# Completing the census of heavily obscured AGN with Athena

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(building on work by the Athena WG
"Obscured Accretion and galaxy evolution")

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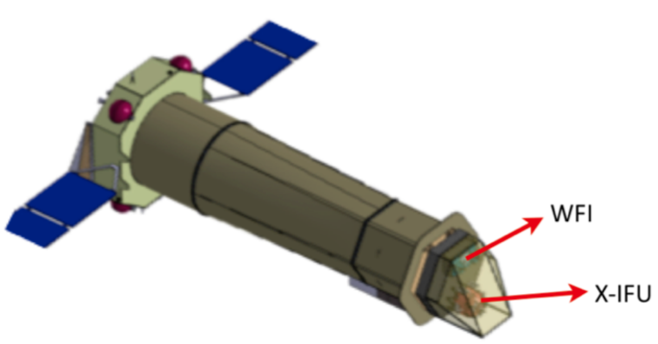
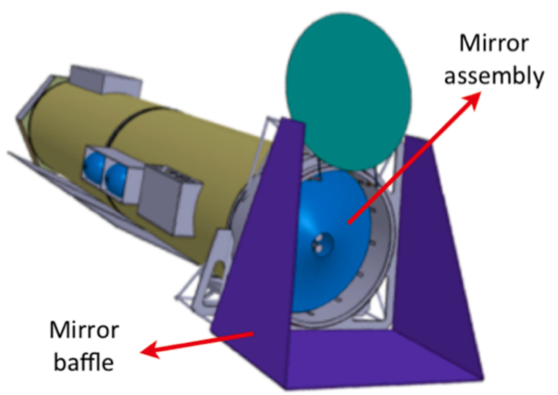
# Outline

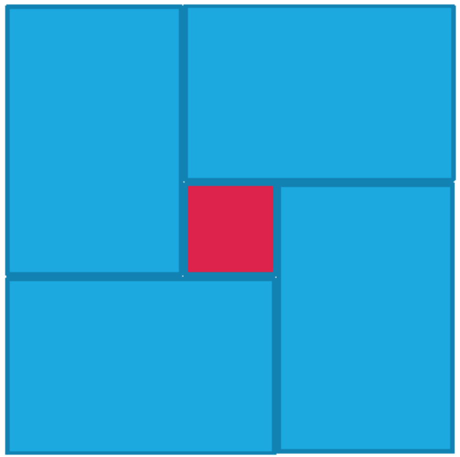
- Athena/WFI for dummies
- Why bother with heavily obscured AGN?
- Method
- Resolved extragalactic XRB fraction
  - Detection of Compton Thick AGN
- Spectral simulations:
  - Recognition of mildly CT AGN
  - Characterization of mildly CT AGN
- logN-logS and survey:
  - Numbers
- Summary
- (De-scoping options and consequences)

# Athena/WFI for dummies

- ESA approved "Hot and Energetic Universe" for L2 (2028) (Parmar'X14)
- Proposed Athena as X-ray observatory to implement "H&EU" (Nandra'X14):
  - Single mirror module:
    - ~$2m^2$ @1keV $0.25m^2$ @6keV
    - HEW: 5" on-axis
  - Two instruments:
    - X-IFU (Barret'X14): hi-res spcpy $\Delta E$<2.5eV, 5'x5' FoV
    - WFI (Rau'X14): imaging 40'x40' FoV, $\Delta E$<150eV
  - Wide range of subjects within topic above, plus observatory science
- For wide-area surveys WFI is instrument of choice

