Modeling Compton Thick Obscuration in Accreting Supermassive Black Hole Systems

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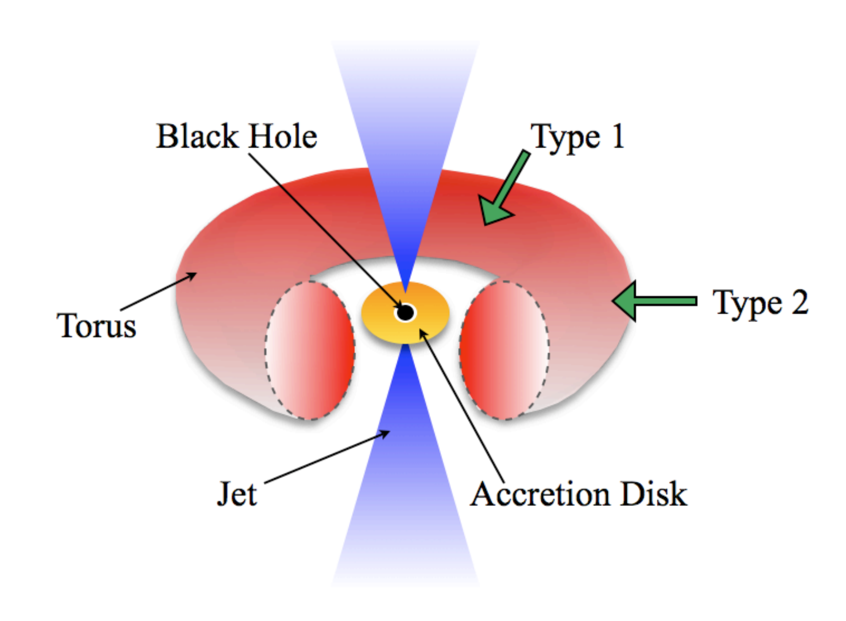
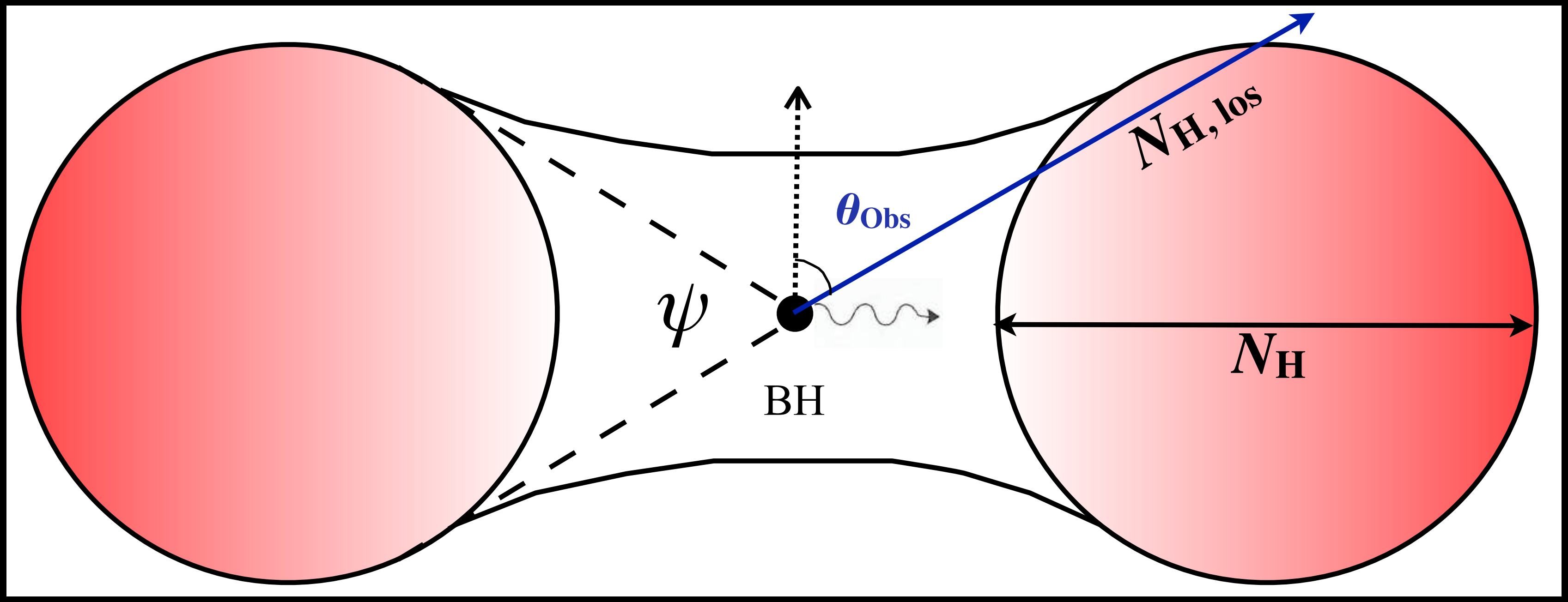
Overview



- 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
  - spectral fitting example
- Results from the Monte Carlo simulations
  - Fe Kα equivalent width and Compton shoulder
  - Observed/Intrinsic luminosity ratios: where are the CT AGN?
  - Energy losses in the obscuring structure: is the IR/X-ray ratio an indicator of N_H?

To be or not to be Compton-thick

- "Compton Thick" if $N_H > 1.24 \times 10^{24}$ cm^{-2}. But which N_H? Column and intrinsic X-ray luminosity are highly model-dependent *even with high SNR*.



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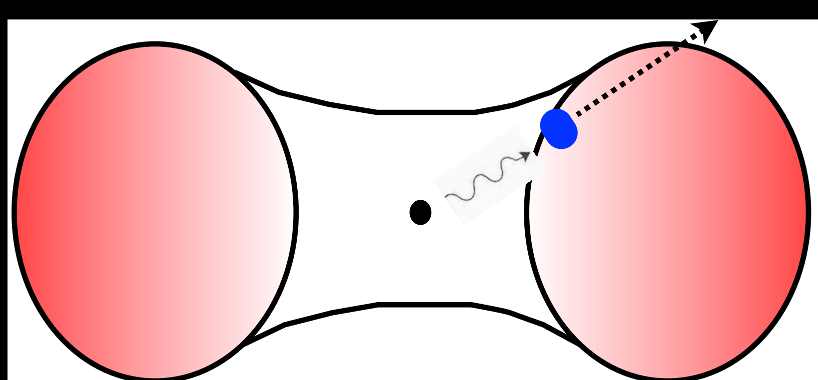

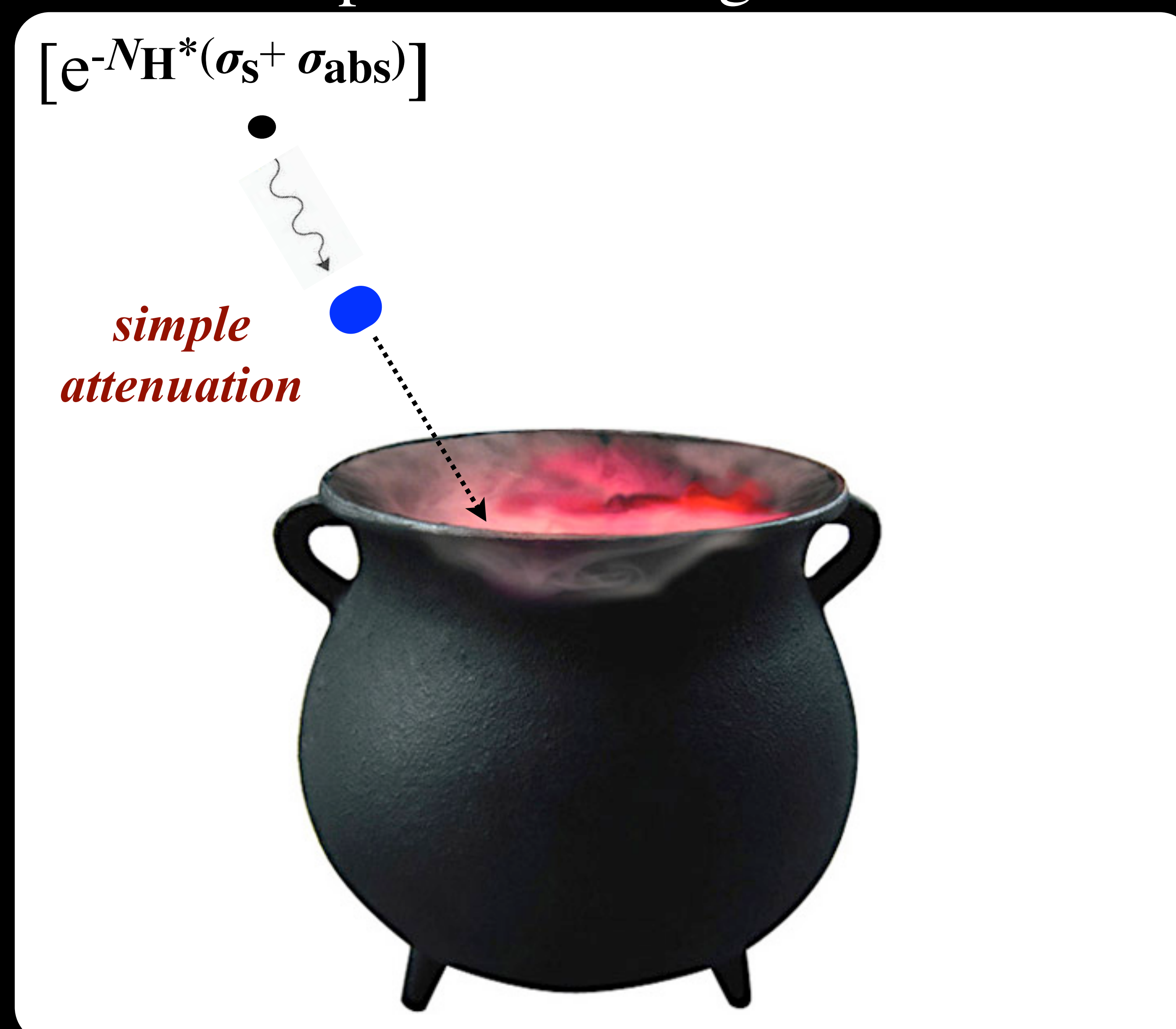

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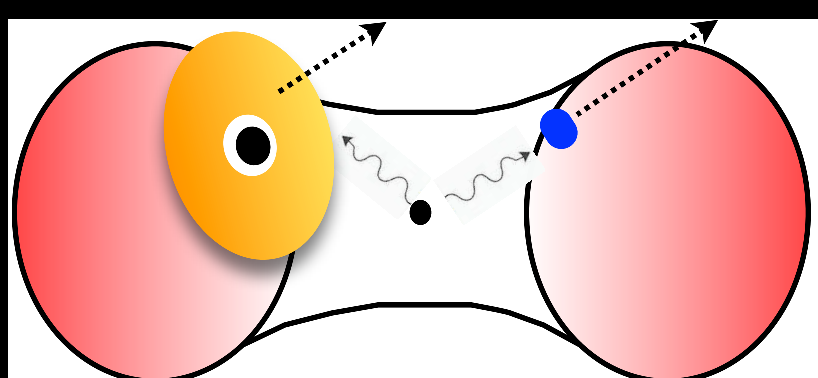

