Characterizing the AGN populating the NuSTAR Extragalactic Survey fields

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Explaining the Cosmic X-ray Background

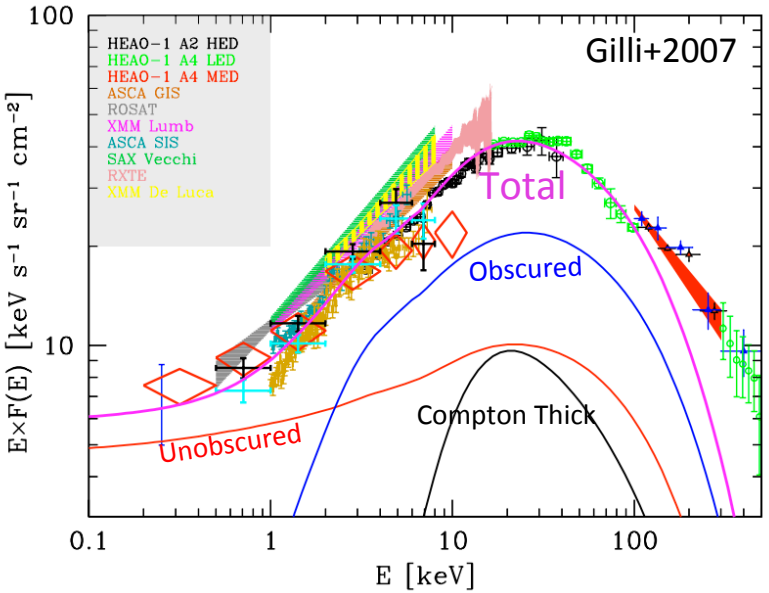
Cosmic X-ray Background (CXB)

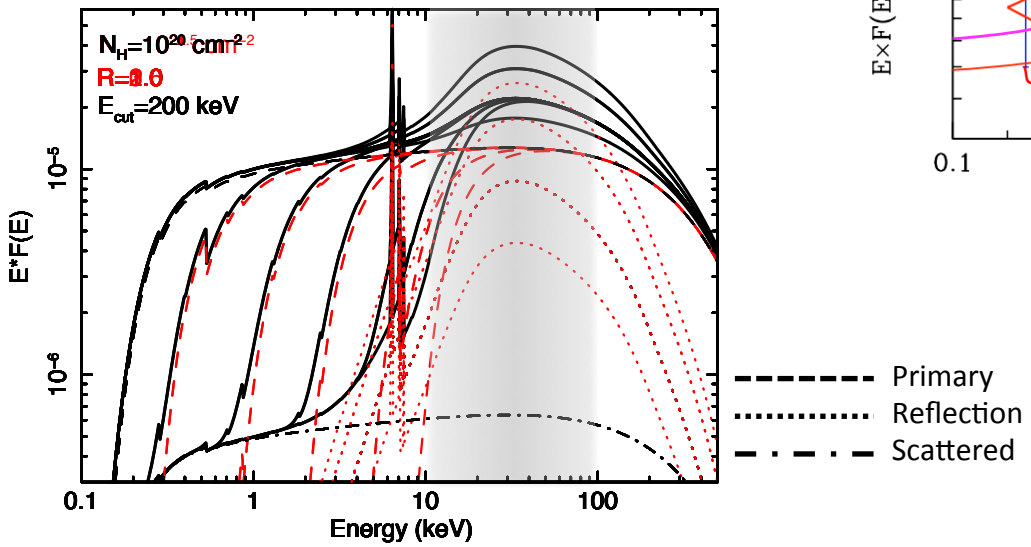
→ mixture of obscured and unobscured AGN (Setti & Woltjer 1989, Comastri et al. 1995)

CXB Population Synthesis Models

→ residual contribution in the peak at 20-30 keV

- unaccounted sizable population of Compton Thick (CT) AGN (Gilli+2007, Treister+2009).
- Compton reflection (R): degenerate with CT fraction (e.g. Akylas et al. 2012)

