ΙΑΑΔΕΤ

A precise census of compTON-thick AGN

using NUSTAR and SWIFT/BAT

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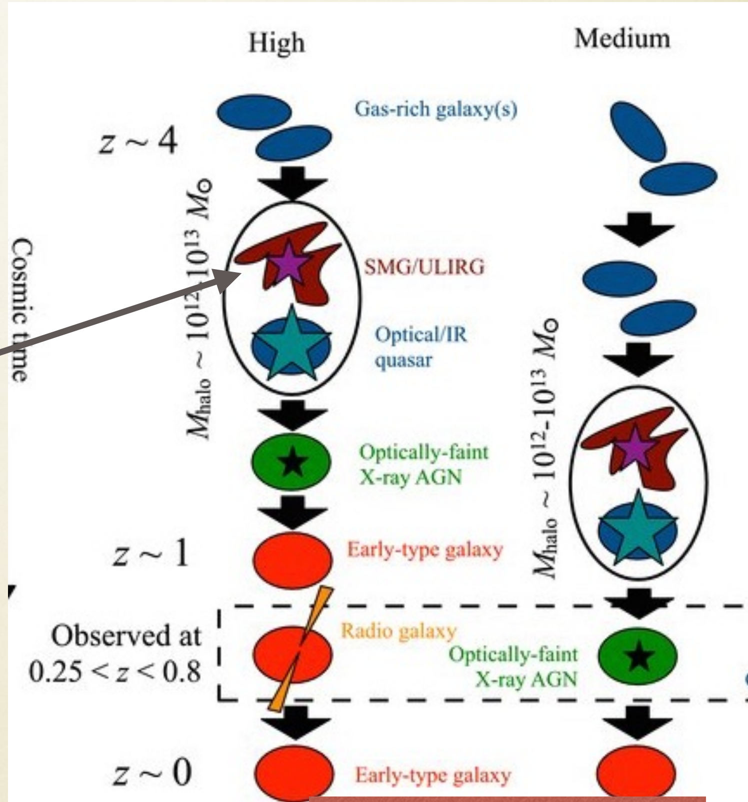
outline

- Brief Introduction to Compton-thick (CT) AGN
- Why CT AGN are important and how can we constrain their numbers ?
- Introduce our recent results on **CT AGN density using SWIFT/BAT in conjunction with recent CT NUSTAR spectra**

Why do we care so much about CT ?

- 1) CT AGN represent the dark side of accretion and **X-rays are most probably the only reliable way to find them** (at least the low luminosity ones see e.g. Ciesla+15)

CT ?



Hickox+10

- 2) according to models of galaxy formation, the Compton-thick stage may <u>mark the birth of an AGN</u> i.e. the period before it blows away the surrounding obscuring material

Previous work: diversity of results

- method 1. Soltan argument (see e.g. Marconi+06) 40-50% TOTAL AGN POPULATION
- method 2. X-ray background synthesis models (Comastri + 95) and many others (Gilli+2007, Treister+09, Akylas+12) ~**10-50% AGN**
- method 3. **Direct estimates** mainly at ultra-hard energies (>10 keV) Burlon +11, Ricci+15, Akylas+16) **ACTUALLY MEASURED 7%** (extrapolation 20%)
- More direct estimates from the 2-10 keV band COSMOS, CDFS (Georgantopoulos+13, Brightman+2014, Lanzuisi+15, Buchner+15). Buchner+15 **40%** contribution of CT to the XRB intensity (actually measured ~5-10% CT)
- In a nutshell, a wide range of estimates ranging from 10-50%