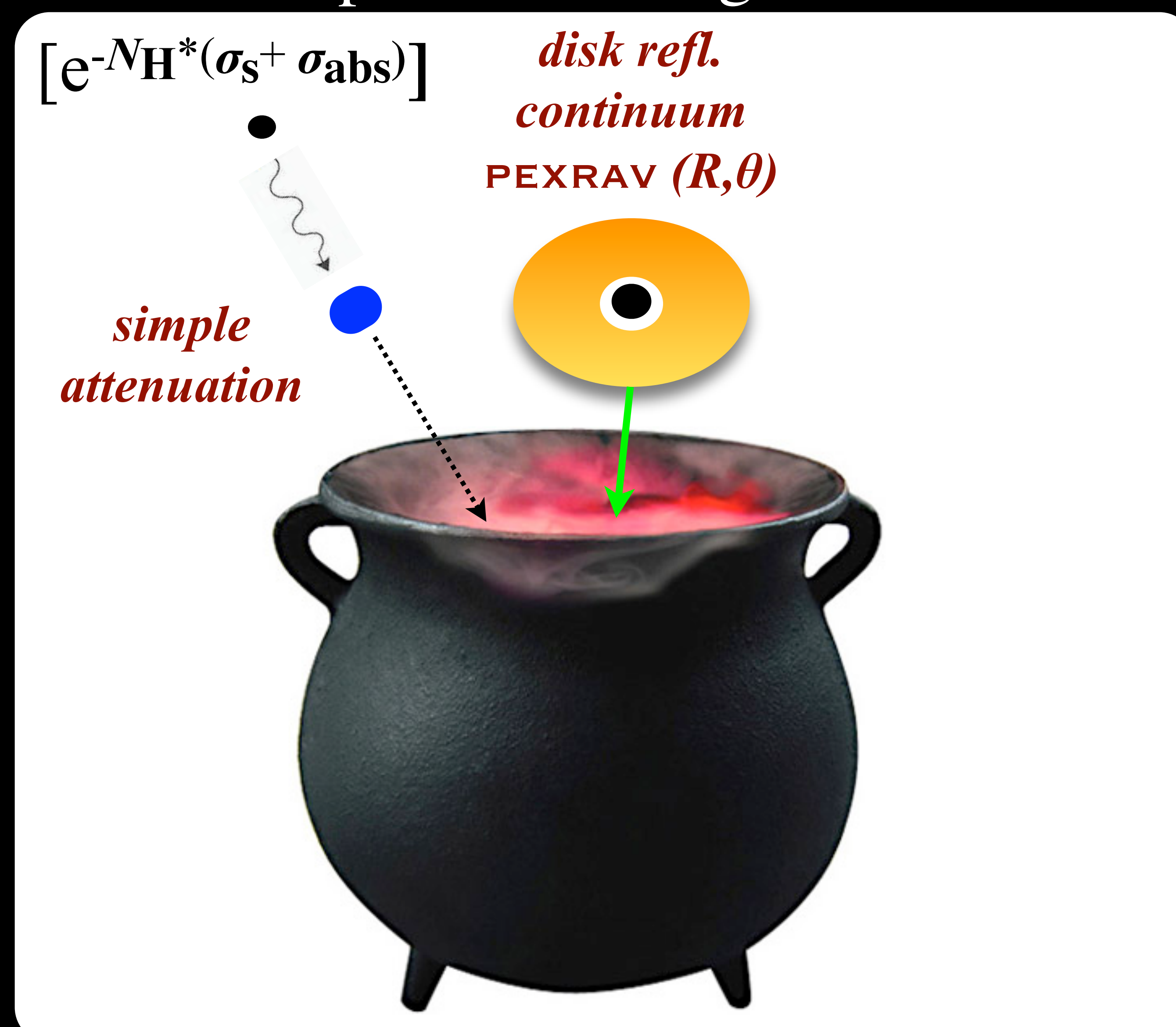

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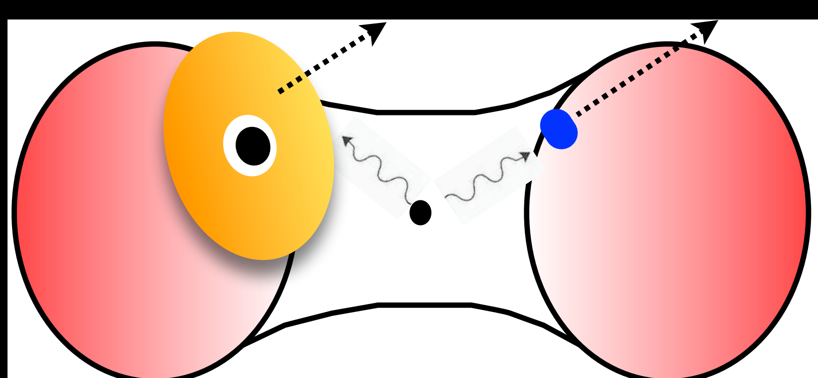

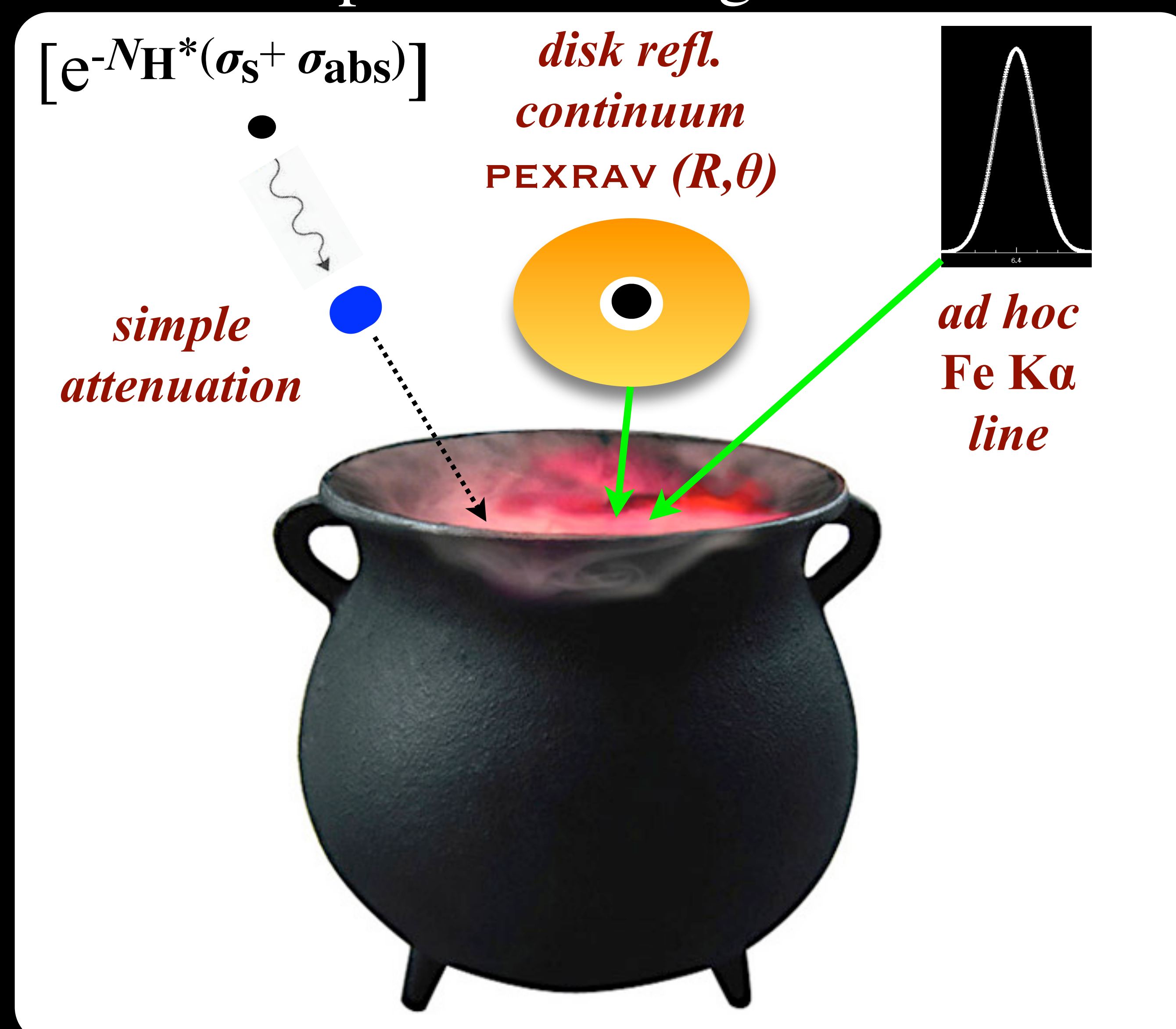

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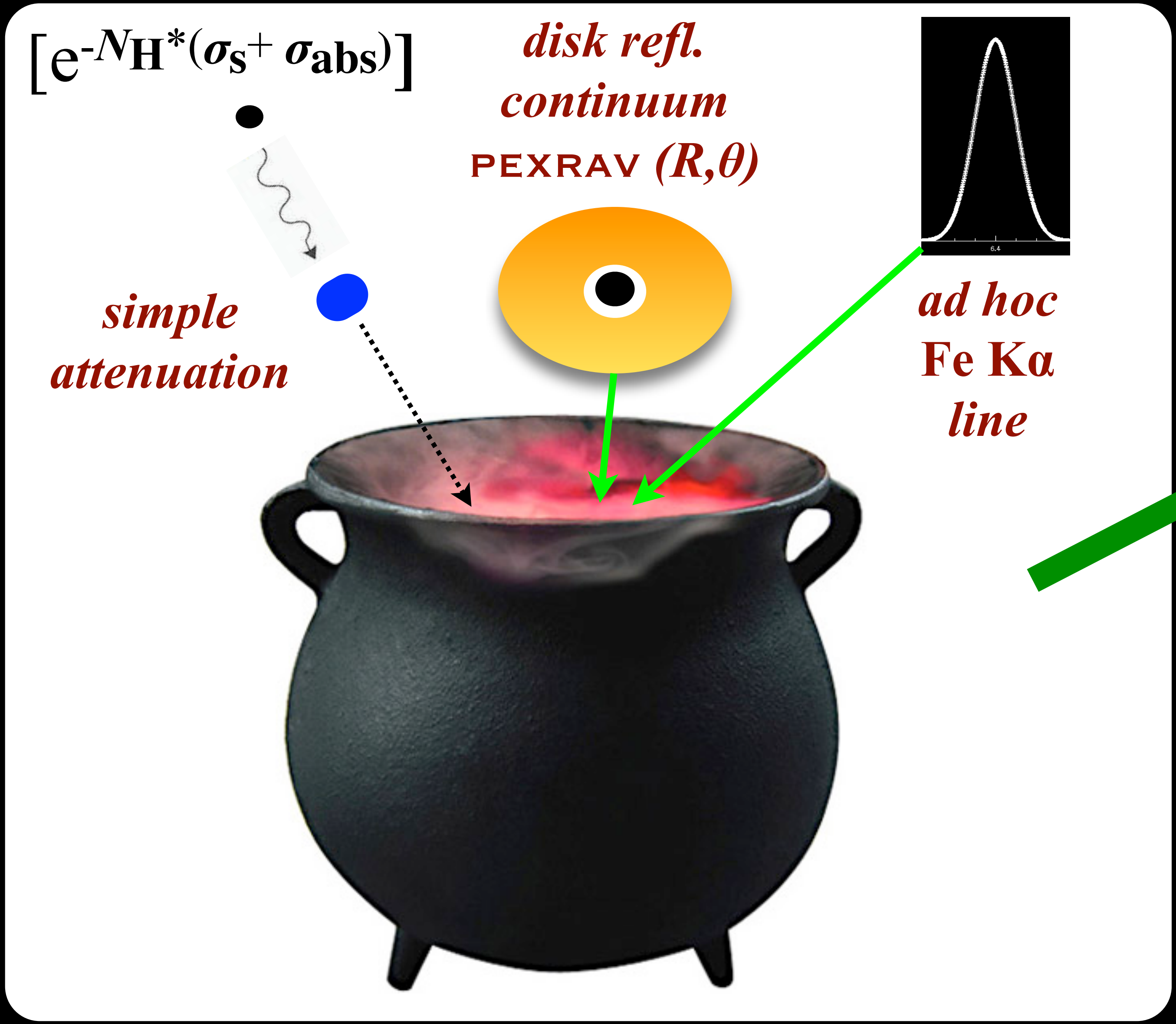

