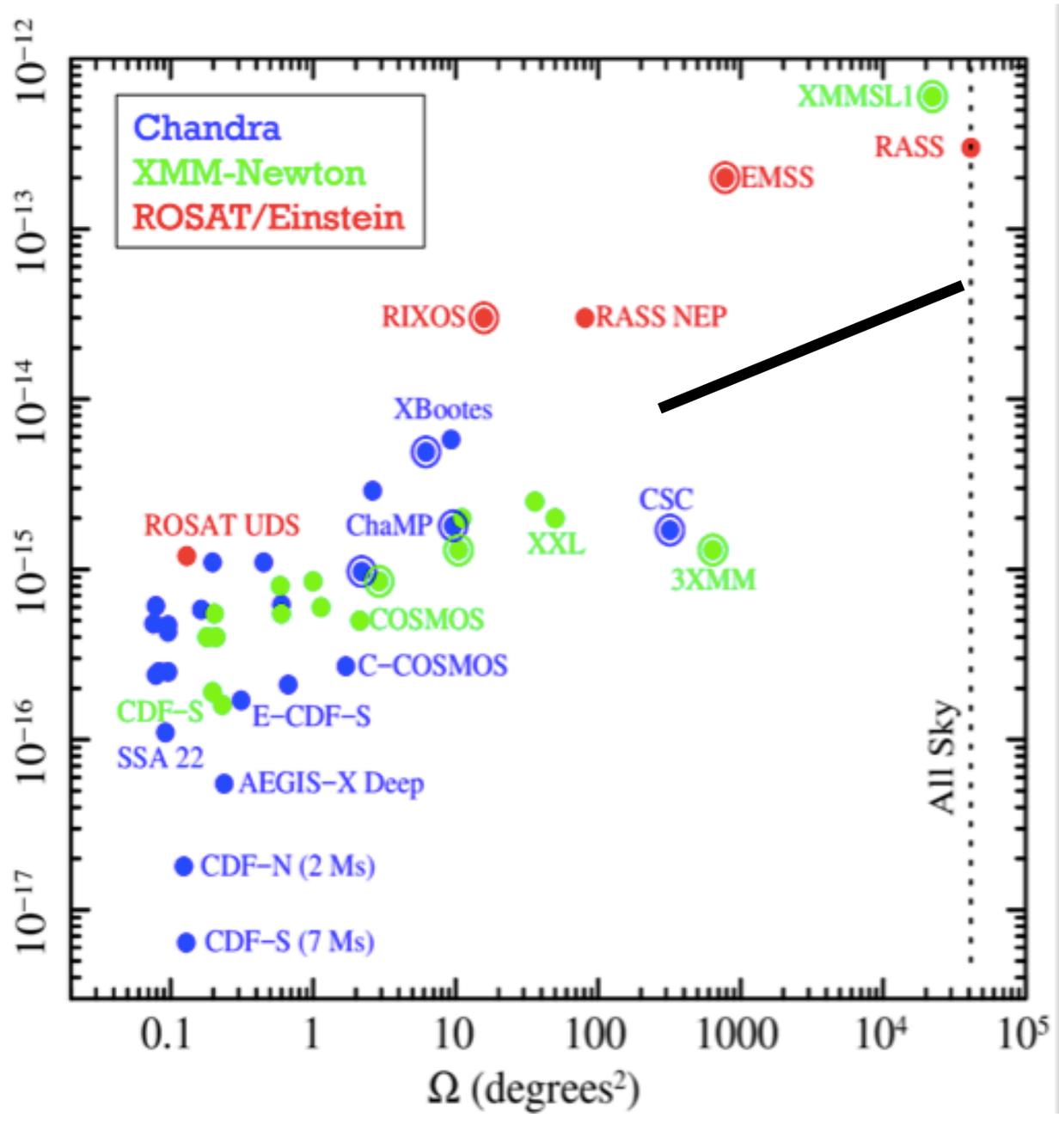
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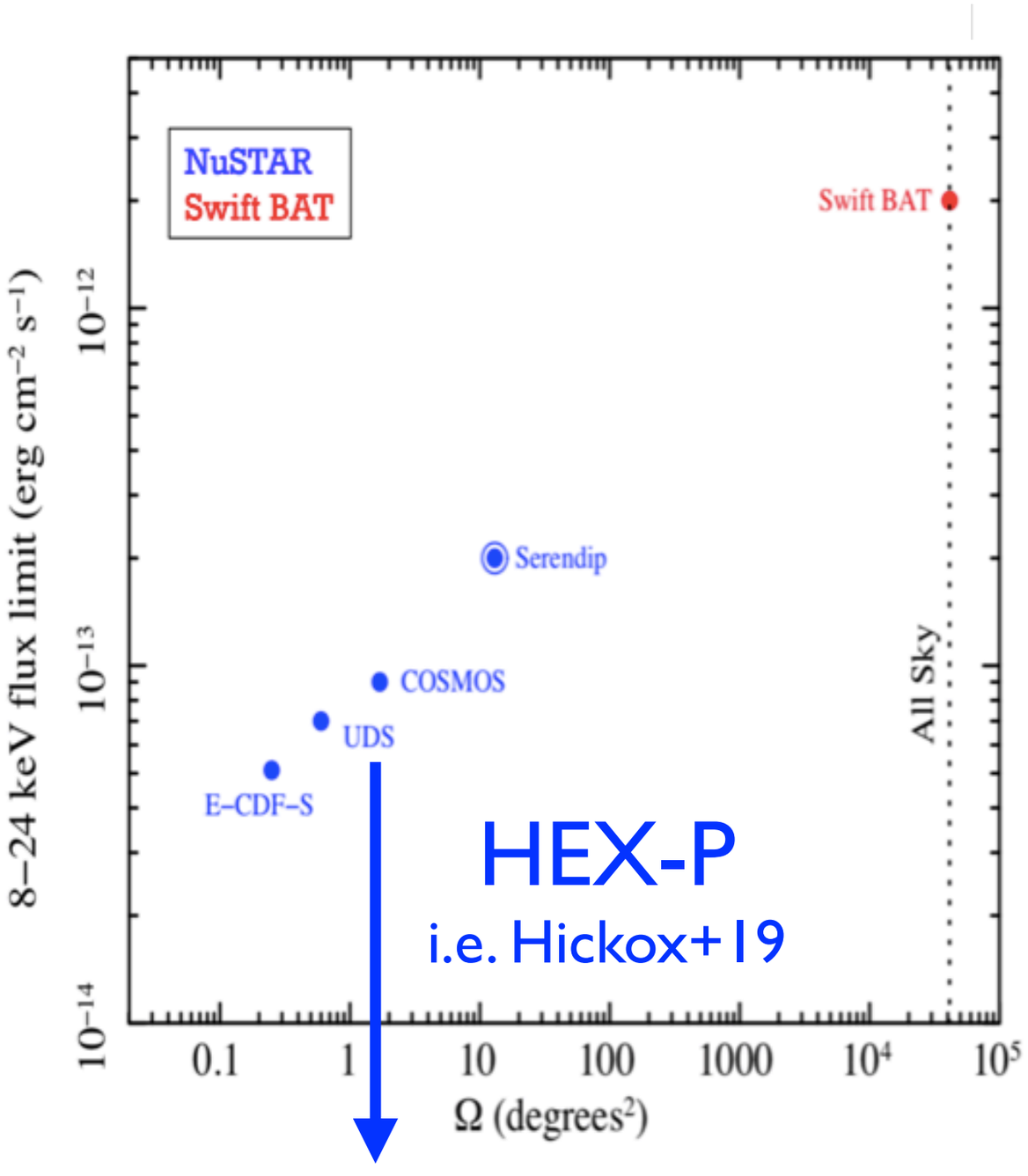
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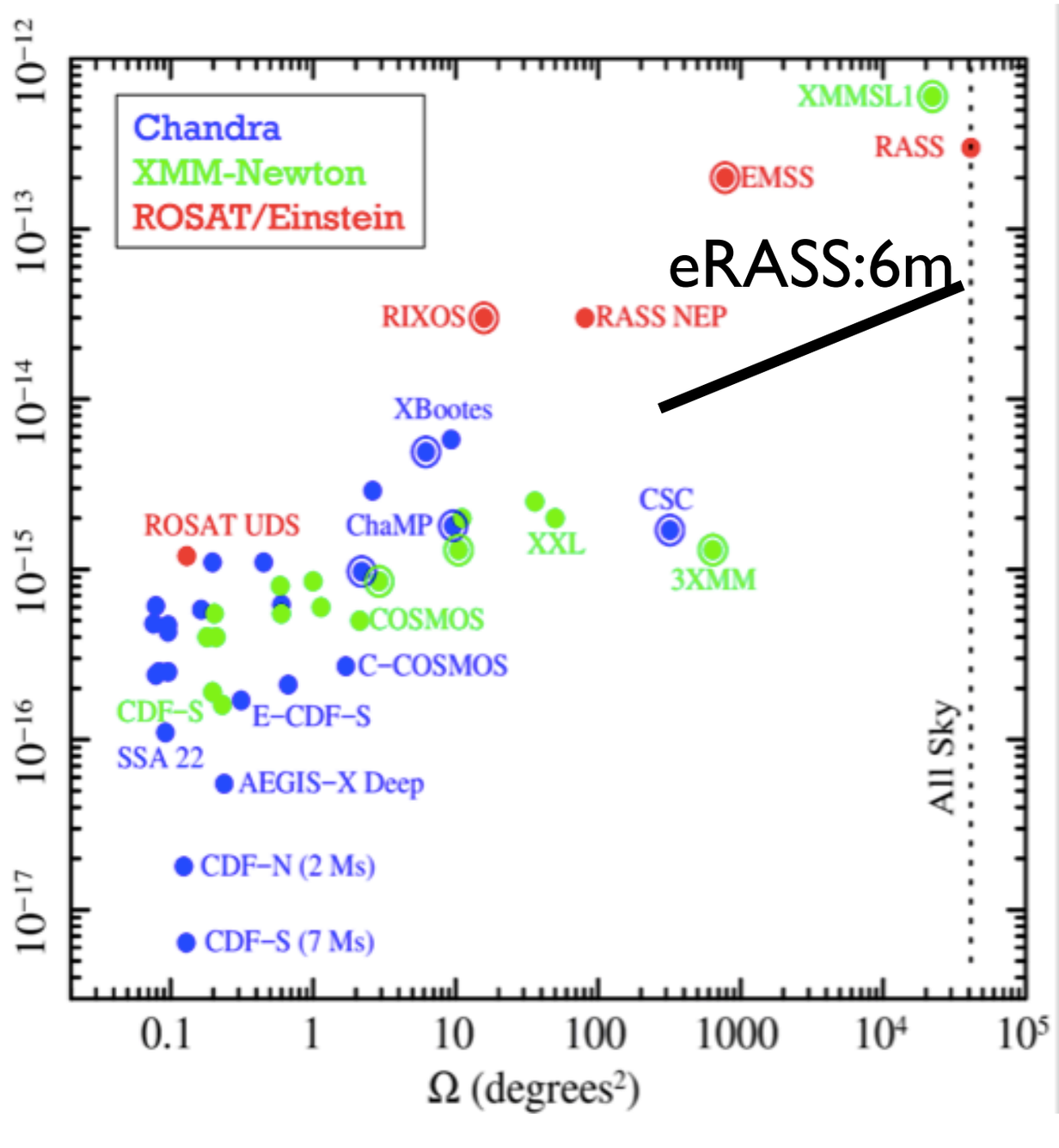