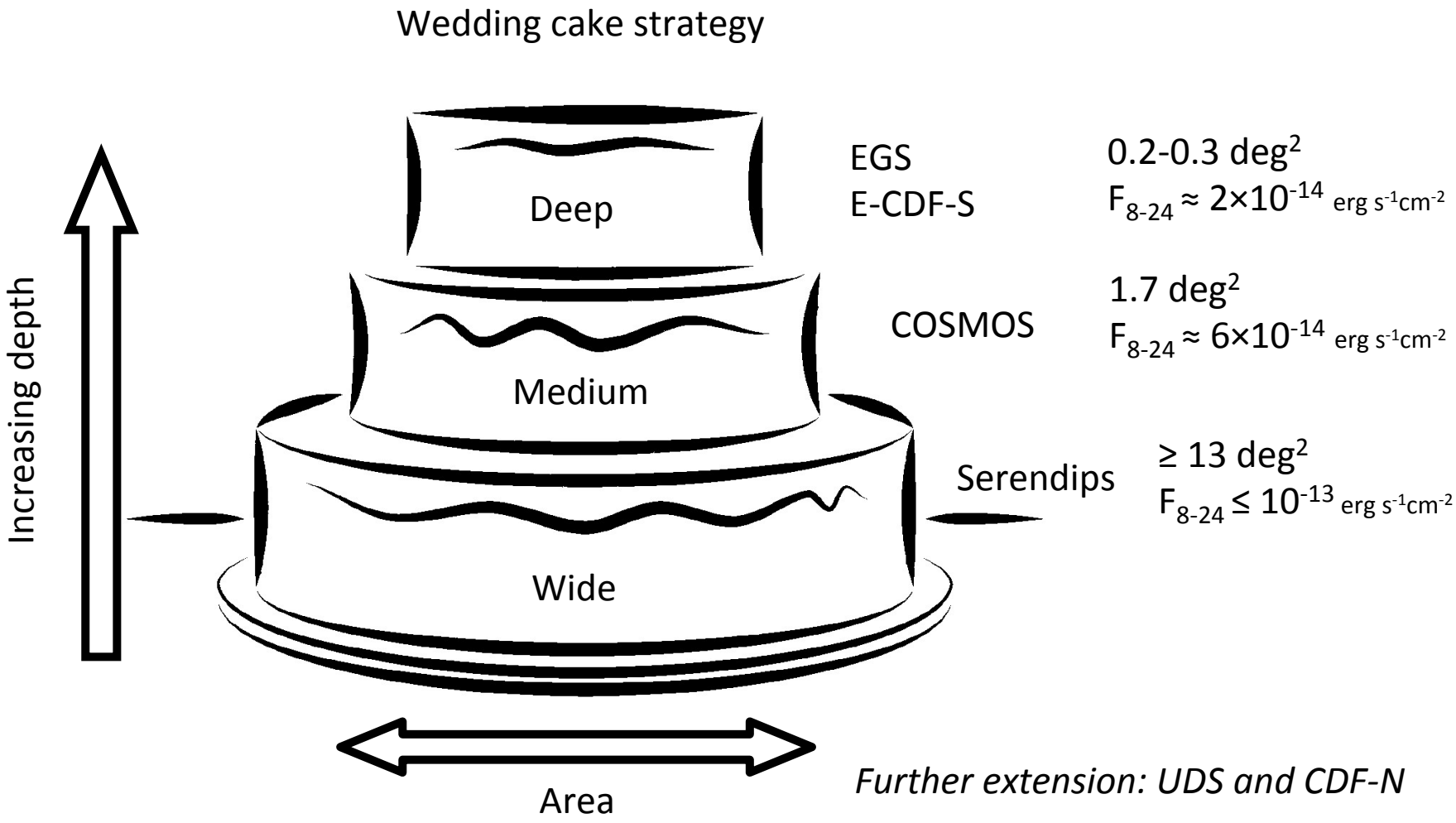




AGN census: X-ray surveys

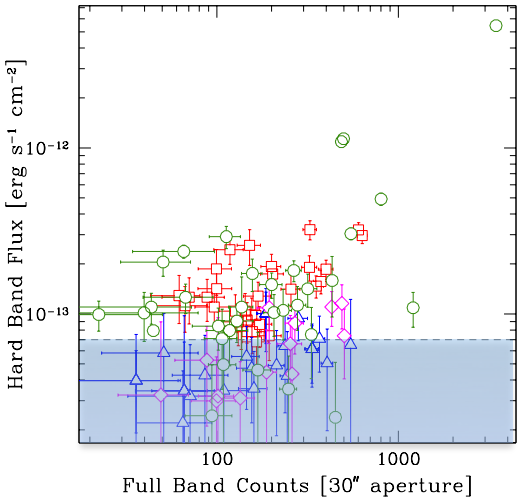
- at < 10 keV (XMM-Newton, Chandra)
  - up to ~80-90% CXB resolved
  - biased against heavy obscuration
  - little info on reflection
- Pre-NuSTAR studies (Swift-BAT/INTEGRAL) at 20-30 keV
  - ~1-2% CXB resolved
  - local CT estimate (20-30%) → biased toward local (z<0.2) sources
- NuSTAR → 35% CXB resolved (Harrison et al. 2016) at the peak detecting AGN to z~3
  - less prone to obscuration bias
  - can probe more distant sources
  - direct view of reflection component
  - can shed light on the degeneracy in CXB modeling between CT sources and degree of reflection

