

Measure Silicon X-ray absorption towards bright sources in the Galactic Bulge

How to measure the Si gas to dust ratio with Chandra HETG

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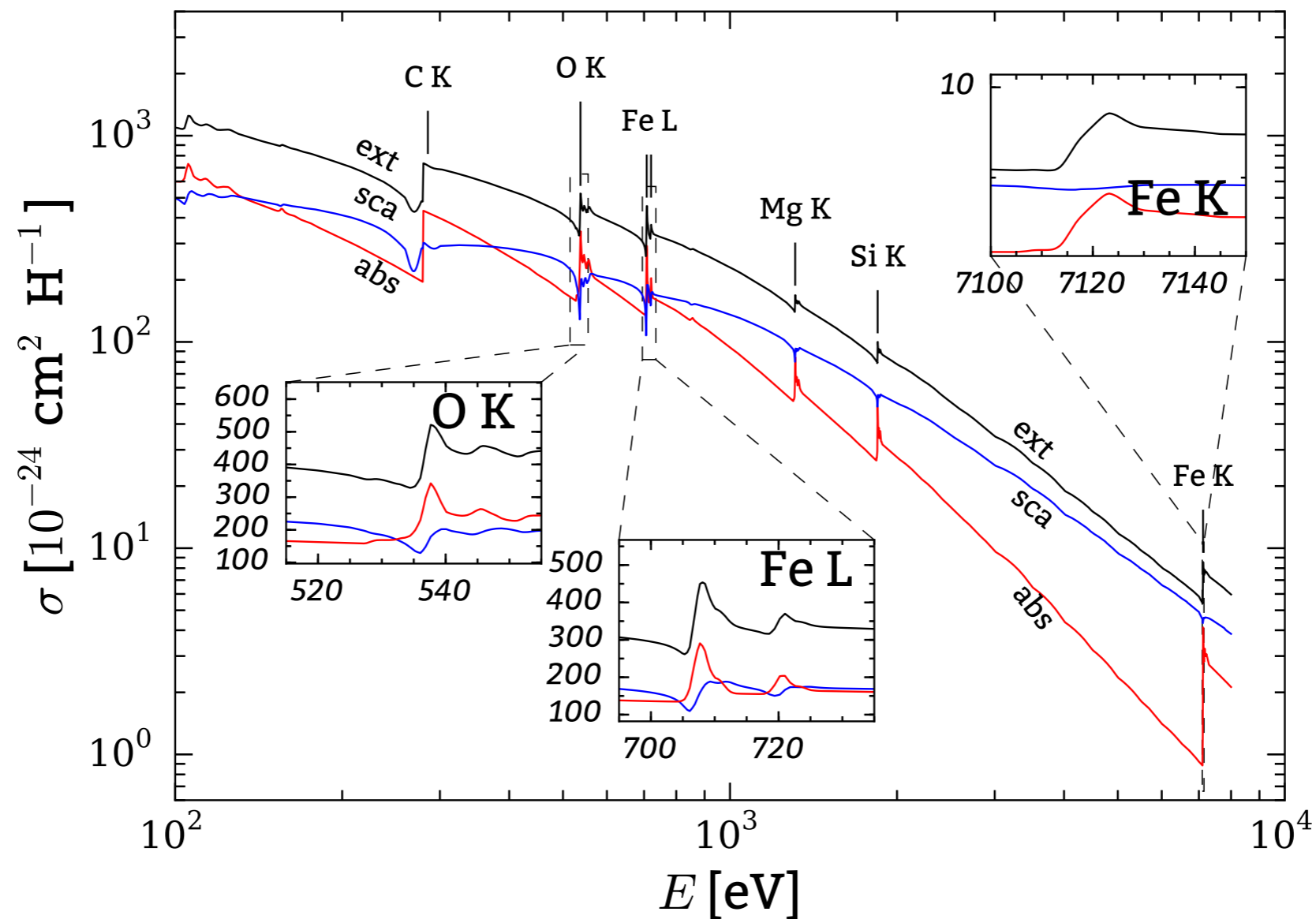
Outline