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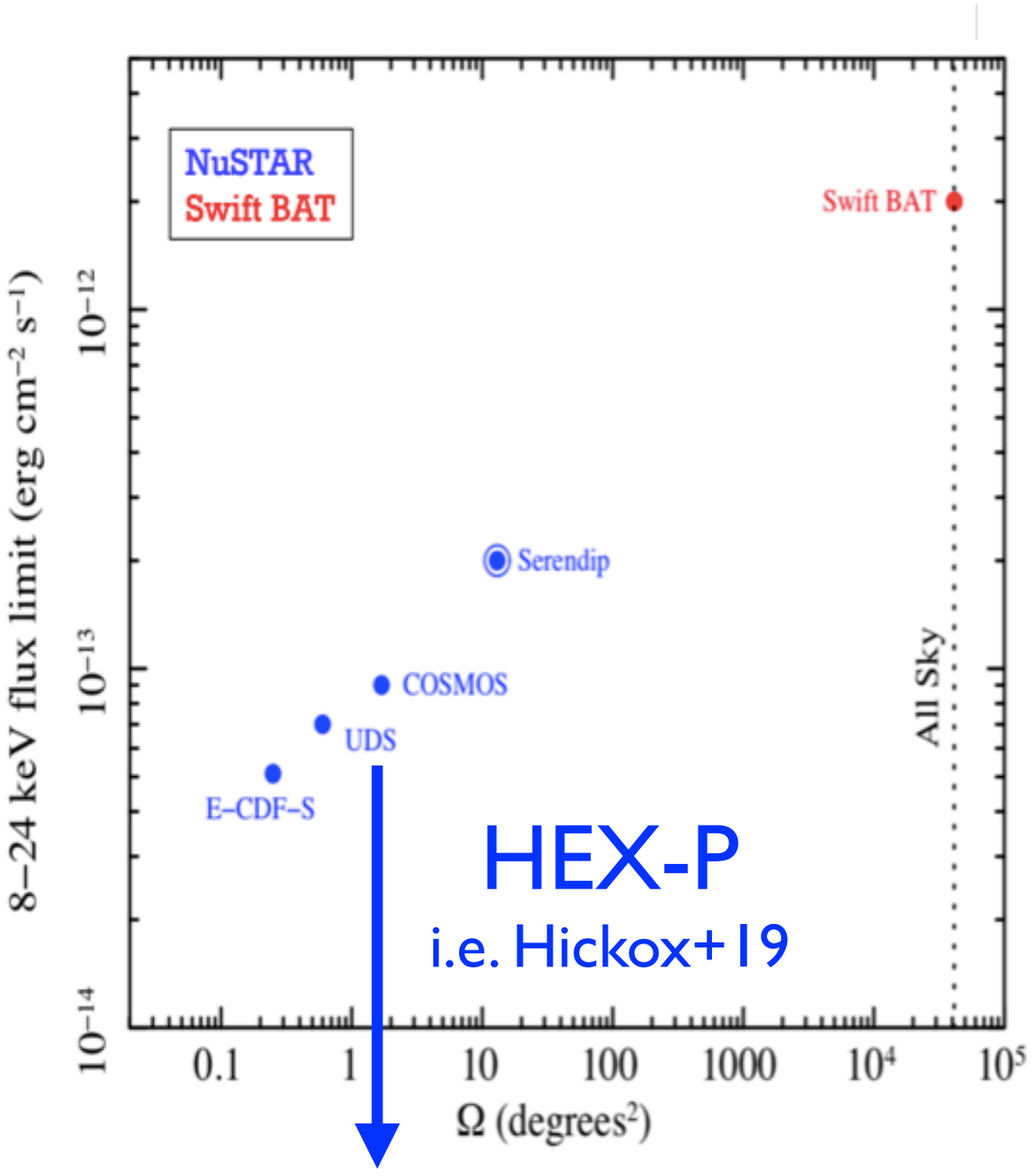
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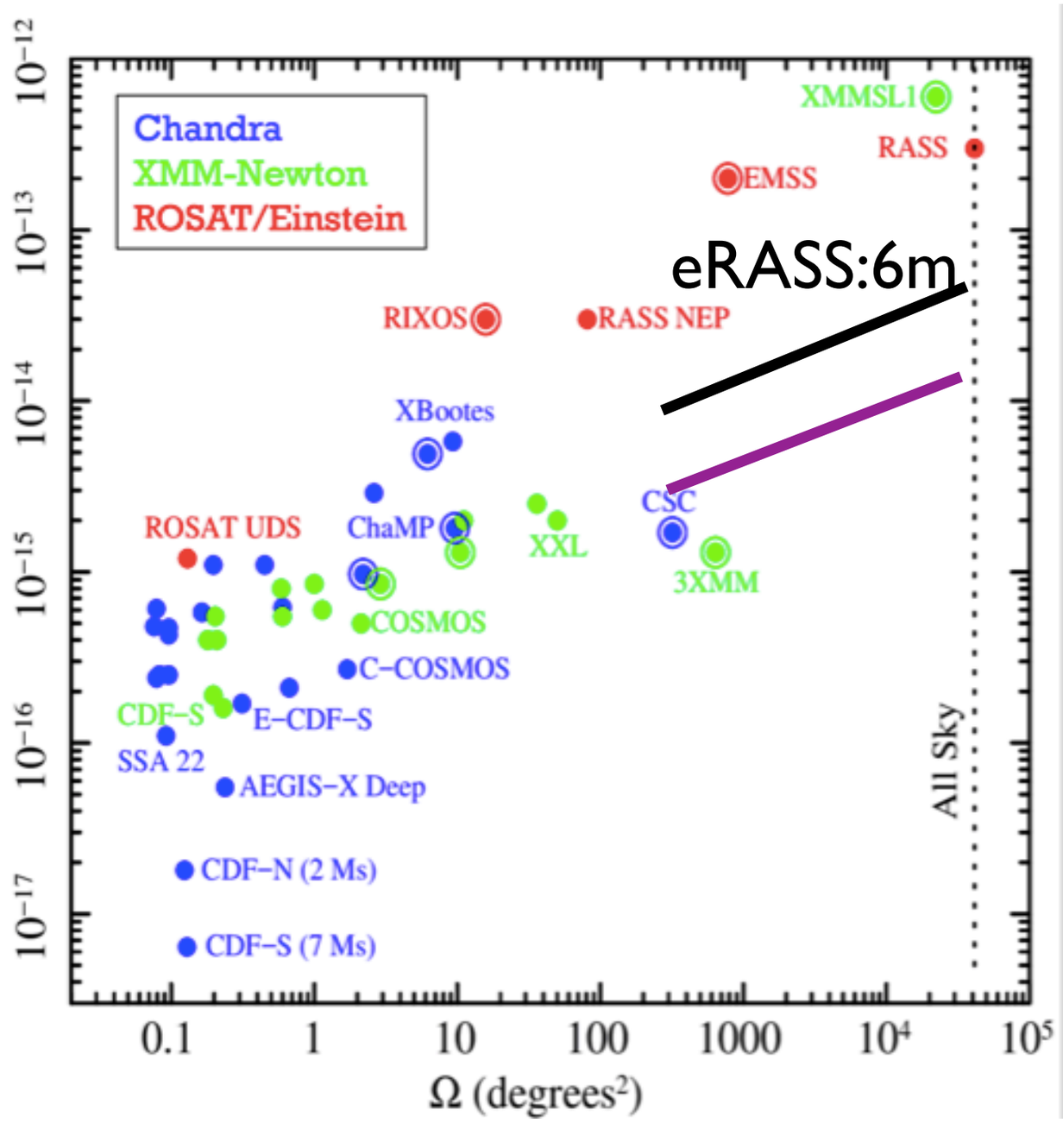
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