X-ray Spectroscopy of Compton-thick AGN & the Infra-Red Connection

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Exploring the Extreme Universe

Leicester 50 year anniversary, July 2010

Overview

★ How do we model Compton-thick AGN? -> *ad hoc* models cannot yield column density and other physical parameters.

★ Continuum & fluorescent line spectra from self-consistent physical models -> new spectral-fitting model now available. Comparison with conventional methods.

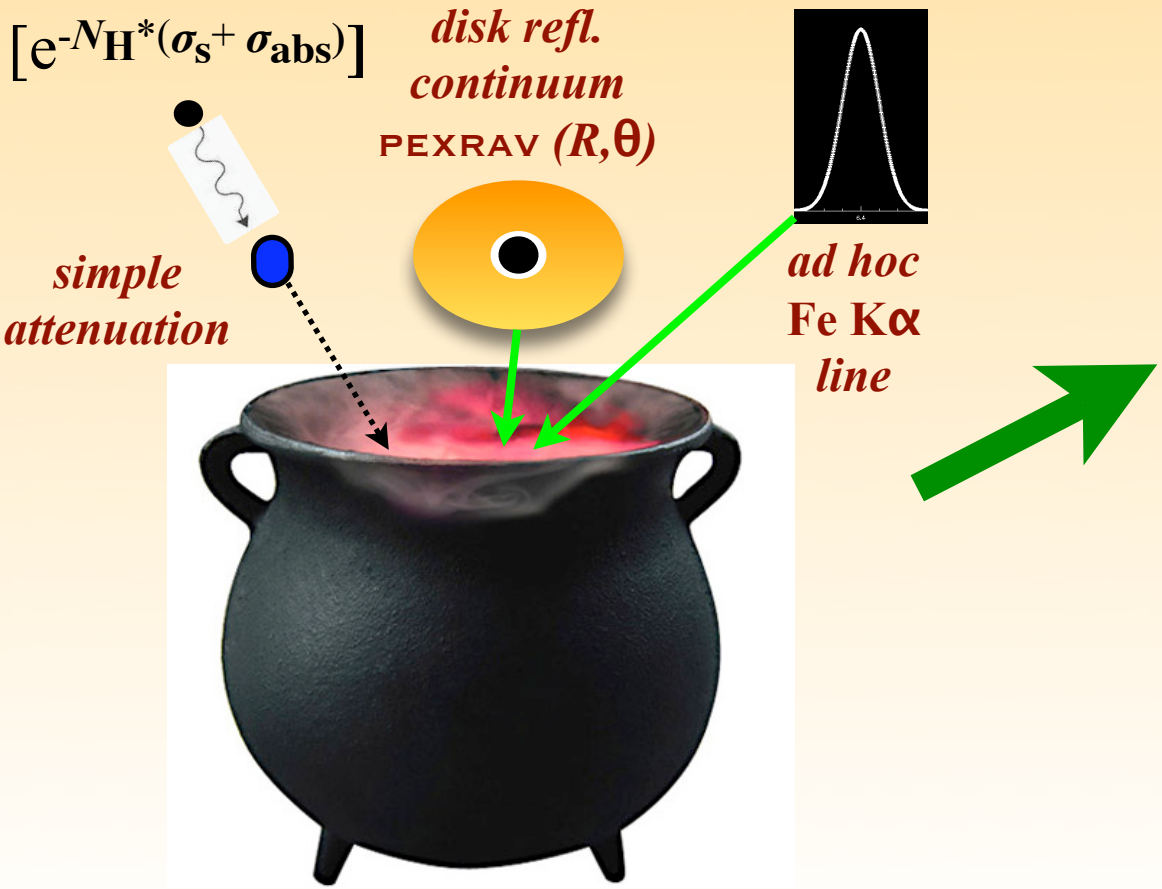
★ Swift BAT & other hard X-ray AGN surveys- where are the CT AGN?

★ Energy losses in the obscuring structure: is the IR/X-ray ratio an indicator of column density? Quantify the relationship between IR to X-ray ratio and column density as well as other parameters.

To be or not to be Compton-thick

★ Strictly, $N_H > 1.24 \times 10^{24}$ cm^{-2} . But what N_H? Column and intrinsic X-ray luminosity are highly model-dependent *even with high SNR*.

★ Usual (ad hoc) procedure: [high snr & cxrb models] simple l.o.s. attenuation plus disk-reflection (PEXRAV) to mimic Compton scattering:



- *Cannot relate any of the components to each other, in particular R, N_H, and* Fe Kα *line EW.*
- *Amplitude of reflection, R, is arbitrary, θ has no meaning in this context: scattered continuum is highly geometry and angle-dependent.*
- *No physical meaning can be assigned to derived parameters, including element abundances and intrinsic luminosity.*

Yaqoob & Murphy, Leicester 2010

Brewing the CXRB

N_H distribution f(L,z)

luminosity function

evolution

spectral templates

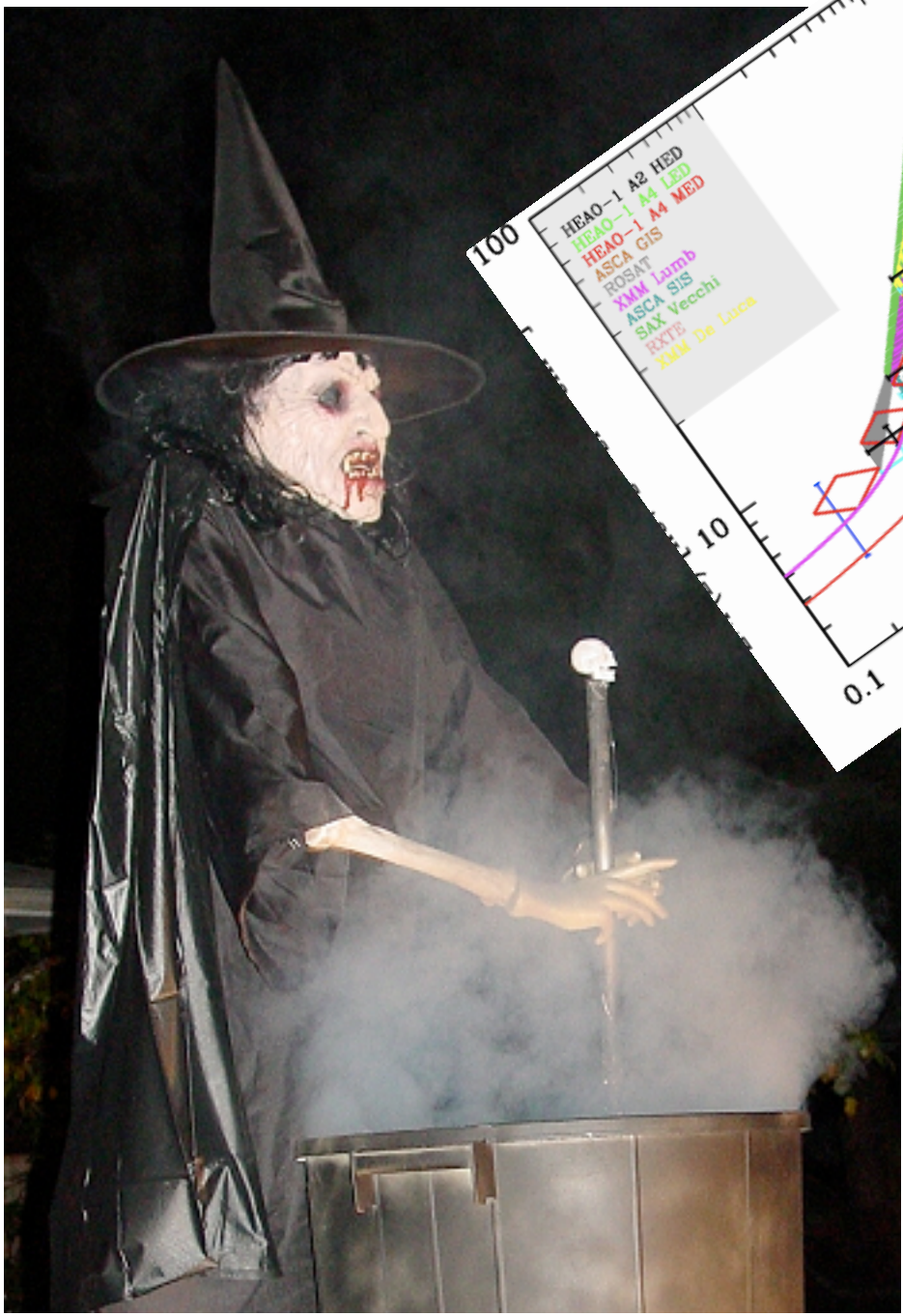
fraction of each "type"