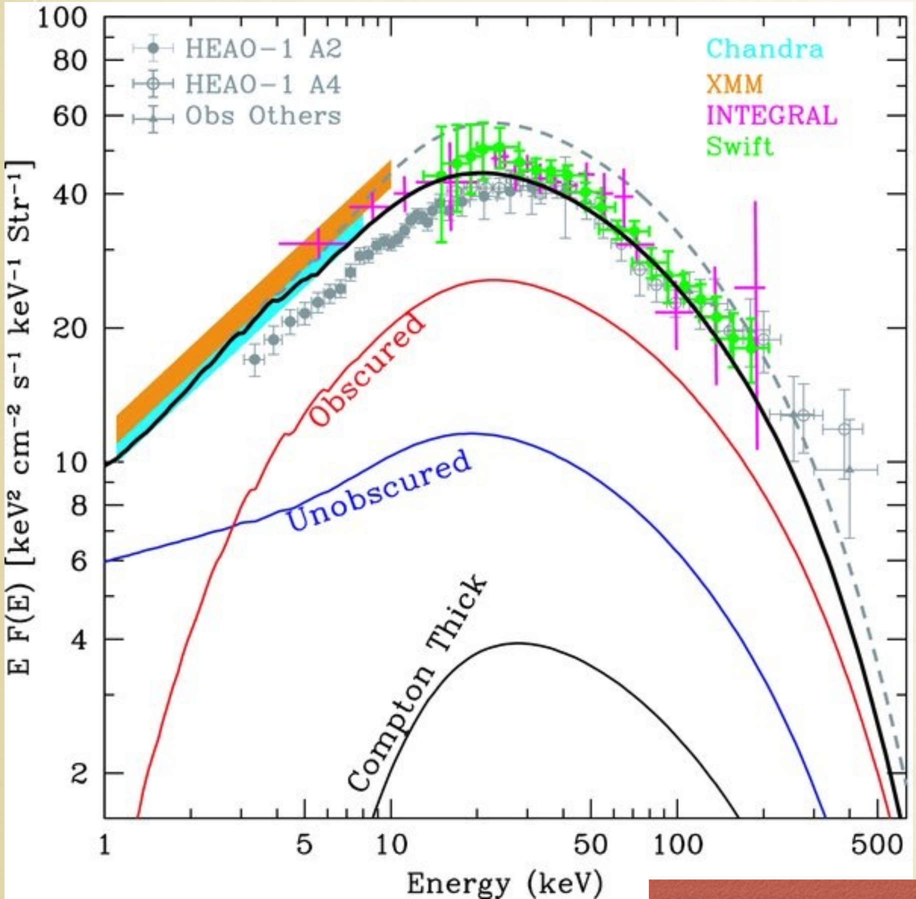
Soltan argument

- **One compares the AGN X-ray LF (current accretion rate) with the masses of BH in the local Universe (accreted mass)** Soltan 1982.
- So if not seen in the LF it must be obscured (or it radiates inefficiently)
- Marconi+2006 estimates 45% are CT AGN (assuming accretion eff. $\varepsilon=0.1$)
- Since then there are revised estimates of the local BH density (see discussion in Comastri+15)

X-ray background synthesis models

- The idea is that **we convolve the AGN LF together with the AGN spectrum**. This is then compared with the spectrum of the total X-ray light in the Universe the X-ray background Comastri+95
- See also Gilli+07, Treister+09, Ballantyne+12, Akylas+12 for
- The major point is that the hump of the XRB at 20-30keV -where most of its energy lies- can be reproduced only by using an adequately large number of CT AGN.

XRB synthesis



Gilli+07

- But how many exactly ?
- Examples of this exercise: Gilli+07, Treister+09,Akylas+12
- problem 1. there are too many free degenerate parameters, e.g. the spectrum of AGN (slope, cut-off, reflection) OF **ALL AGN obscured and unobscured**

First, Treister+09 then Akylas+12 tried to alleviate this degeneracy using the SWIFT number counts

- problem 2. There are considerable uncertainties in the XRB spectral measurements at high energies