- **Dust content with Si** in interstellar matter with Chandra HETG
- Broadband **hydrogen** equivalent absorption **comparison** in bright Low-Mass X-ray Binaries: 4U 1636-53, Ser X-1, GX 3+1, 4U1728-34, 4U 1705-44, GX 340+0, GX 13+1, GX 5-1
- Goal: obtain **Si gas to dust optical depth ratio** toward 8 bright sources in the Galactic Bulge

Cross section per Hydrogen nucleus

Hoffman & Draine 2015, arXiv:1509.08987v1:

Weingartner & Draine (2001)

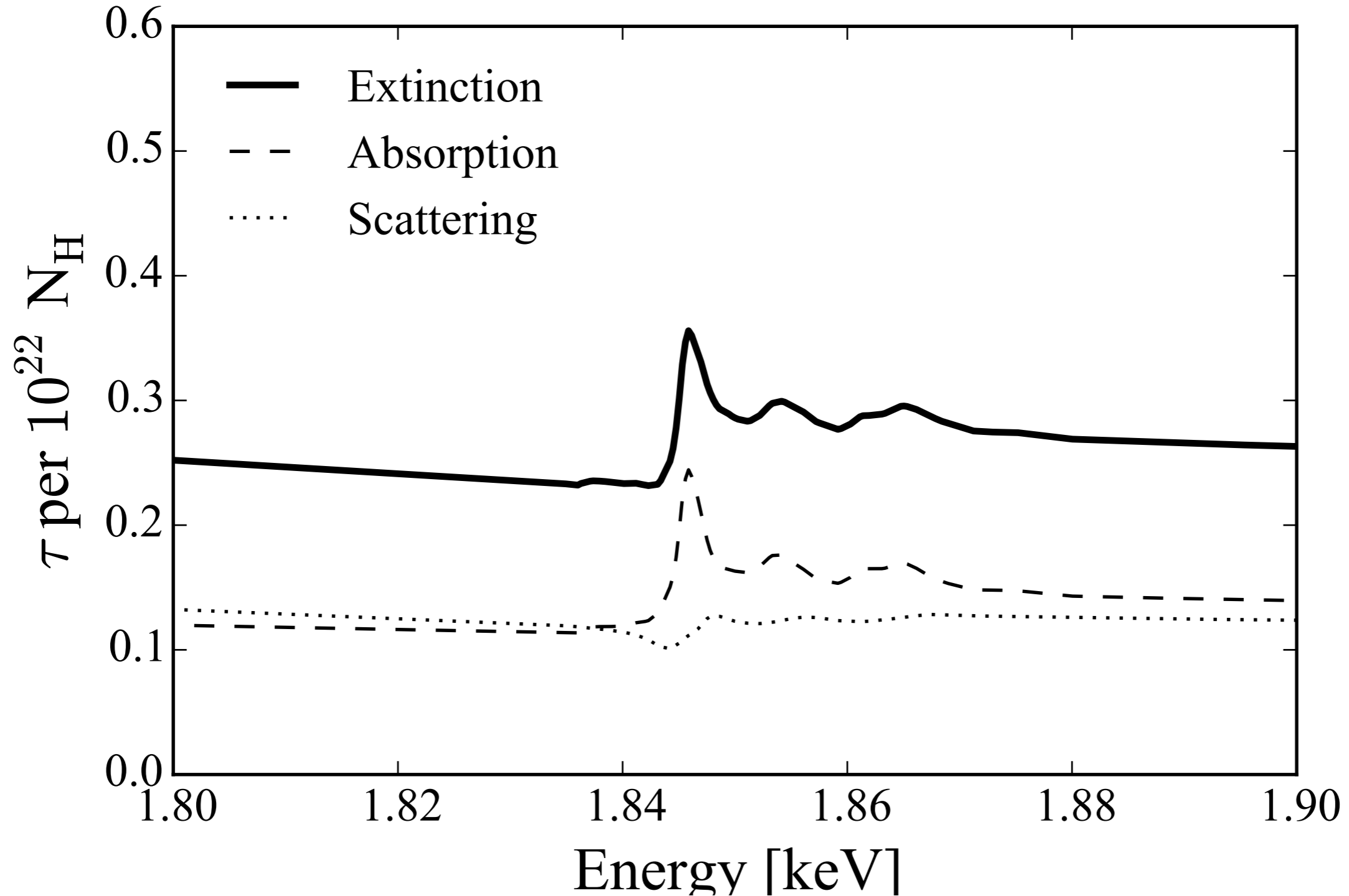


Cross section per Hydrogen nucleus for the Weingartner & Draine (2001) dust model based on Crystalline Olivine.