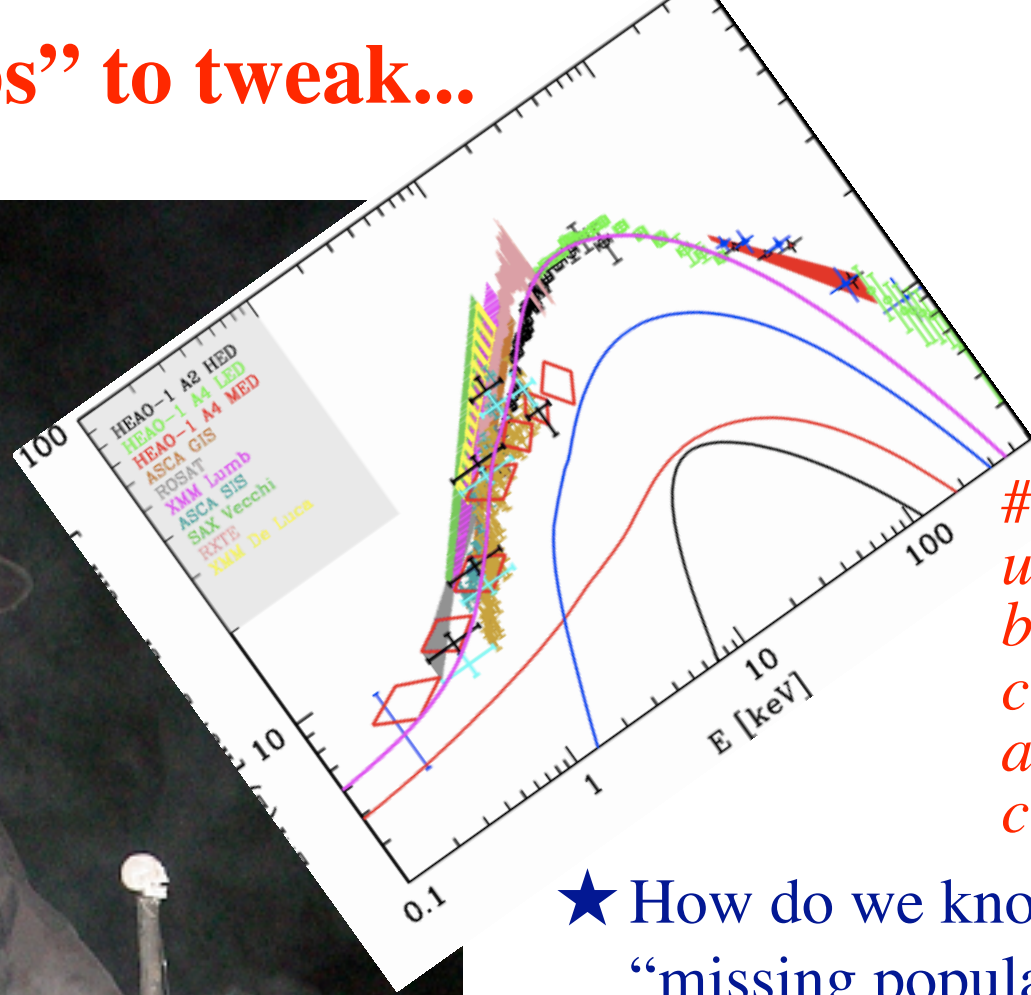
deep surveys

Derived column density distribution is based on ad hoc models with arbitrary sets of assumptions about components of the model that bear no physical relationship to each other -different groups have obtained different column density distributions.

Yaqoob & Murphy, Leicester 2010

Many "knobs" to tweak...





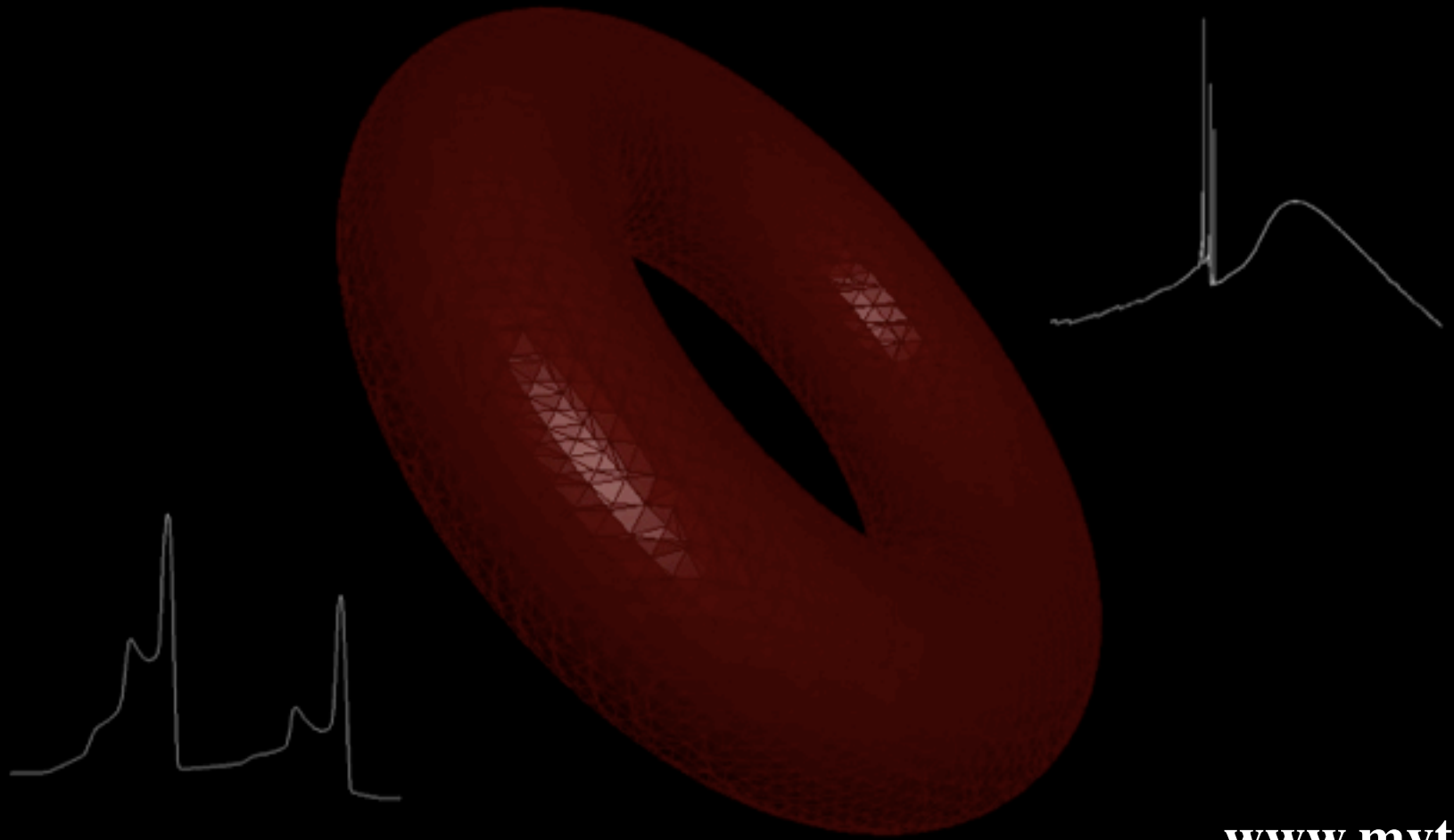
#of knobs unnecessarily high because the model components are ad hoc and don't enforce correct physics.

★ How do we know there is a "missing population" of CT AGN when the spectra are modeled with ad hoc, non-physical models?

★ Spectral templates used for the "missing population" are also unphysical. No continuity in C-thin & C-thick definition of templates.