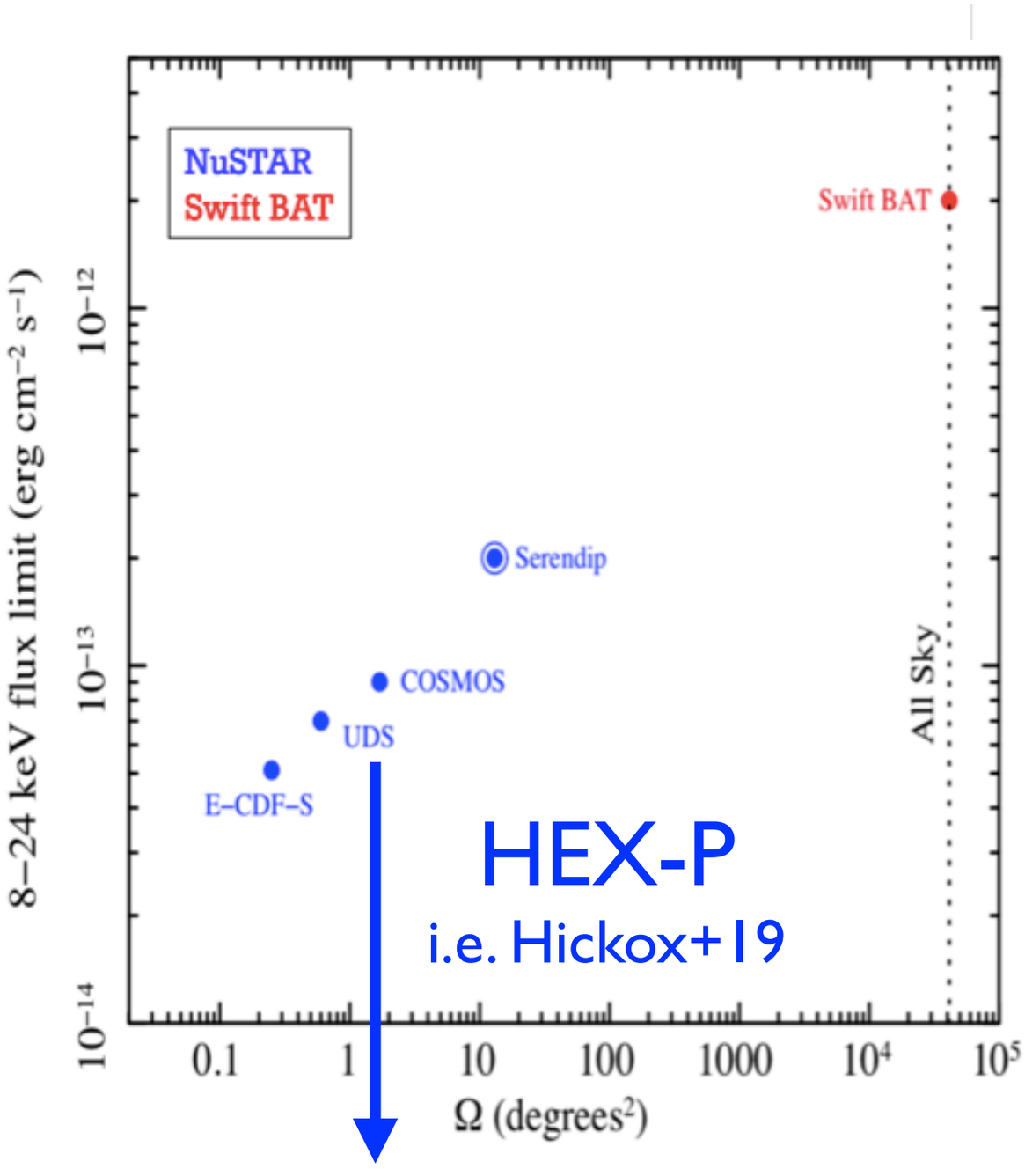
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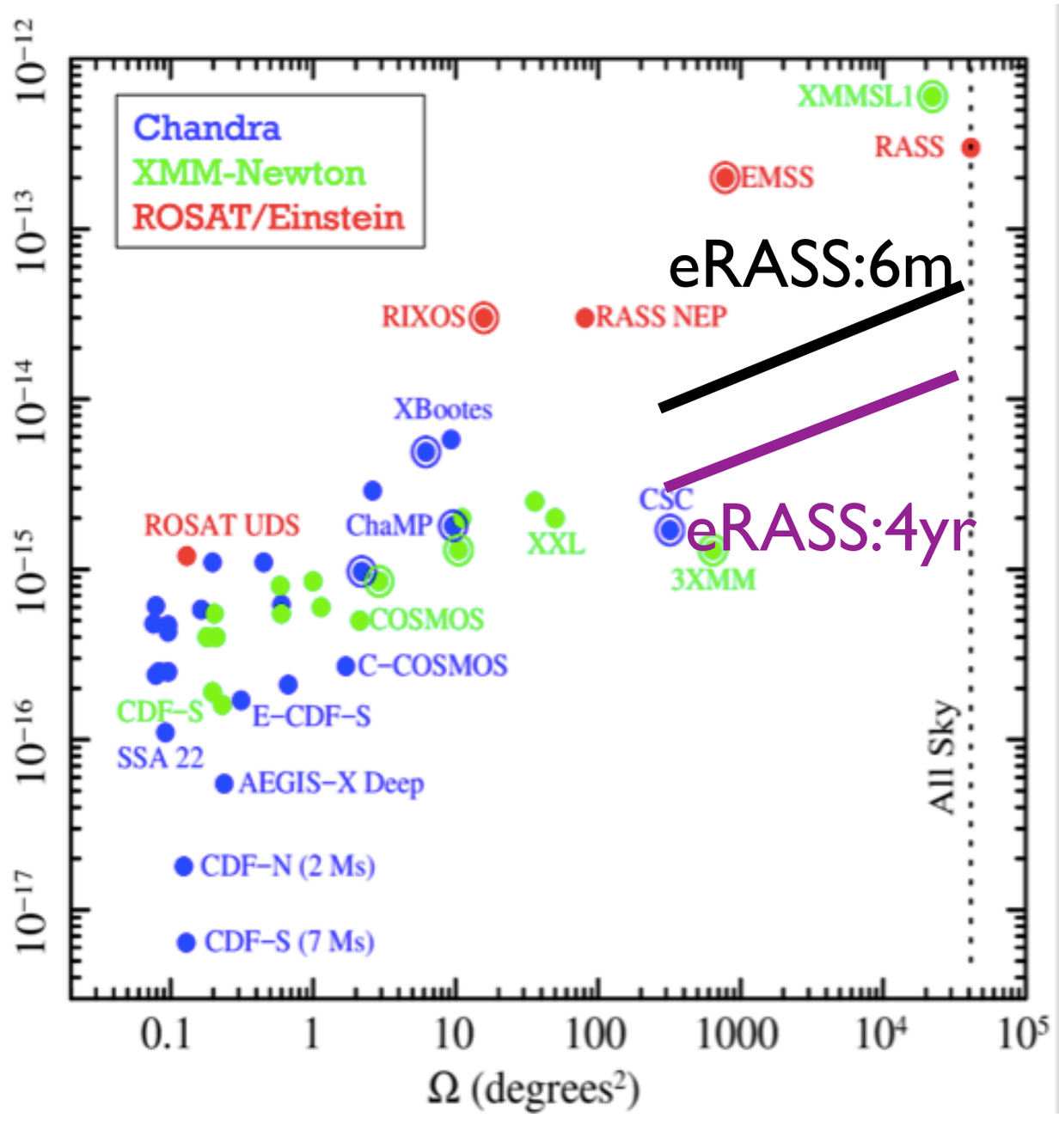
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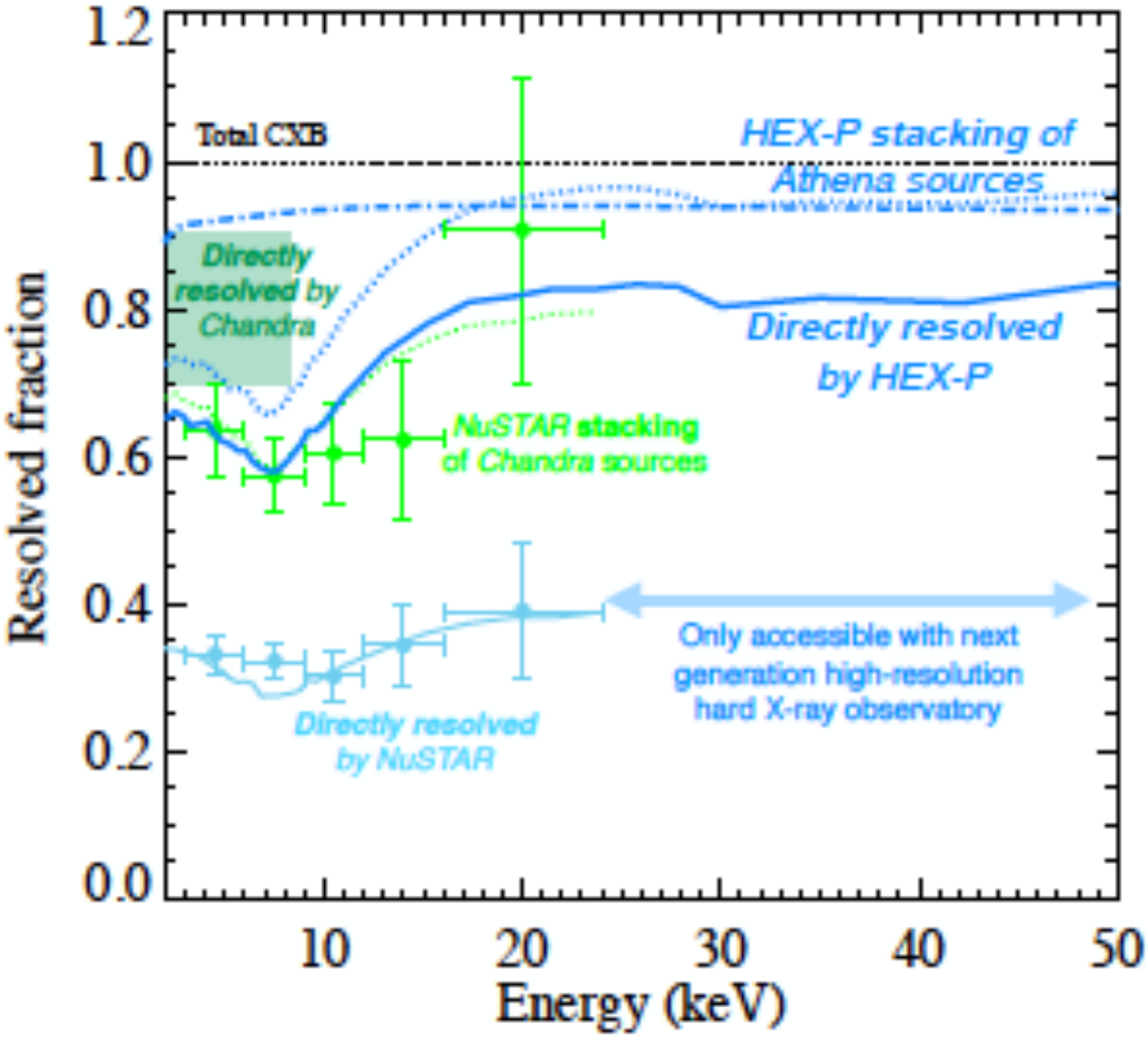
Go DEEP