- *Cannot relate any of the components to each other, in particular R, N_H, and* **Fe Kα** *line EW.*
- *Amplitude of reflection, R, is arbitrary, θ has no meaning in this context: scattered continuum is highly geometry and angle-dependent.*
- *No physical meaning can be assigned to derived parameters,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

MYTorus Compton-thick X-ray Reprocessor Model

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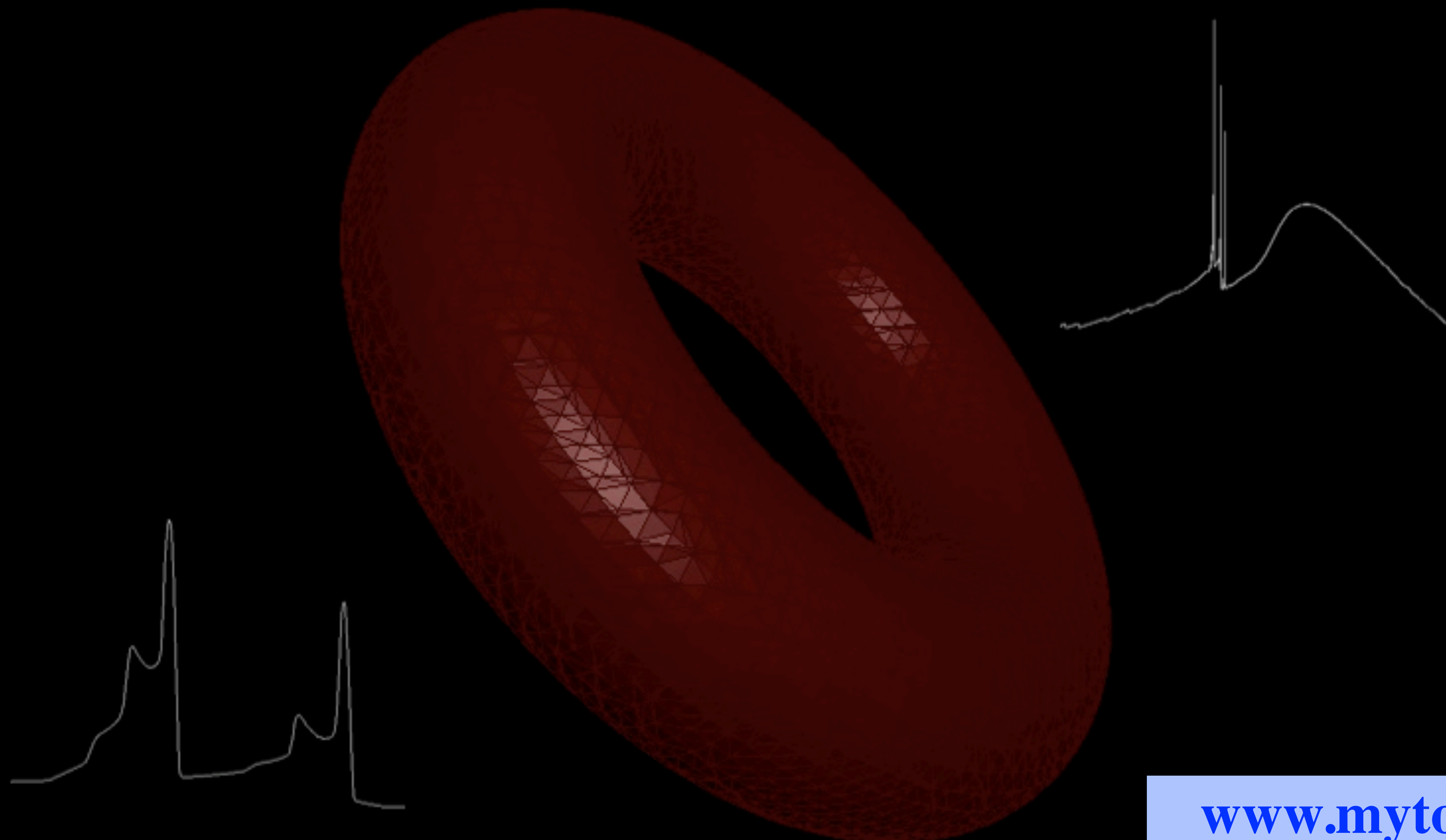

www.mytorus.com

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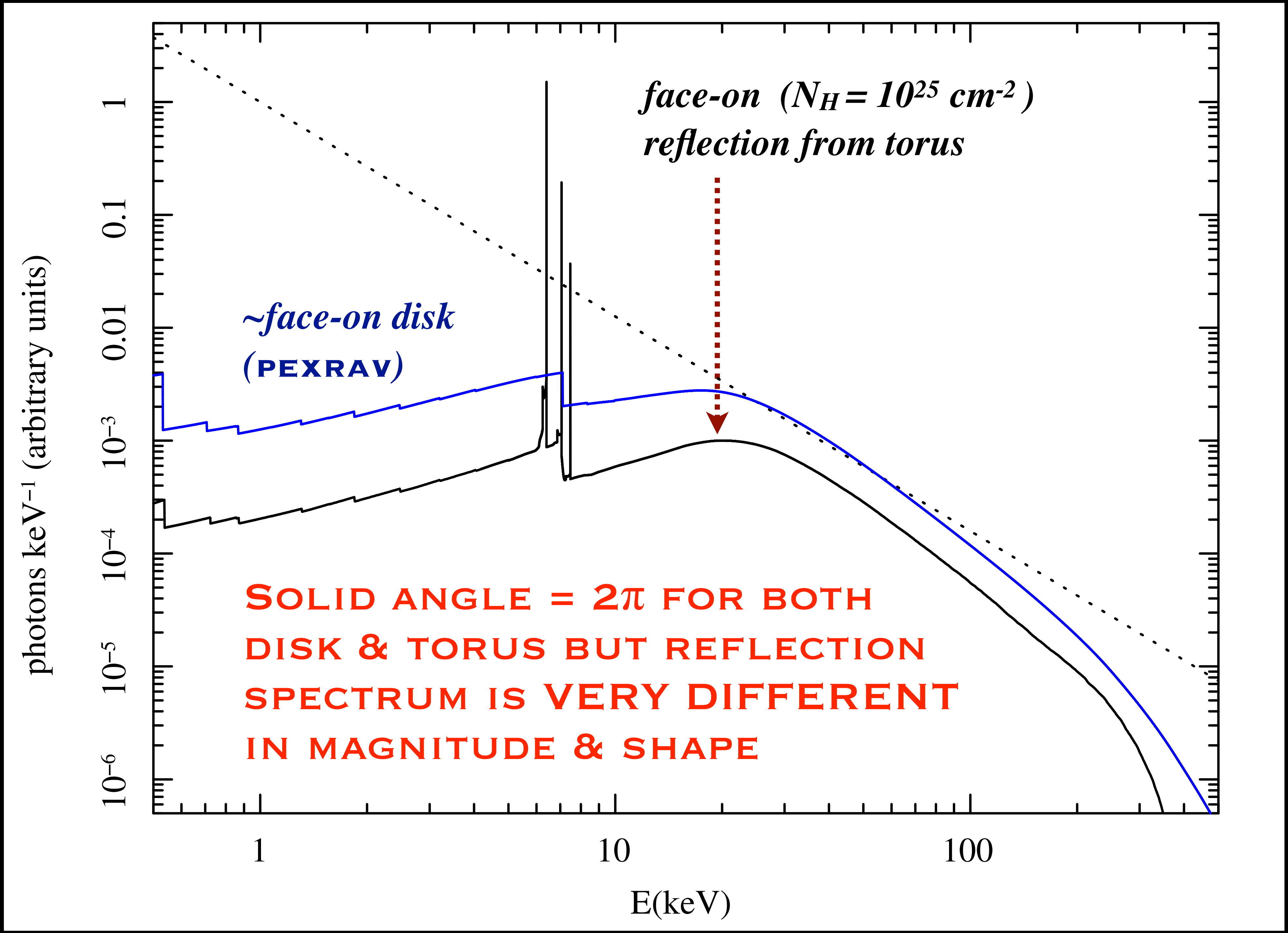
Direct comparison of toroidal reflection spectrum with PEXRAV (disk)

Severe geometry dependence because of angle-selection



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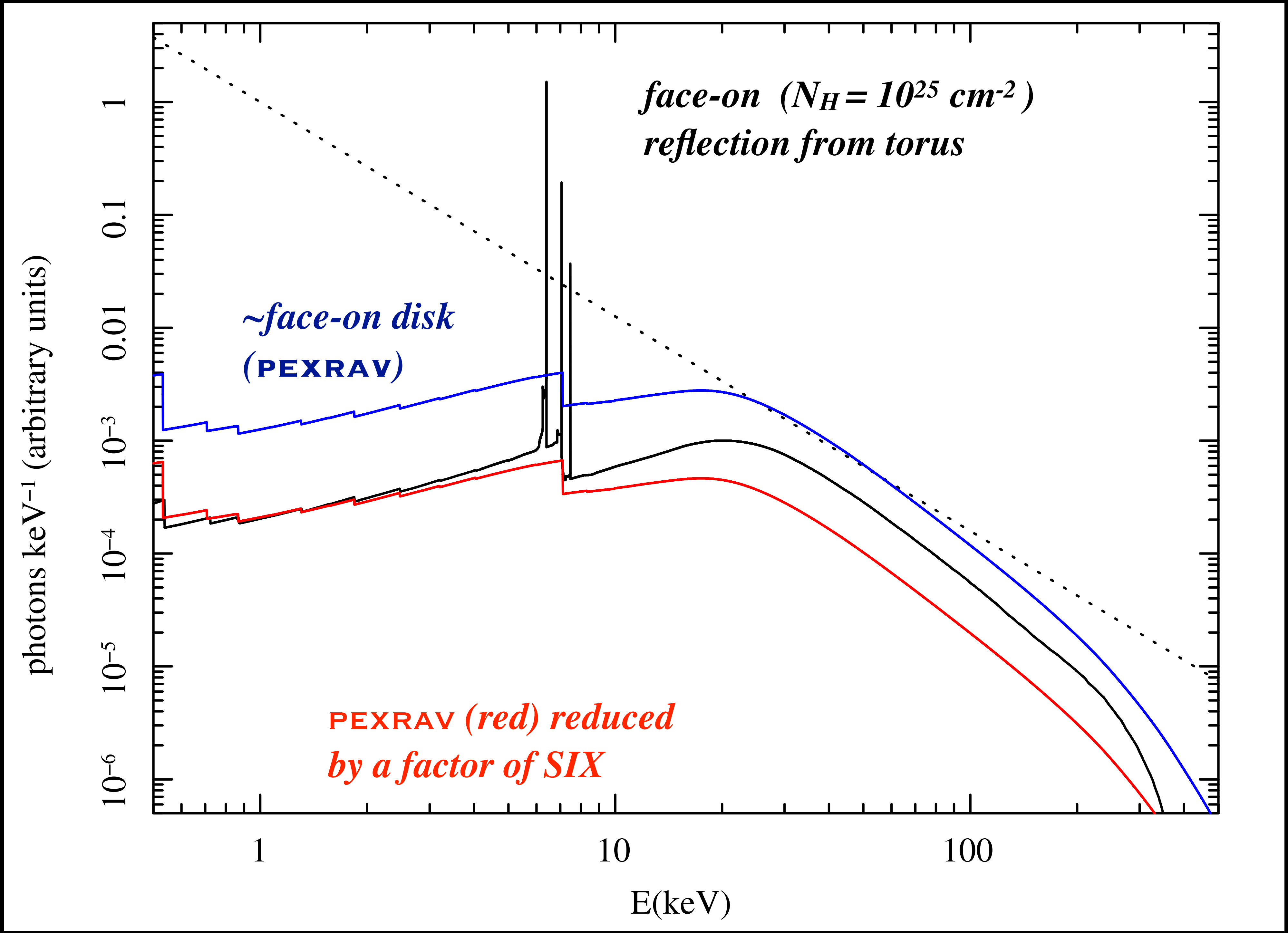