Scattering contributes significantly to the extinction.

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Corrales et al. 2016:



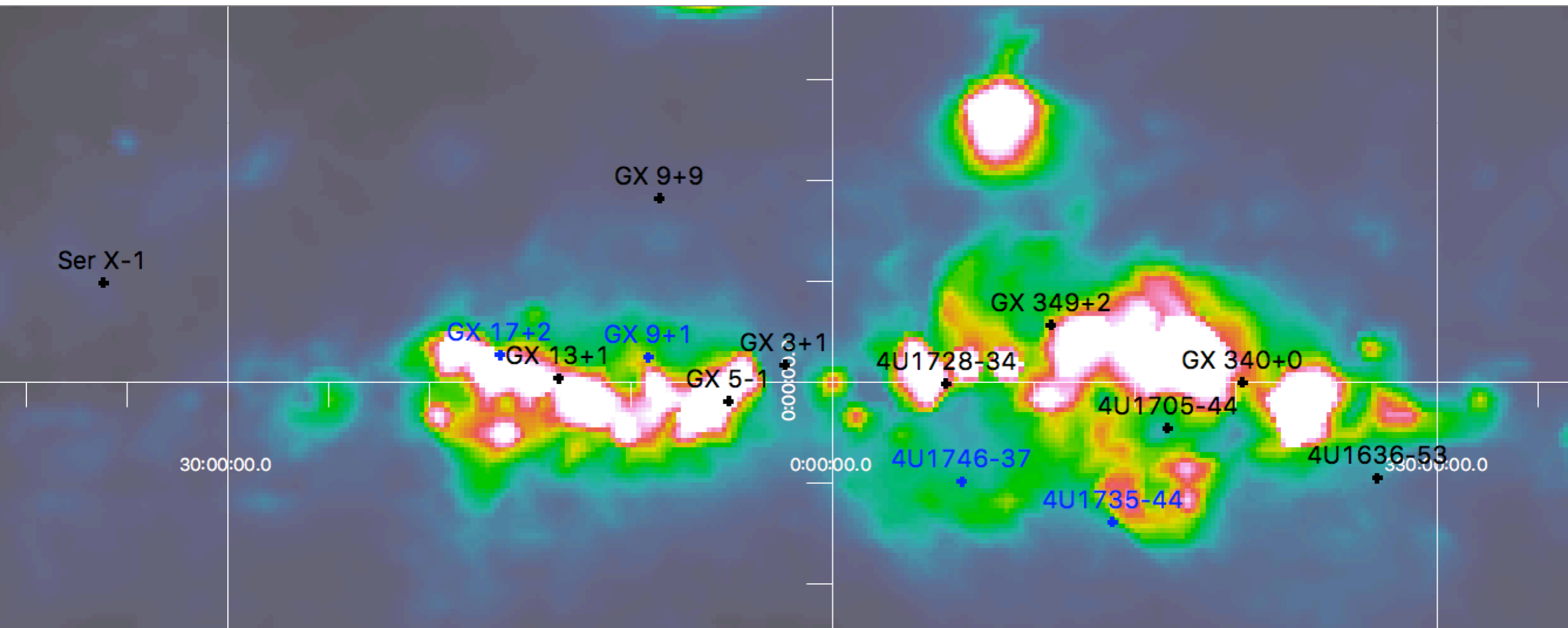
Data

- New Chandra data with very low systematic uncertainty

sources	total exposure time
4U 1636-53:	127.9 ks
4U 1705-44:	131.3 ks
4U 1728-34:	111.1 ks
GX 13+1:	141.8 ks
GX 3+1:	212.6 ks
GX 340+0:	144.9 ks
GX 5-1:	92.6 ks
Ser X-1:	120.3 ks

(See also [Zeegers et al. 2017](#), [Rogantini et al. 2019](#))