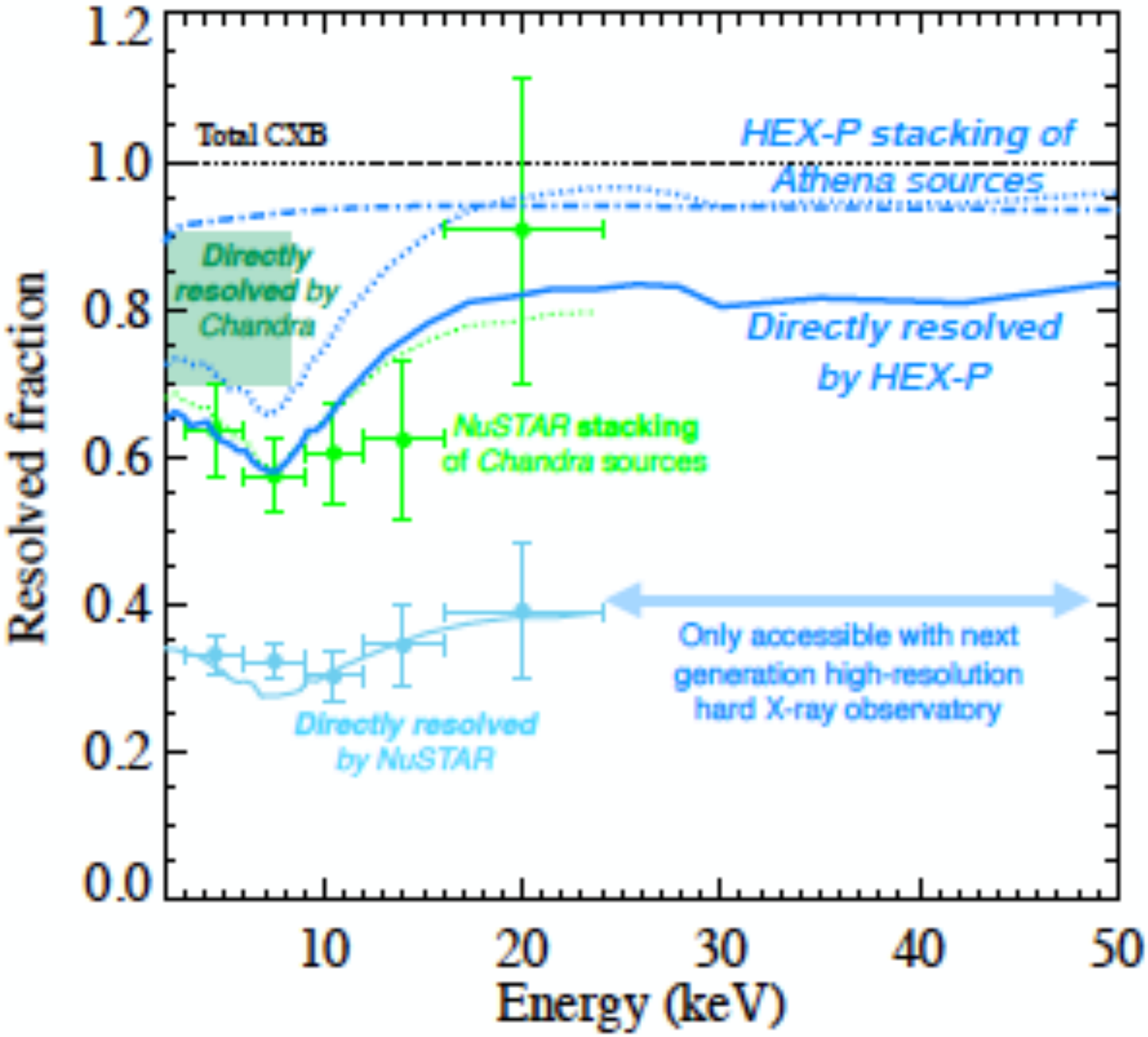


Resolve a fraction of the XRB similar to that resolved by Chandra but at the peak of its emission at 20-40 keV

Super CT AGN making mass and "no" radiation? Need IR surveys

Super fast AGN evolution proposed to account for the tension between NuSTAR and Swift/BAT hard counts

Go DEEP



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Super CT AGN making mass and "no" radiation? Need IR surveys

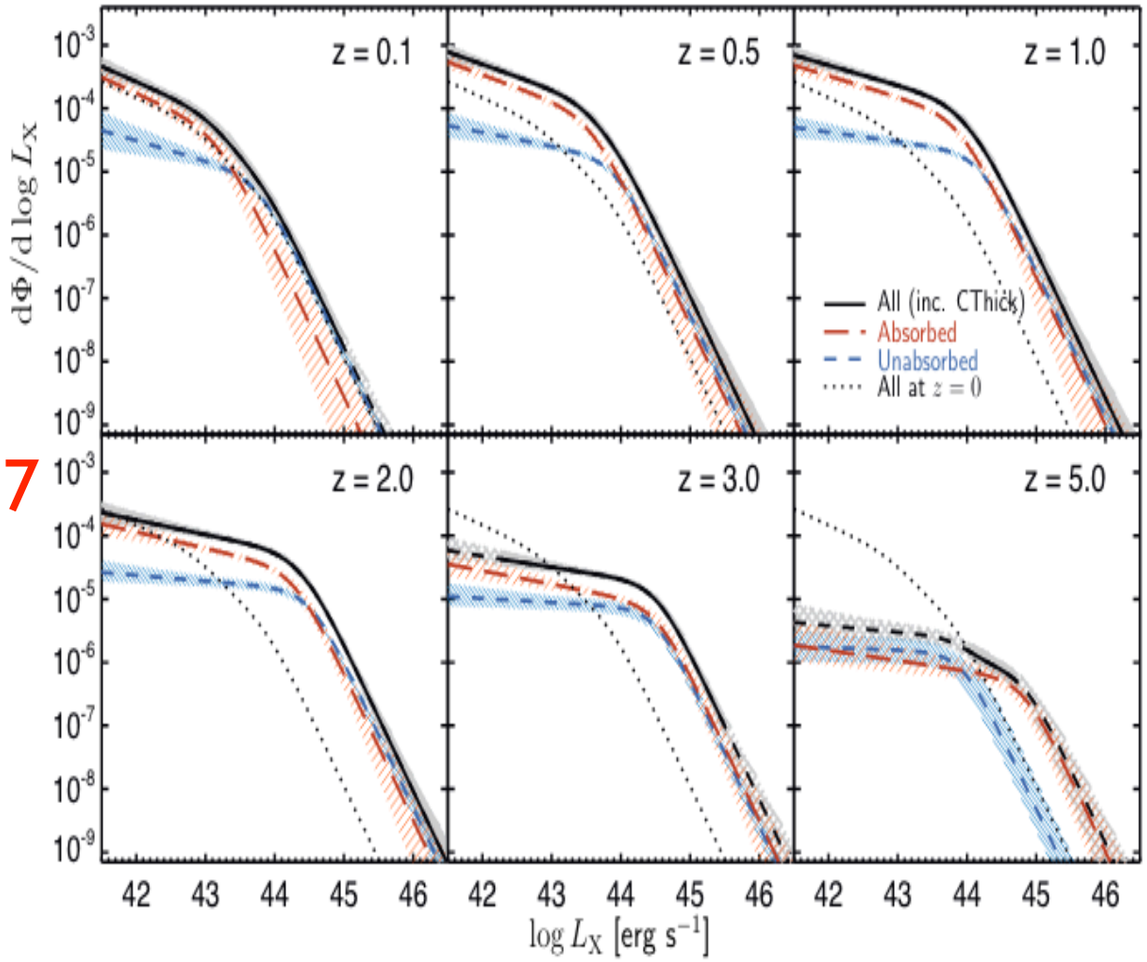
Super fast AGN evolution proposed to account for the tension between NuSTAR and Swift/BAT hard counts