Yaqoob & Murphy, Leicester 2010

MYTorus Compton-thick X-ray Reprocessor Model



www.mytorus.com

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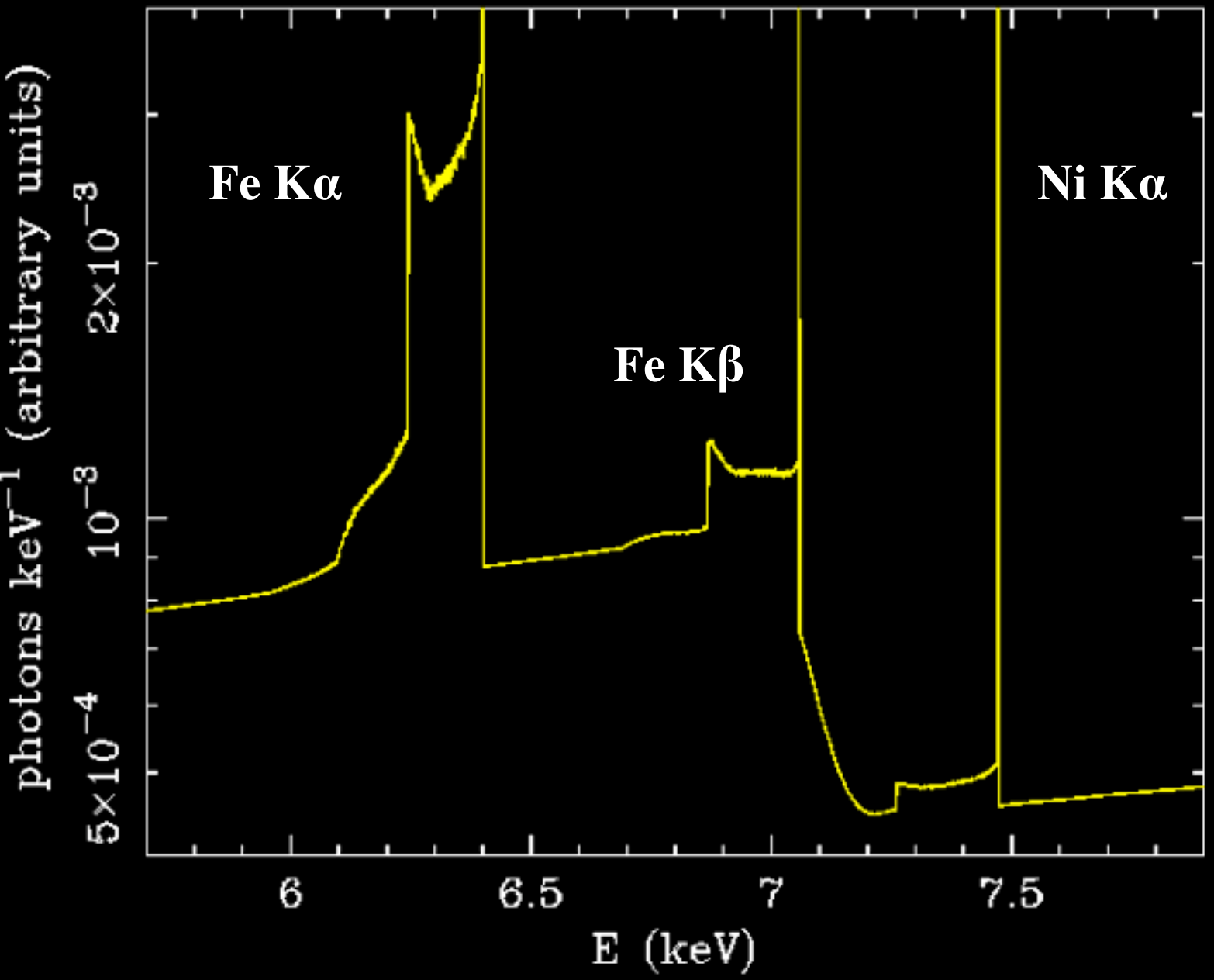
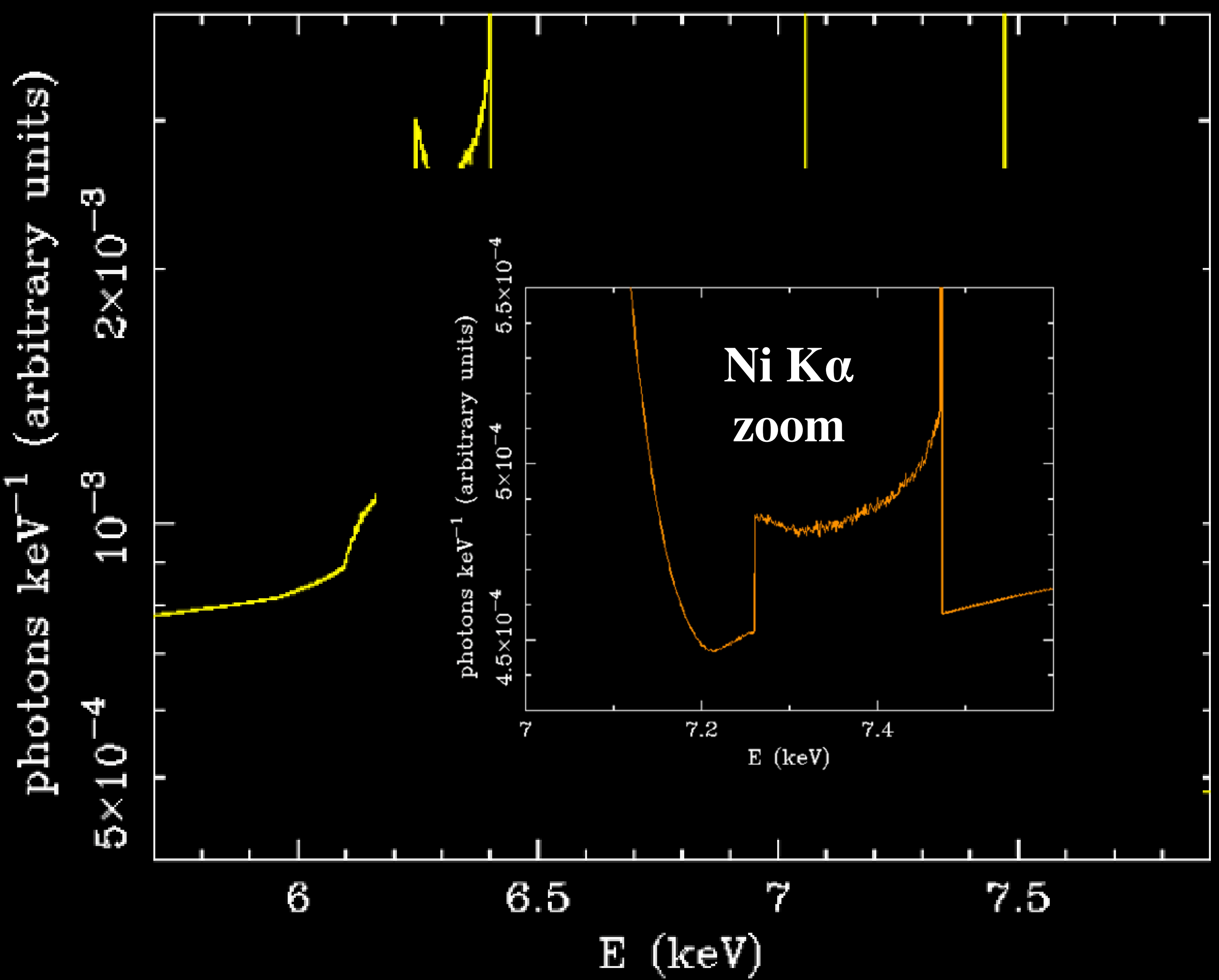
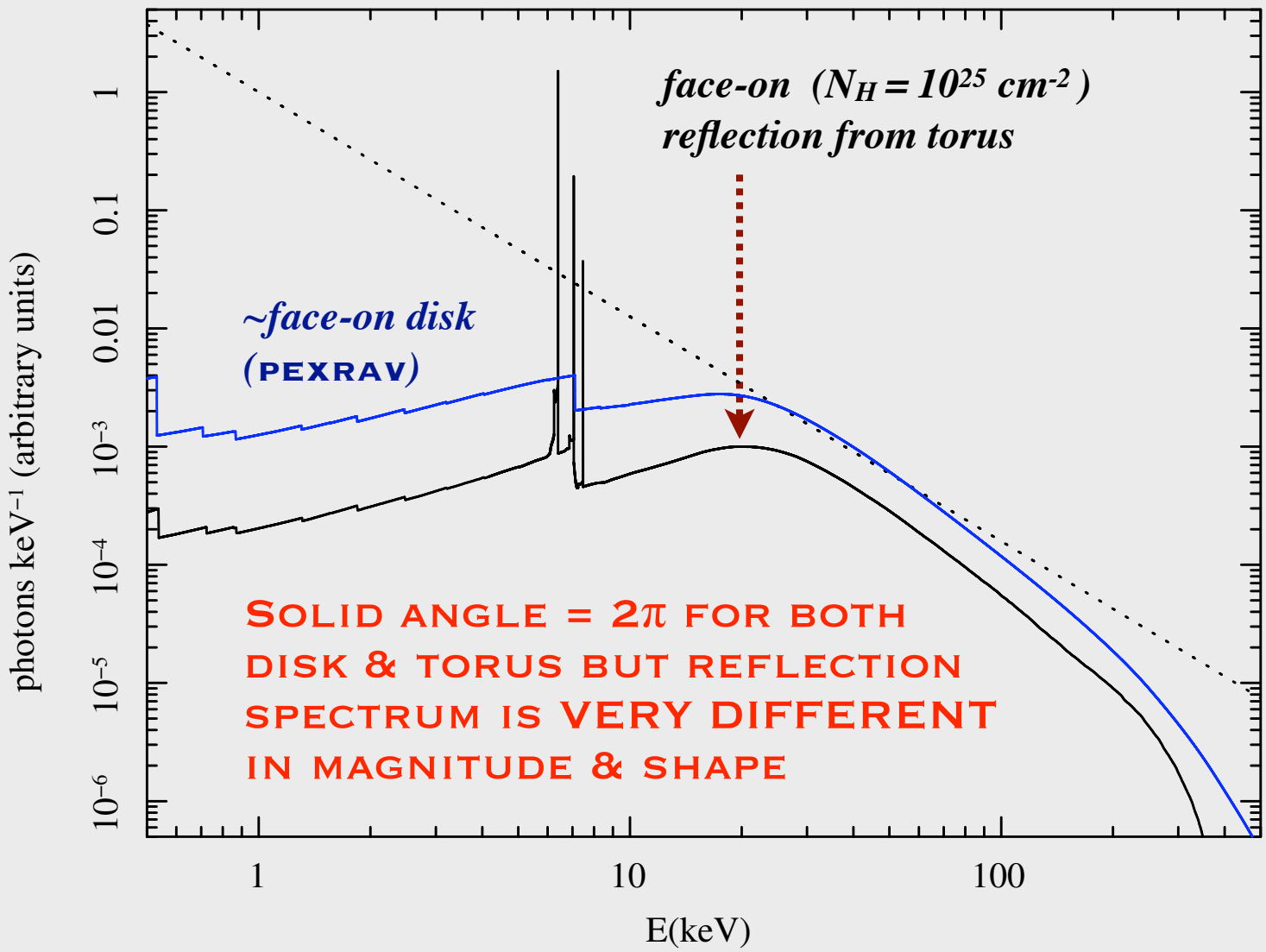