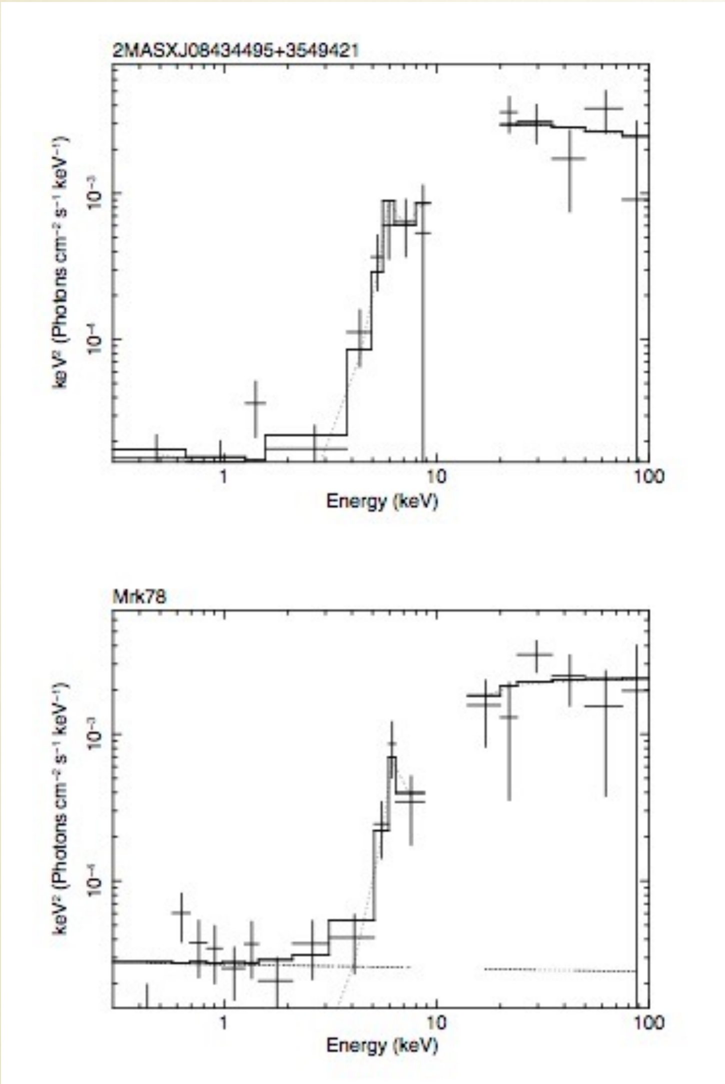
Direct ESTIMATES

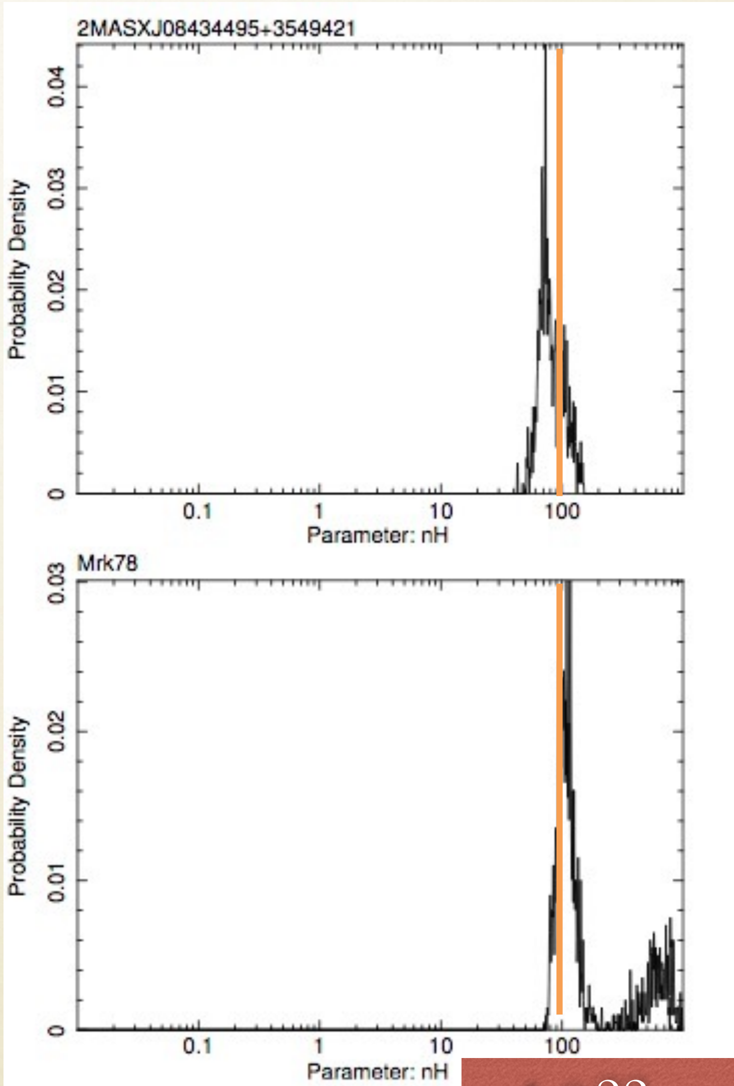
- hardest X-ray bands SWIFT/BAT 14-195keV
- Burlon+11 (measured 7% extrapolated to 20%)
- Ricci+15, Akylas+16   70-month survey more detailed work (Ricci including the data from all missions available, Akylas applied **Bayesian statistics**)