NuSTAR survey program

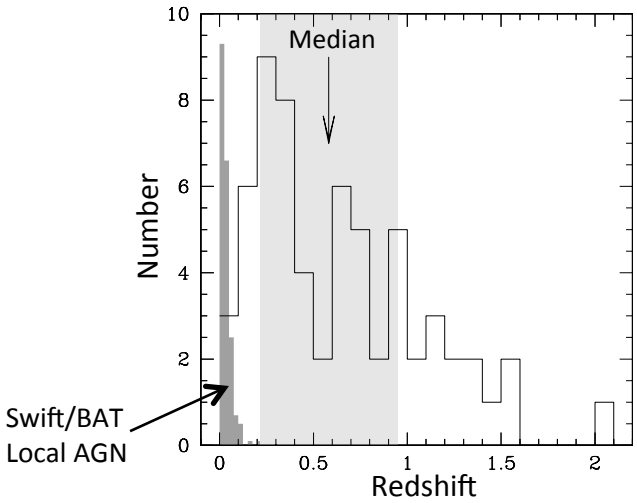


Spectroscopic study: bright hard-selected sample

- Flux limited sample
  - **Detected in 8-24 keV band**
  - **F(8-24 keV) ≥ 7×10^{-14} erg s^{-1} cm^{-2}**
- 31 from COSMOS (Civano+2015)
- 3 from ECDF-S (Mullaney+2015)
- 5 from EGS (Del Moro in prep.)
- 24 from Serendips (Lansbury et al 2017, Aird+2015 selection)