Fe Kα
Fe Kβ
Ni Kα
photons keV^{-1} (arbitrary units)
5×10^{-4}
10^{-3}
2×10^{-3}
6
6.5
7
7.5
E (keV)



photons keV^{-1} (arbitrary units)
2×10^{-3}
10^{-3}
5×10^{-4}
6
6.5
7
7.5
E (keV)
Ni Kα
zoom
photons keV^{-1} (arbitrary units)
5.5×10^{-4}
5×10^{-4}
4.5×10^{-4}
7
7.2
7.4
E (keV)

Direct comparison of toroidal reflection spectrum with PEXRAV

Severe geometry dependence because of angle-selection



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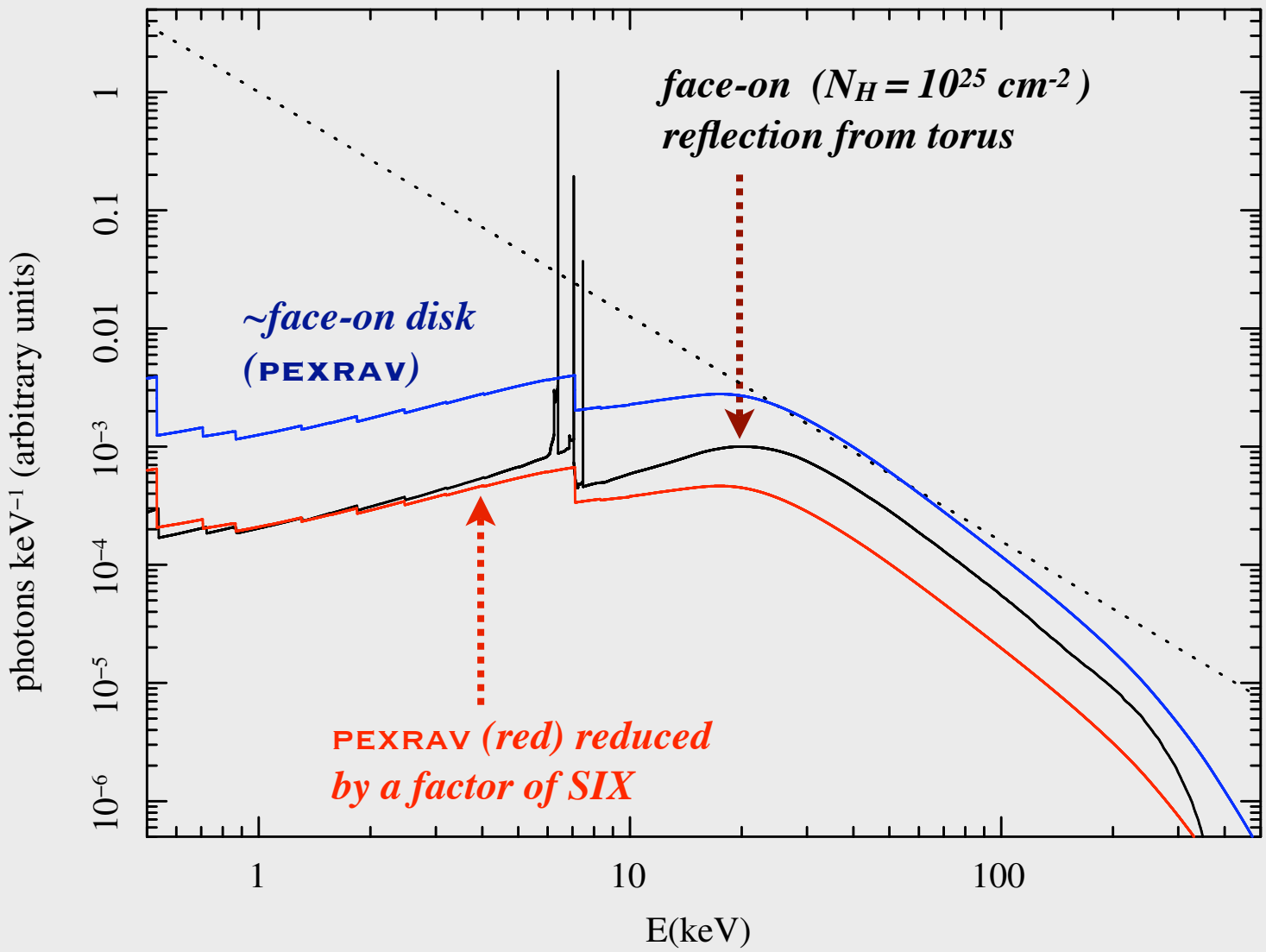

