X-ray Extinction From Dust Scattering

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Collaborators:
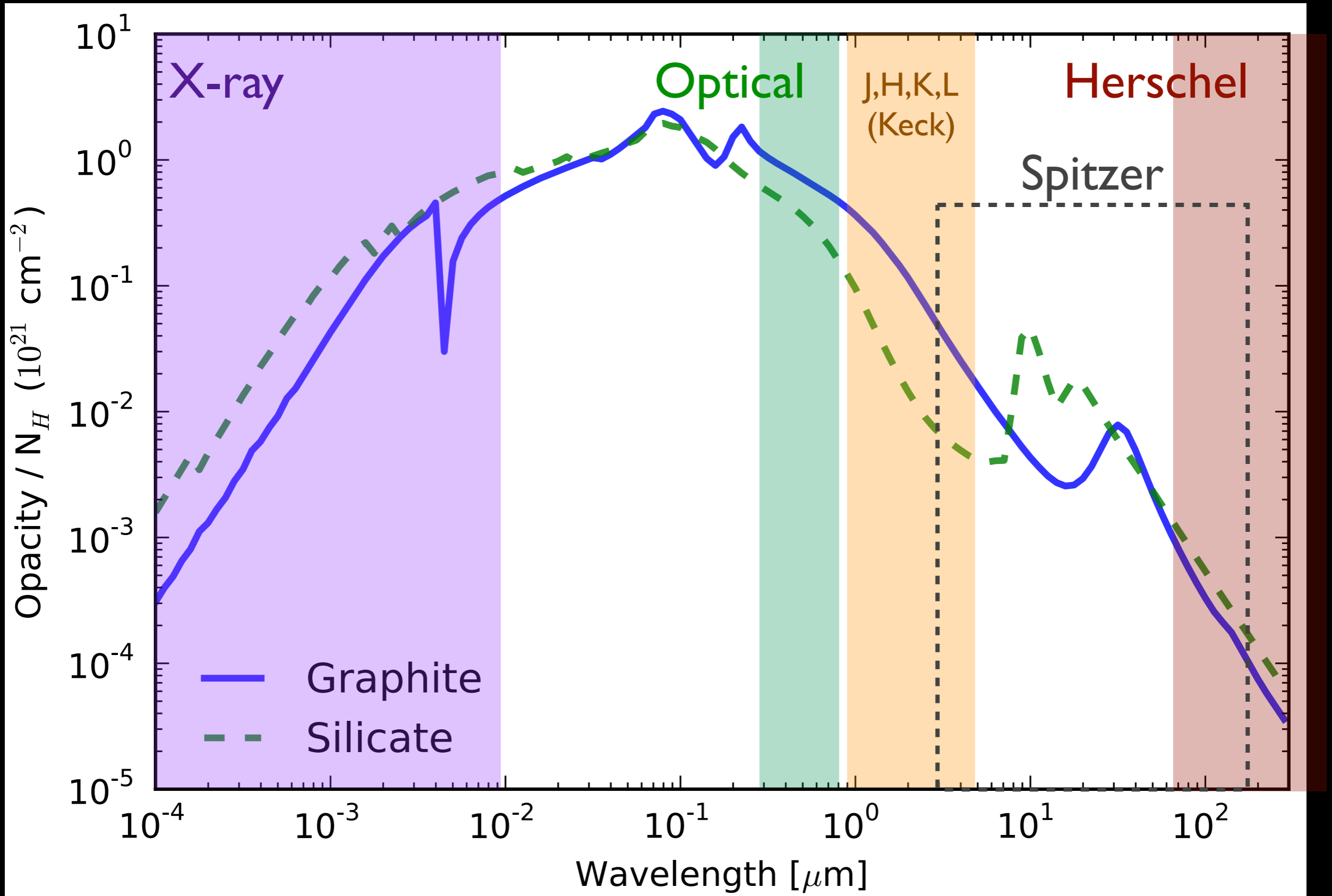Joern Wilms (Remeis), Mike Nowak (MKI), Norbert Schulz (MKI),
Frederick Baganoff (MKI), Javier Garcia (CfA)

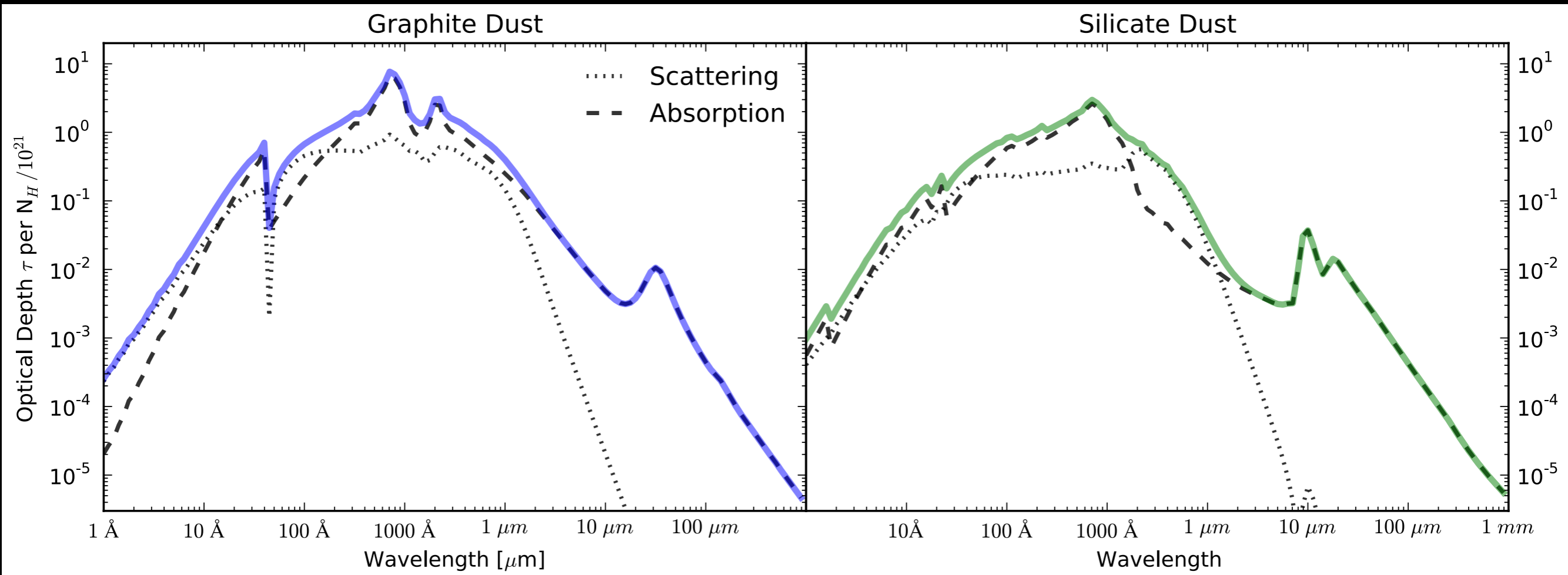# Total ISM optical depth due to dust extinction