CT AGN IN SWIFT/BAT

- The 70-month SWIFT/BAT catalogue (Baumgartner et al. contains 688 'likely' AGN
- Akylas et al. find 51 candidate CT AGN performing XRT+BAT spectral fits (probability of a few to 100%)
- the novelty is that Bayesian statistics are used in XSPEC and therefore each objects is assigned a particular probability i.e. it is not a BLACK or WHITE situation "CT" or 'not CT".
- This has important implications for the LF or logN-logS derivation.

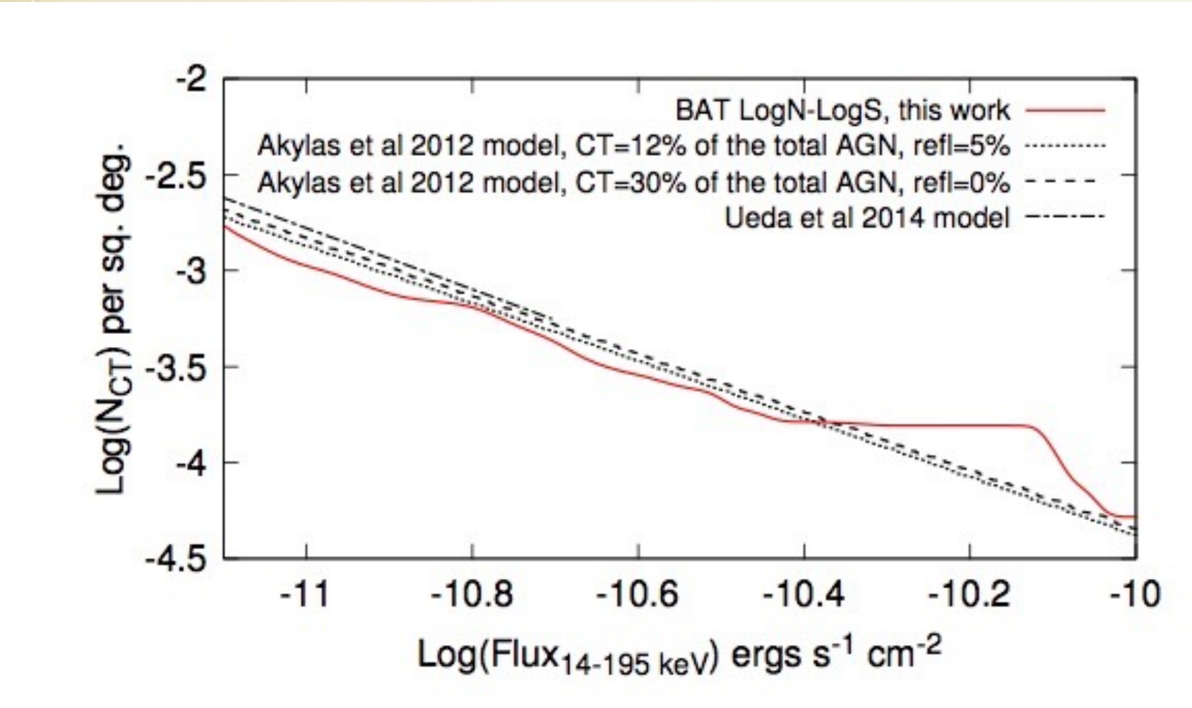
SWIFT/BAT CT examples





$x10^{22}$ cm^{-2}

logN-logS in SWIFT/BAT

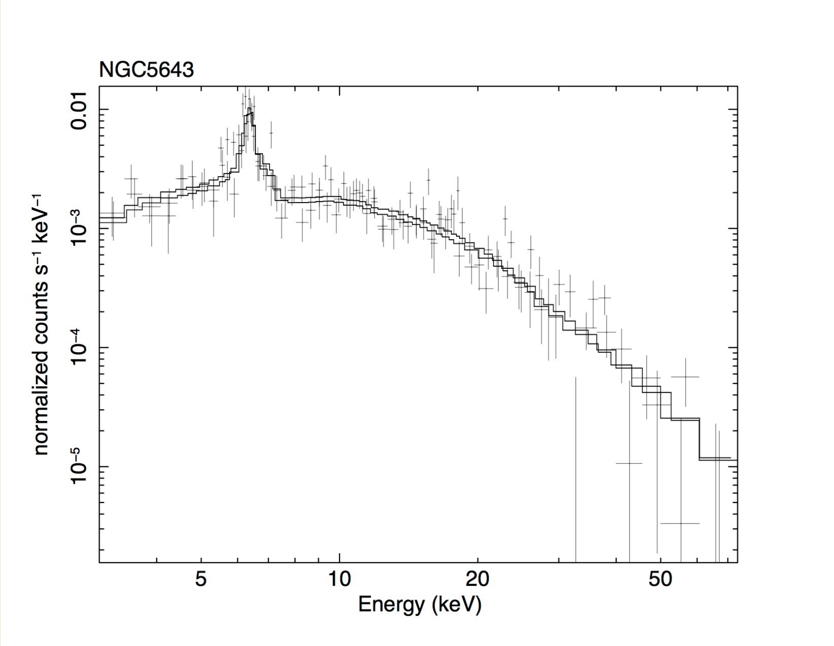


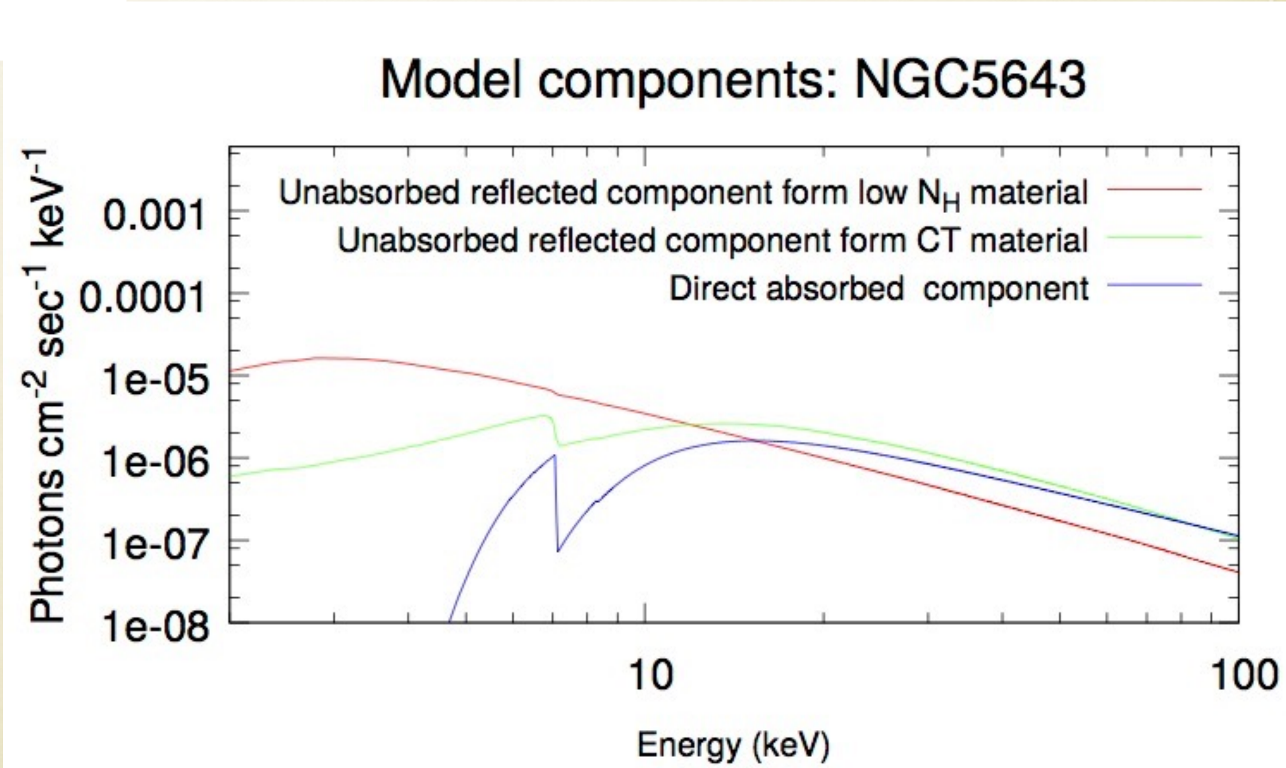
- logN-logS: observation (RED) vs models for both reflection 5% and 0%
- CT fraction varies between ~10-30%