Hickox, Civano +19 Decadal White paper

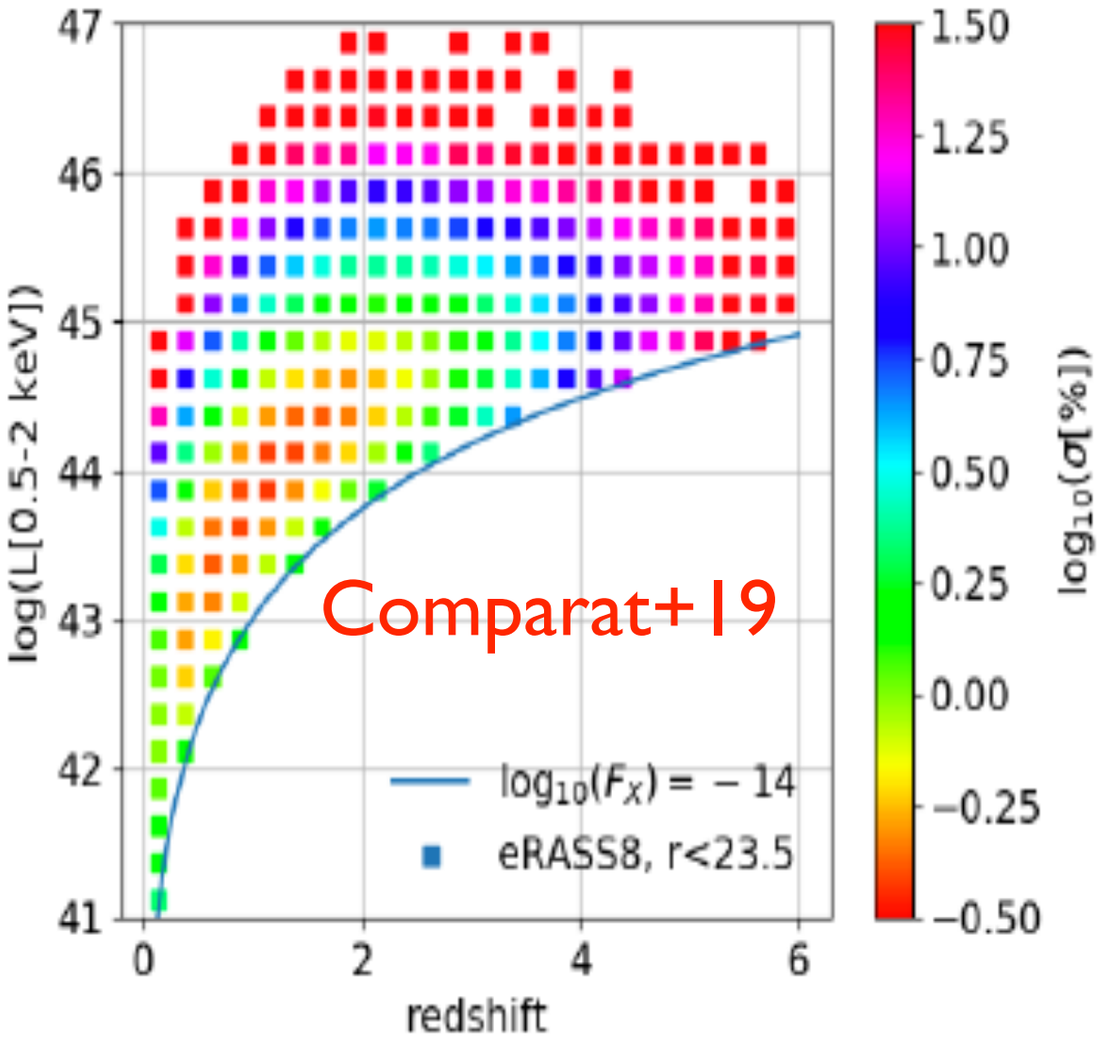
Go WIDE

X-ray LF of Compton Thin and unabsorbed AGN is well sampled up to z~5

Ueda+14; Buchner+15; Miyaji+15; Fotopolou+16;Ranalli+16; Georgakakis+17

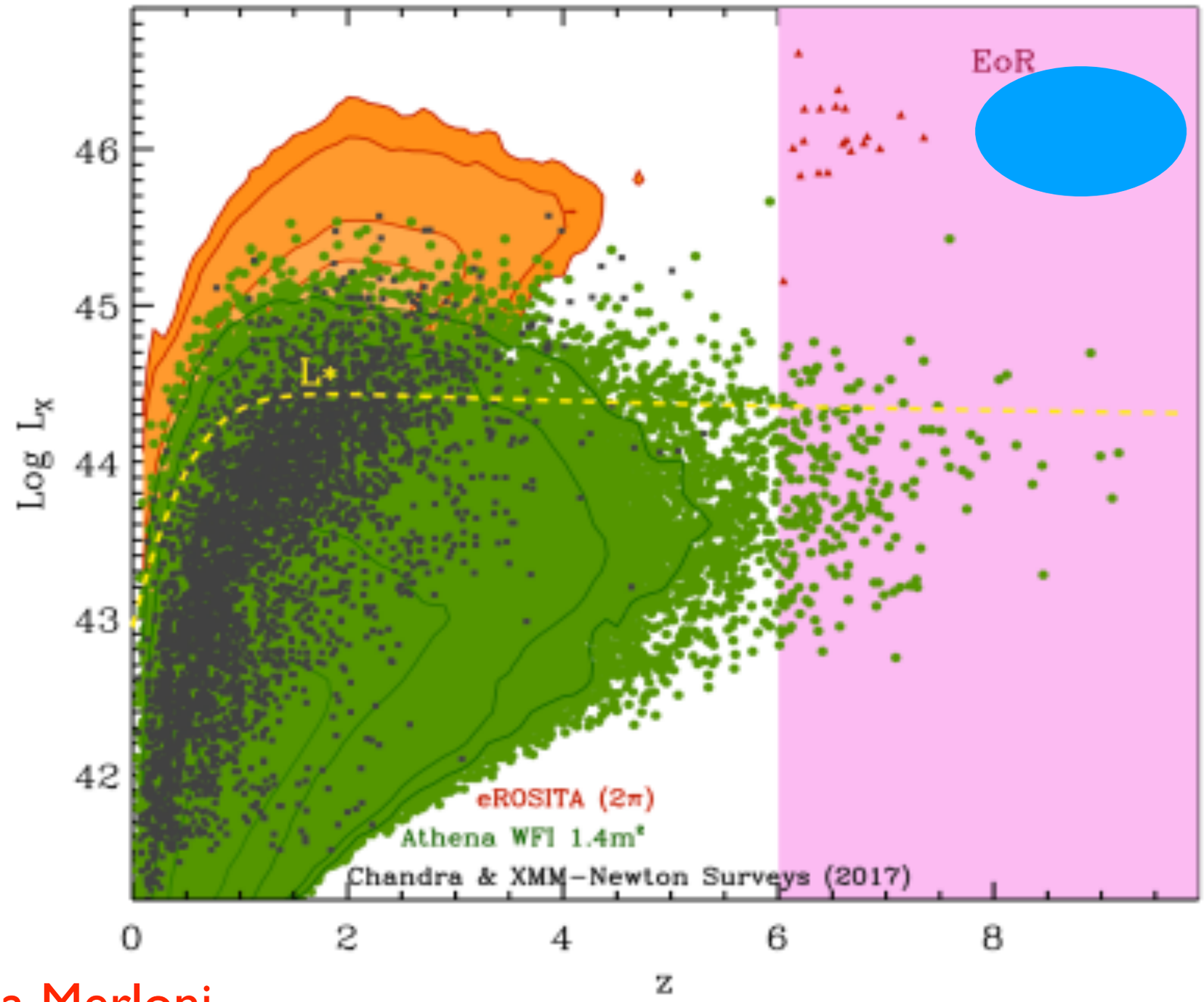


3000-4000 Objects in the 0.5-7 keV band
Strong evolution in Luminosity and Density
Aird+15



Bring the study of AGN evolution in the X-ray band to the statistical quality of galaxy evolution after SDSS

GO DEEP AND WIDE: i.e ATHENA (also hard thanks to redshift)

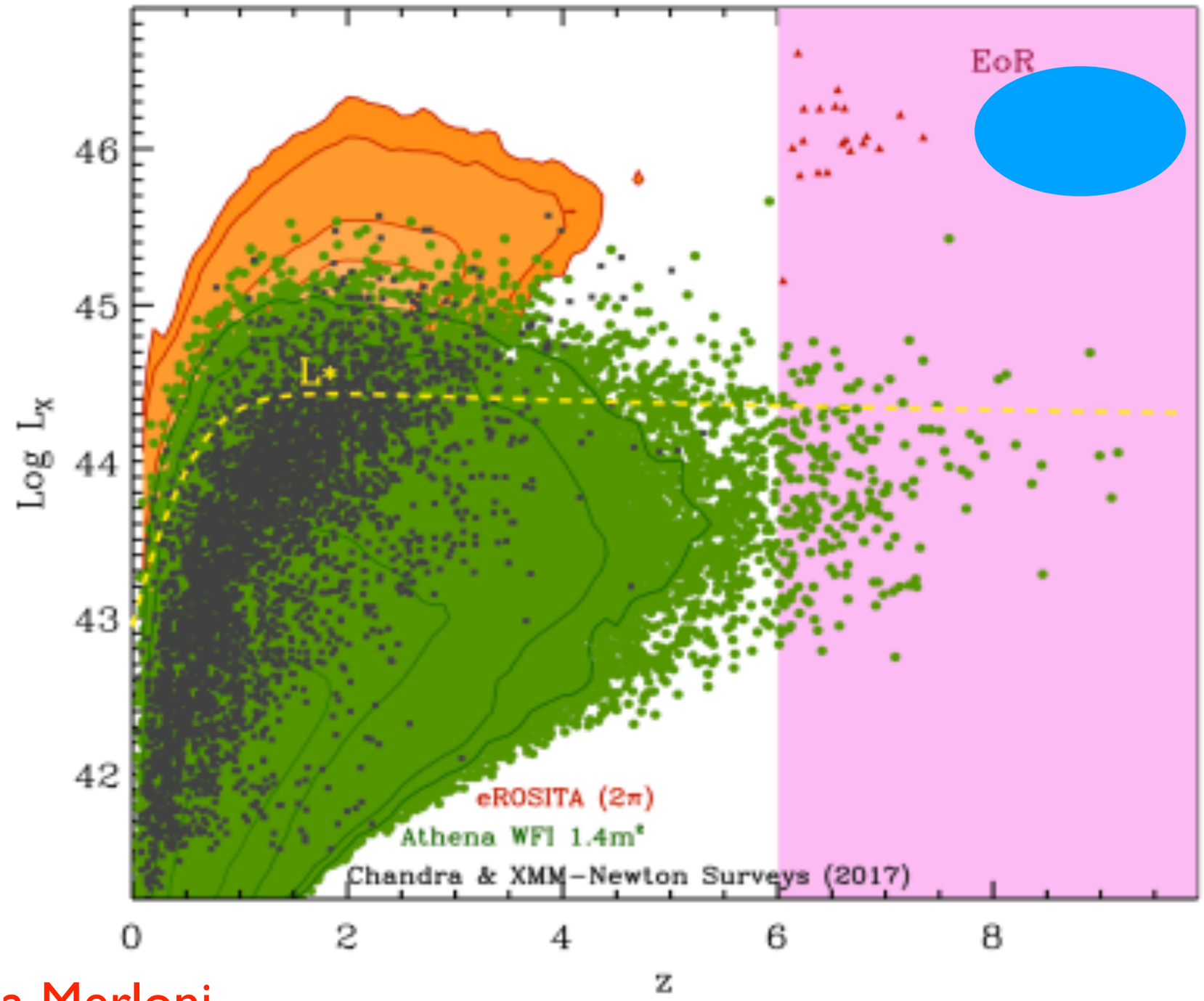


Euclid

Credit: Andrea Merloni

GO DEEP AND WIDE: i.e ATHENA (also hard thanks to redshift)