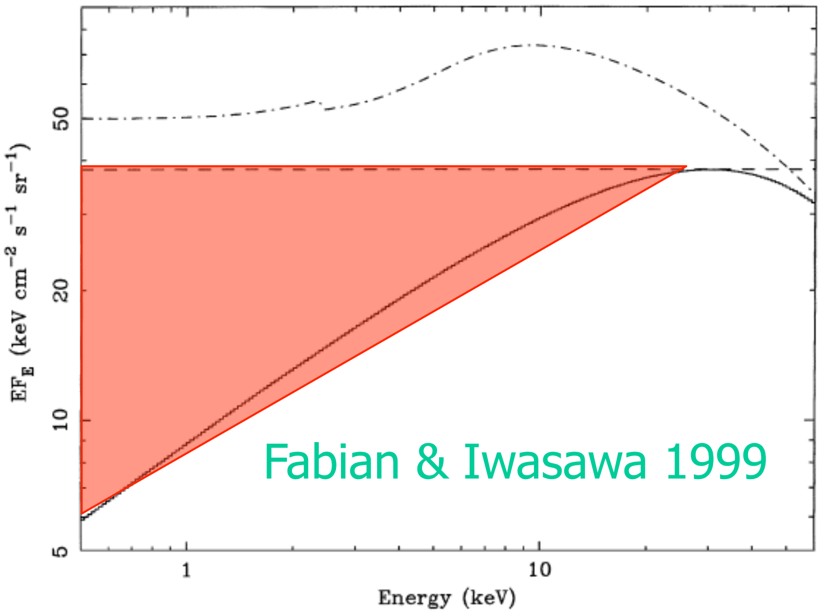


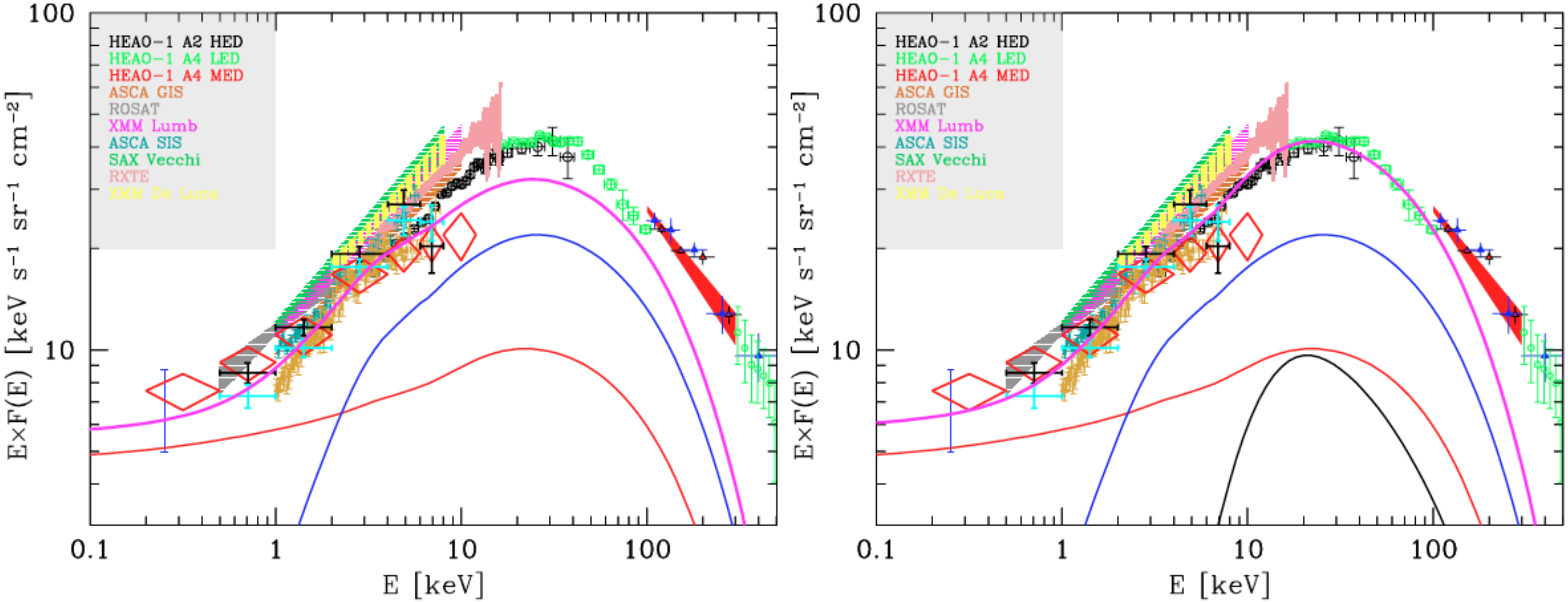
# Why bother about heavily obscured AGN?

- Most energy emitted from accretion in the Universe is obscured
- Relationship between build-up of SMBH and growth of host galaxies:
  - through obscured phase z~1-4




- Many different synthesis models (..., Gilli et al. 2007, Treister et al. 2006, Akylas et al. 2012...):
  - Using: source counts, XLF, CXB spectrum... extrapolating to z>3
  - Based on Unified AGN Model
- Unclear (but significant) contribution of Compton Thick objects

# Why bother about heavily obscured AGN?

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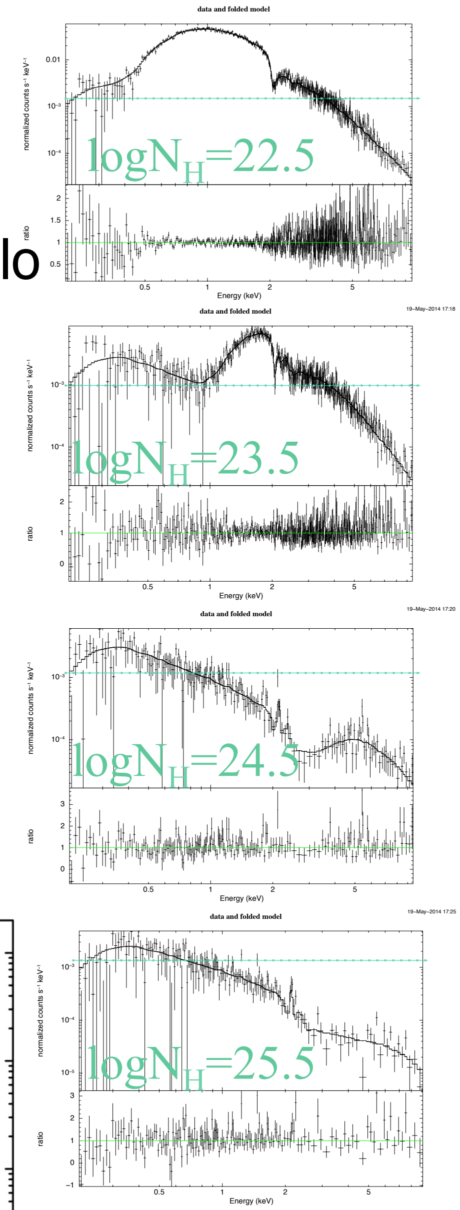
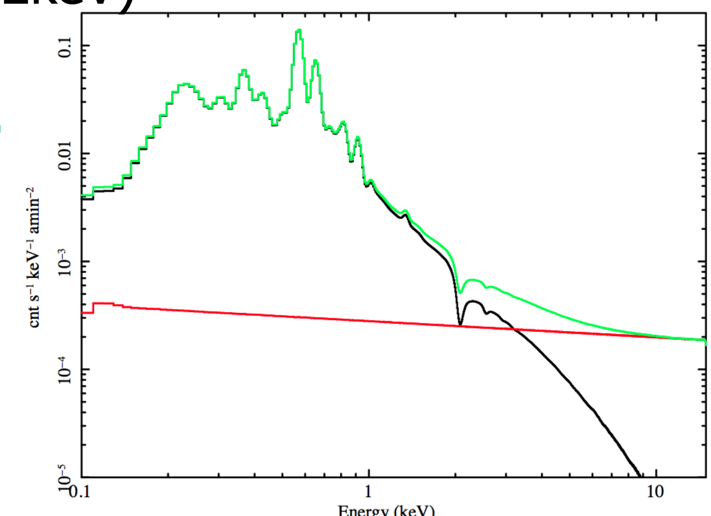
# Method

- Spectral model:
  - Brightman & Nandra (2011): torus model from Montecarlo simulations, high inclination
  - Additional 1% scattering component
- FoV-averaged:
  - Response matrix
  - PSF: HEW~6.4arcsec
- Backgrounds:
  - xgal and Gal: Lumb
  - Particle: Hauf+11 ×2 (>2keV)