We can increase or reduce the INTRINSIC number of CT by a factor of 2.5 by changing the reflection !

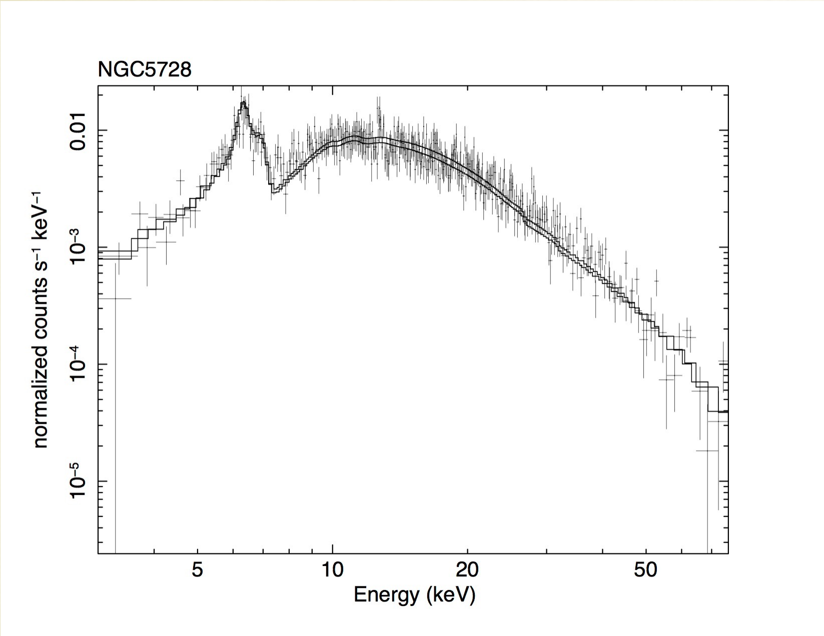
NuSTAR spectra of CT AGN

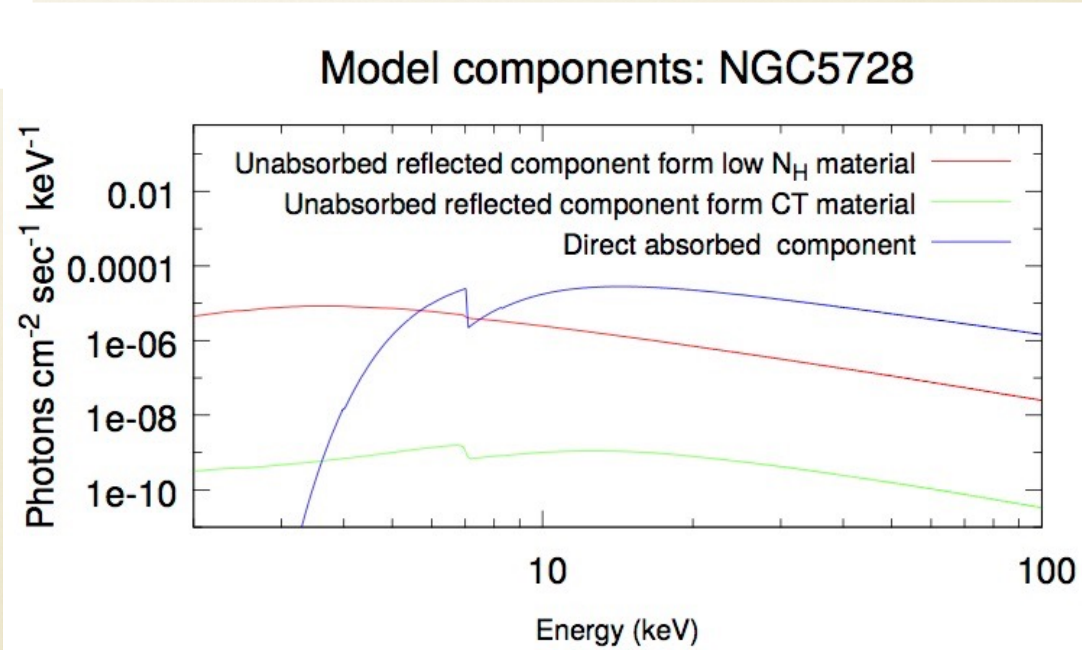
- 19 CT AGN with prob > 70% have been observed by NUSTAR
- We derive their spectra putting constraints on their spectral shape (Γ, **Reflection**) Ec=100 keV
- Mytorus model Yaqoob & Murphy in decoupled mode


NGC5643
normalized counts s⁻¹ keV⁻¹
0.01
10⁻³
10⁻⁴
10⁻⁵
5
10
20
50
Energy (keV)


Model components: NGC5643
Photons cm⁻² sec⁻¹ keV⁻¹
Unabsorbed reflected component form low N_H material
Unabsorbed reflected component form CT material
Direct absorbed component
0.001
0.0001
1e-05
1e-06
1e-07
1e-08
10
100
Energy (keV)

NGC5728: Low hARD reflection





RESULTS & IMPLICATIONS

- No significant hard reflection in the majority of cases
- Reflection to low Nh material in most cases which dominate the flux <10keV (see also Yaqoob 2012 in the case of NGC4945)
- Average reflected flux in the 20-40 keV is ~8%
- Assuming that the CT AGN here are the STANDARD, the INTRINSIC fraction of Compton-thick sources is roughly 25% (of the total AGN population) -cf Burlon 2011