Bright sources in the Galactic Bulge



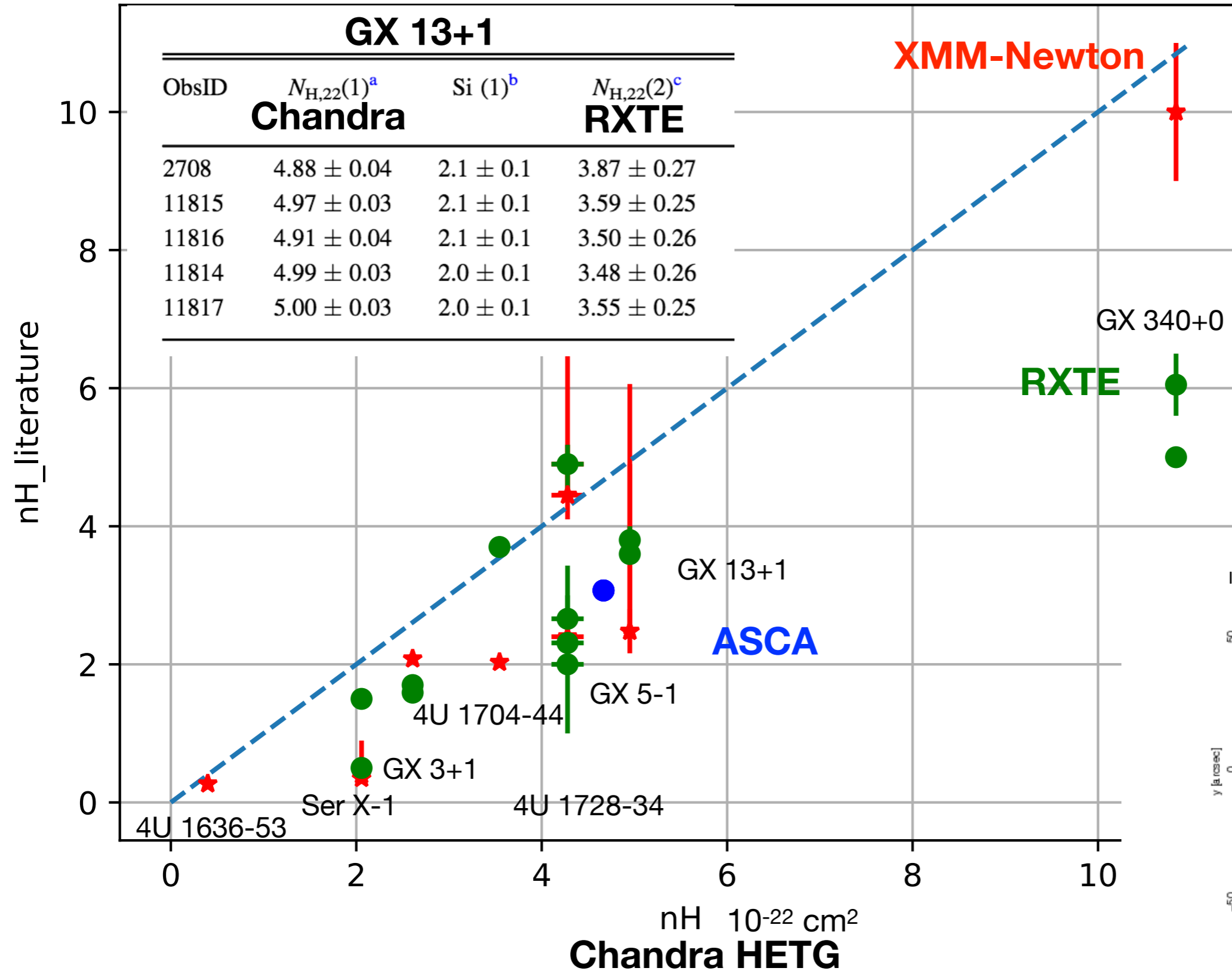
Wisconsin H-Alpha mapper (WHAM) survey

Sources labeled in Black: part of our current survey

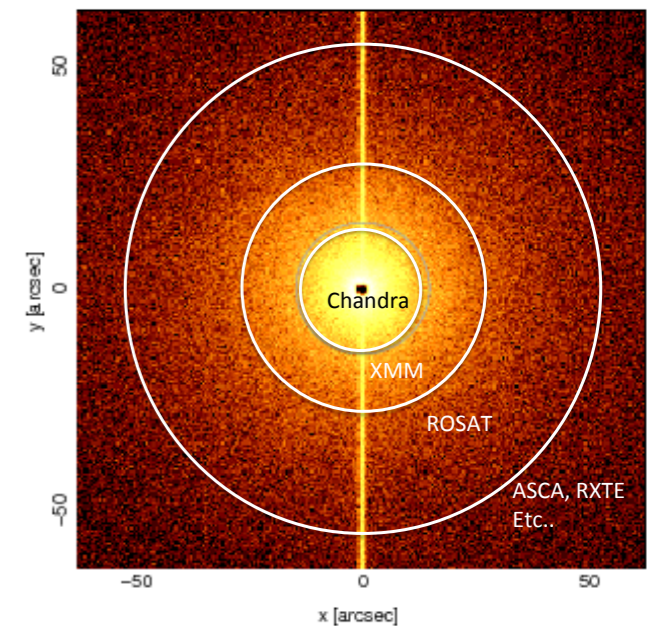
Blue: our newly proposed data of the highly absorbed sources in the Galactic Bulge.

Chandra nH v.s. Missions nH

(Broadband nH: 1-7 keV)