- Final sample: **63 sources**
  - Median redshift: ~0.58



Zappacosta et al. submitted

Spectral analysis

- Broad band: 0.5-24 keV
- NuSTAR + XMM and/or Chandra

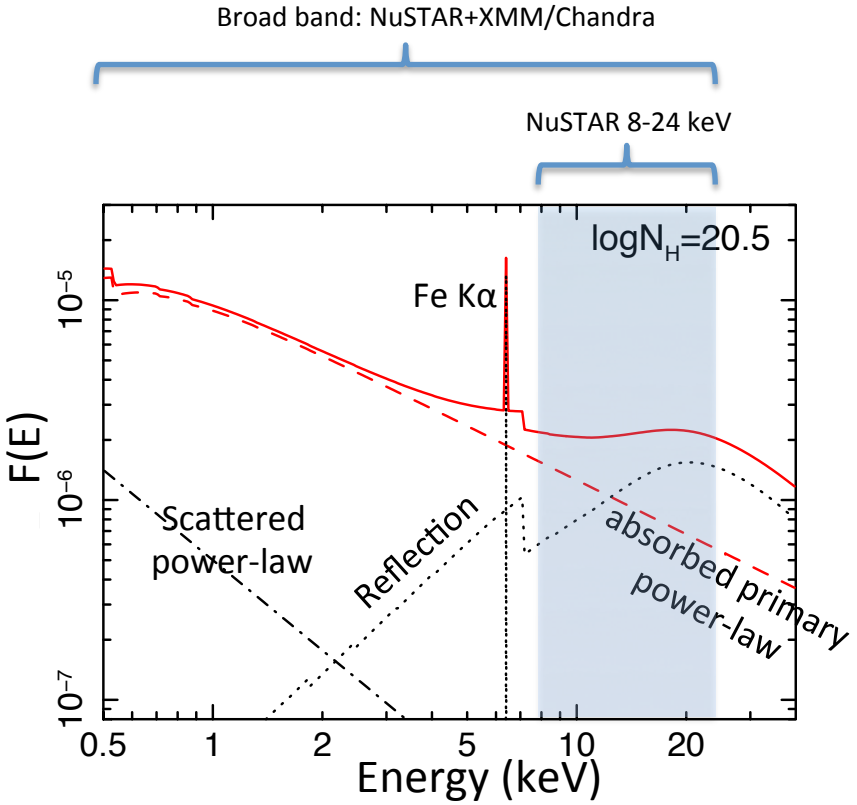
Modelling

Baseline model

- absorbed primary powerlaw + reflection component (pexrav) + scattered powerlaw

Torus models → for obscured sources

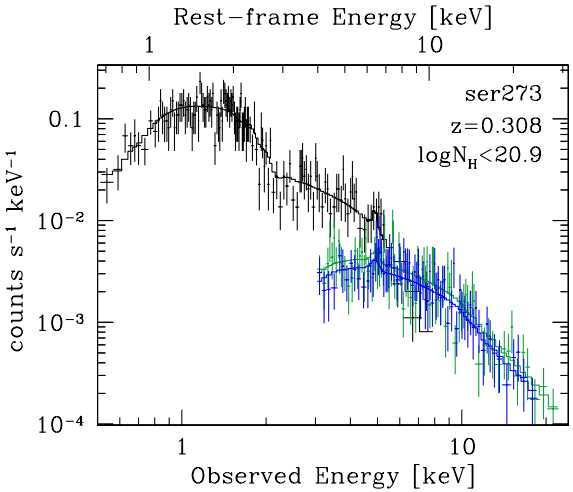
- BNTorus (Brightman & Nandra 2011)
- MYTorus (Murphy & Yaqoob 2011)