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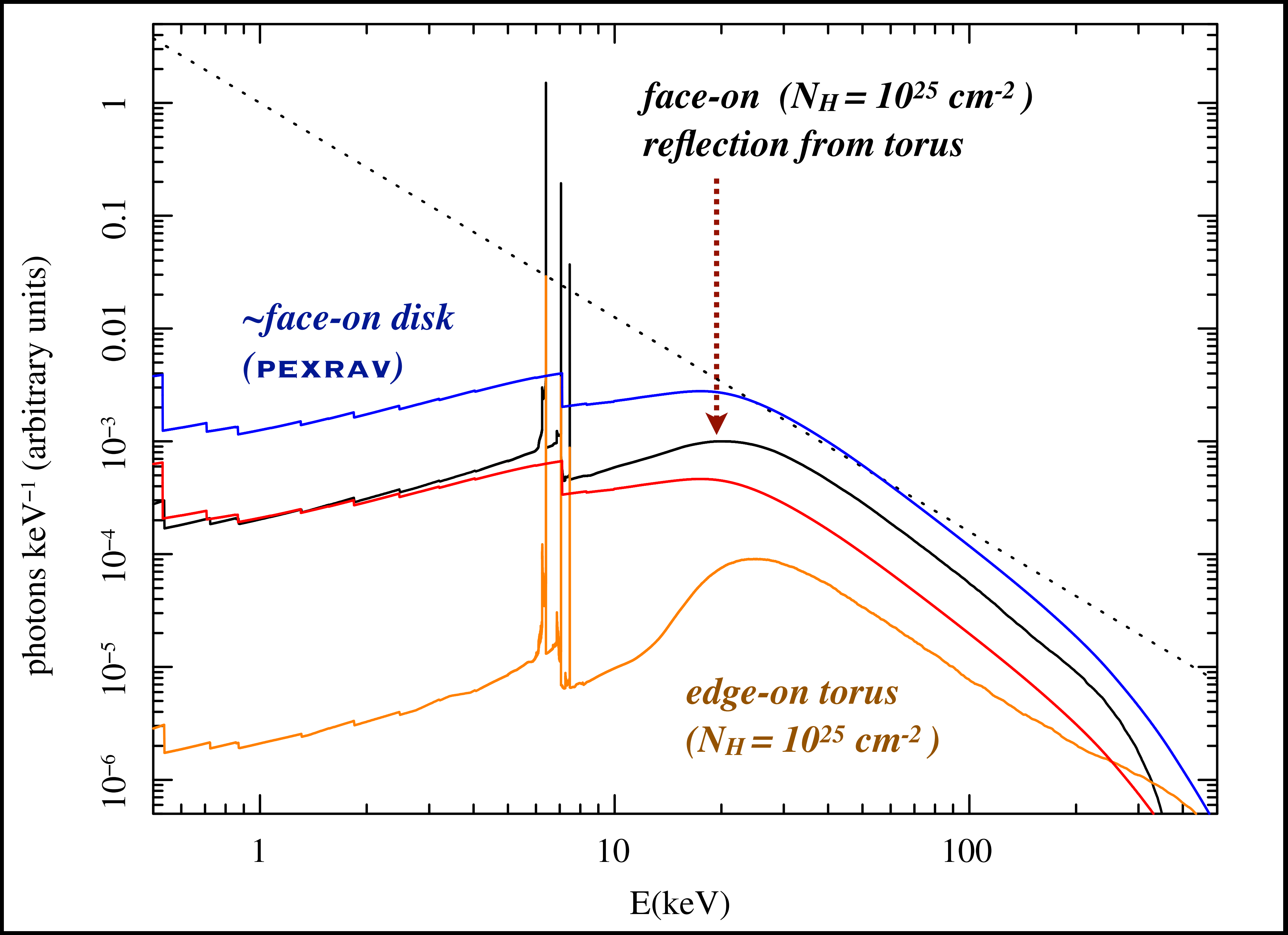
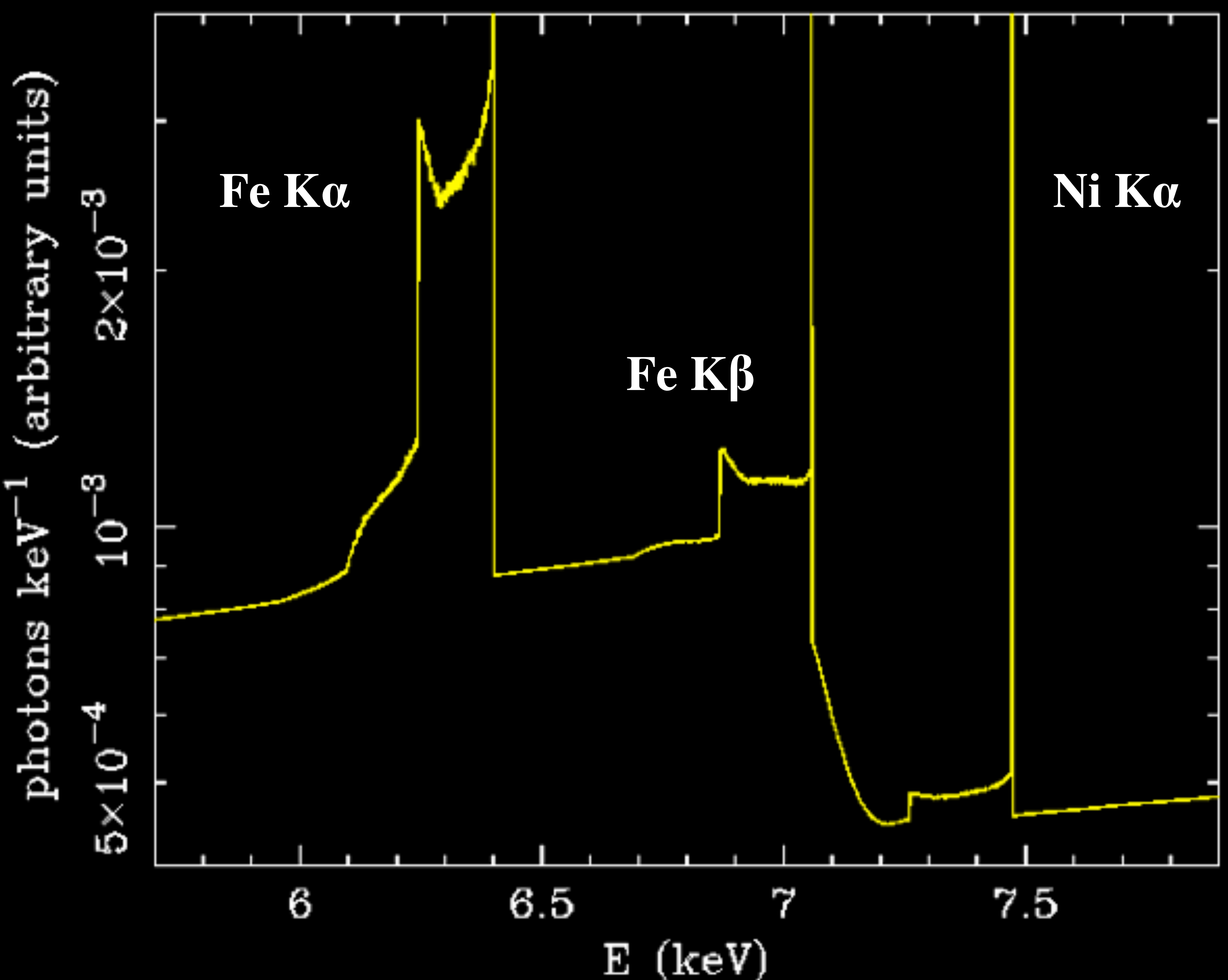
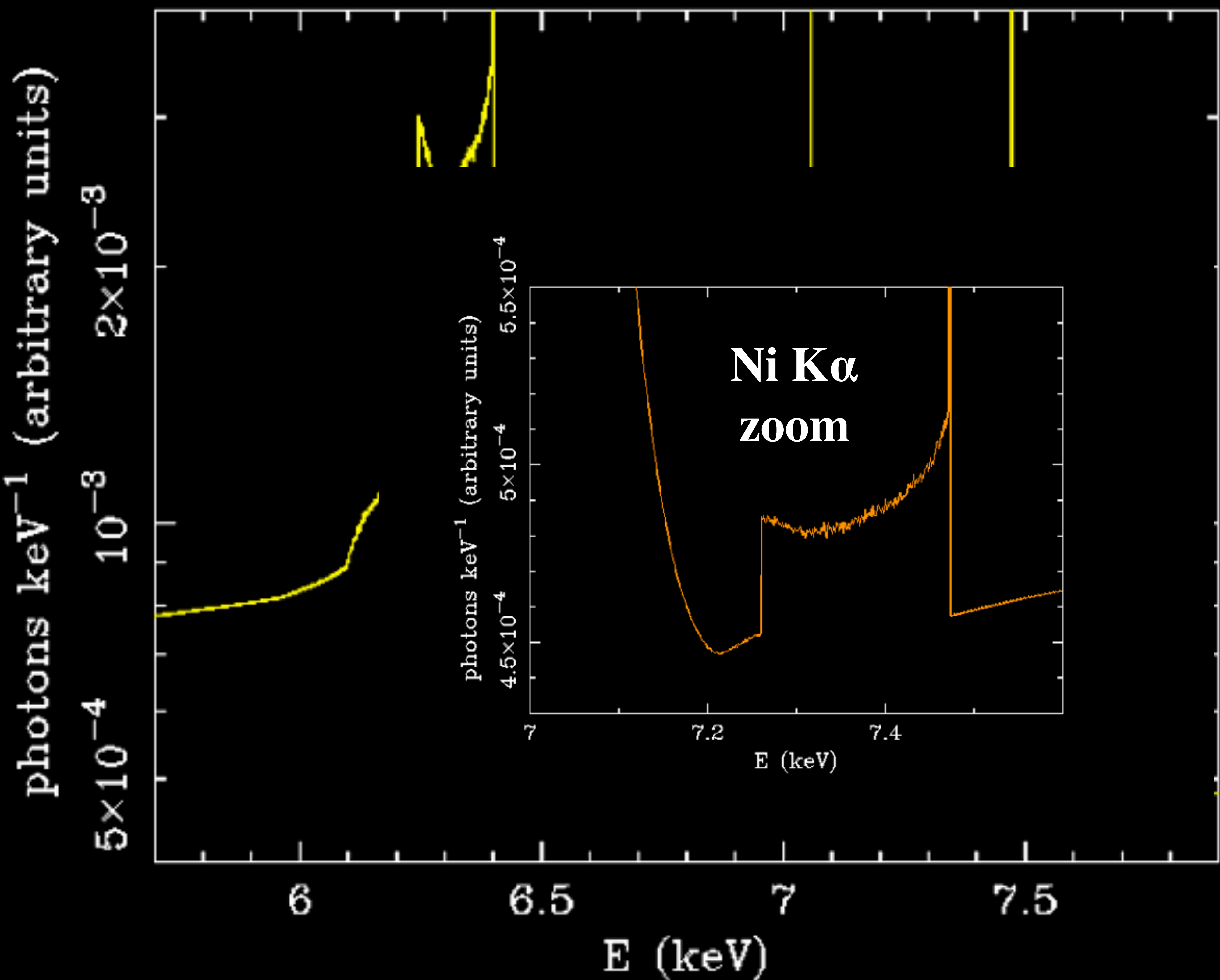



Fe Kα
Fe Kβ
Ni Kα
photons keV^{-1} (arbitrary units)
2×10^{-3}
10^{-3}
5×10^{-4}
6
6.5
7
7.5
E (keV)