– Source counts: Gilli+07

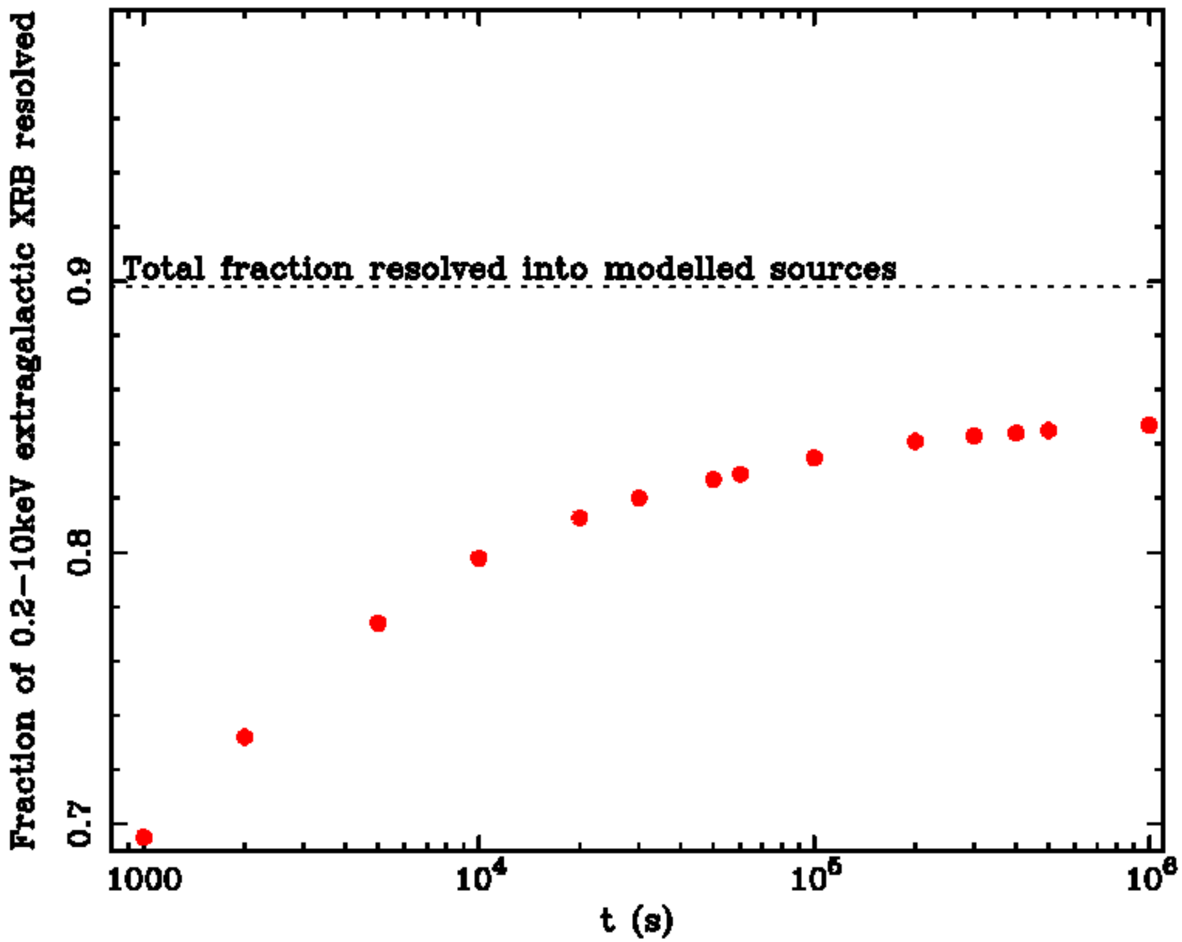



$L_X$(2-10keV)
$=5\times10^{44}$ erg/s
z=2 t=1Ms



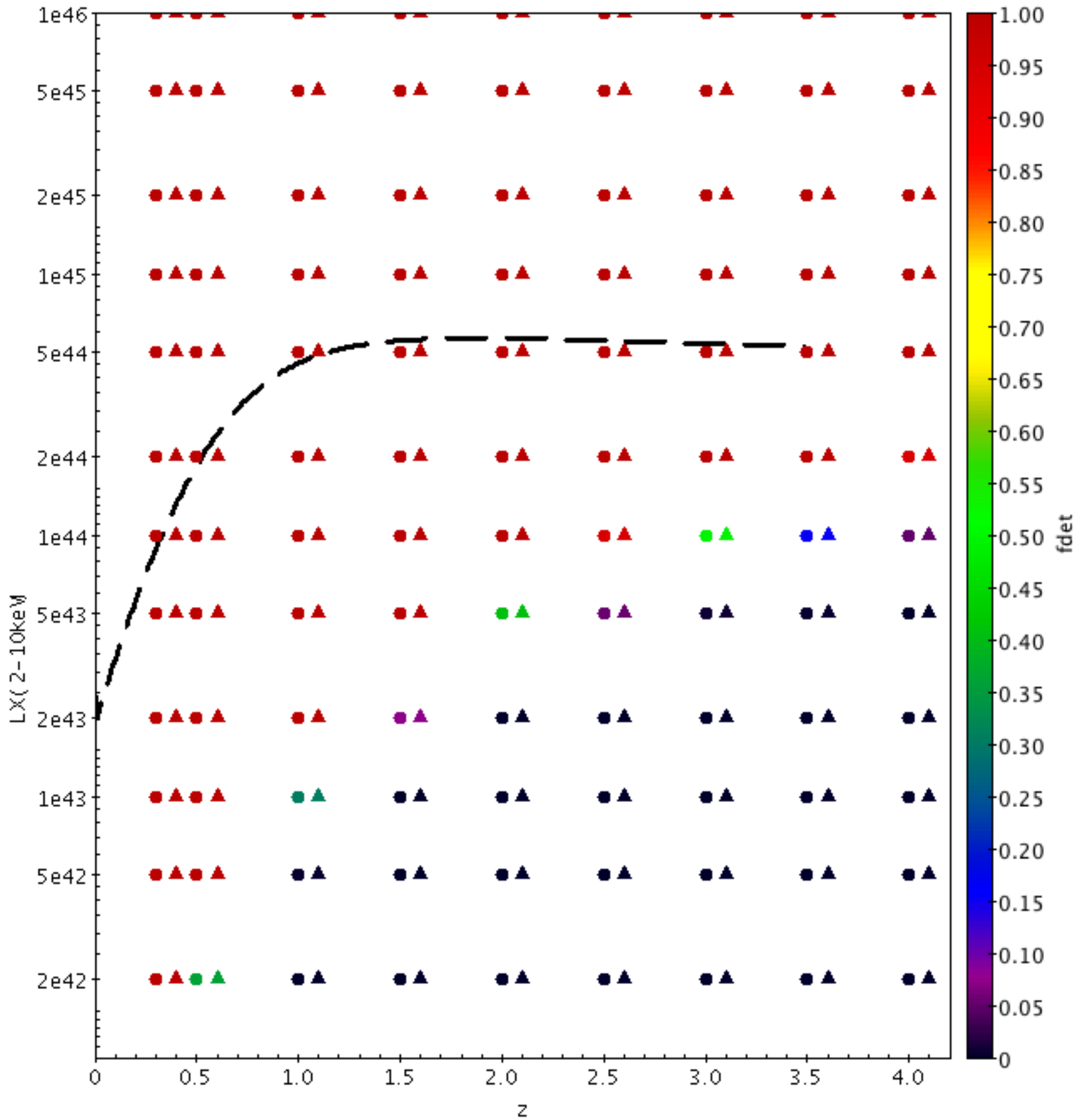
# Resolved extragalactic XRB fraction

- Divided full par. space into $N_H$,z,$L_X$ "cubes"
- Calculated intensity from each "cube"
- For each exposure time t:
  - Iteratively calculated SNR in each "cube"⇒ fracion of sources detected in that "cube" ⇒ total xgal XRB resolved