Effect on continuum models (low-res)
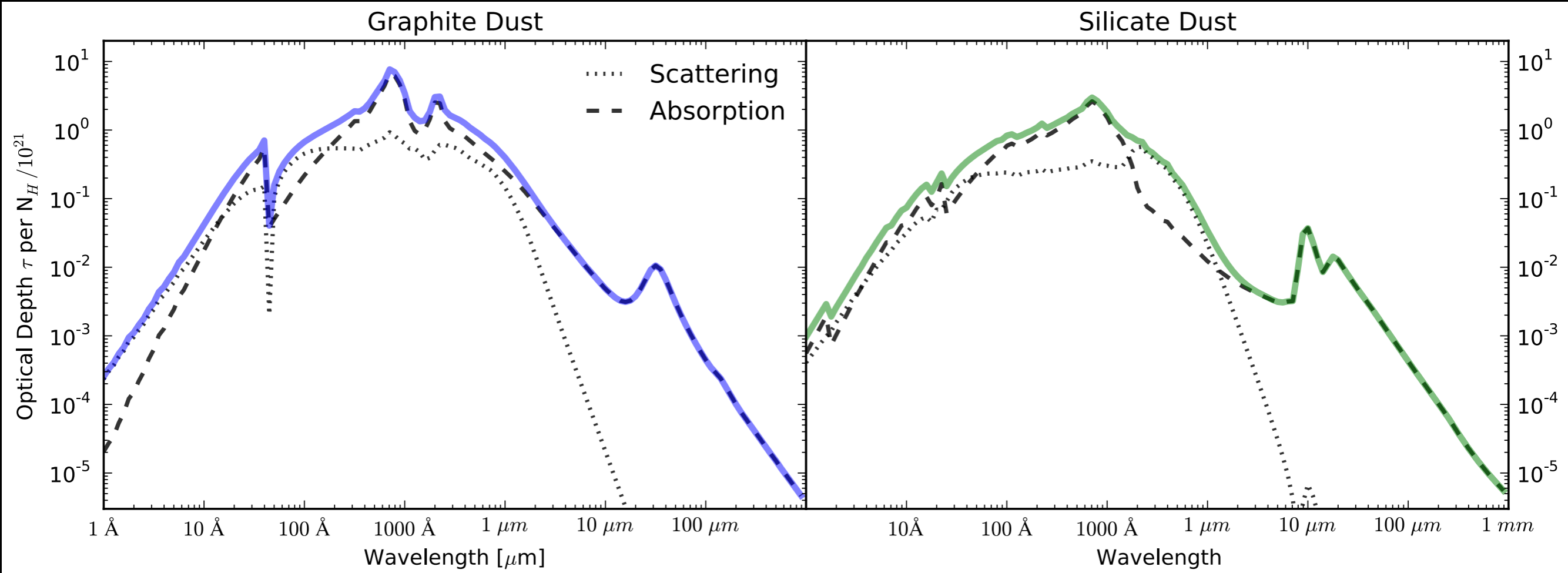
Effect on edge models (high-res)

Corrales et al. in prep

Milky Way optical depth due to dust

Chandra Workshop 2015

Corrales et al. in prep

extinction = absorption + scattering

Graphite Dust

Silicate Dust

Scattering (dotted)
Absorption (dashed)

Optical Depth τ per $N_H / 10^{21}$

Wavelength [μm]

Wavelength

extinction = [phabs TBabs TBnew | absorption] + [~~dust~~ | scattering]

Graphite Dust

Silicate Dust

Optical Depth τ per $N_H / 10^{21}$

Wavelength [μm]