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2	2	2	phabs	nH 1e22	1.790000E-02	frozen	$N_{\rm H,Gal}$
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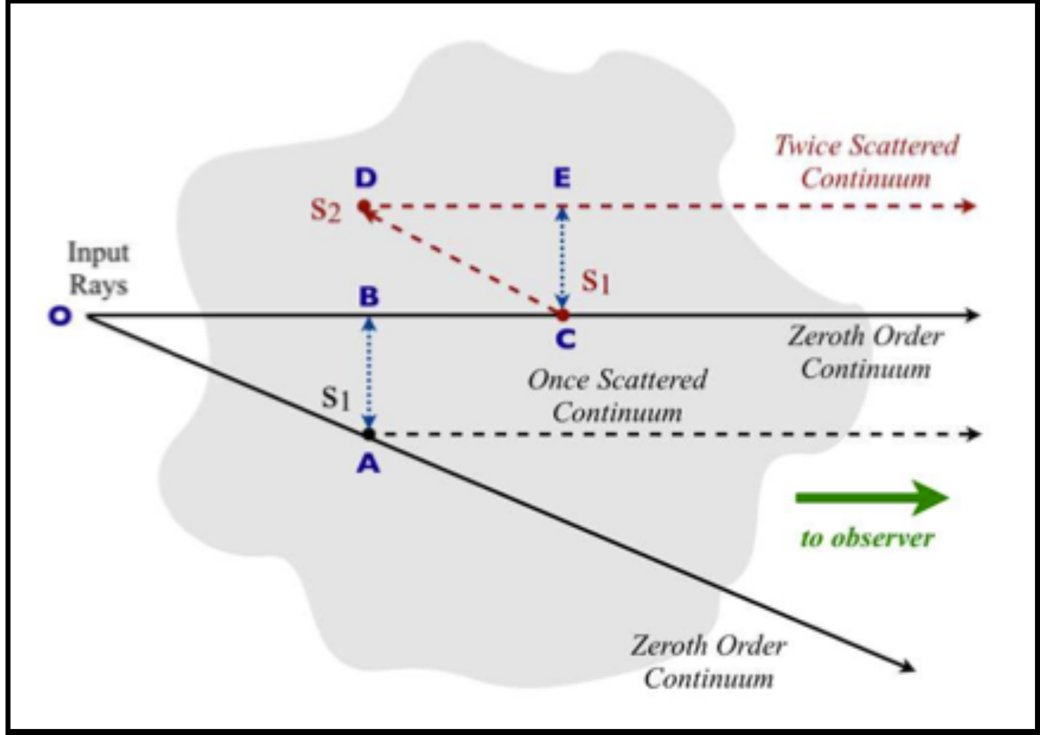

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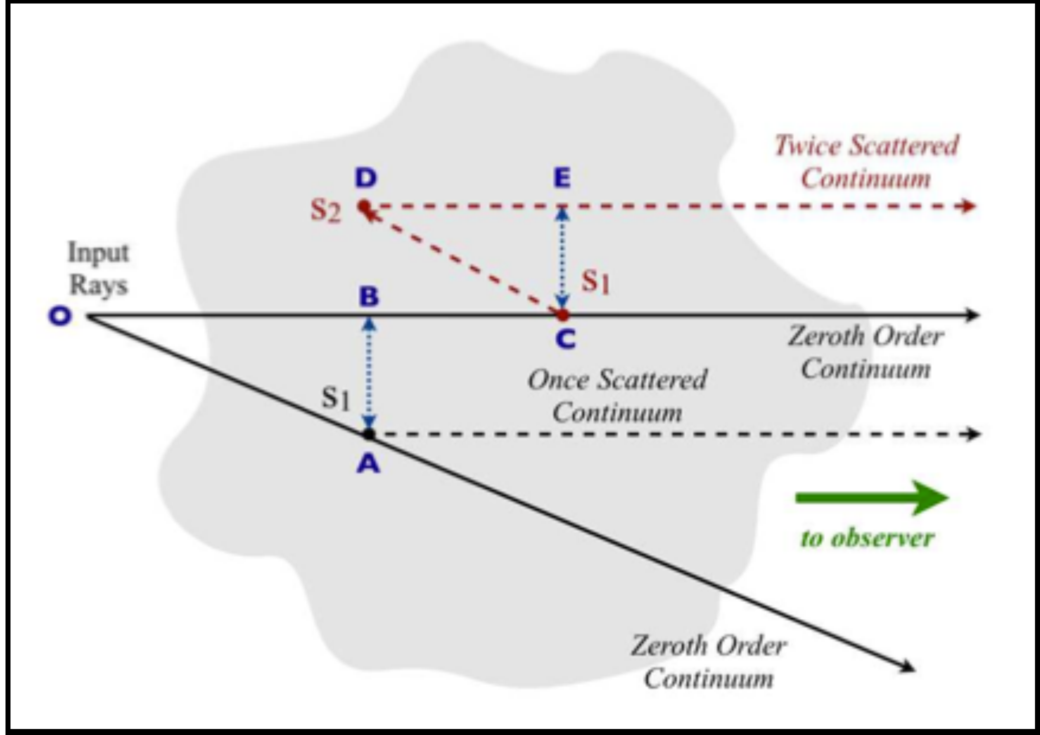

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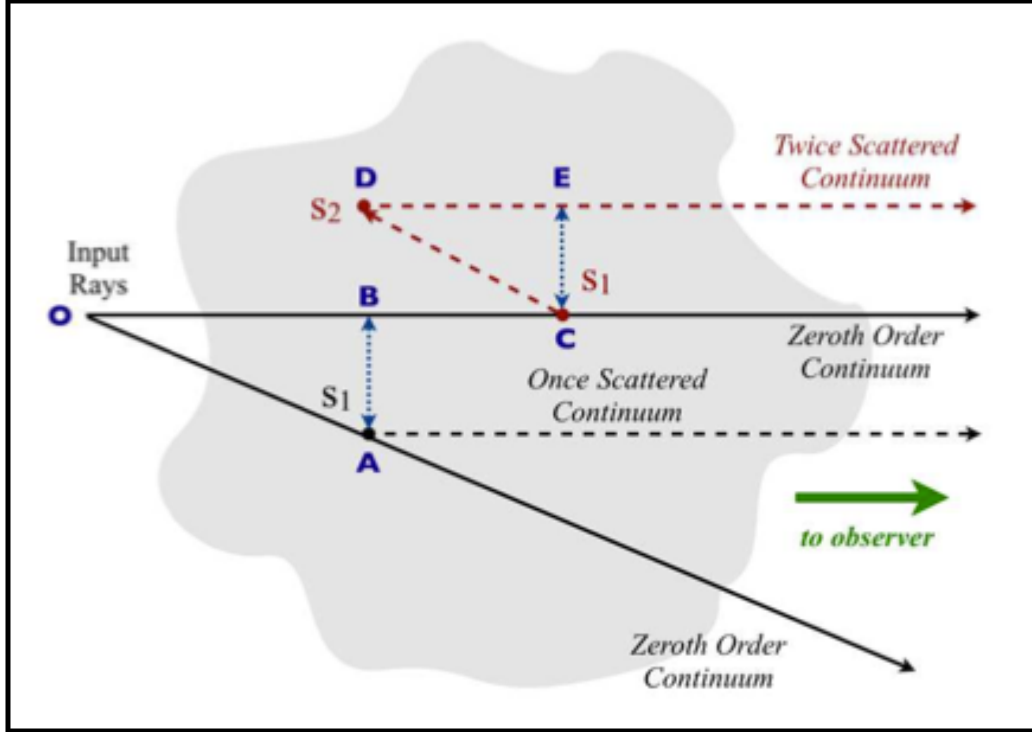

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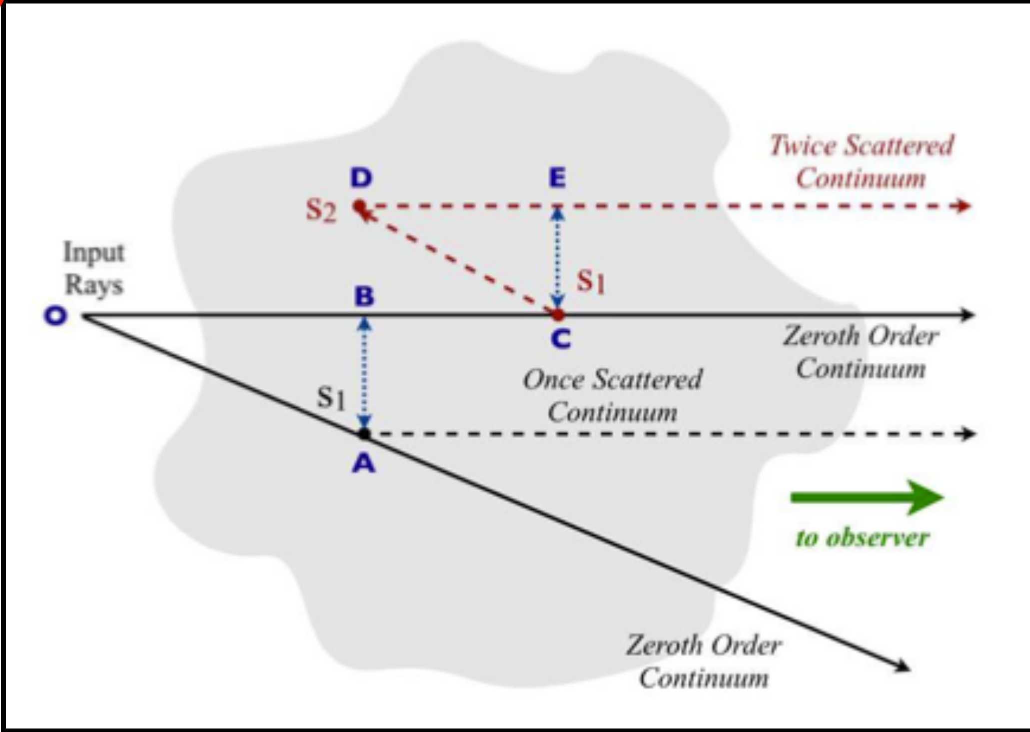