  - Until convergence
- 70-80% reached with modest exposures (~10ks):
  - After that improvements are very modest



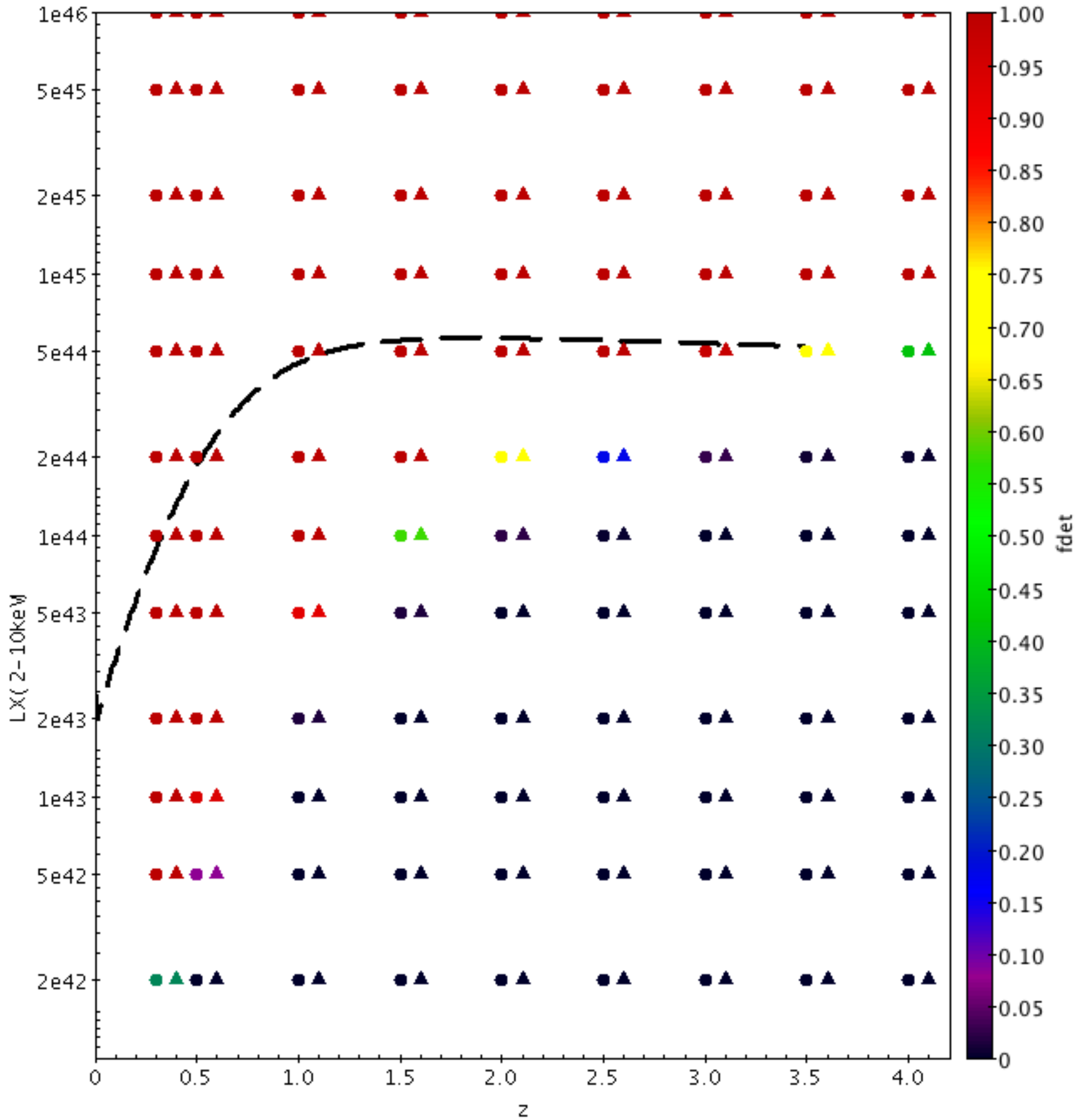
# Detection of CT objects: 1Ms

- Immediate by-product of previous work
- Source detected if SNR≥5 in 0.5-2, 2-10 or 0.5-10keV
- Detection fraction in $L_X$(2-10keV)-z plane
- Together with L*, dashed line (Aird +10)
- t=1Ms:
  - ●$\log N_H$=24.5
  - ▲$\log N_H$=25.5
  - L* up to z=4