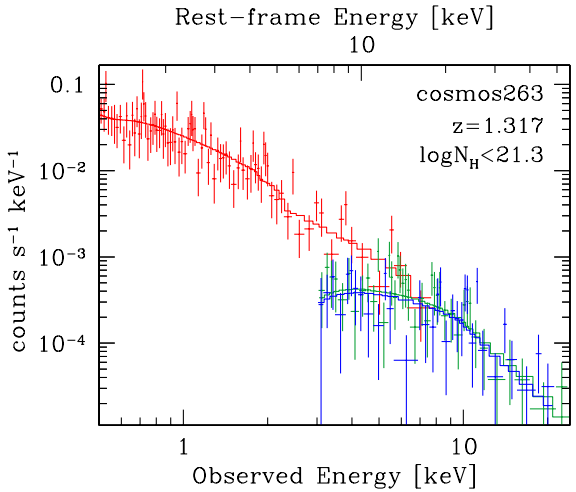


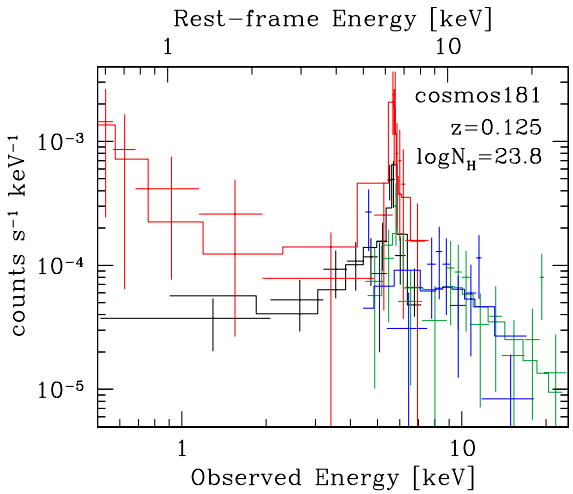
Sample spectra

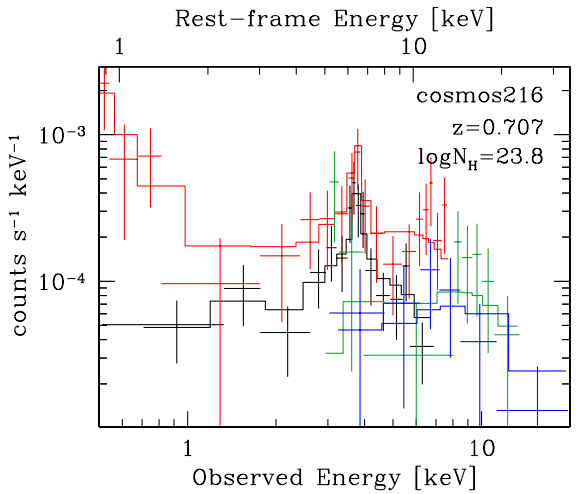
Unabsorbed

Absorbed







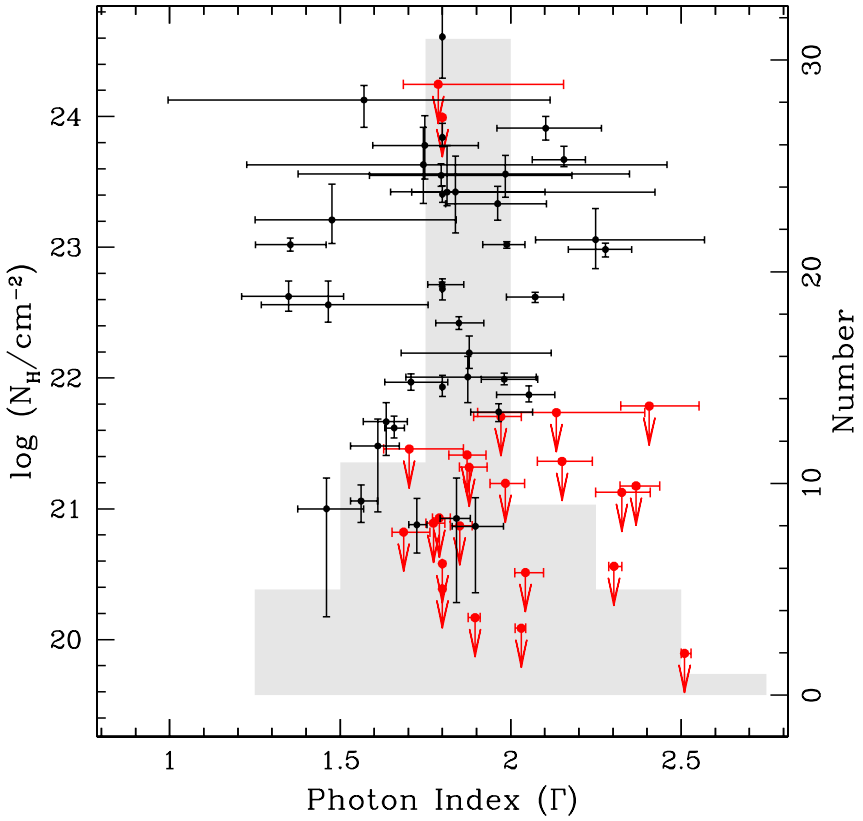


- Chandra,
- XMM,
- NuSTAR-FPMA
- NuSTAR-FPMB

Local

Distant

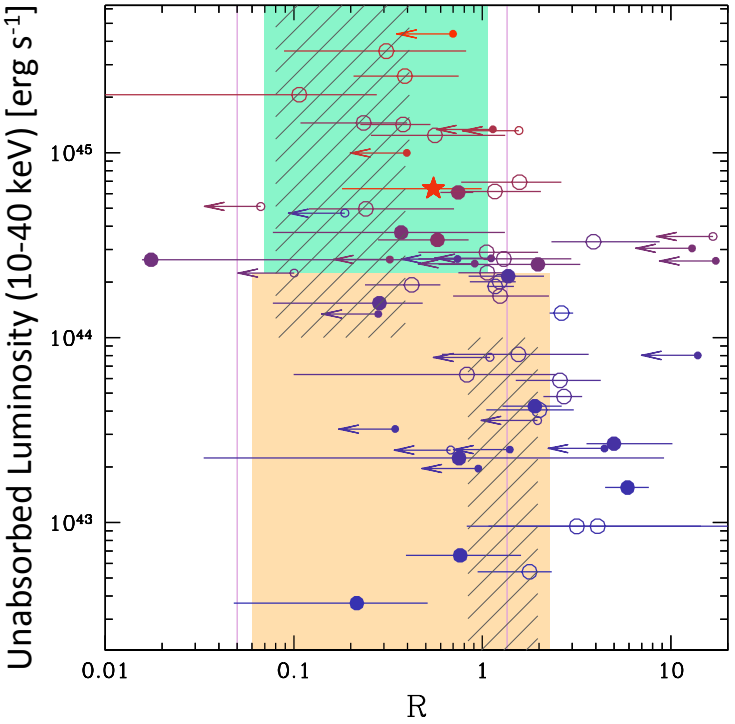
Photon index vs column density

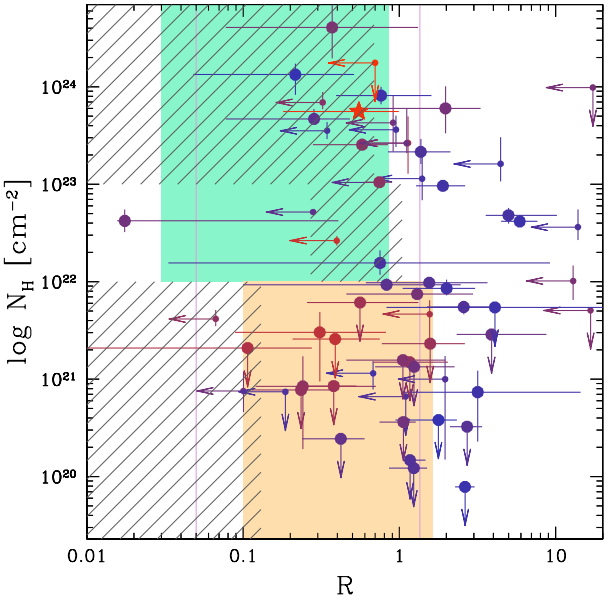


- 2 CT AGN
- 2 upper limits in CT regime
- Effective selection @ 8-24 keV
  - ~30% of heavily obscured AGN ($N_H > 10^{23}$ cm^{-2})
  - Similar selection on Swift-BAT
  - At lower energy much smaller fractions (e.g. Mainieri+2007, Lanzuisi+2013)