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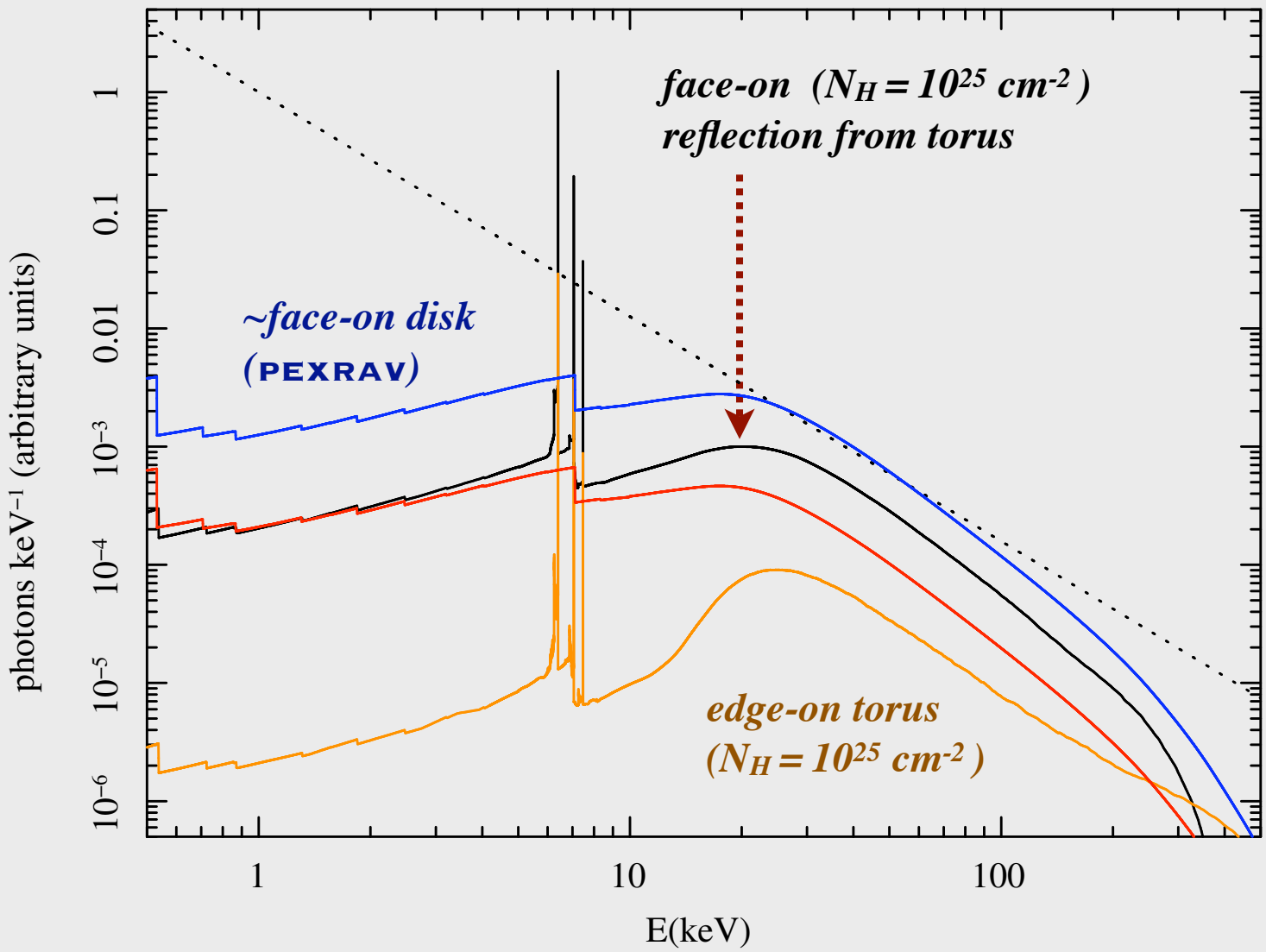

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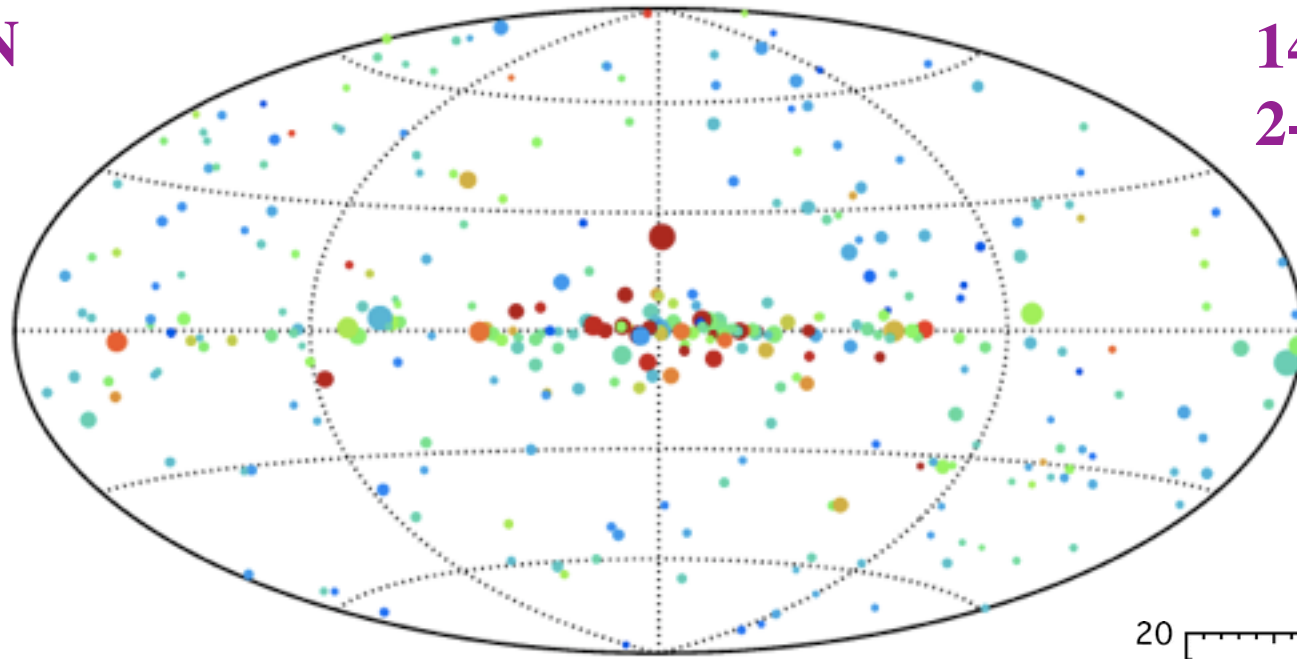
Hard X-ray Surveys: find the Compton-thick AGN?

(Swift BAT, INTEGRAL)

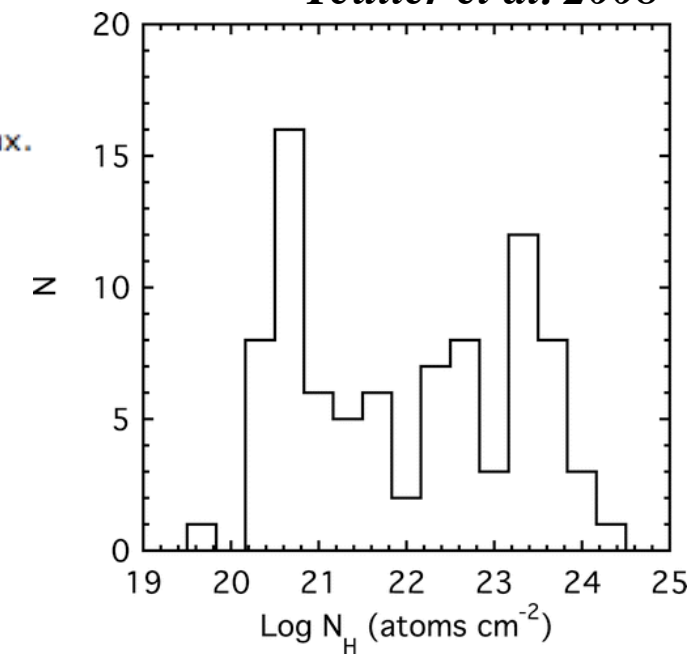
BAT AGN sample



Red dots are soft sources, blue are hard sources,
and the dot diameter is proportional to the source flux.