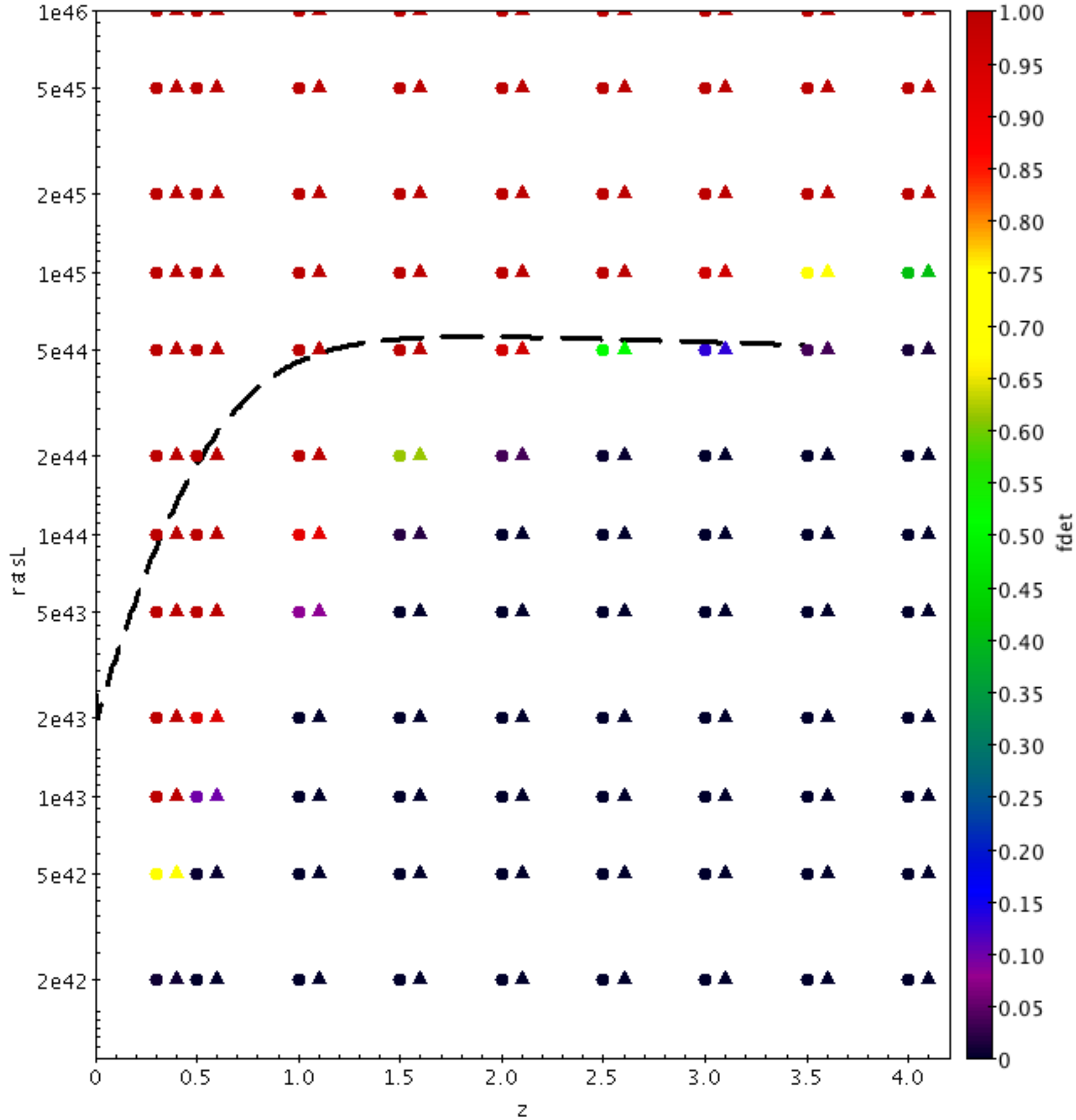
# Detection of CT objects: 100ks

- Immediate by-product of previous work
- Source detected if SNR≥5 in 0.5-2, 2-10 or 0.5-10keV
- Detection fraction in $L_X$(2-10keV)-z plane
- Together with L*, dashed line (Aird +10)
- t=100ks:
  - ●$\log N_H$=24.5
  - ▲$\log N_H$=25.5
  - L* up to z=3



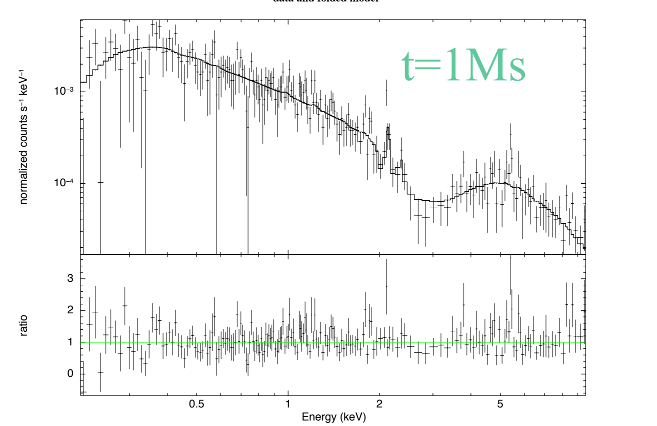
# Detection of CT objects: 30ks

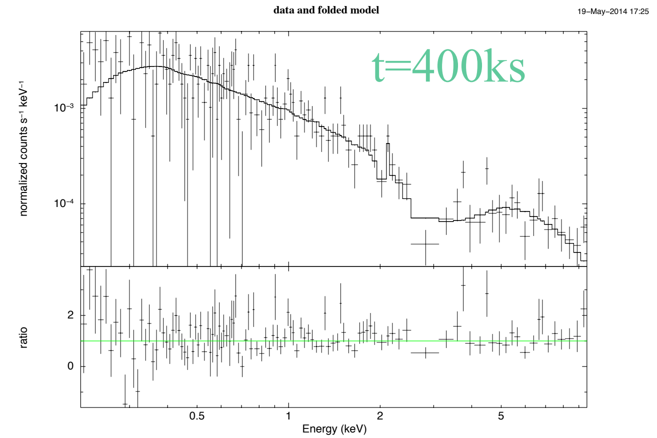
- Immediate by-product of previous work
- Source detected if SNR≥5 in 0.5-2, 2-10 or 0.5-10keV
- Detection fraction in $L_X$(2-10keV)-z plane
- Together with L*, dashed line (Aird +10)
- t=30ks:
  - ● $\log N_H$=24.5
  - ▲ $\log N_H$=25.5
  - L* up to z=2