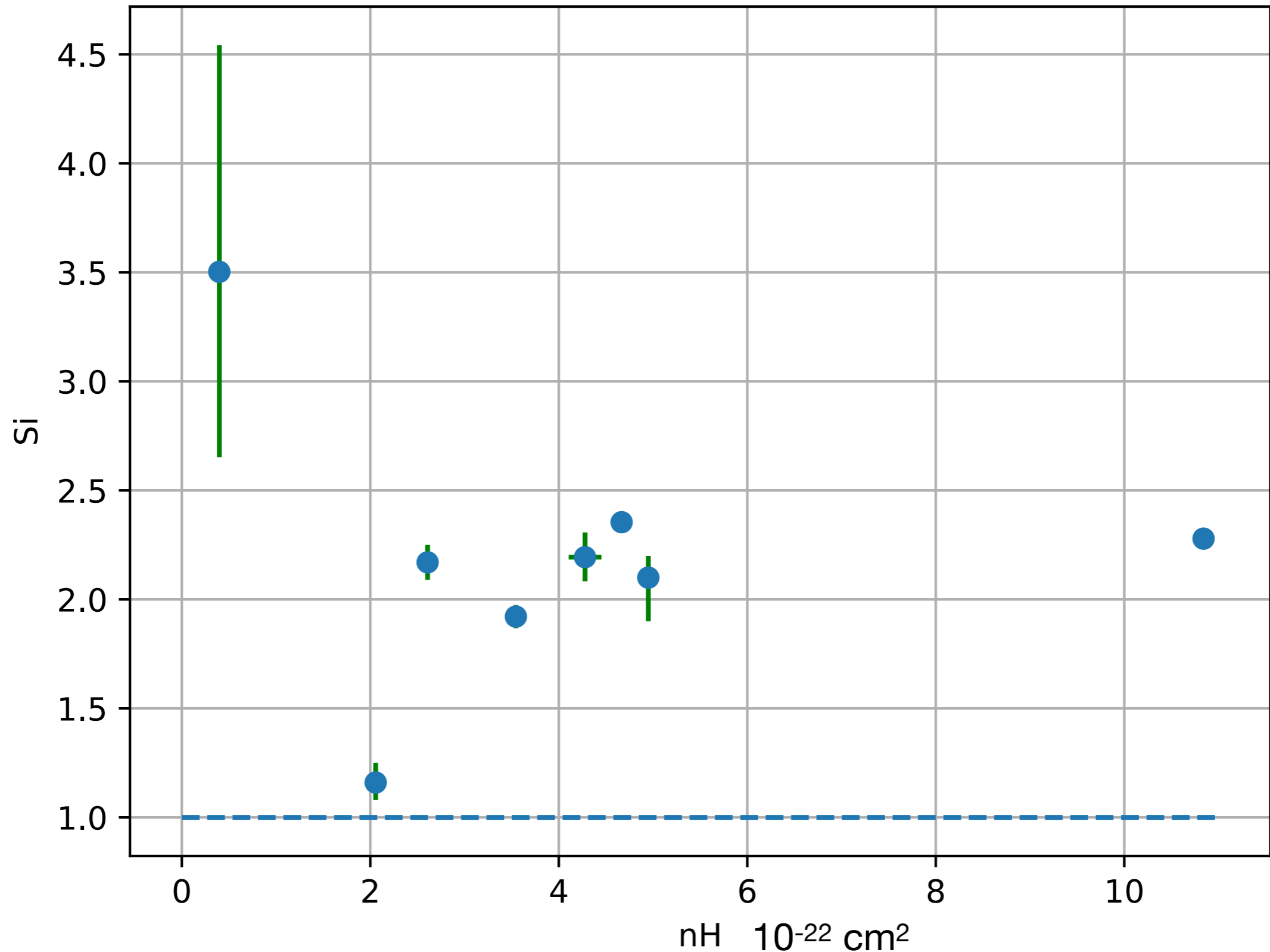


Inclusion of Scattering for various Missions



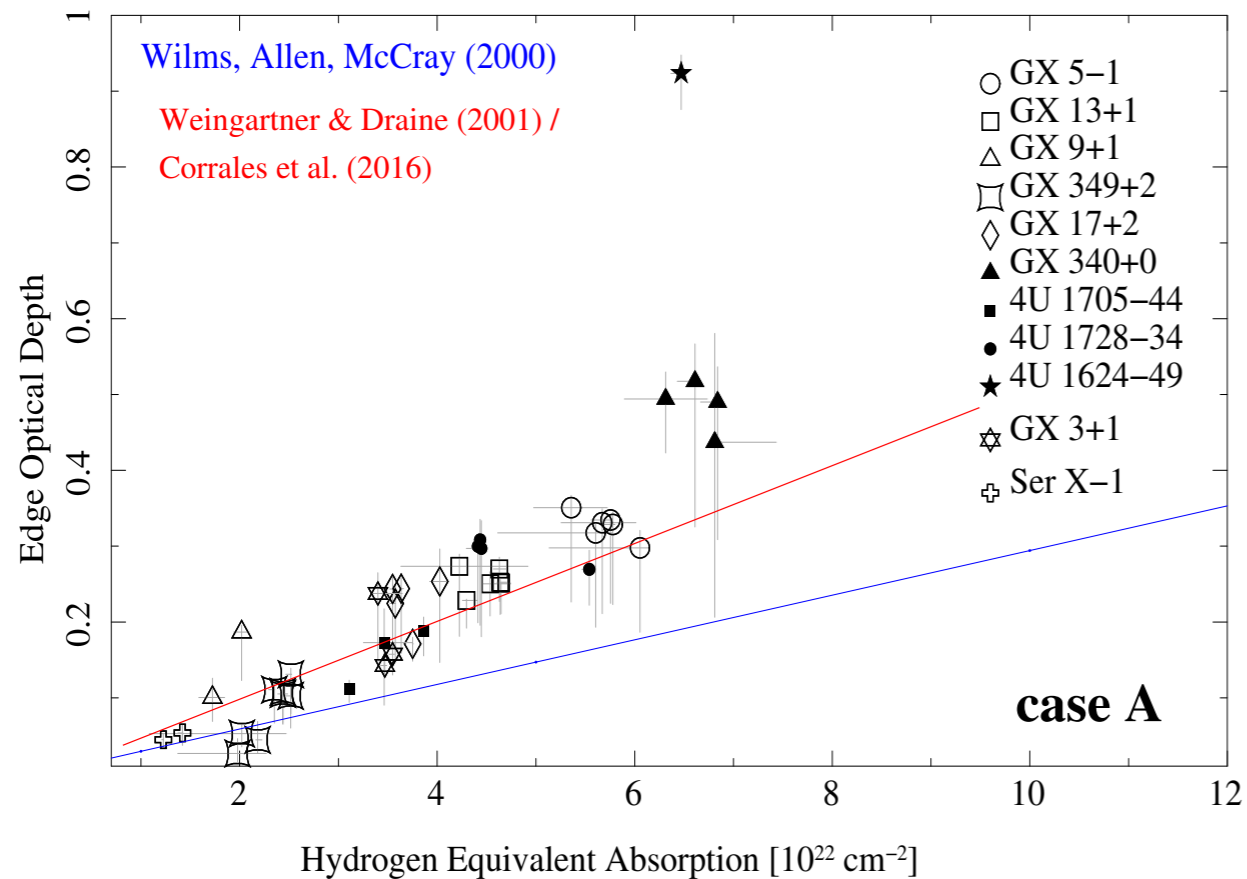
Broadband nH v.s. Si abundance

(abundance relative to ISM from Wilms, Allen, & McCray 2000)