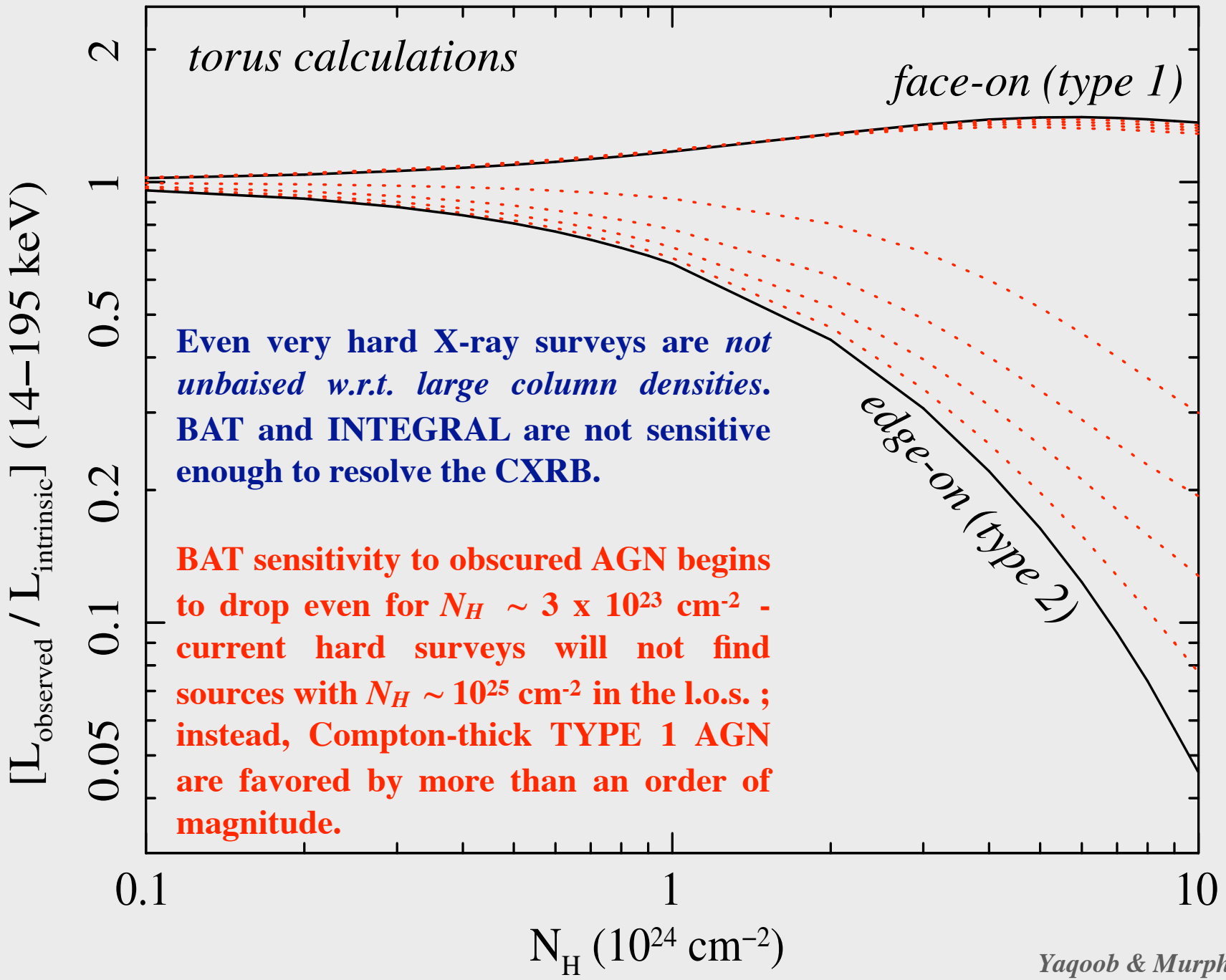
14-195 keV, 2-5 arcmin

Teuller et al. 2008



N_H distributions do not show up the Compton-thick AGN. Where are they?

Where are the Compton-thick AGN?



Yaqoob & Murphy, Leicester 2010

The IR:X-ray signature of CT AGN

How do we measure N_H for weak sources (e.g. in deep surveys)?

★ X-ray spectroscopy unfeasible

★ Hardness ratios degenerate

★ Optical to X-ray ratio? Large uncertainties.

We calculate the total energy loss (absorption and Compton-scattering) using our X-ray reprocessing code:

(i) per keV as a fraction of the incident energy per keV (independent of the shape of the input spectrum: what energies are most important for heating?);

(ii) cumulative energy loss as a fraction of the total incident energy, as a function of incident spectral shape, and column density;

(iii) (total energy loss as a fraction of the incident energy)/ (observed:intrinsic X-ray luminosity ratio) [proxy for the IR:X-ray ratio used to identify CT AGN].

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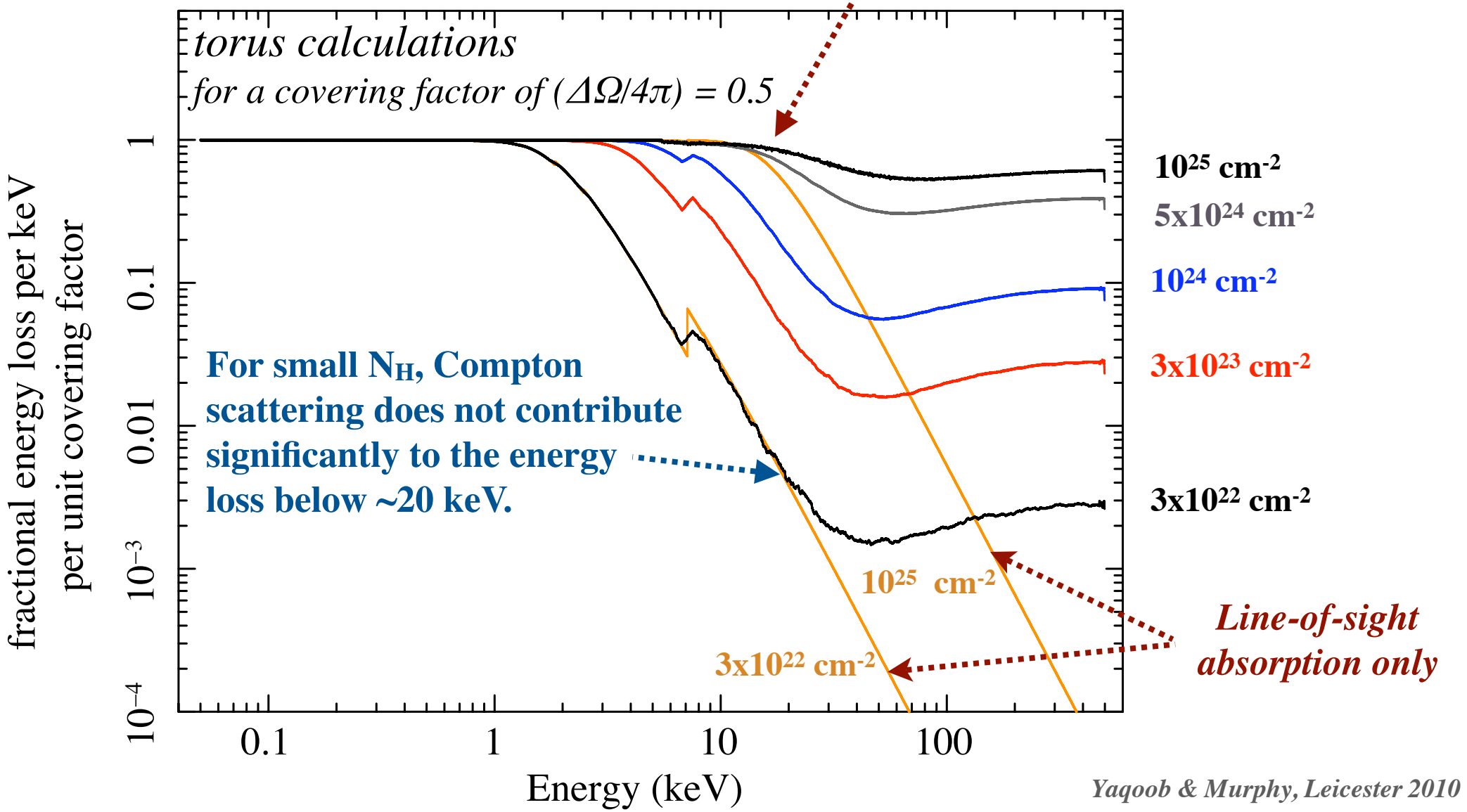
Fractional energy loss per keV per unit covering factor

If a source is Compton thick, the difference between an absorption-only model and one which includes both Compton scattering and absorption is very large above 10 keV.