eROSITA



Euclid

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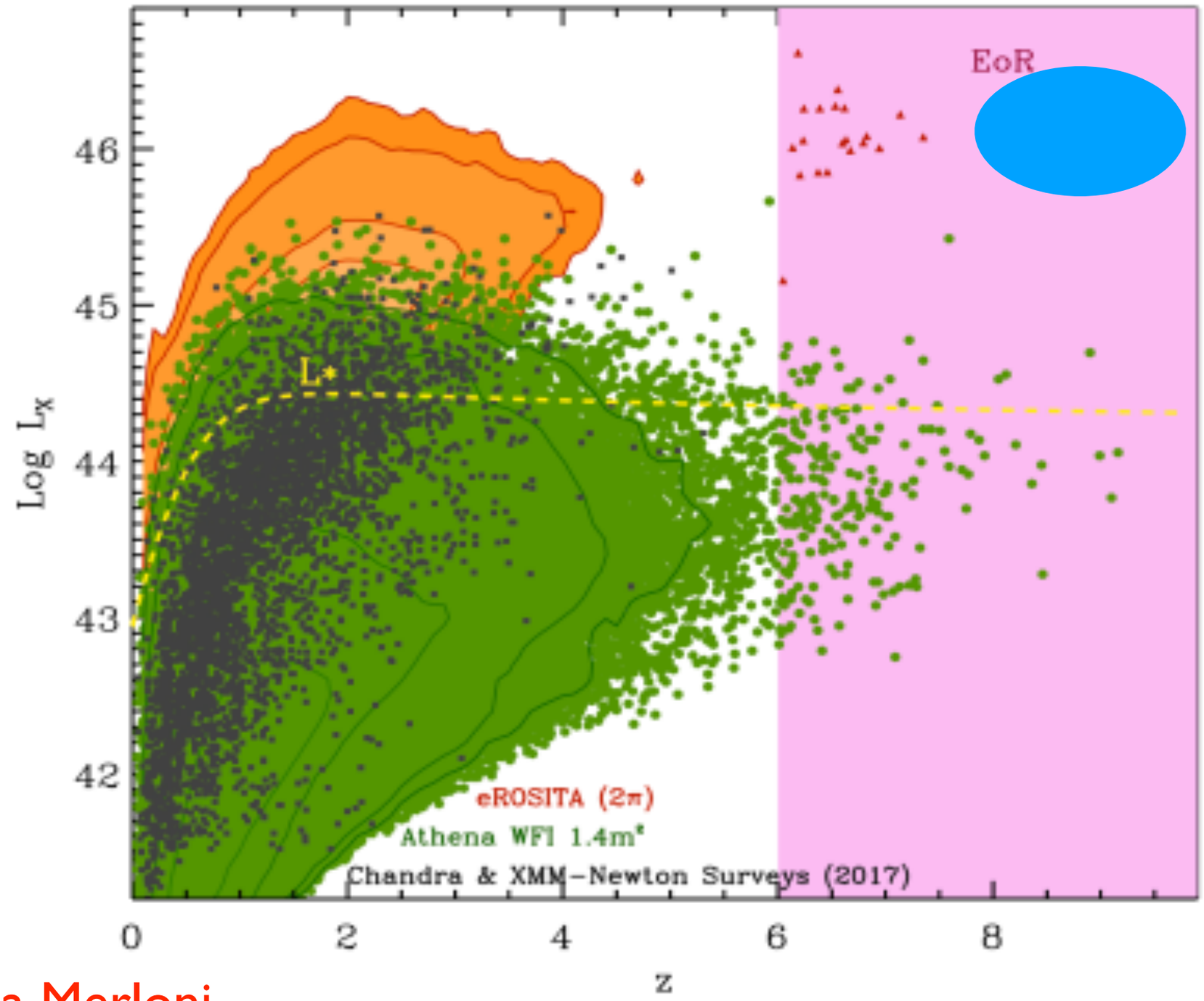
Chandra /XMM



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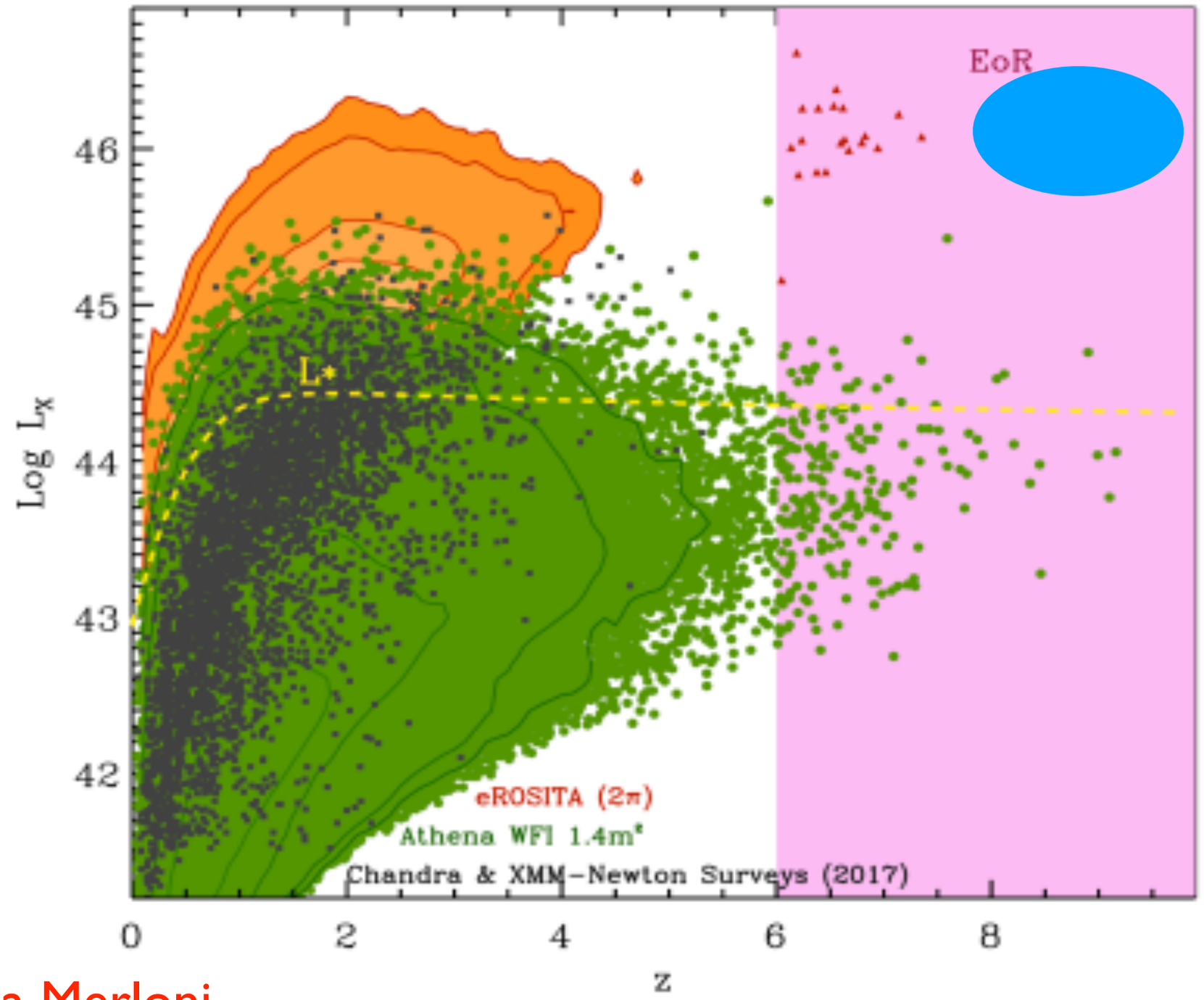