Wavelength

Scattering
Absorption

Corrales et al. in prep

What do I mean by dust?
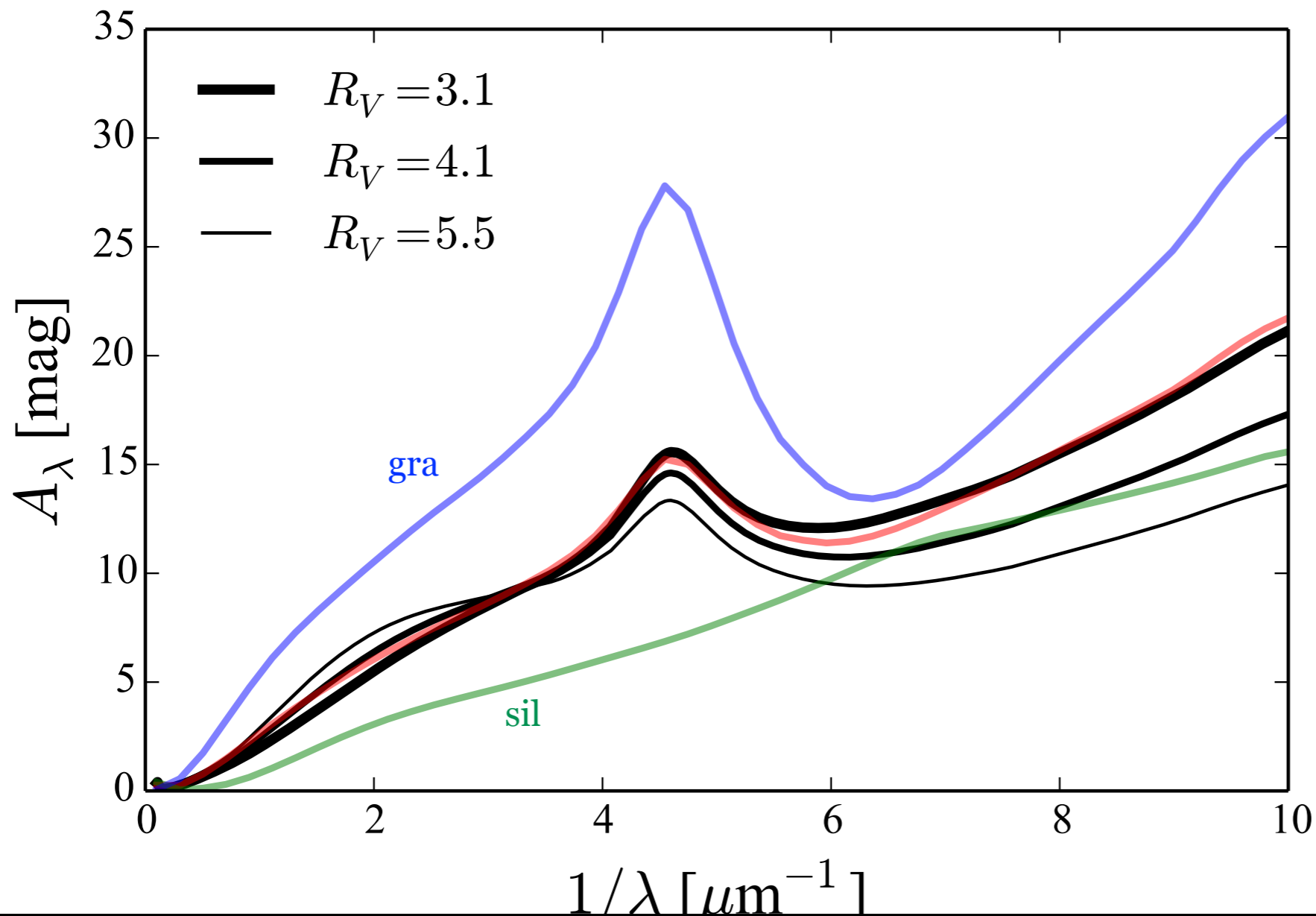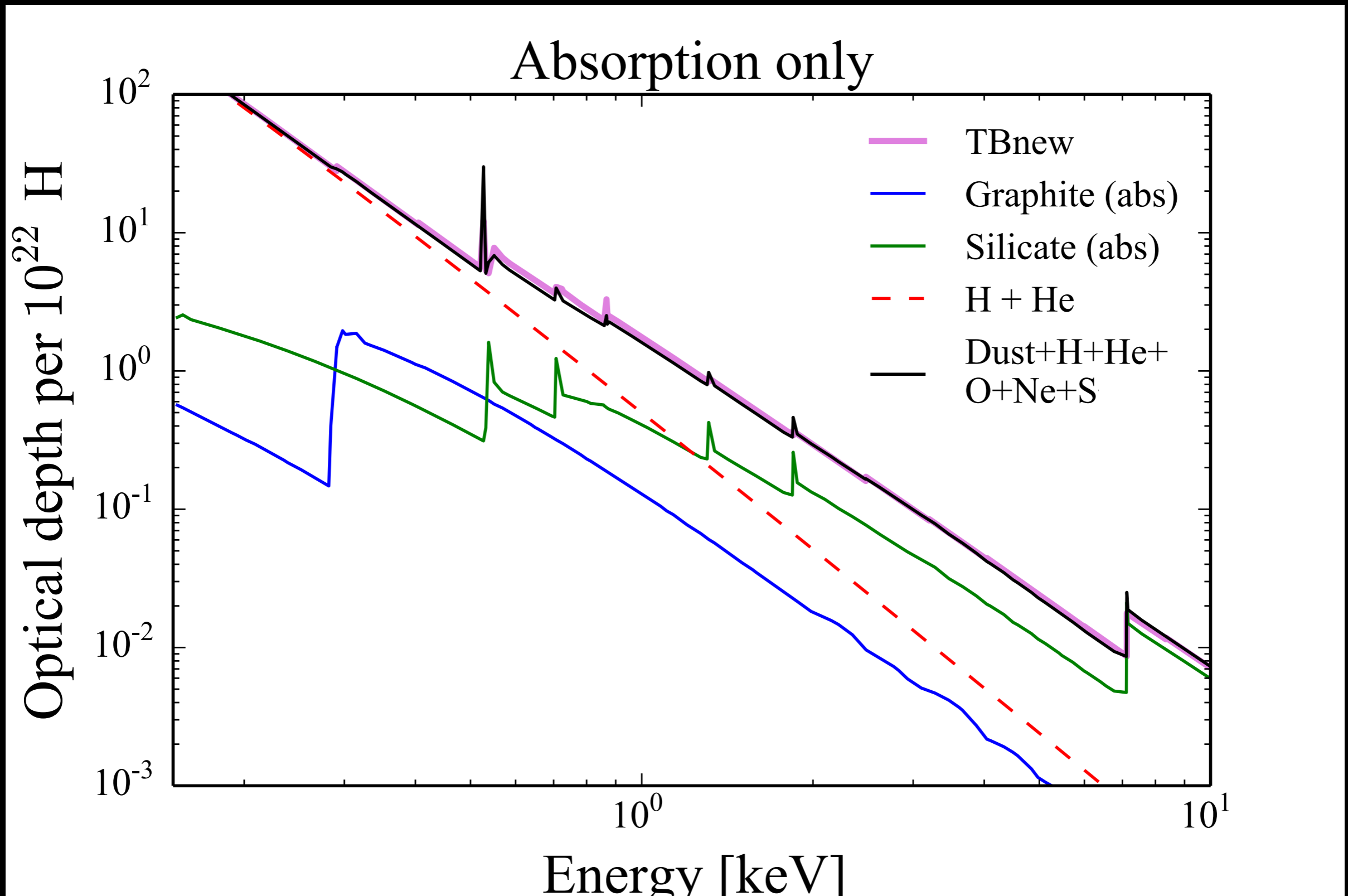

MRN 1977

$$\frac{dn_d}{da} \propto a^{-3.5}$$

$0.005\mu m \leq a \leq 0.3\mu m$

Astrosilicate and
Graphite
optical constants
from Draine (2003)