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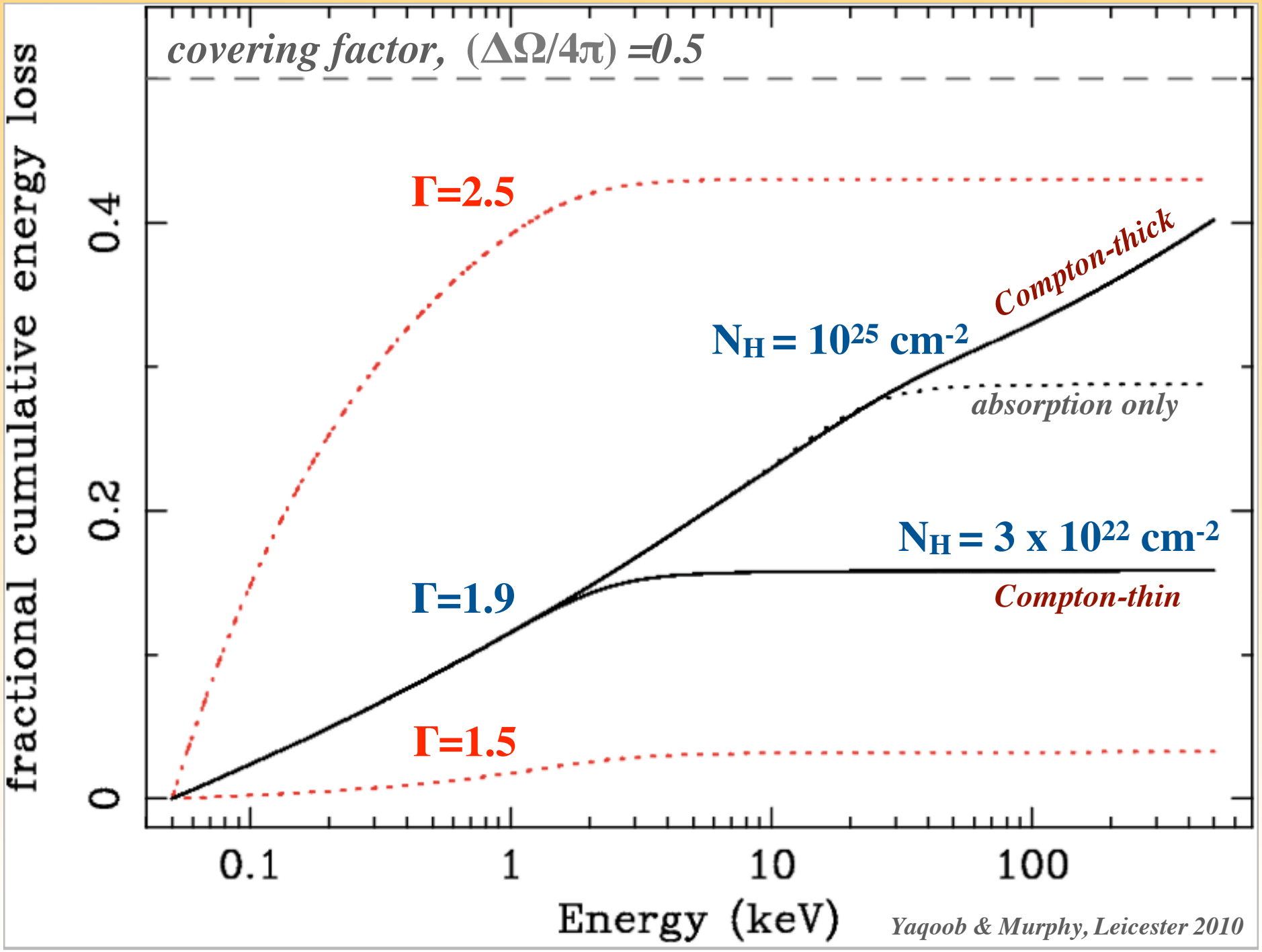
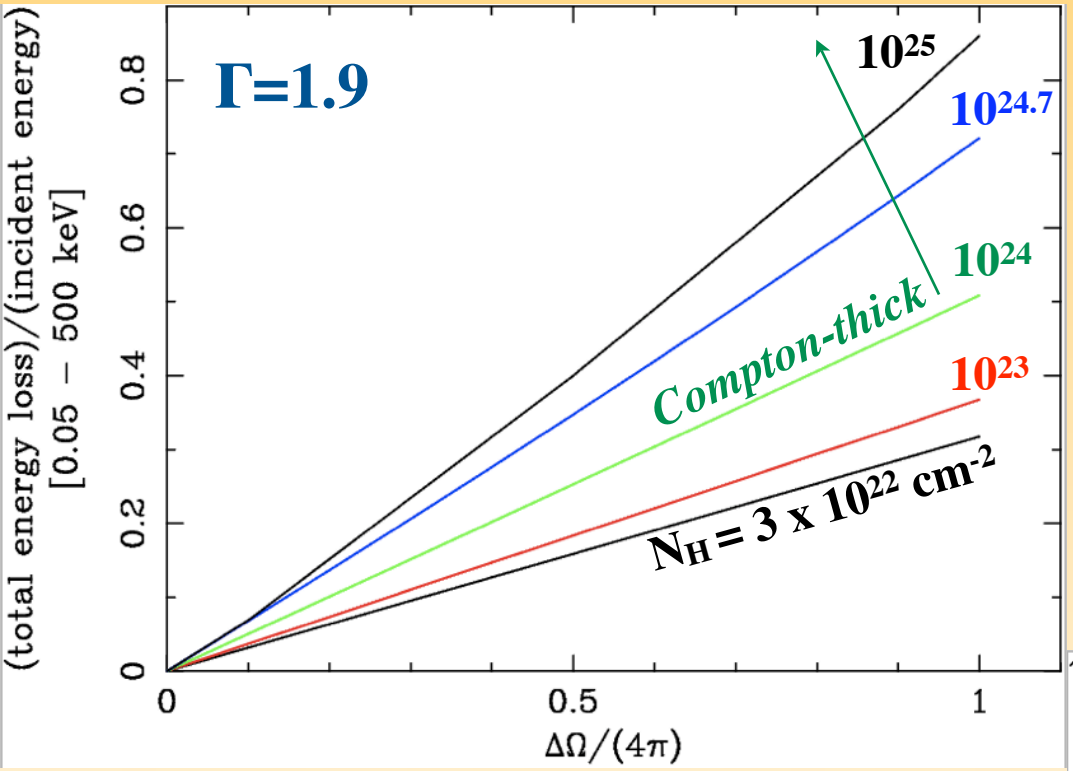
Cumulative fractional energy loss

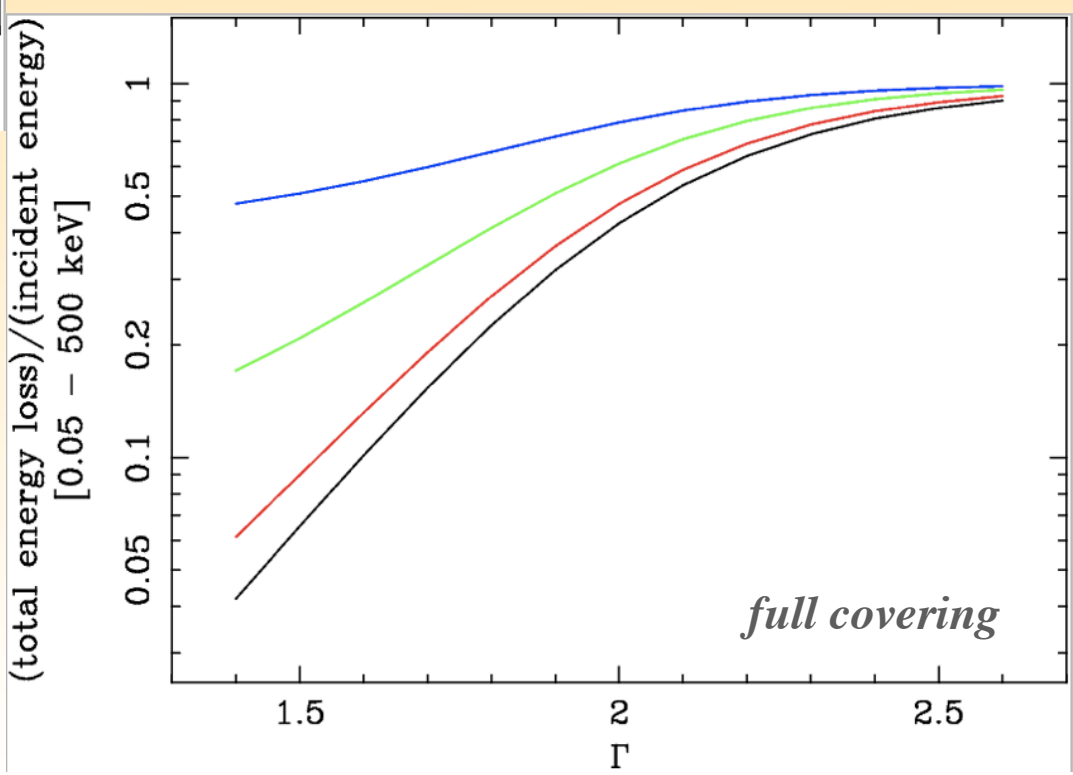


Covering factor and incident spectrum



Energy loss in the reprocessor is approximately linear as a function of covering factor.

Difference between Compton-thin and Compton-thick reprocessor need not be great: it could be much less than an order of magnitude.