Euclid

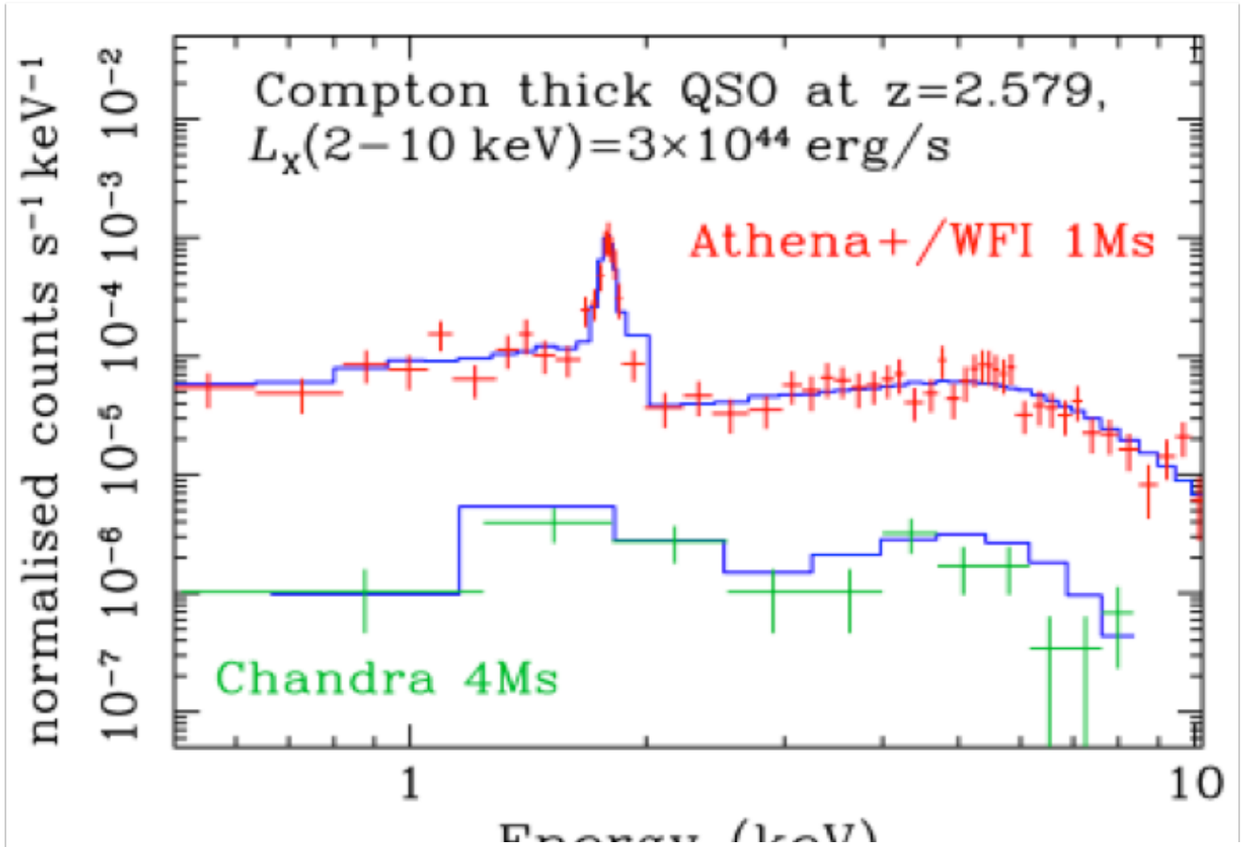
Credit: Andrea Merloni

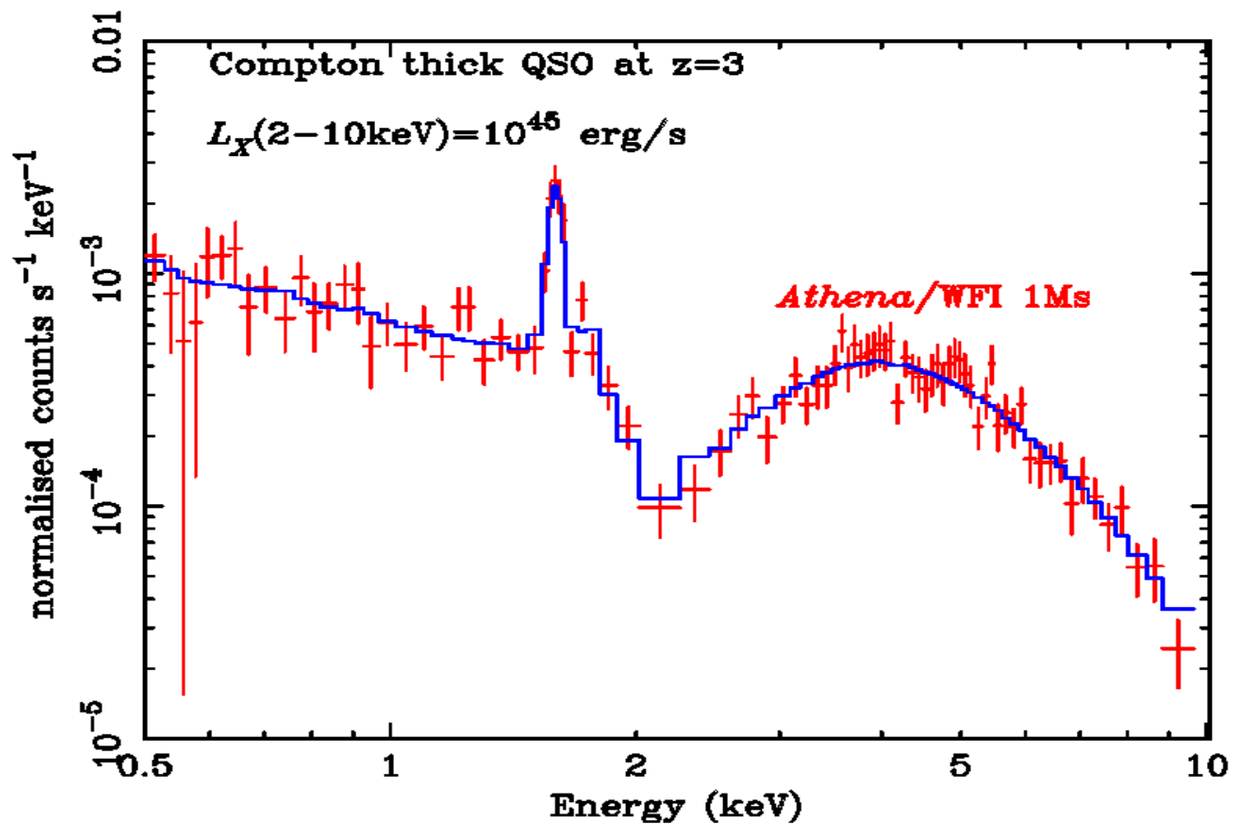
The Athena view of the Energetic Universe

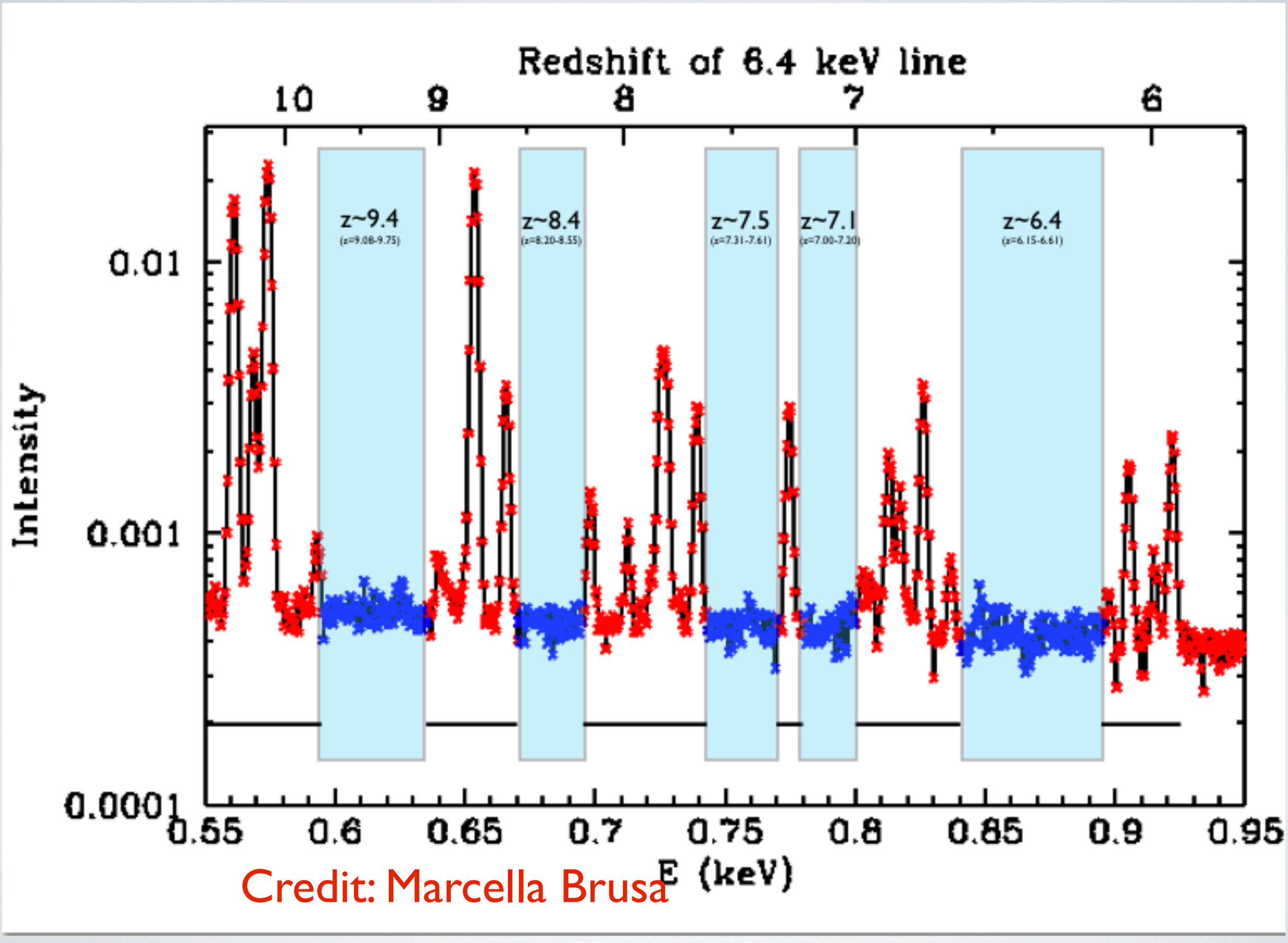
- How do black holes grow and influence the Universe?
  - The history of SMBH growth
  - Obscured AGN census z~1-3
  - AGN winds and outflows z~0-3
  - SMBH growth: accretion vs. mergers
  - BH & SMBH physics
  - Luminous extragalactic transients

X-ray spectra of relatively faint sources will be mainly observed with the WFI. XIFU and before XRISM may also be useful ..