- We have analysed a limited CT sample in the local Universe. ONLY in the <u>extreme case</u> where most CT sources farther away (z~0.7) resemble NGC5643, then the INTRINSIC fraction of CT AGN will be ~15%.
- Another important parameter not fully yet taken into account is the AGN power-law cut-off.A cut-off at 60-70 keV would decrease the reflection and hence increase the number of CT.

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SUMMARY

- The simplest place to begin with to find the number density of CT AGN is ultra-hard X-rays (>10 keV)
- The OBSERVED number is 7% BUT one can extrapolate to the INTRINSIC NUMBER by using the spectrum of CT AGN.
- This can be derived using the average NUSTAR CT AGN spectrum
- Based on the NUSTAR spectrum of 19 SWIFT/BAT selected AGN , most CT spectra appear to have a low level of HARD ~10^24 cm-2 or higher reflection
- This suggests a fraction of ~25% CT AGN

THE END

NAME	
Circinus	9
NGC6240	3
NGC4945	3
NGC424	6
2MFGC2280	13
NGC1068	17
NGC1194	7
MCG06-16-028	3.3
NGC3079	0.7
NGC3393	0.5
NGC4941	7
NGC5728	1
ESO137-34	10
NGC7212	5
NGC1229	10
NGC6232	5
2MASXJ09235371	0.3
NGC5643	53
NGC7130	12
MEAN	9 % (0-21%)

Both soft and hard reflection i.e. NH~10^{22-23}

NH~10^{24}

E_C=100 keV