Characterizing the reflection

- <R>: 0.41
- Large scatter: 0.05-1.35



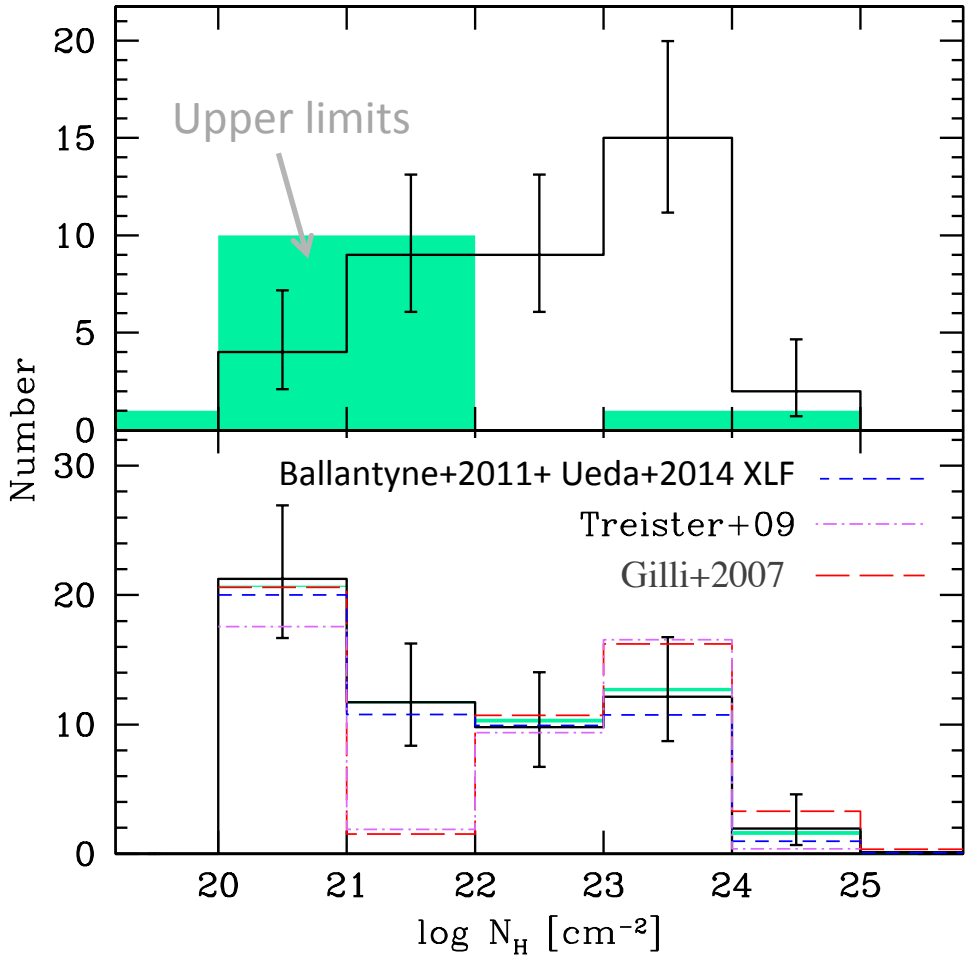


- Luminosity: significant anti-correlation
- N_H: hint of a weak anti-correlation

See also Del Moro et al. companion paper

Pop. Synthesis Models need to account for distribution in R and dependence in L_X