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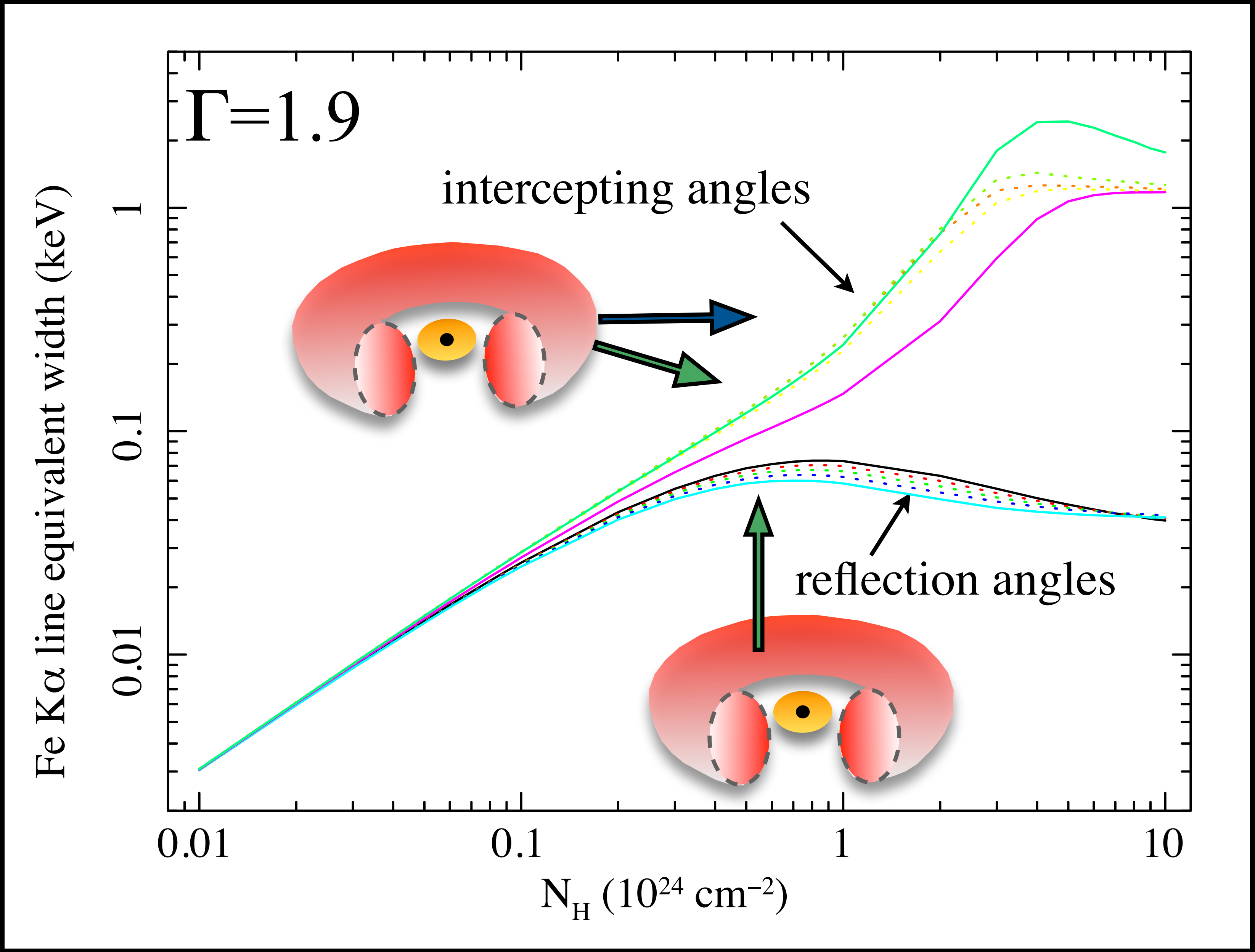
Results

- Fe Kα Emission Line EW
- Shape of Compton shoulder
- Luminosity ratios
- IR:X-ray luminosity



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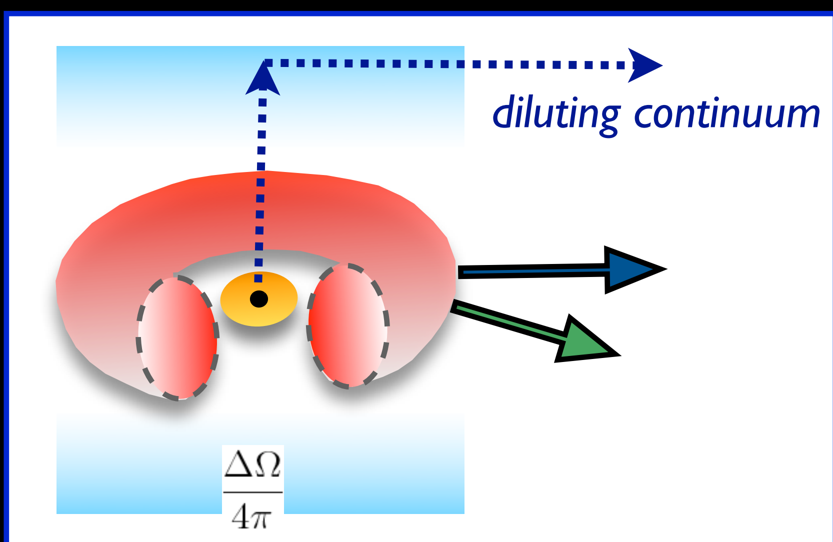

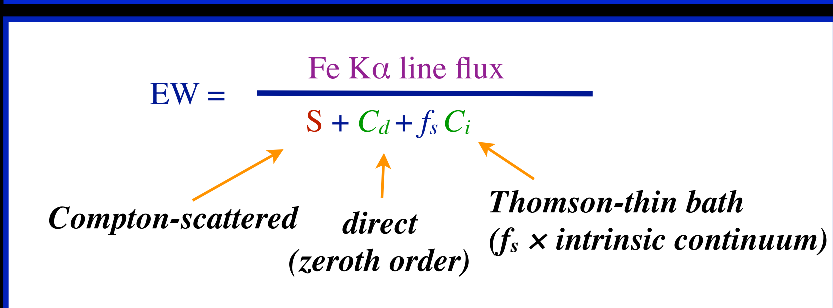

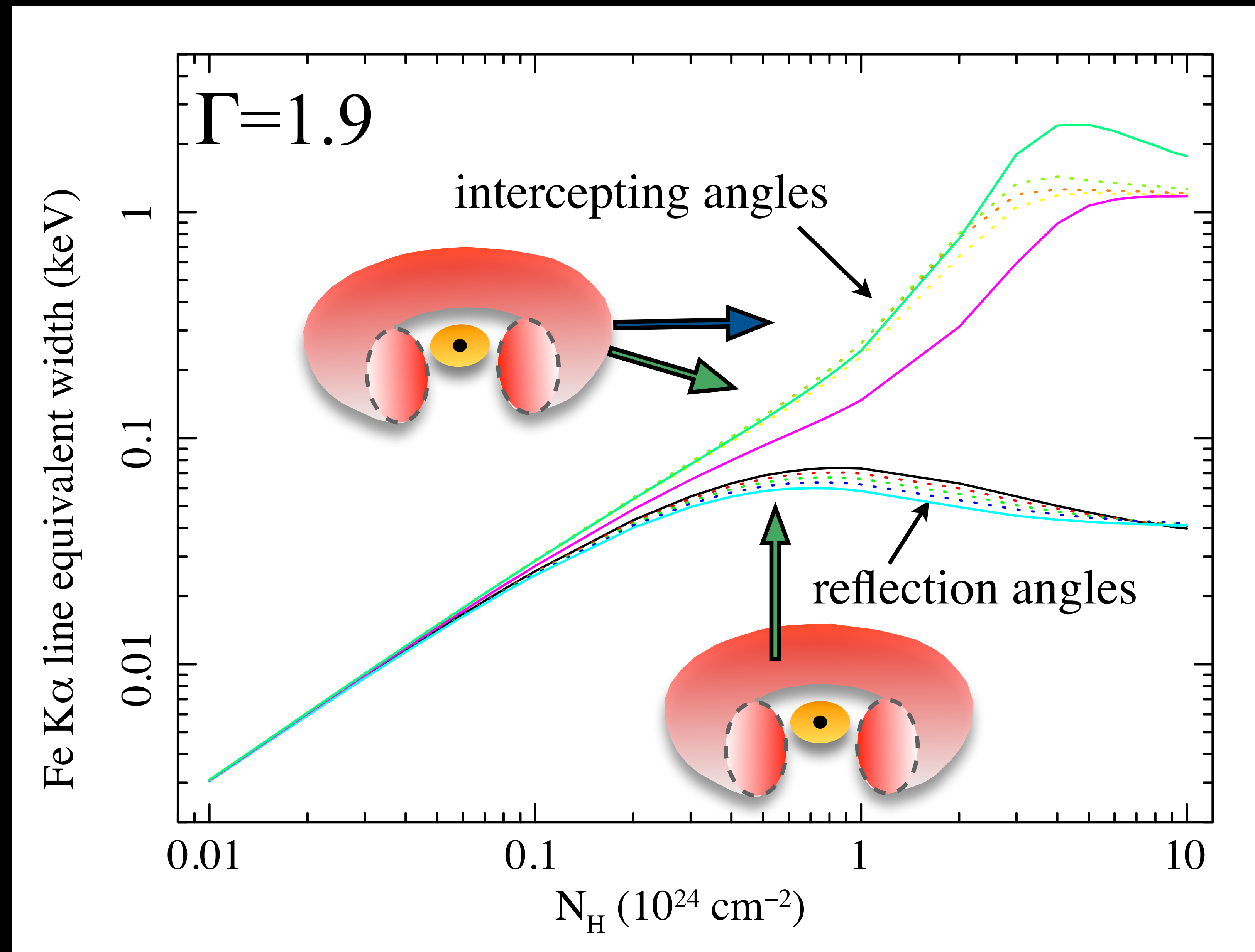

BUT...these curves change if the continuum is diluted by a scattered component from a warm, optically thin zone

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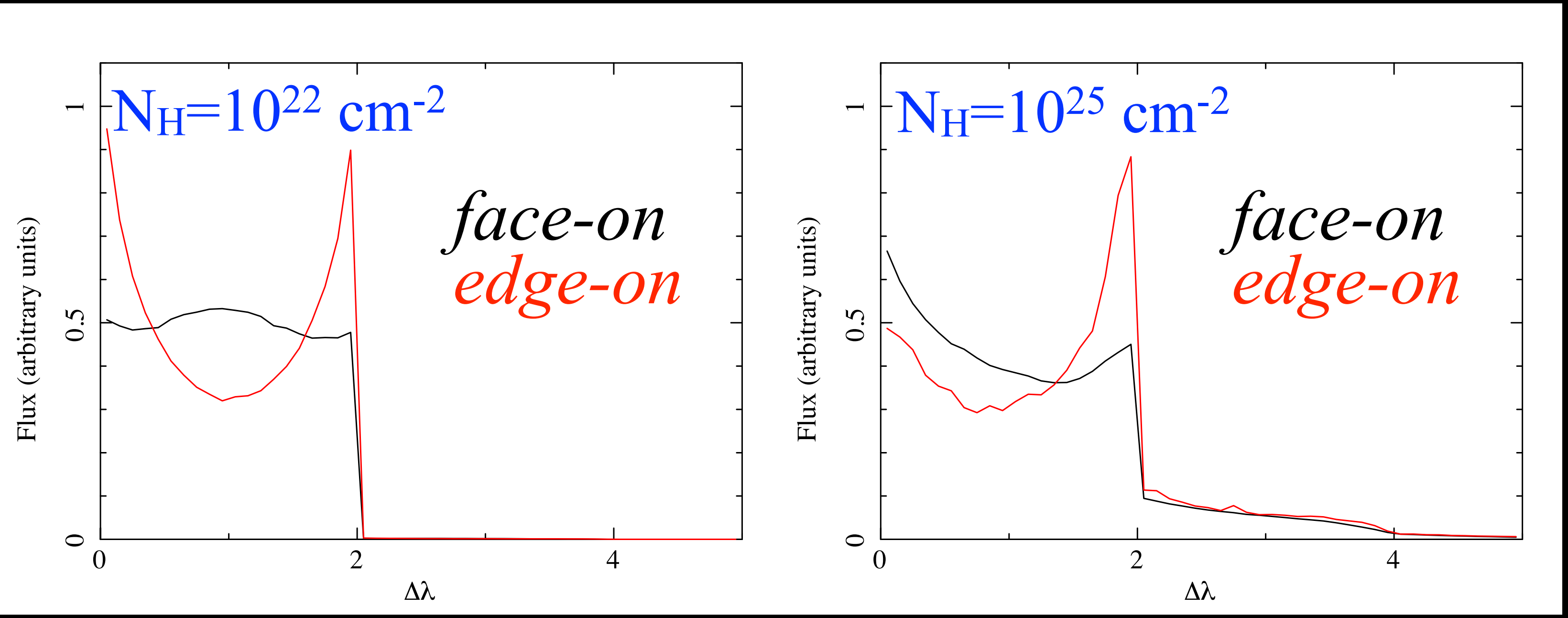