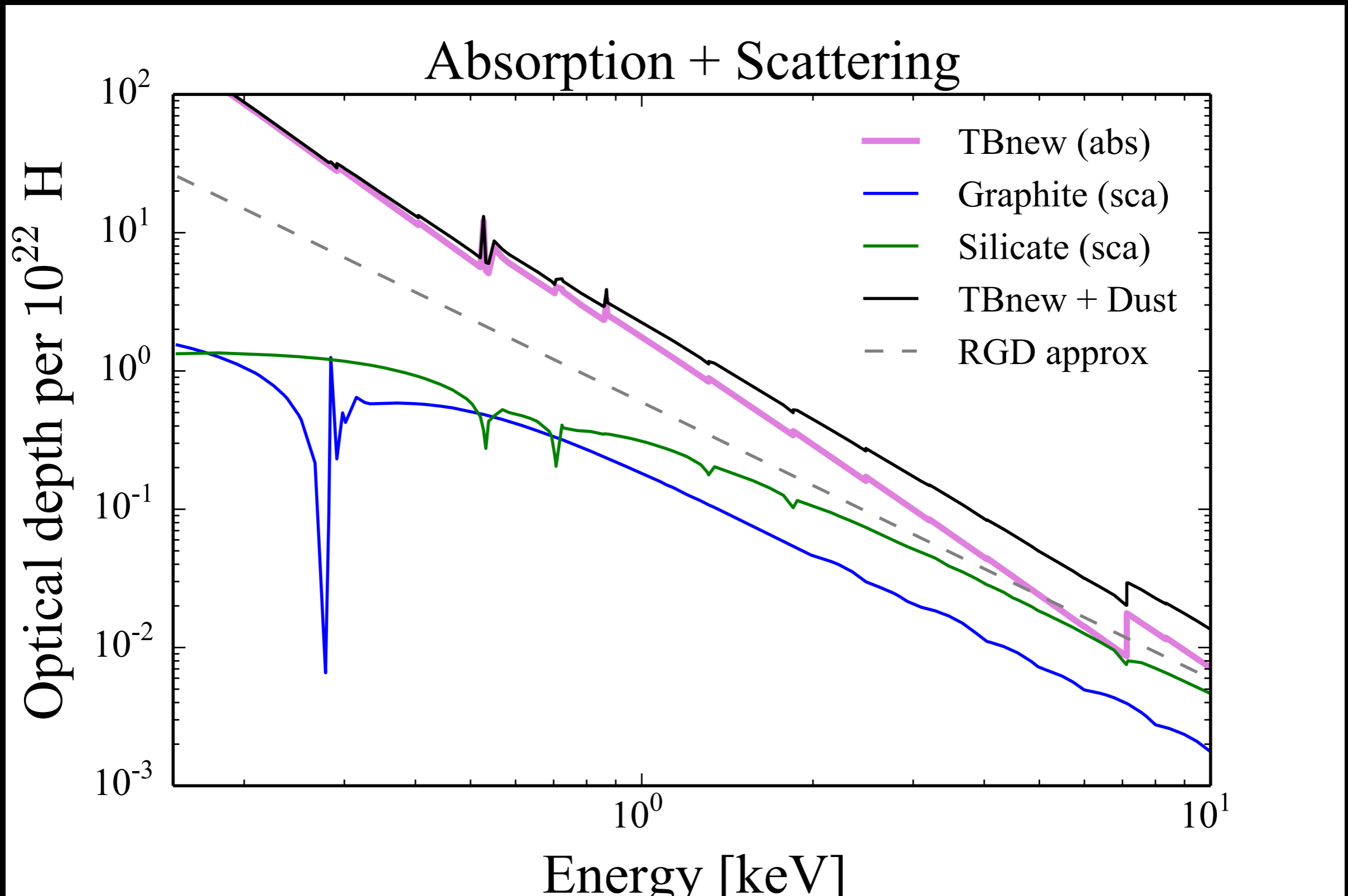**60% silicate**
40% graphite

**no amorphous, iron needles,
or low-filling factor ("fluffy") dust**

Corrales et al. in prep

Dust scattering has sizable contribution to ISM extinction

Dust scattering has sizable contribution to ISM extinction

Absorption + Scattering

Legend:
- TBnew (abs)
- Graphite (sca)
- Silicate (sca)
- TBnew + Dust
- RGD approx

Y-axis: Optical depth per 10^{22} H
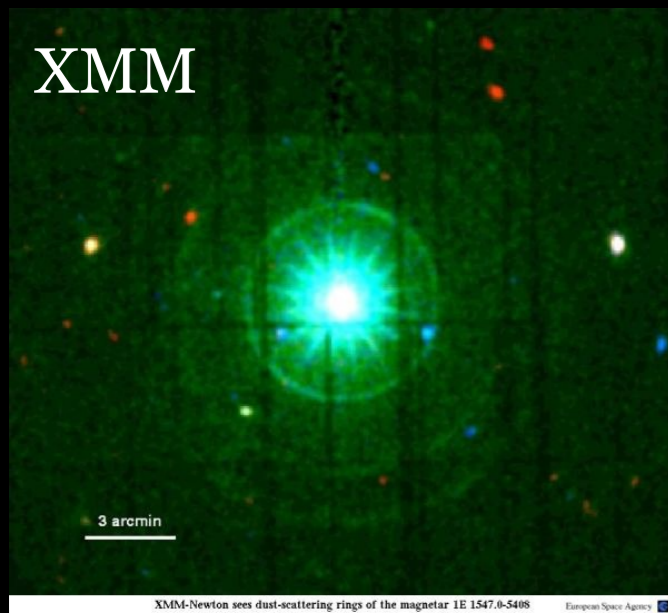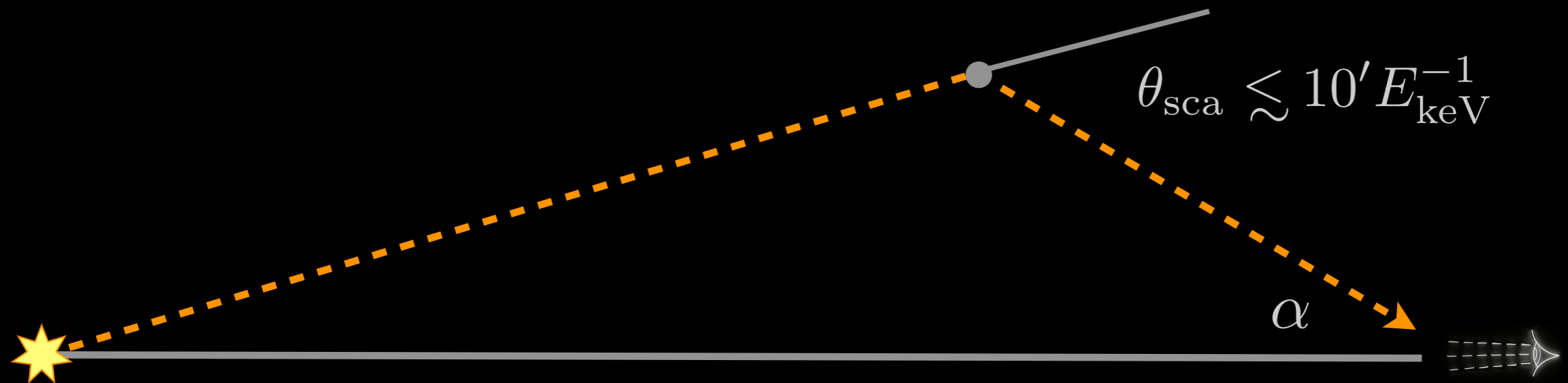
X-axis: Energy [keV]
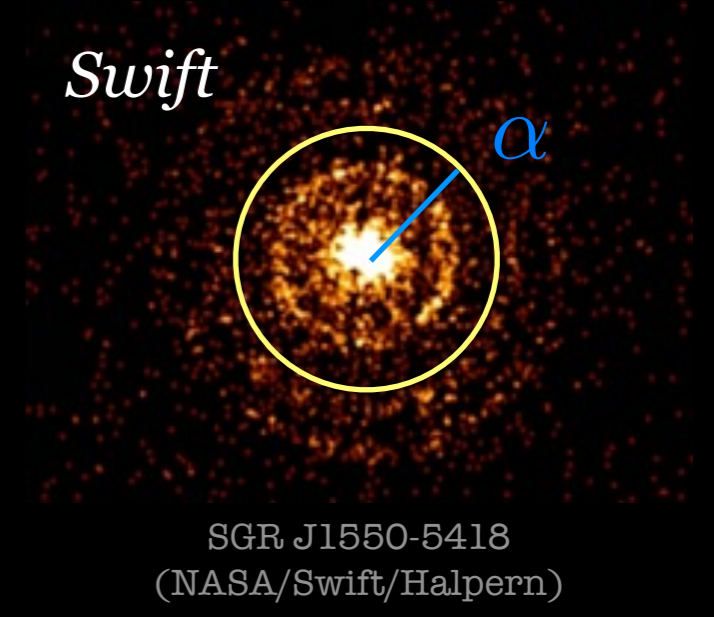
Total ISM optical depth due to dust extinction