N_H distribution and model comparison



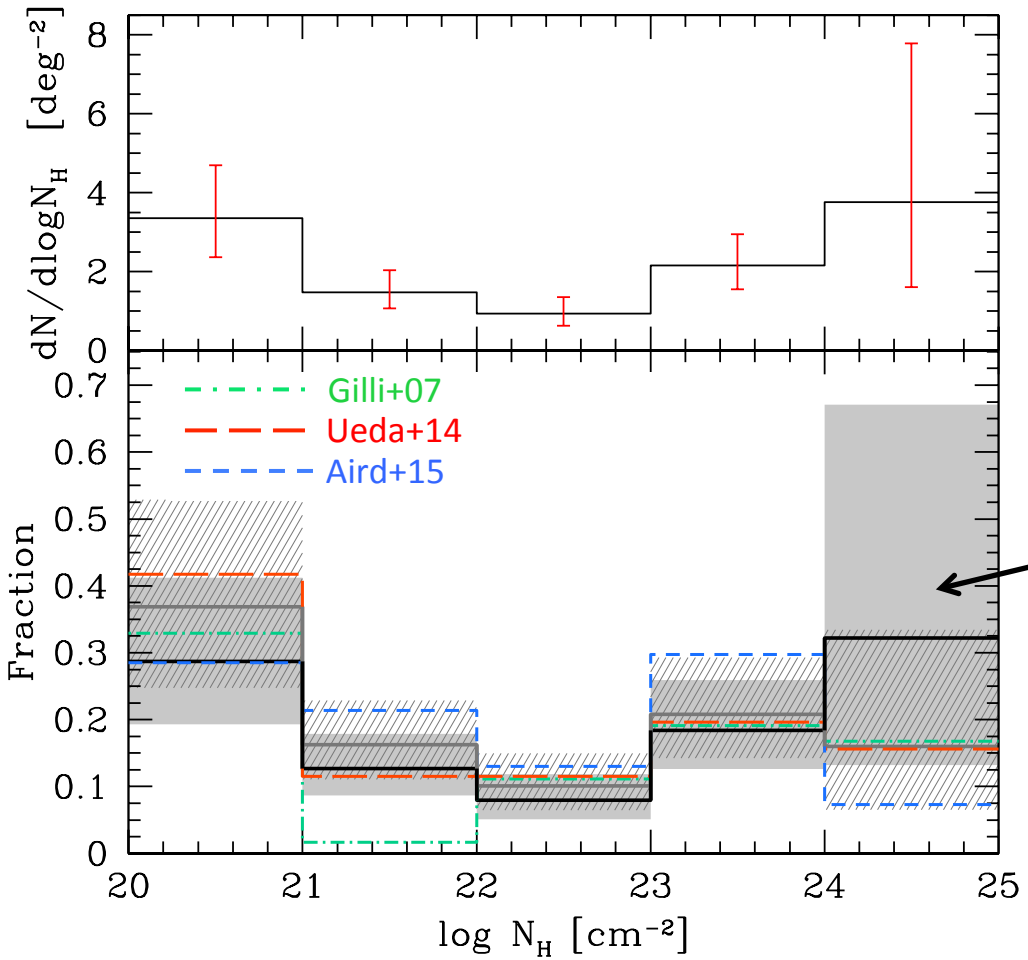
Observed N_H distribution

Solid: "Averaged" N_H distribution

- 1000 realizations of the sample with best fit values and upper limits randomly drawn

Dashed: models folded through the survey sensitivity

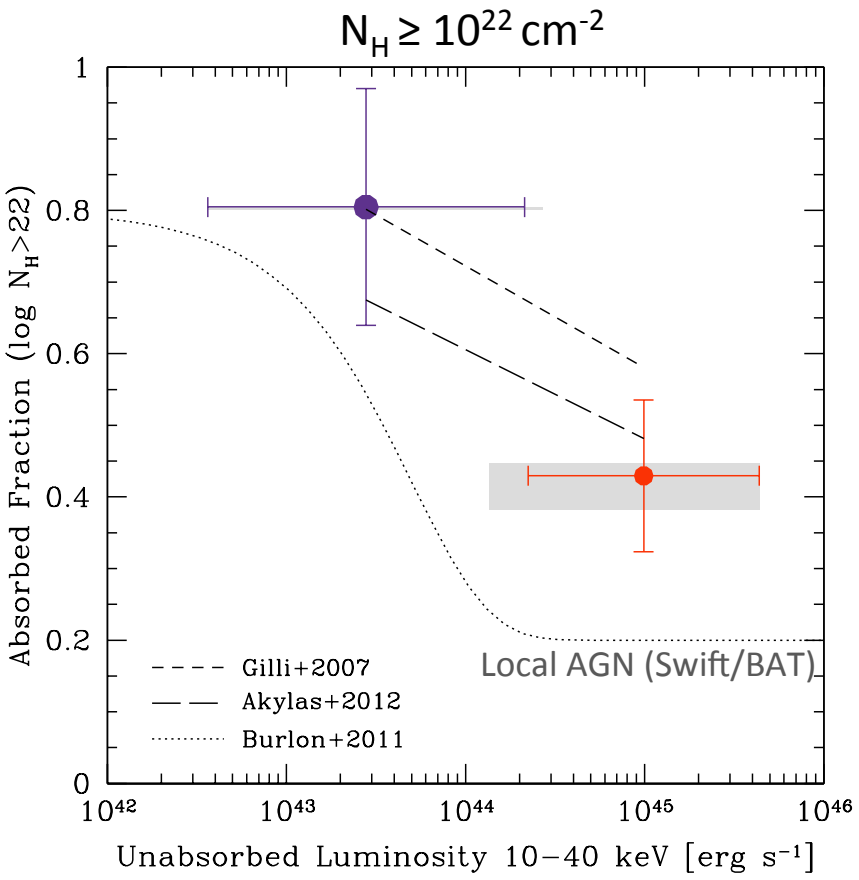
Intrinsic N_H distribution and CT fraction