Gas Optical depth previous data

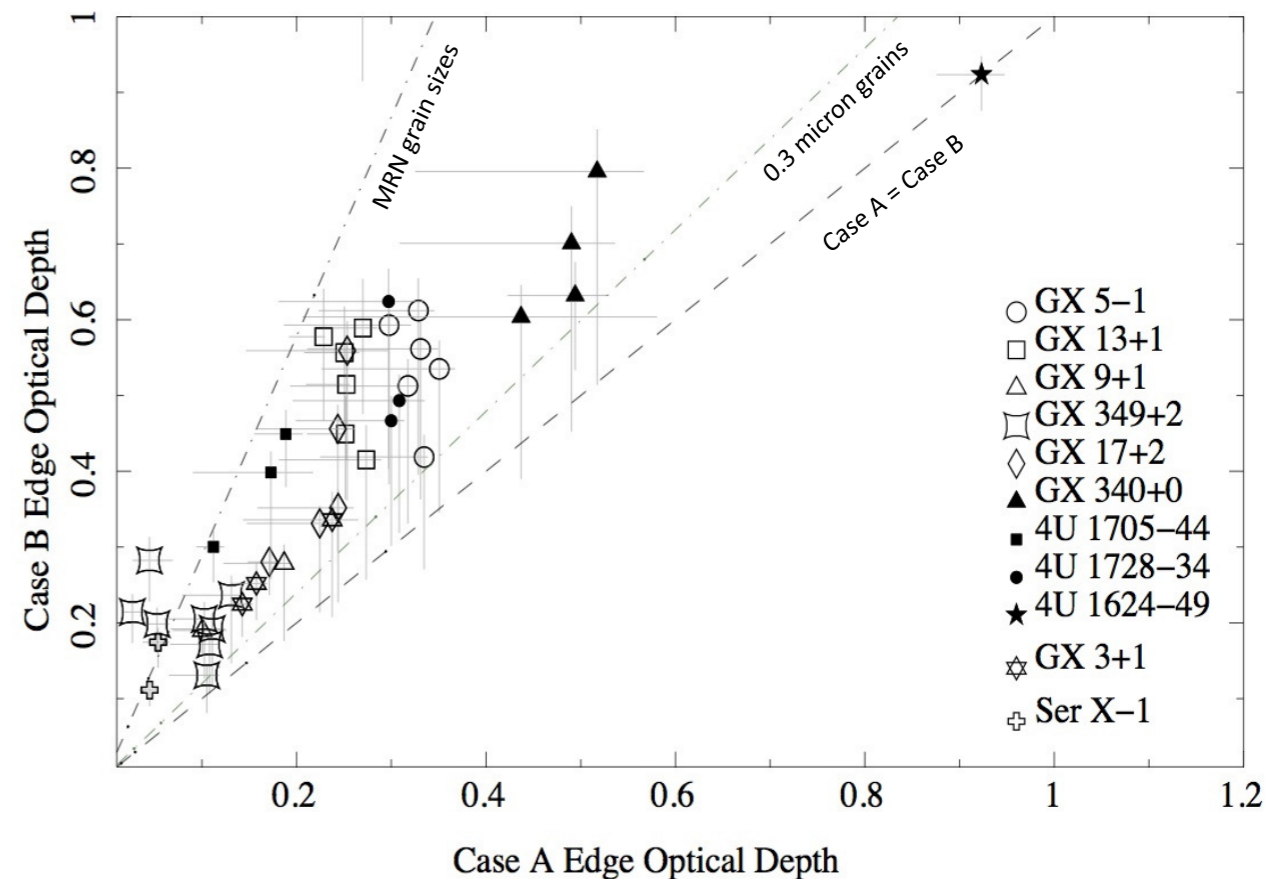
- Si optical depth comparison between **different instruments**.