Effect on continuum models (low-res)

Effect on edge models (high-res)

light scattered by dust **intermediate in line of sight**
produces a scattering halo image

$$\theta_{\mathrm{sca}} \lesssim 10' E_{\mathrm{keV}}^{-1}$$

α

XMM

3 arcmin

XMM-Newton sees dust-scattering rings of the magnetar 1E 1547.0-5408   European Space Agency

IE 1547.0-5408 (ESA)

Chandra

Cygnus X-3

Swift

α

SGR J1550-5418
(NASA/Swift/Halpern)
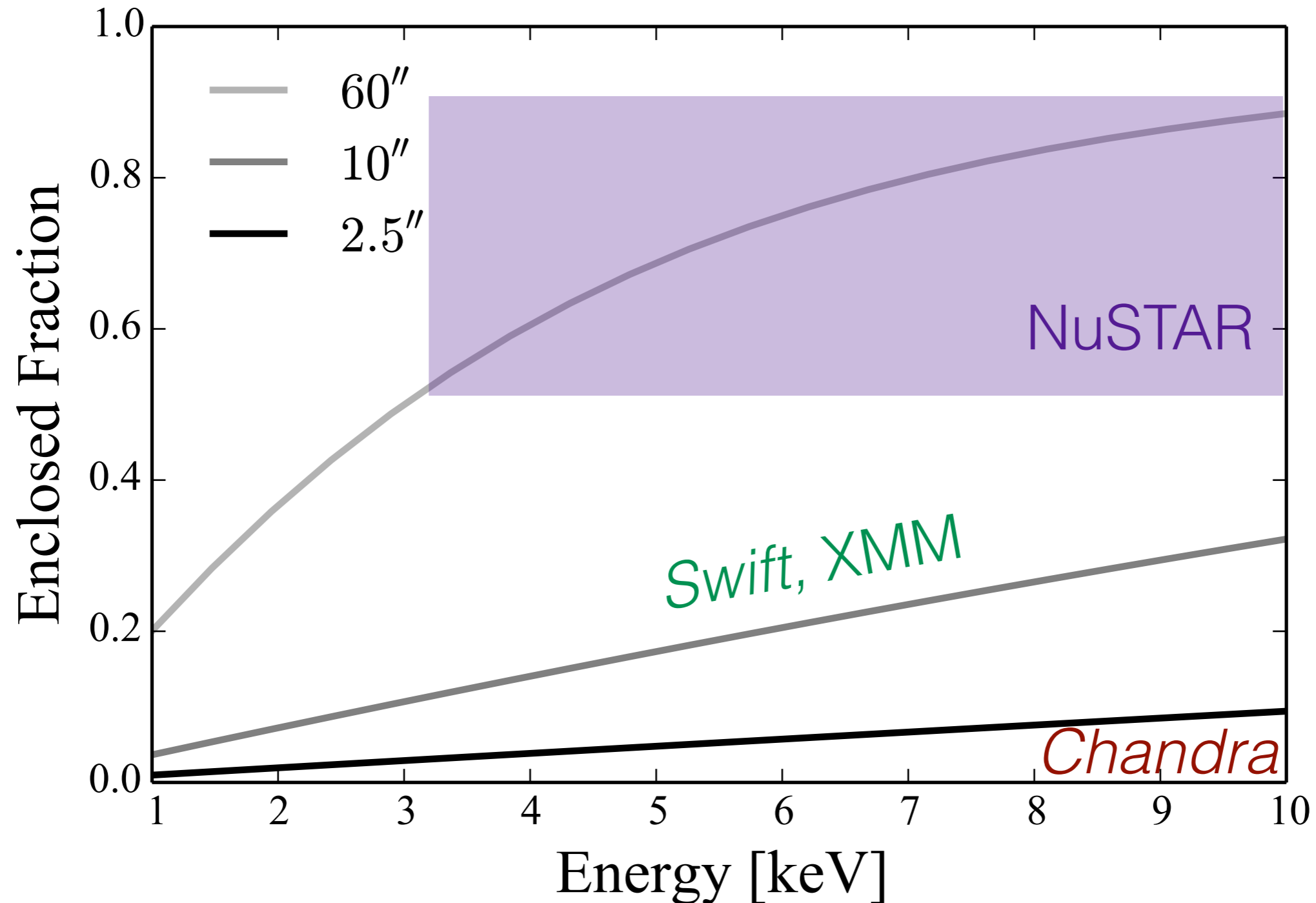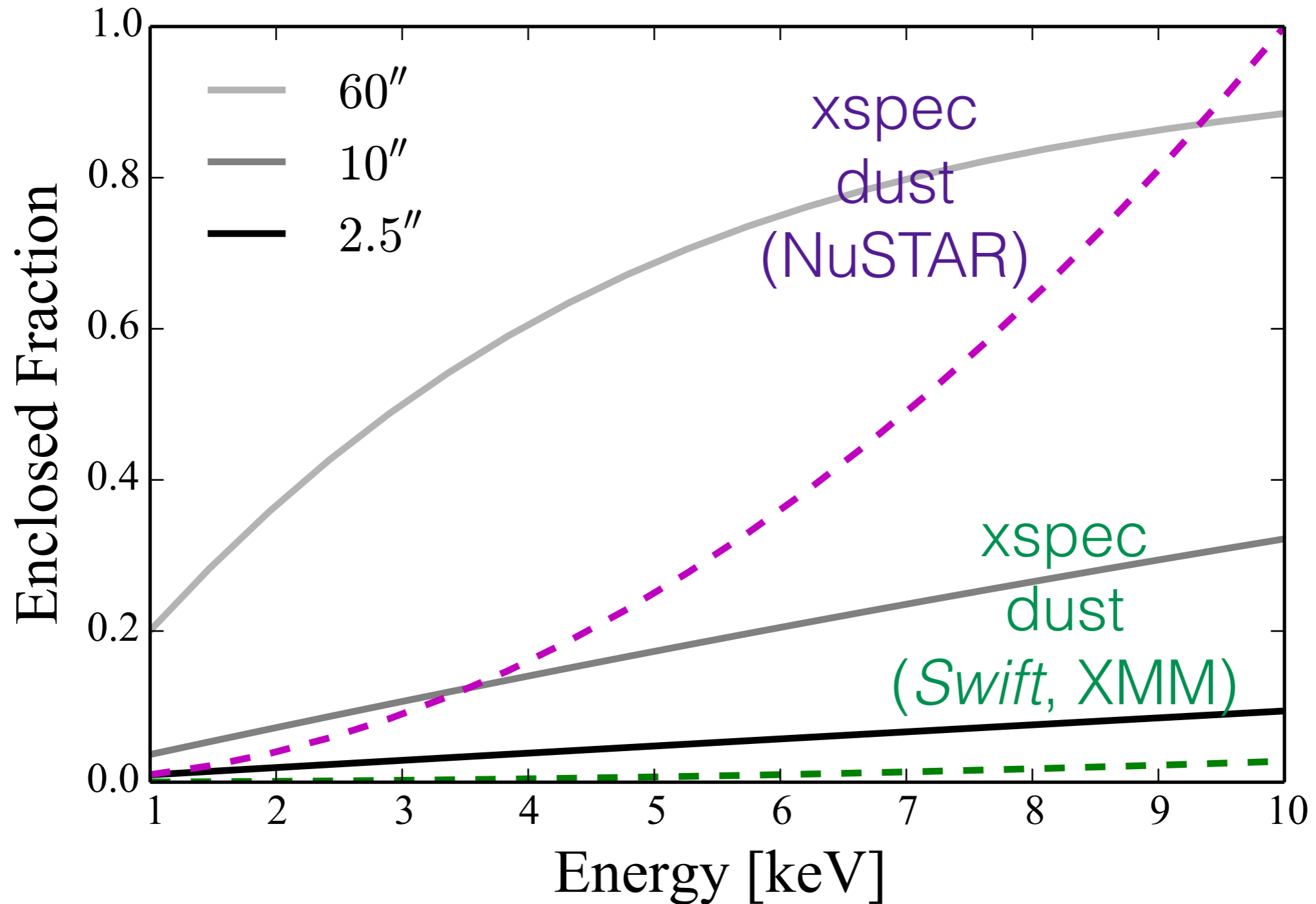
dust scattering mainly affects
sub-arcmin resolution instruments