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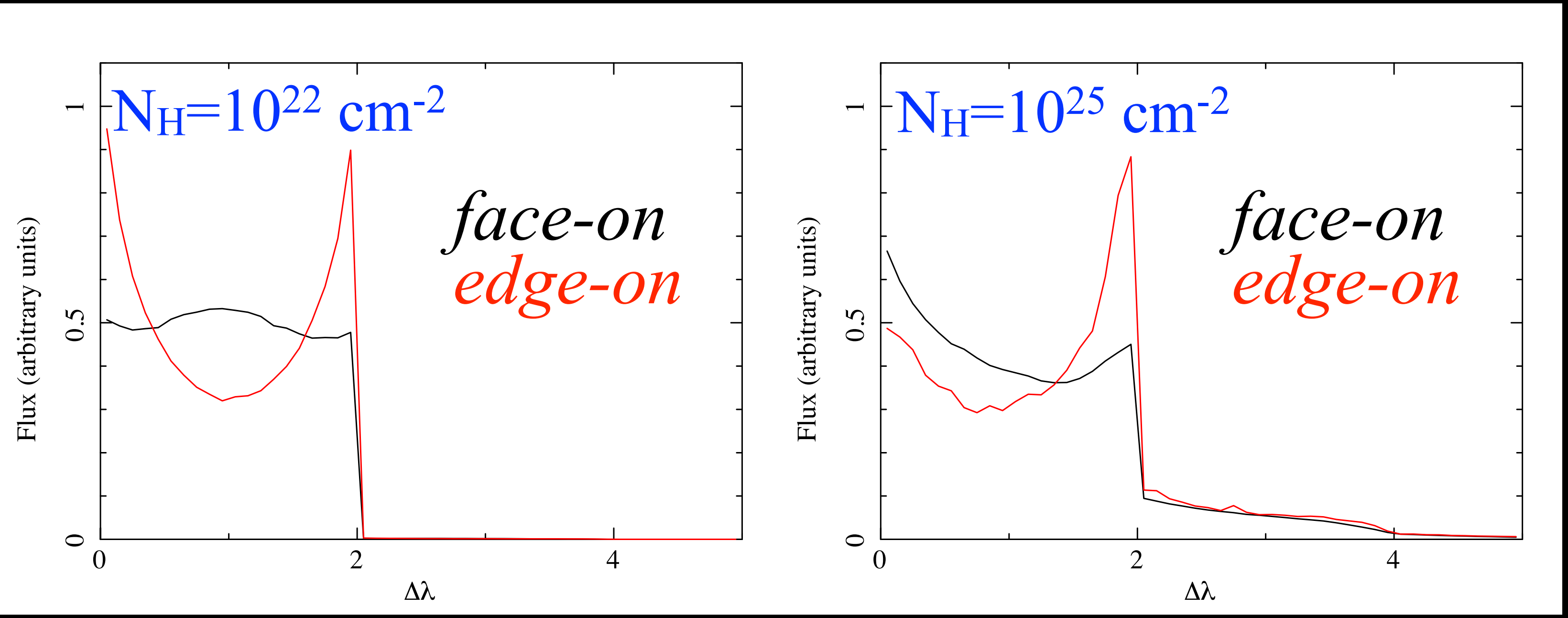

Gaussian convolution: $N_H=10^{25}$ cm^{-2}, face-on

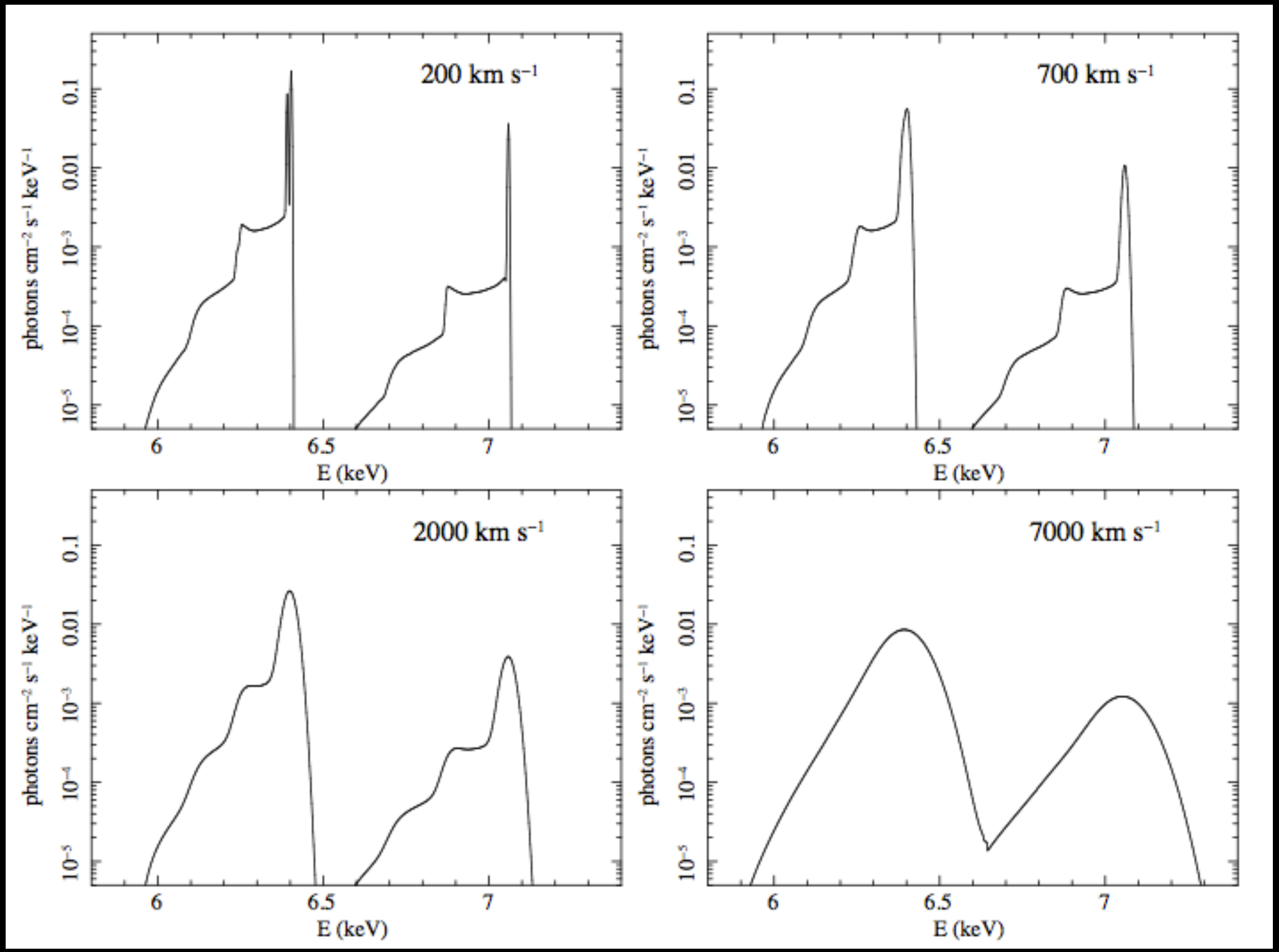

Table 7.3: Emission-line table energy bin widths

Energy Range (keV)	Bin Width (eV)
0.5–4.0	one bin
4.0–5.8	20 eV
5.8–7.2	0.4 eV
7.2–9.0	20 eV
9.0–500	one bin

Results

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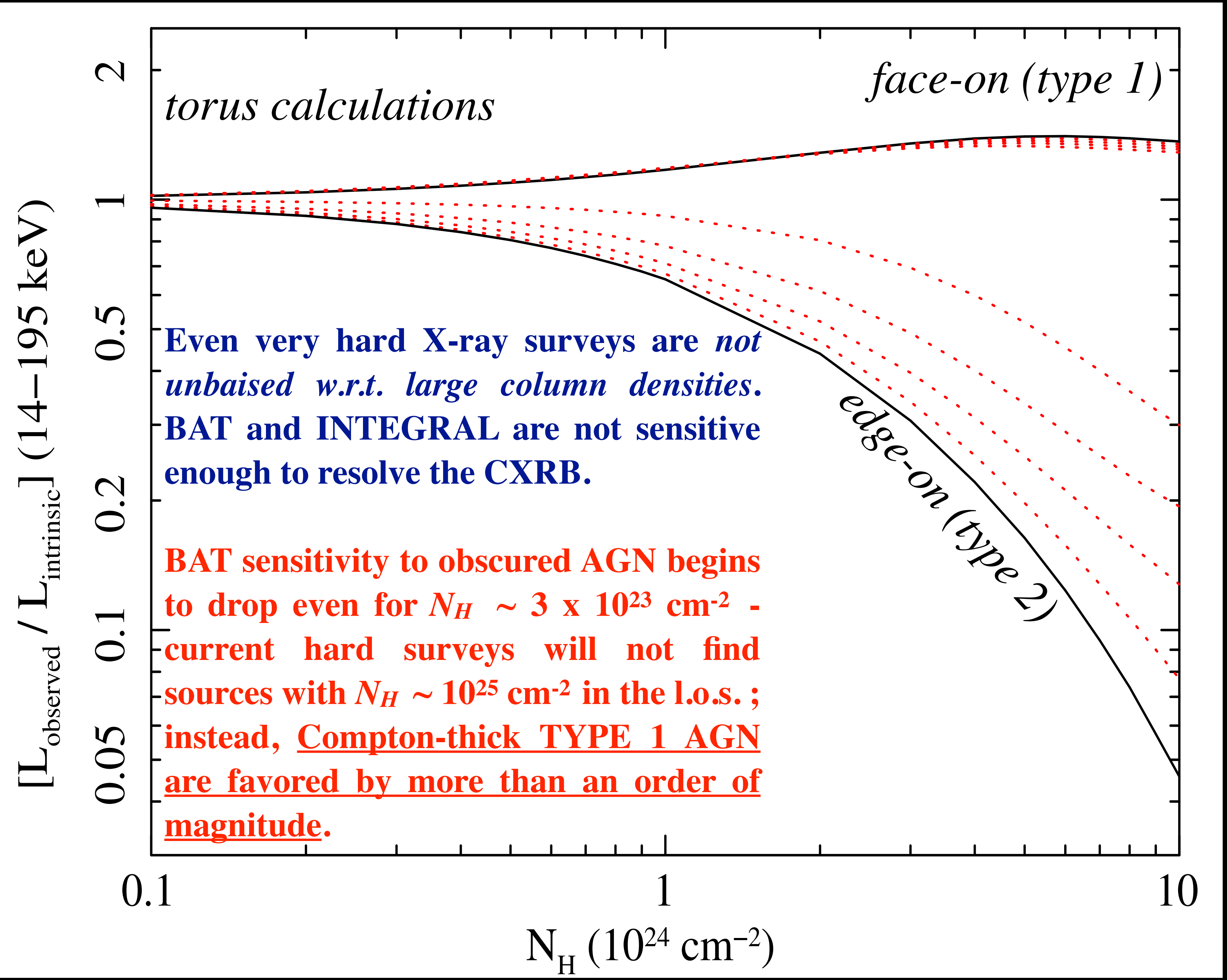
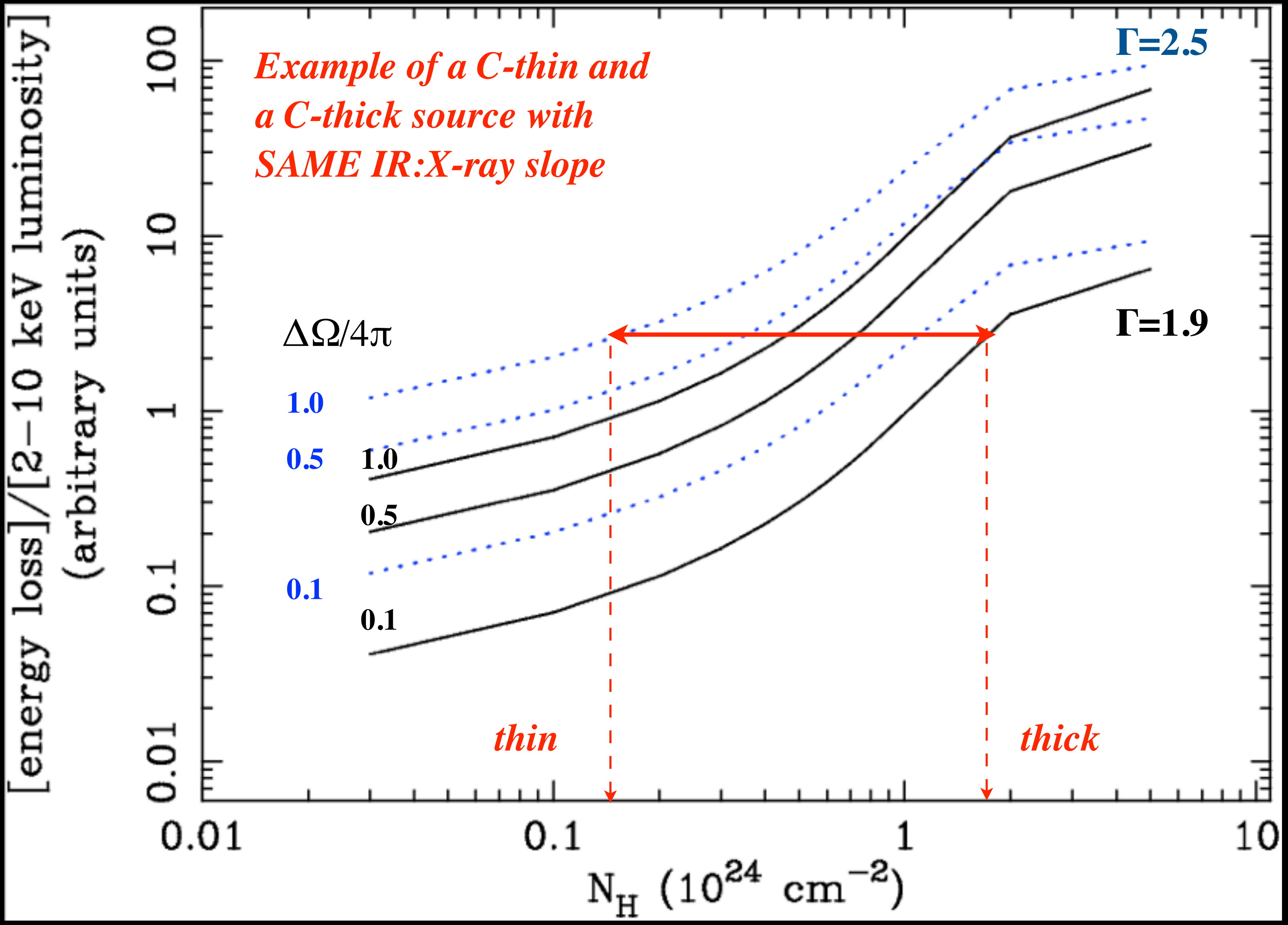
In the case of a "face-on" line-of-sight, the enhancement of the continuum luminosity over the intrinsic luminosity due to the reprocessor can be as large as 40%.