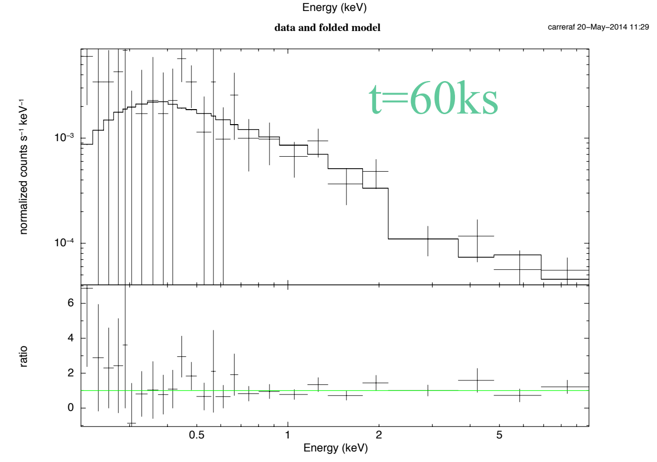


# Spectroscopic simulations

- But detections are not enough:
  - Need to actually recognize CT objects as such ⇒Spectroscopic simulations
- For a subset of:
  - $N_H$,z,$L_X$
  - Exposure times:1Ms, 400ks, 300ks, 100ks, 60ks, 30ks
- 20 simulations of each combination:
  - Including Poisson noise in spectrum and backgrounds
  - Taking into account resolved xgal XRB fraction
  - Each sim. spectrum fitted
    - Calculated $\Delta\chi^2$ 90% uncertainties in $N_H$,$L_X$ for each sim. spectrum
  - Found for which fraction of the sim. spectra the input parameters were recovered within 30%