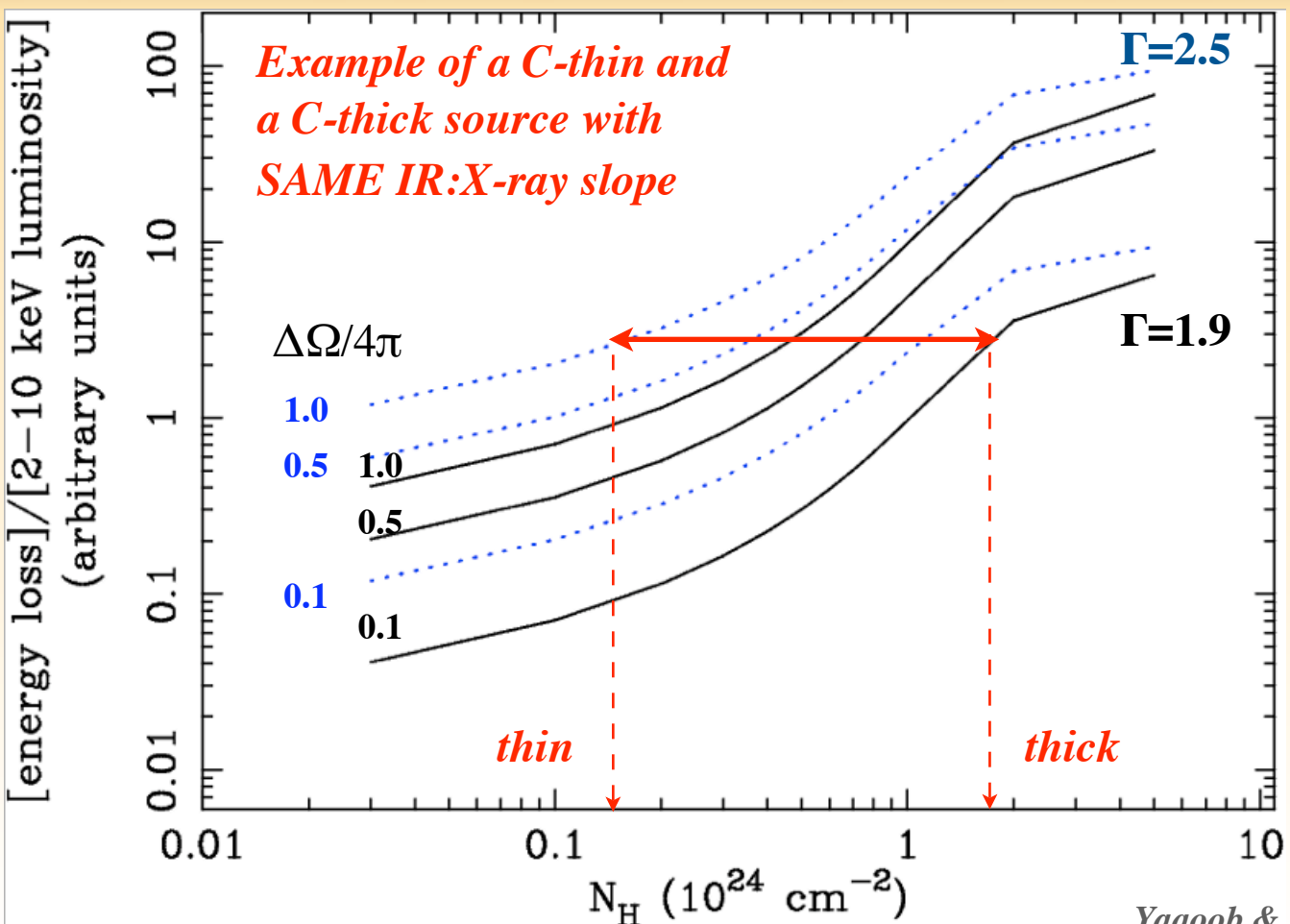


Fraction of incident energy lost in the reprocessor (->heating ->IR) strongly depends on steepness of the incident spectrum. For **Γ=2.5** *the difference between Compton-thin and Compton-thick energy loss is <20% !!*

Yaqoob & Murphy, Leicester 2010

Degeneracy of the IR:X-ray signature

★ IR:X-ray ratio from the X-ray reprocessing contribution in a Compton-thin AGN can be the SAME or MORE than a Compton-thick AGN.
★ The dependence of IR/X on covering factor and steepness of intrinsic continuum can be stronger than the dependence on N_H .
★ Of course there will be other contributions to IR/X (e.g. starburst) this can only make the lack of correlation of IR/X with N_H WORSE.



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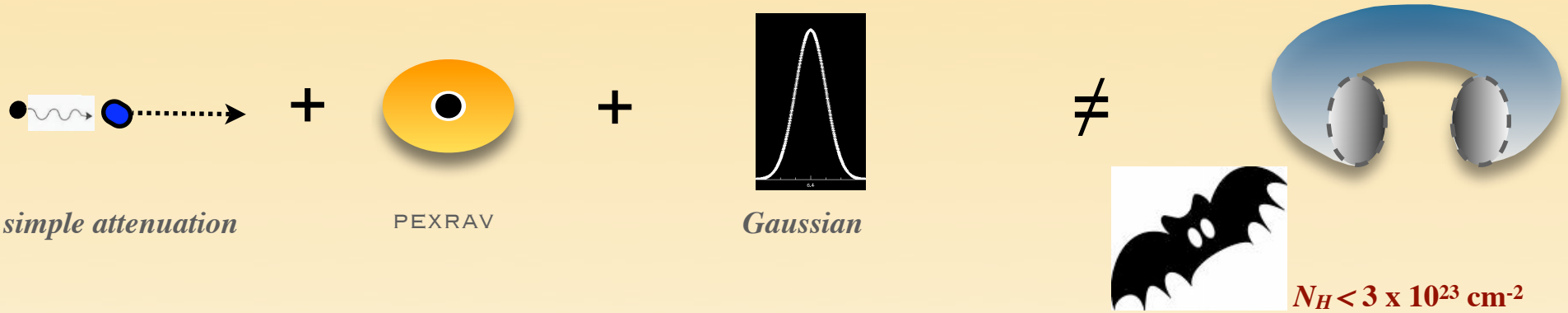
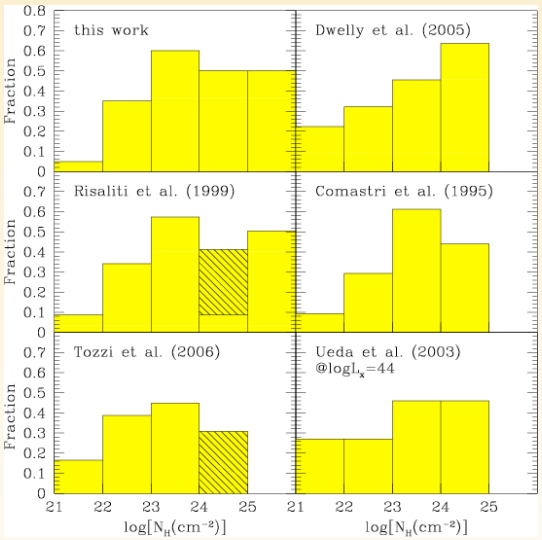
Summary



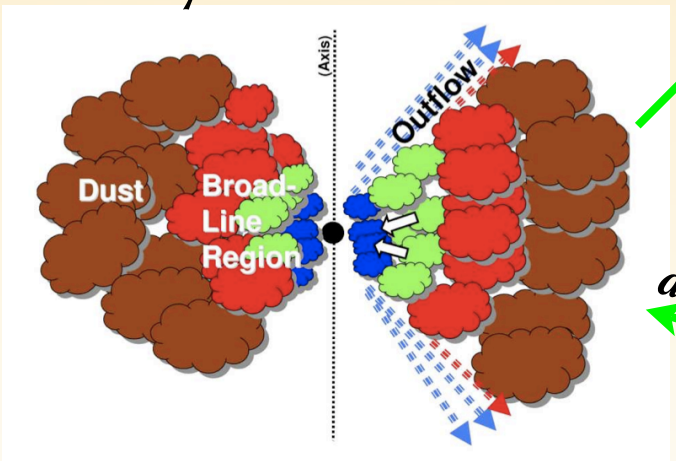
$N_H < 3 \times 10^{23}$ cm^{-2}

N_H distribution yet to be measured



Gilli et al. 2007

heavy obscuration



Gaskell et al. 2008

IR/X has stronger dependence on incident X-ray spectrum steepness and covering factor than N_H.

does not require large IR/X

Hard X-ray deep surveys will be more sensitive to CT type 1 than edge-on CT AGN. Latter may actually be observationally unimportant.

Yaqoob & Murphy, Leicester 2010

Thank you!