fraction of dust scattering halo captured within source extraction region (PSF)

Legend:
- 60″
- 10″
- 2.5″

NuSTAR

Swift, XMM

Chandra

Y-axis: Enclosed Fraction (0.0 – 1.0)

X-axis: Energy [keV] (1 – 10)

Corrales et al. in prep

fraction of dust scattering halo captured
within source extraction region (PSF)

~10,000 simulated ACIS-I spectra

Simulations with dust:

$$powerlaw * \boxed{TBnew} * exp(\boxed{-tau\_dust})$$

absorption only

**5% scattering per 10^{21} H
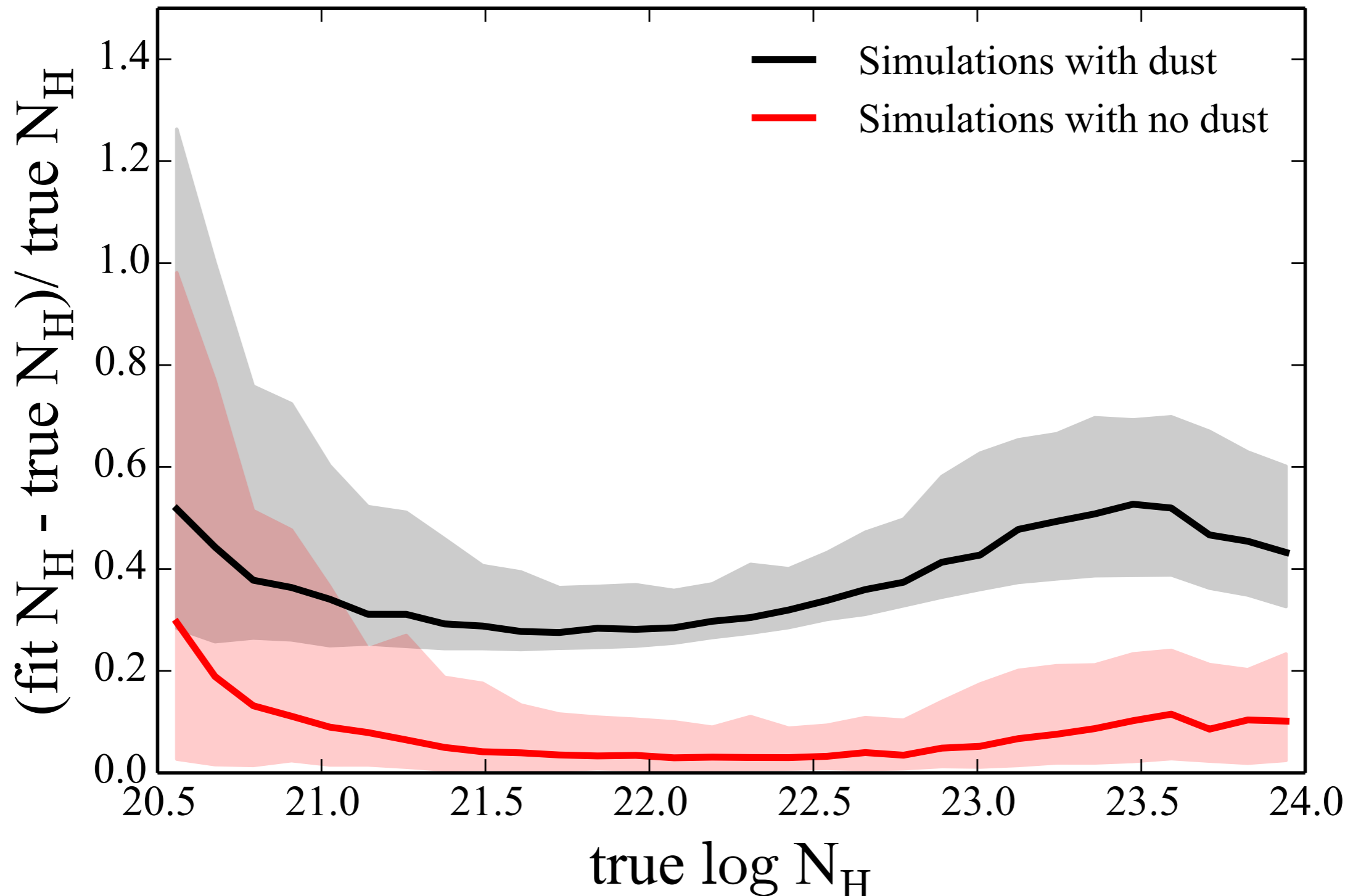with E^{-2} dependence
(for now 100% loss)**

Simulations without dust:

$$powerlaw * TBnew$$
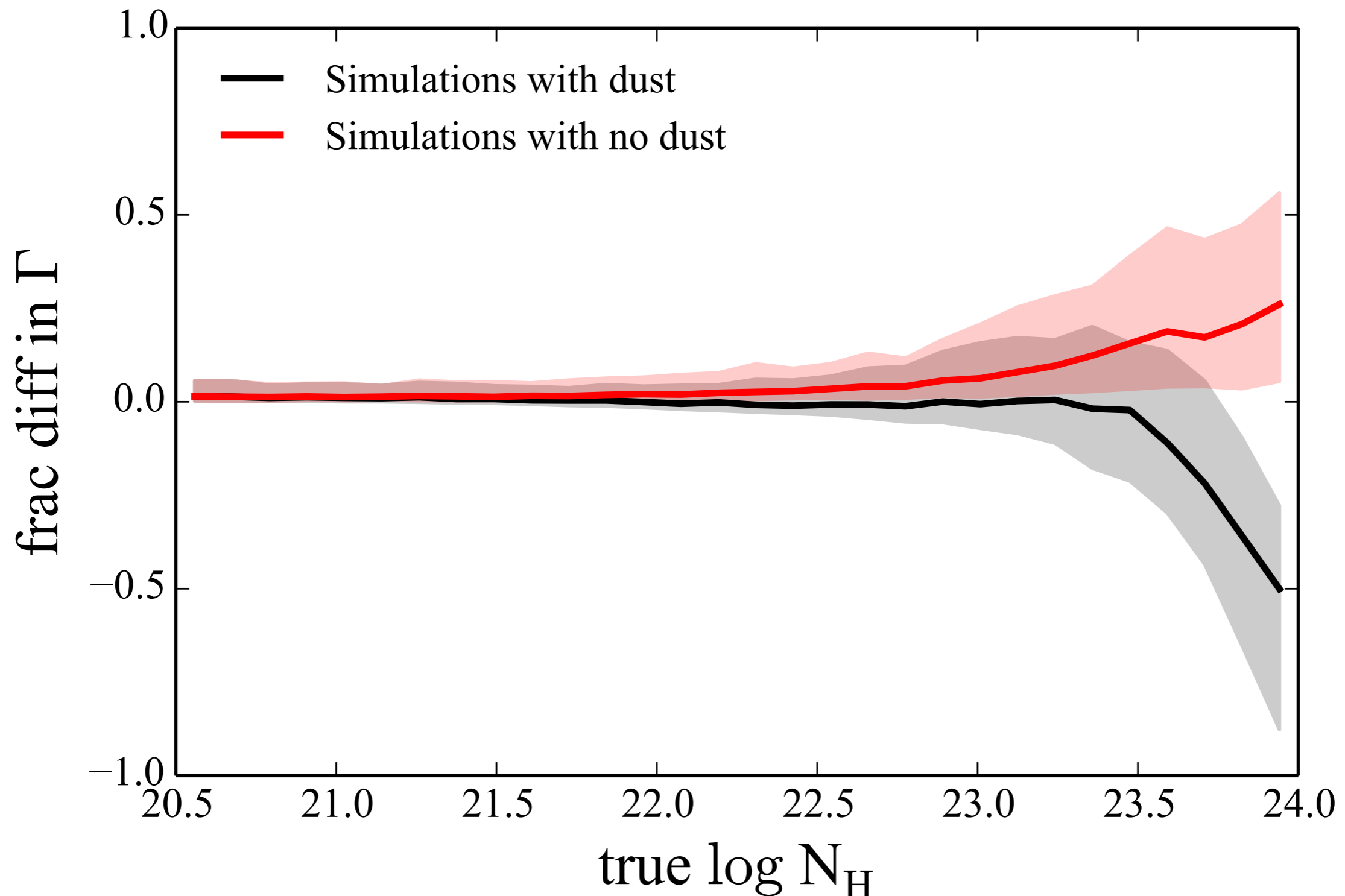
All fits performed without dust (same as above)
0.3 - 8 keV

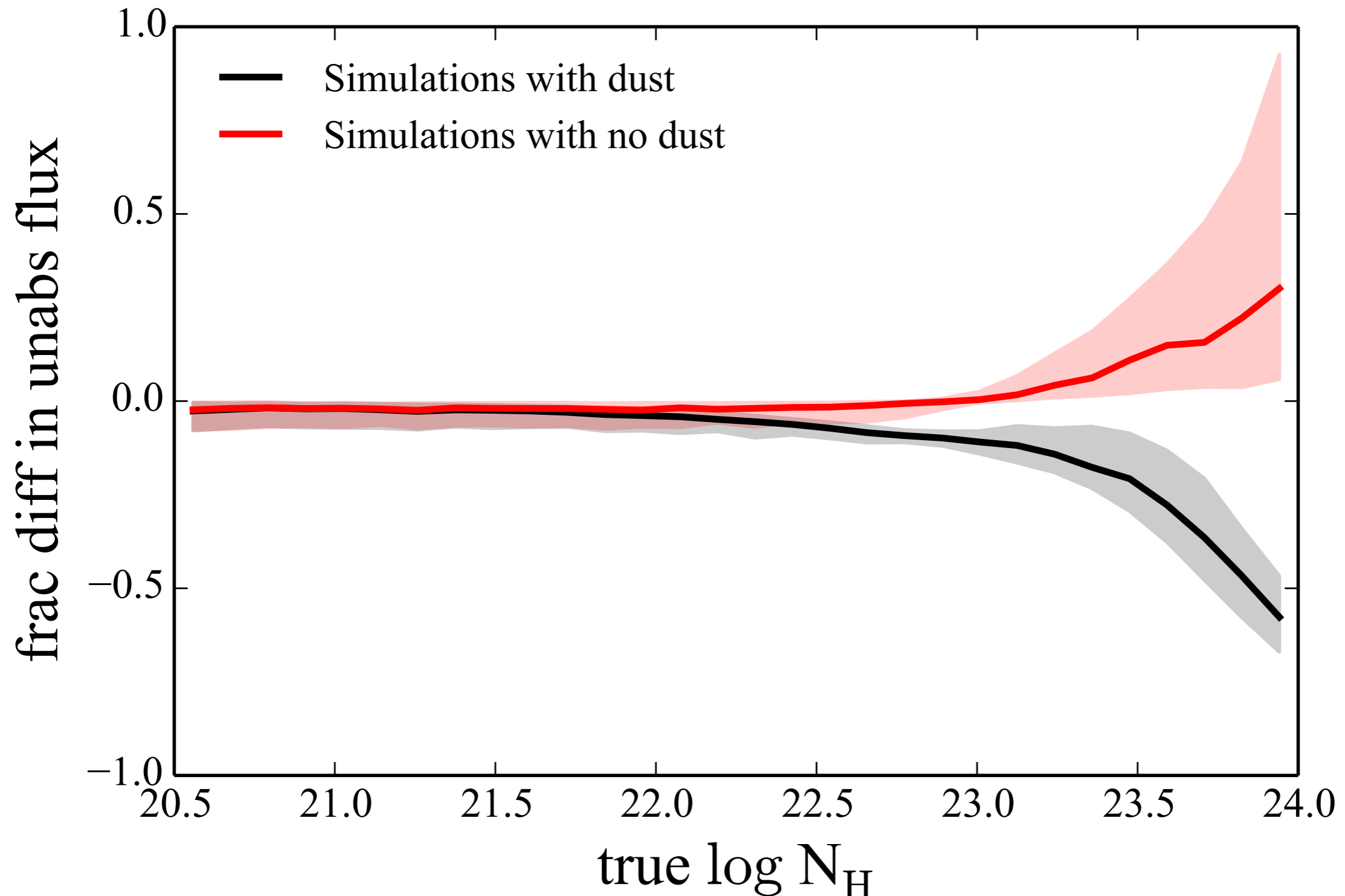# Without dust extinction, systematic offset in fit parameters