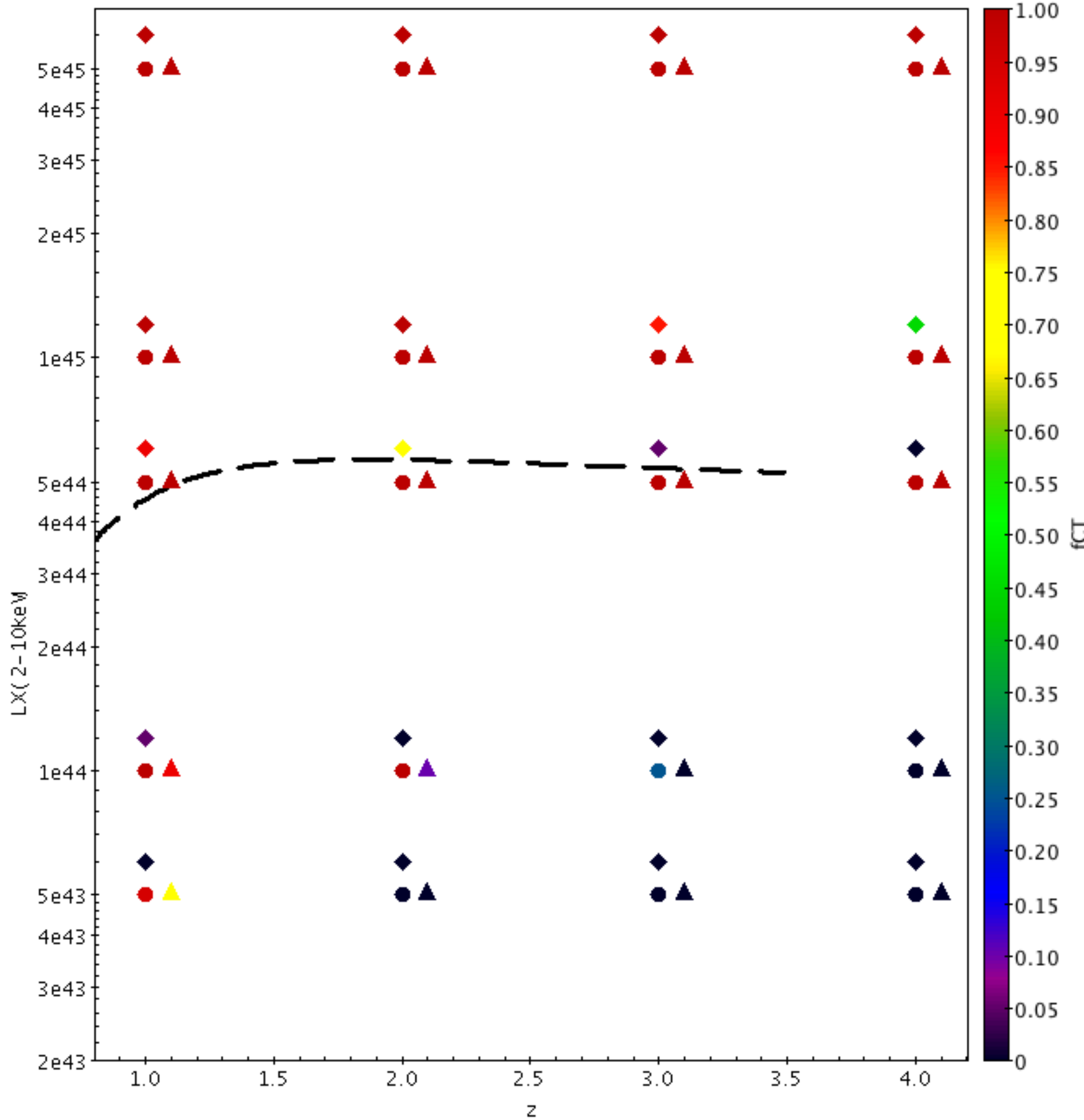




$\log N_H$=24.5 $L_X$(2-10keV)=$5\times10^{44}$ cgs z=2

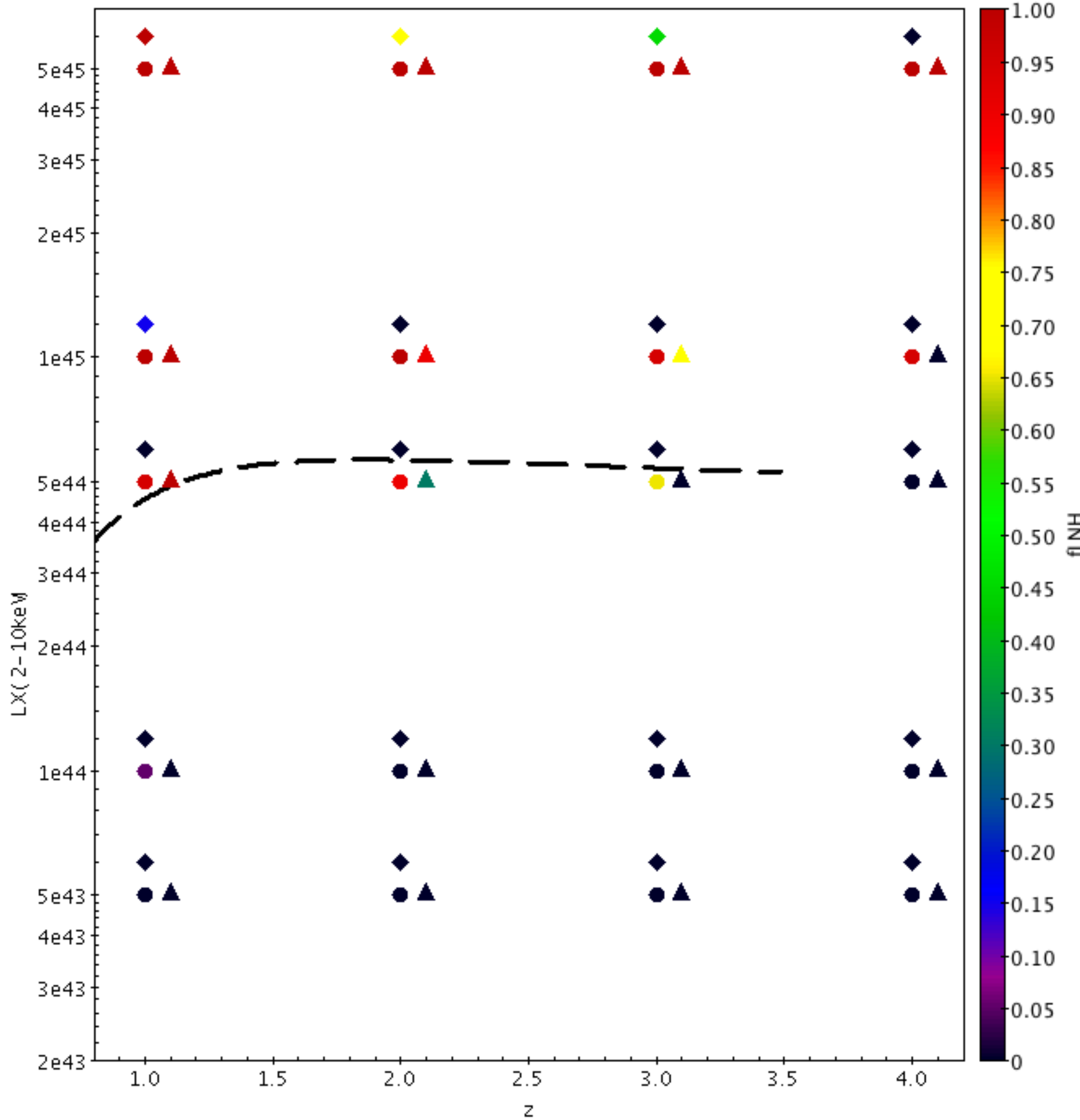
# Recognition of mildly CT objects

- Fraction of spectra for which at 95% $N_H > 1.5 \times 10^{24} cm^{-2}$
- Concentrating on $\log(N_H/cm^{-2}) = 24.5$
- Together with L*, dashed line (Aird +10)
- ● t=1Ms
  - L* up to z=4
- ▲t=400ks
  - L* up to z=4
- ◆ t=60ks
  - L* up to z=1



# Characterization of mildly CT objects

- Fraction of spectra for which both $N_H$ and $L_X$ are recovered within 30%
- Concentrating on $\log(N_H/cm^{-2})=24.5$
- Together with L*, dashed line (Aird +10)
- ● t=1Ms
  - L* up to z=2
- ▲t=400ks
  - L* up to z=1
- ◆ t=60ks
  - ...



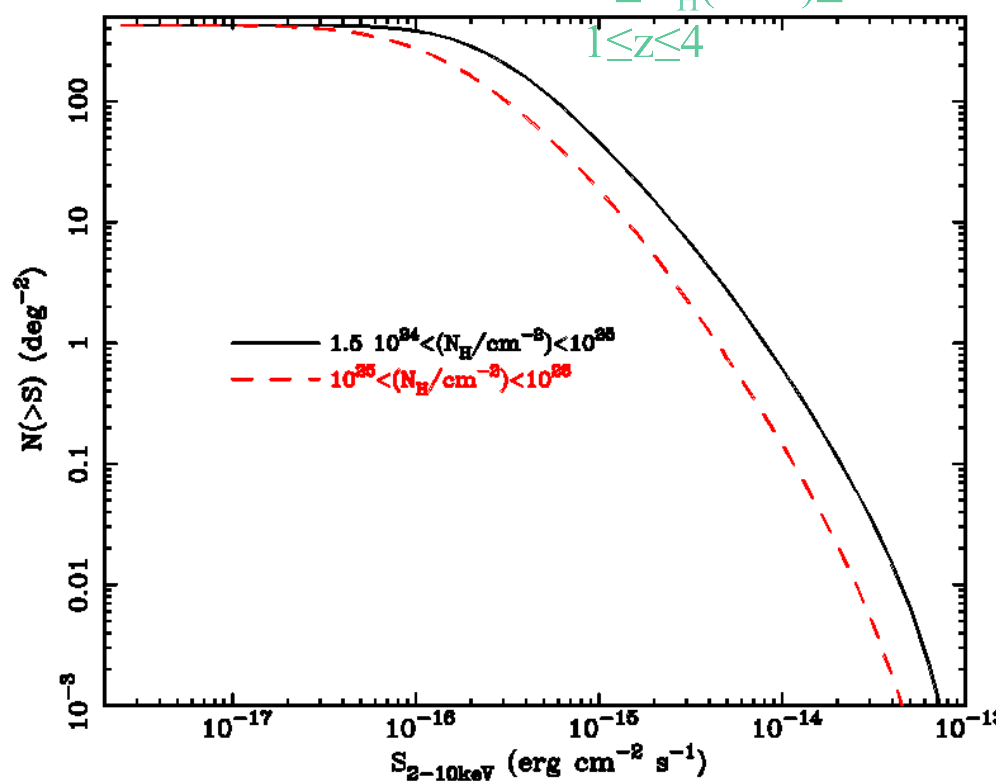
# Source counts

- But fractions are not enough:
  - Need to get sufficient sources to do some sort of population studies
- Now we need additionally:
  - logN-logS: using Gilli+07 (next Akylas+12)
  - Survey geometry: ambitious ~25Ms
    - 4×1Ms+14×400ks+249×60ks
    - Over 5y nominal mission
    - Not only for this!:
      - High z AGN
      - Outflows/feedback
      - ...