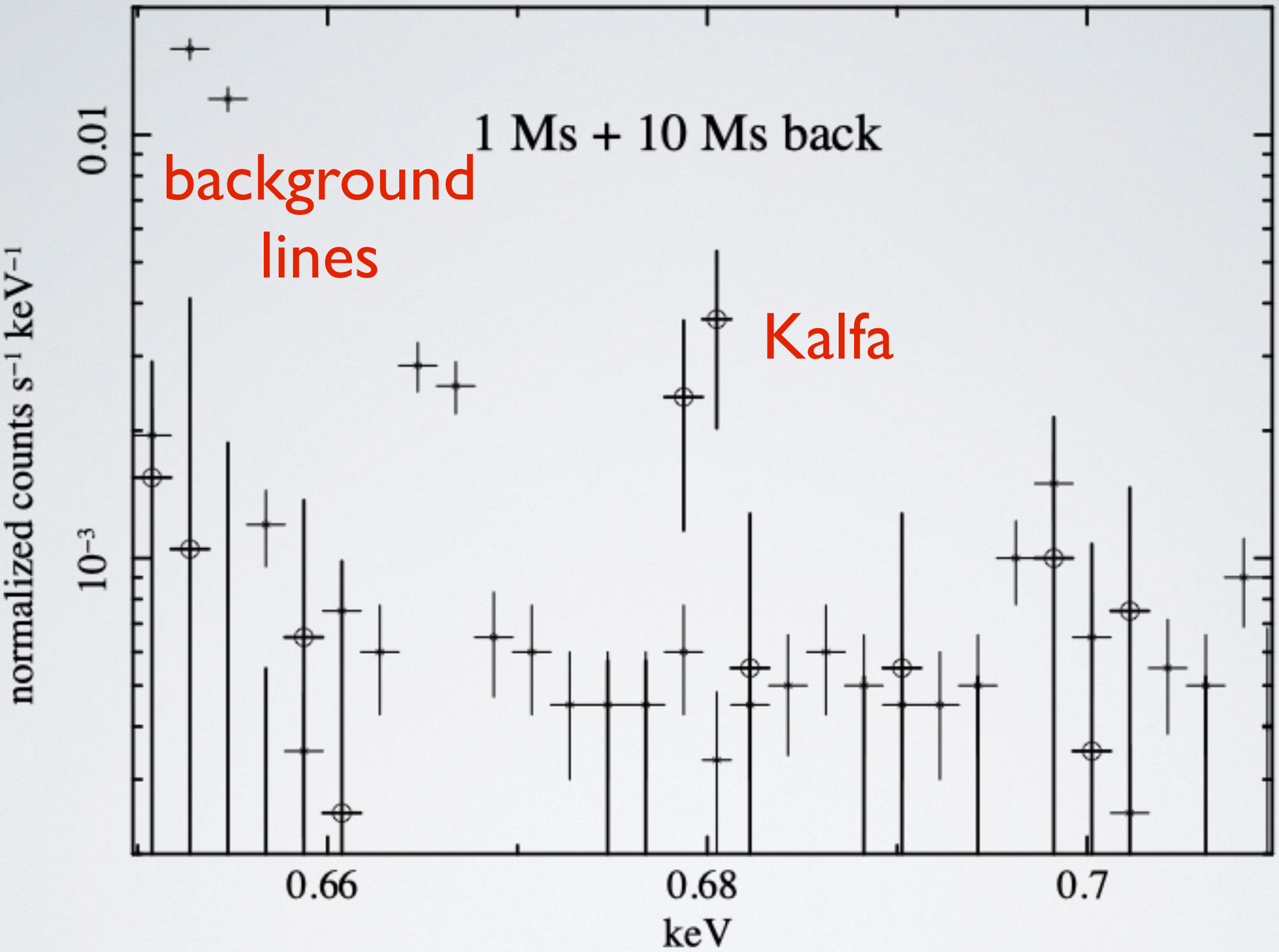
Credit: Francisco Carrera







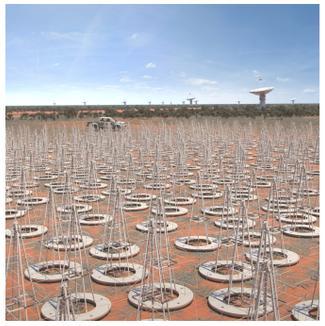
Credit: Marcella Brusa



L_X ~ 6 x 10^{42} z=8.41 EQW ~ 1 keV

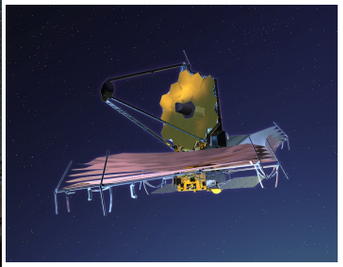
Obscured AGN in the 2030 framework

SKA

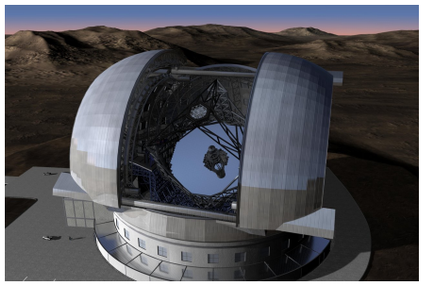


ALMA

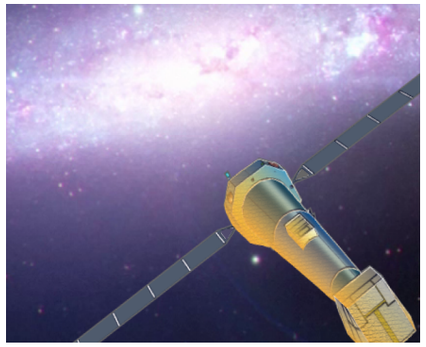
JWST



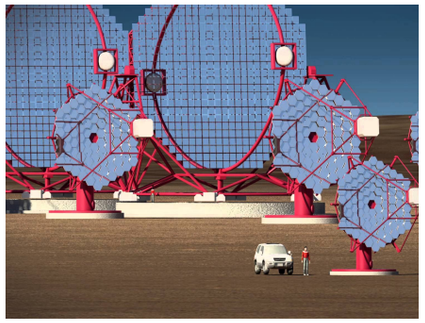
ELT



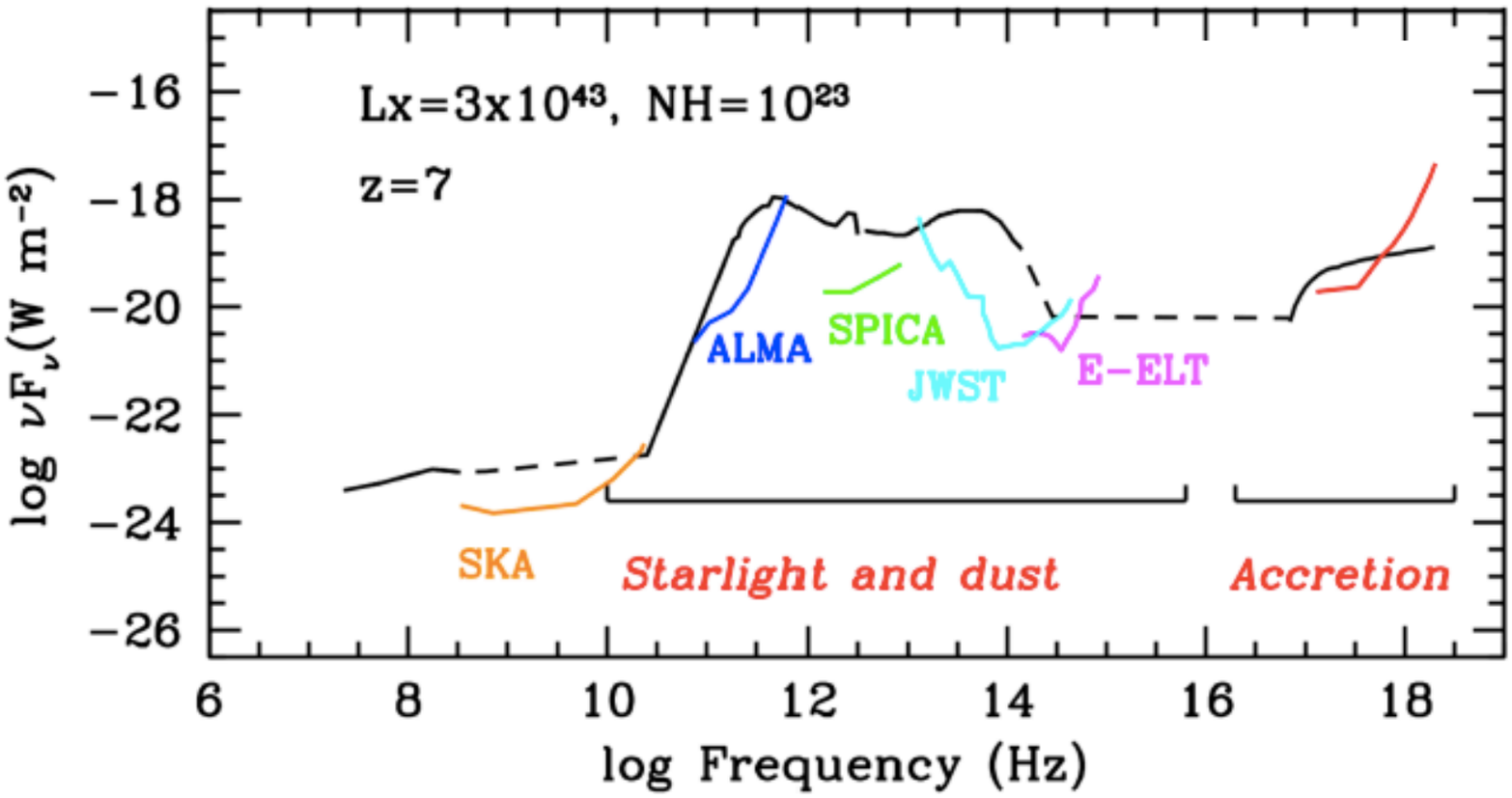
Athena



CTA



- *Athena* will be a transformational X-ray observatory addressing the Hot and Energetic Universe theme, with the potential to impact all corners of astrophysics
  - Will be part of the suite of large facilities in the early 2030s enabling unprecedented studies & discoveries
- Synergies exercises between *Athena* and other facilities done and on-going



Credit: Marcella Brusa

Conclusions

Obscured AGN are responsible for the bulk of accretion power integrated over the cosmic history.

There might be a "numerous" population of "Super" Compton thick AGN likely highly obscured (> 10^{25} cm^{-2}) and highly covered. They could be associated with the rapid obscured growth of SMBH envisaged by theoretical models.

Tantalizing evidence of fast evolution of nuclear physical properties from hard X-ray surveys.

Deep Chandra/XMM/NuSTAR surveys coupled with near-IR/sub-mm observations will provide interesting constraints.

Sensitive Hard X-ray mission able to resolve ~80% of the XRB at its 20-30 keV peak

eROSITA will probe the bright end of the luminosity distribution which is possibly particularly relevant to study outflows and feedback and scratch the tip of luminosity function of very high-z (> 6) QSO

ATHENA will allow to explore the entire parameter space