Intrinsic N_H distribution – accounts for absorption bias

CT fraction 13-67%

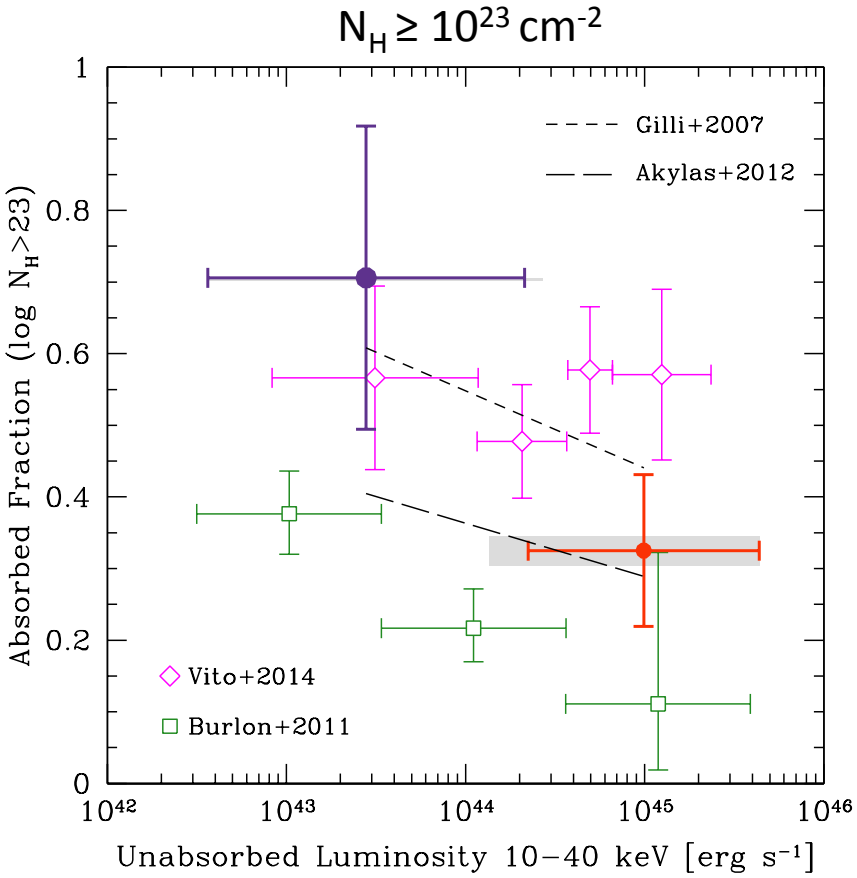
Fraction of absorbed sources



Past works on absorbed fractions:
- decrease in luminosity
- increase in redshift

- Whole sample: hint of decreasing trend
- Larger fractions than local AGN
- Agrees with Pop. Synthesis Models

Fraction of heavily absorbed sources



Comparison with AGN at z=0-0.3 (green) and z=3-5.1 (magenta)

→ increase in absorbed sources for luminous AGN with redshift

Consistent with two AGN populations:

- low-z low luminosity: secular evolution
- high-z high luminosity: strong chaotic accretion

Conclusions

- NuSTAR effective in selecting heavily obscured sources (~30% of the sample)… still only 2 CT AGN → limited sample size
- Low energy data crucial for good constraints on N_H
- Reflection parameter: broad scatter
  - Luminous sources tend to have smaller R
- N_H distribution → CXB synthesis model predictions consistent with data
- Fraction of CT in the range 13-67%.
- Absorbed fractions:
  - decreasing trend with luminosity
  - consistent with scenarions invoking two different accretion modes