Corrales et al. in prep

Without dust extinction, systematic offset in fit parameters

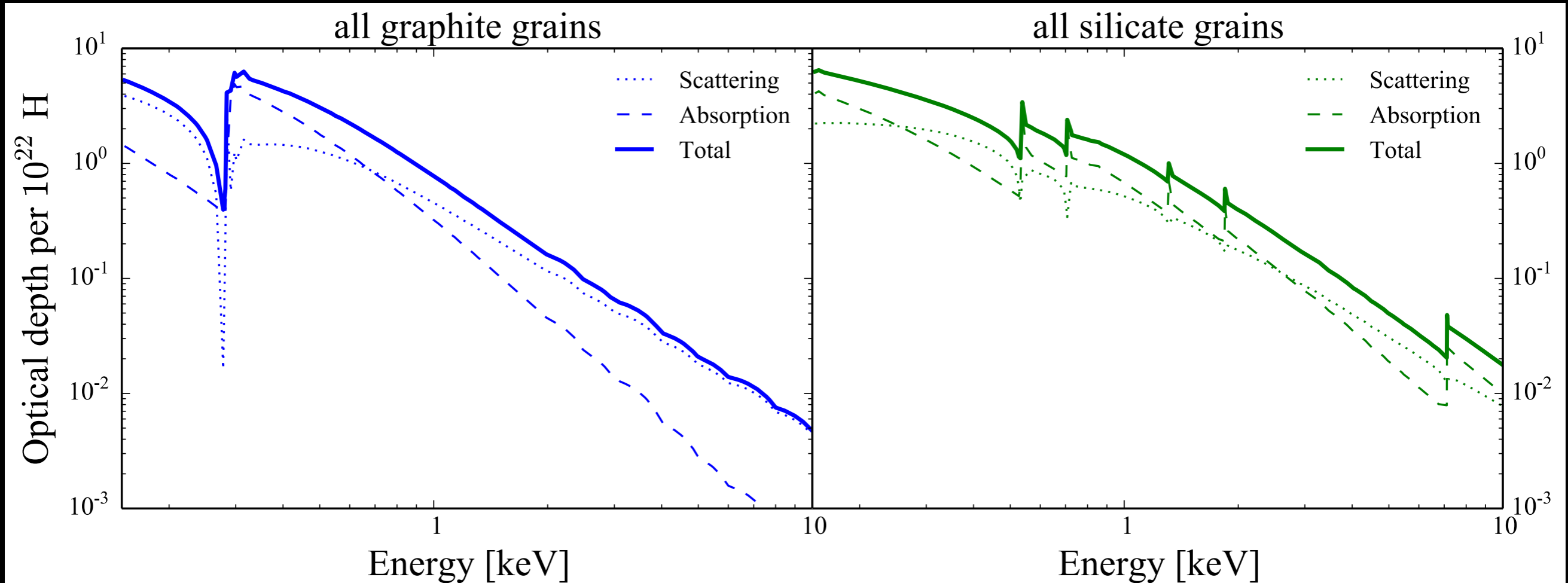# Without dust extinction, systematic offset in fit parameters

Total ISM optical depth due to dust extinction

Effect on continuum models (low-res)

Effect on edge models (high-res)

Dust scattering affects absorption edge structure

Dust scattering affects absorption edge structure

all graphite grains

all silicate grains

Fe-L edge

Draine (2003) by way of van Aken & Liebscher (2002)
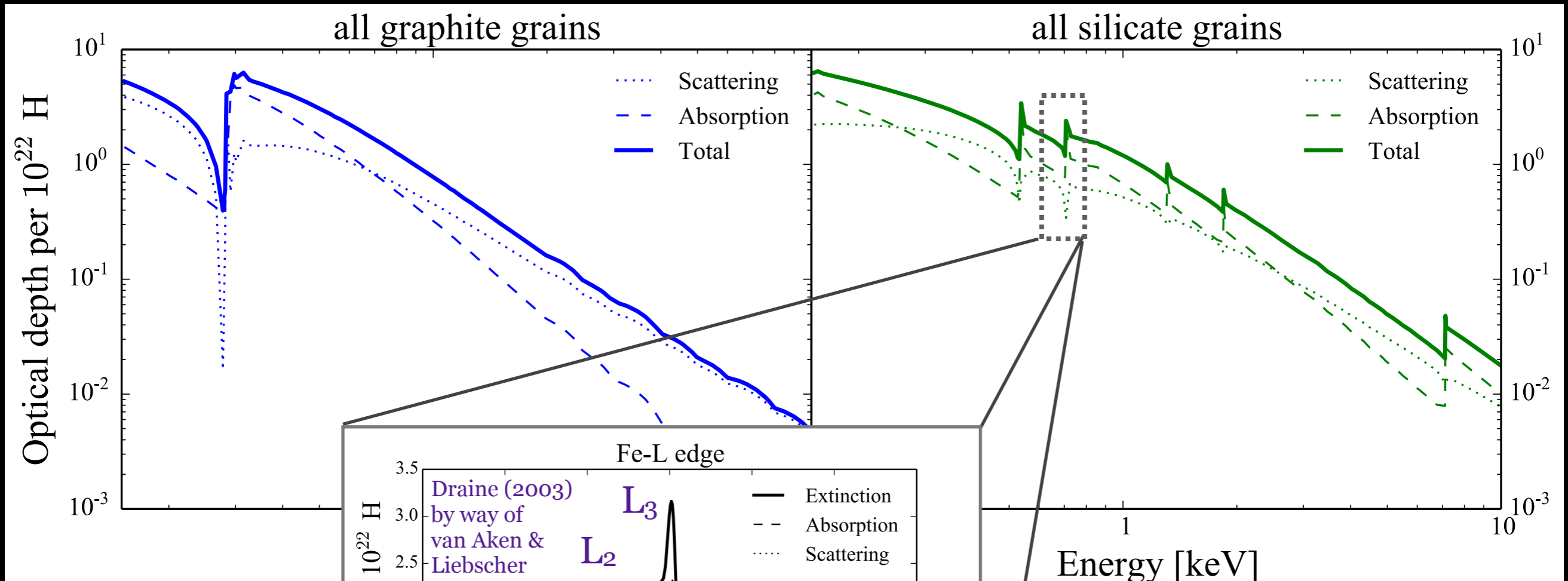
Fe-L: see also Juett+ (2006) and Kortright & Kim (2000)

scattering contribution: see also Costantini, Zeeger

Corrales et al. in prep

Dust scattering affects extinction for most X-ray telescopes

- Percent loss depends on **telescope resolution**
- Percent loss also depends on **dust cloud structure**

Chandra, XMM, *Swift*:
NH > 10^{22} cm^{-2}

NuSTAR:
NH > 10^{23} cm^{-2}

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NH > 10^{22} cm^{-2} NH > 10^{23} cm^{-2}

If you don't put dust in your continuum models:

- 25-50% **overestimate of NH column**
- ~50 **underestimate of source luminosity**

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instrument resolution

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