The difference between the luminosity ratios for edge-on and face-on lines-of-sight at $N_H = 10^{25}$ cm^{-2} is very large.
Surveys are much more likely to find type 1 (unobscured) Compton-thick AGN than type 2 (obscured) Compton-thick sources.



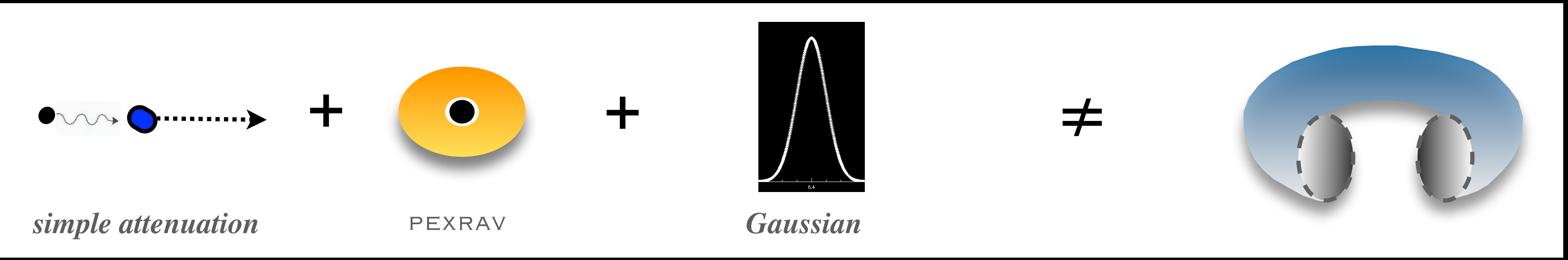
Results

- Fe Kα Emission Line EW
- Shape of Compton shoulder
- Luminosity ratios
- IR:X-ray luminosity



- **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.**

Summary



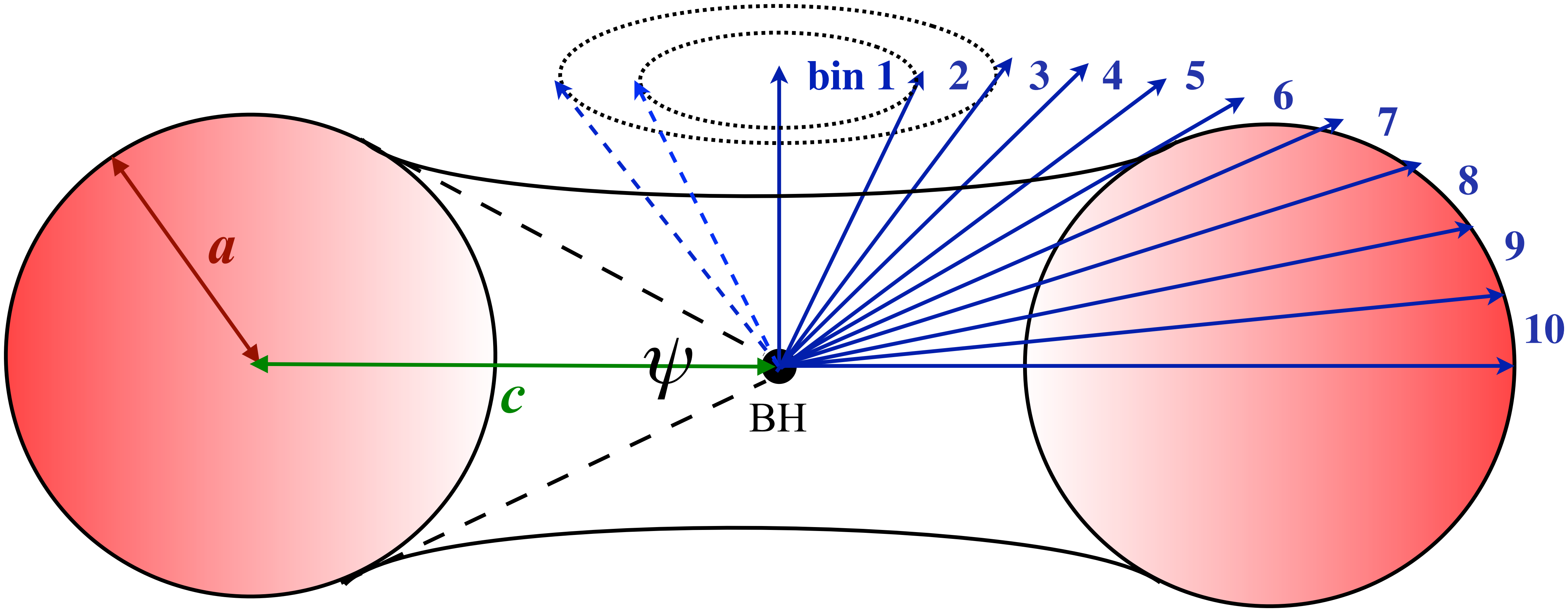
- MYTorus: a spectral-fitting tool that self-consistently models the reprocessed X-ray emission from the putative torus in AGN (www.mytorus.com).

- The model is constructed from fully relativistic Monte-Carlo calculations of absorption, scattering, and fluorescent line emission within the circumnuclear material, for column densities covering the Compton-thin to Compton-thick regimes.

- The X-ray reflection continuum, the EW of the Fe K emission, as well as the shape and relative magnitude of its Compton shoulder, are important diagnostics of the geometry, column density, and inclination angle of the reprocessor.

  - MYTorus allows one to extract physical information from X-ray data of accreting supermassive black hole systems, which cannot be obtained via ad-hoc modeling.

    - Interested in keeping informed about updates to the model? model@mytorus.com to subscribe to the email list



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Adding additional components

- Power-law continua
- Soft X-ray thermal continua
- High-energy cutoff
- Additional narrow lines
- Accretion disk reflection
- Cold/neutral absorption
- Partial Covering
- Warm Absorber

Table 8.3: XSPEC parameters for example # 3 (§8.2.3)

Model par #	Fit par #	Mod comp	Component	Parameter	Value	Property	Symbol
1	1	1	constant	factor	1.00000	frozen	C_k
2	2	2	phabs	nH 1e22	1.790000E-02	frozen	$N_{\rm H,Gal}$
3	3	3	zpowerlw	PhoIndex	1.90000		Γ_i
4	4	3	zpowerlw	Redshift	3.300000E-03	frozen	z
5	5	3	zpowerlw	norm	2.700000E-02		A_i
6	6	4	MYtorusZ	NH 1e24	2.00000		N_H
7	7	4	MYtorusZ	IncAng Degrees	90.0000	frozen	$\theta_{\rm obs}$
8	4	4	MYtorusZ	Redshift	3.300000E-03	= par 4	z
9	8	5	constant	factor	1.00000		A_S
10	6	6	MYtorusS	NH 1e24	2.00000	= par 6	N_H
11	7	6	MYtorusS	IncAng Degrees	90.0000	= par 7	$\theta_{\rm obs}$
12	3	6	MYtorusS	PhoIndx	1.90000	= par 3	Γ_i
13	4	6	MYtorusS	Redshift	3.300000E-03	= par 4	z
14	5	6	MYtorusS	norm	2.700000E-02	= par 5	A_i
15	9	7	constant	factor	1.00000		A_L
16	10	8	gsmooth	Sig@6keV keV	4.248000E-03		σ_L
17	11	8	gsmooth	Index	1.00000	frozen	α
18	6	9	MYtorusL	NH 1e24	2.00000	= par 6	N_H
19	7	9	MYtorusL	IncAng Degrees	90.0000	= par 7	$\theta_{\rm obs}$
20	3	9	MYtorusL	PhoIndx	1.90000	= par 3	Γ_i
21	4	9	MYtorusL	Redshift	3.300000E-03	= par 4	z
22	5	9	MYtorusL	norm	2.700000E-02	= par 5	A_i
23	12	10	constant	factor	1.300000E-03		f_j
24	3	11	zpowerlw	PhoIndex	1.90000	= par 3	$\Gamma_j\ (=\Gamma_i)$
25	4	11	zpowerlw	Redshift	3.300000E-03	= par 4	z
26	5	11	zpowerlw	norm	2.700000E-02	= par 5	$A_j\ (=A_i)$

```
Files being used for table models:
Model comp      File
  4             mytorus_Ezero_v00.fits
  6             mytorus_scatteredH500_v00.fits
  9             mytl_V000010nEp000H500_v00.fits
```

$$
\begin{aligned}
N(E) &= [(A_1 E^{-\Gamma_1}) + (A_2 E^{-\Gamma_2})]\mathrm{MYTZ}(z, N_{\rm H}, \theta_{\rm obs}, E) \\
&+ [(A_1 E^{-\Gamma_1})\mathrm{MYTS}(z, A_1, \Gamma_1, N_{\rm H}, \theta_{\rm obs}, E)] \\
&+ [(A_2 E^{-\Gamma_2})\mathrm{MYTS}(z, A_2, \Gamma_2, N_{\rm H}, \theta_{\rm obs}, E)].
\end{aligned}
$$

Implementation of the Spectral Fitting Model