$2.5\times10^{43} \leq L_X(\text{2-10keV,cgs}) \leq 7.5\times10^{45}$

CT: $1.5\times10^{24} \leq N_H(\text{cm}^{-2}) \leq 10^{26}$

$1 \leq z \leq 4$



# Numbers of CT sources in full survey

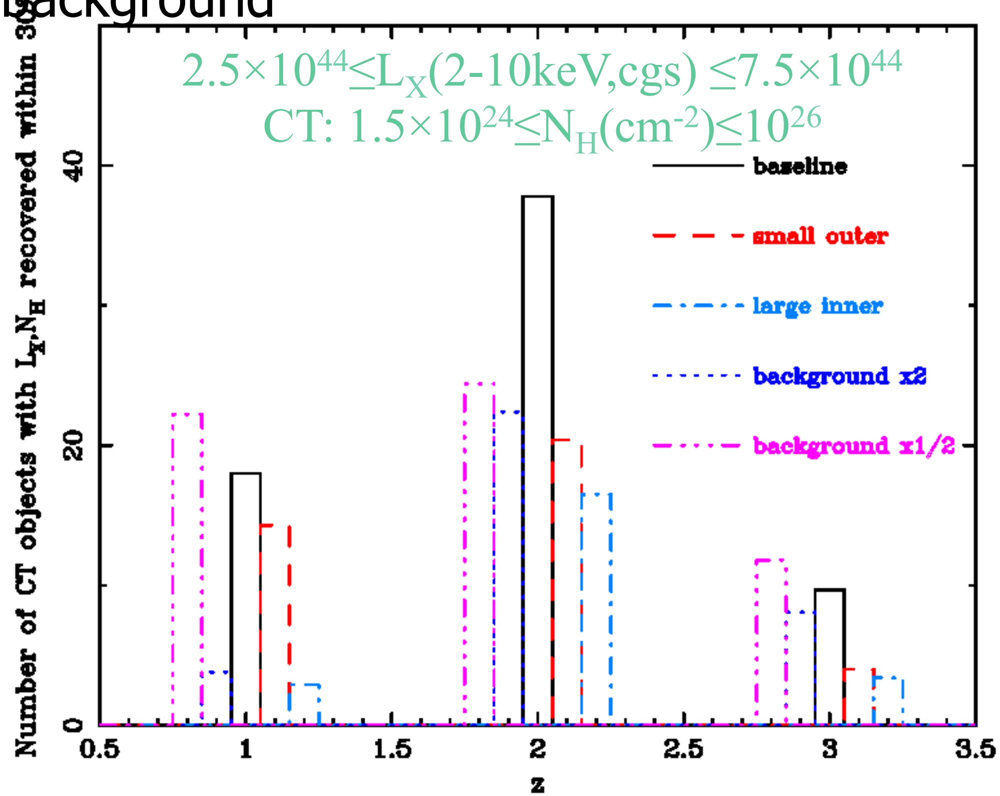
| # | z | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $L_X$(2-10keV) ($10^{44}$erg/s) | 1 | | | 2 | | | 3 | | | 4 | | |
| | det | CT | $N_H$, $L_X$ | det | CT | $N_H$, $L_X$ | det | CT | $N_H$, $L_X$ | det | CT | $N_H$, $L_X$ |
| 0.5 | 11000 | 950 | 0 | 440 | 0 | 0 | 50 | 0 | 0 | 8 | 0 | 0 |
| 1.0 | 5400 | 600 | 2 | 880 | 190 | 0 | 223 | 14 | 0 | 50 | 0 | 0 |
| 5.0 | 540 | 520 | 18 | 2600 | 1380 | 38 | 1700 | 180 | 10 | 420 | 40 | 0 |
| 10 | 50 | 50 | 5 | 400 | 380 | 12 | 380 | 290 | 10 | 150 | 40 | 1 |
| 50 | 3 | 3 | 2 | 30 | 30 | 10 | 30 | 30 | 7 | 12 | 12 | ~0 |

- Sources with L* (or just above):
  - 1000s detected up to z=3 (100s at z=4)
  - 1000s recognized as such up to z=3 (10s at z=4)
  - ~20 characterized in $N_H$,$L_X$ up to z=3

Very rich harvest with $L_X$<L* z≤1

# De-scoping options

- Proposal on budget and with high technical readiness
- But considering potential alternatives:
  - smallouter: removing outer mirror shells (loss of low En. eff. area)
  - largeinner: removing inner mirror shells (loss of eff. area at all En.)
  - highbgd: twice nominal particle background
  - lowbgd: half nominal particle background
- Consequences:
  - Worst are largeinner, highbgd
  - smallouter milder



# Summary

- Athena is proposal for implementation of “Hot and energetic Universe” topic for ESA L2 (2028)
  - Observatory
  - Two instruments: X-ray IFU and Wide Field Imager
- Obscured AGN are important for galaxy-building and understanding history of accretion in Universe
- After some calculations and loads of simulations:
  - ~80% extragalactic XRB resolved in 0.2-10keV
  - Can detect >50% of CT L* for z≤2.5 in ~30ks
  - Can recognize significant fractions of mildly CT L* for z≤3 in ~60ks
  - Can characterize significant fractions of mildly CT L* for z≤2 in ~100ks
  - Assuming a given logN-logS: 1000s CT detected and recognized and 10s characterized to z~3: more than enough to tell apart models
  - Need to assess influence of assumptions (logN-logS...)
- Brilliant future ahead of X-ray (and multi-$\lambda$) AGN Astronomy
- We now need to build and launch it:
  - Opportunity for the full community