Schulz et. al 2016

Hydrogen column density broad band

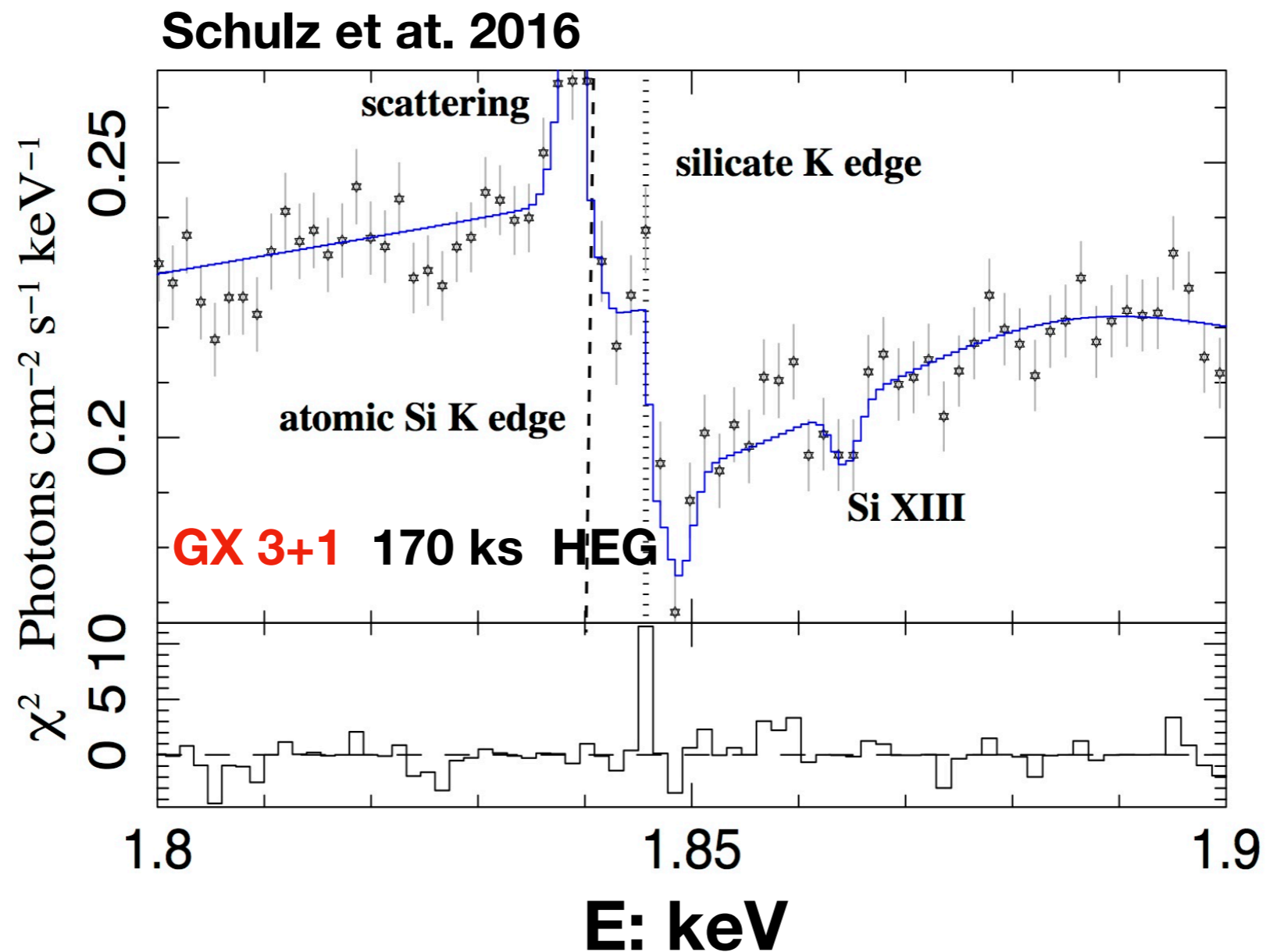
Not comply with Wilms, Allen, McCray prediction



Case A: **gas**

Case B: **gas + dust**

High resolution structure of the Si K edge

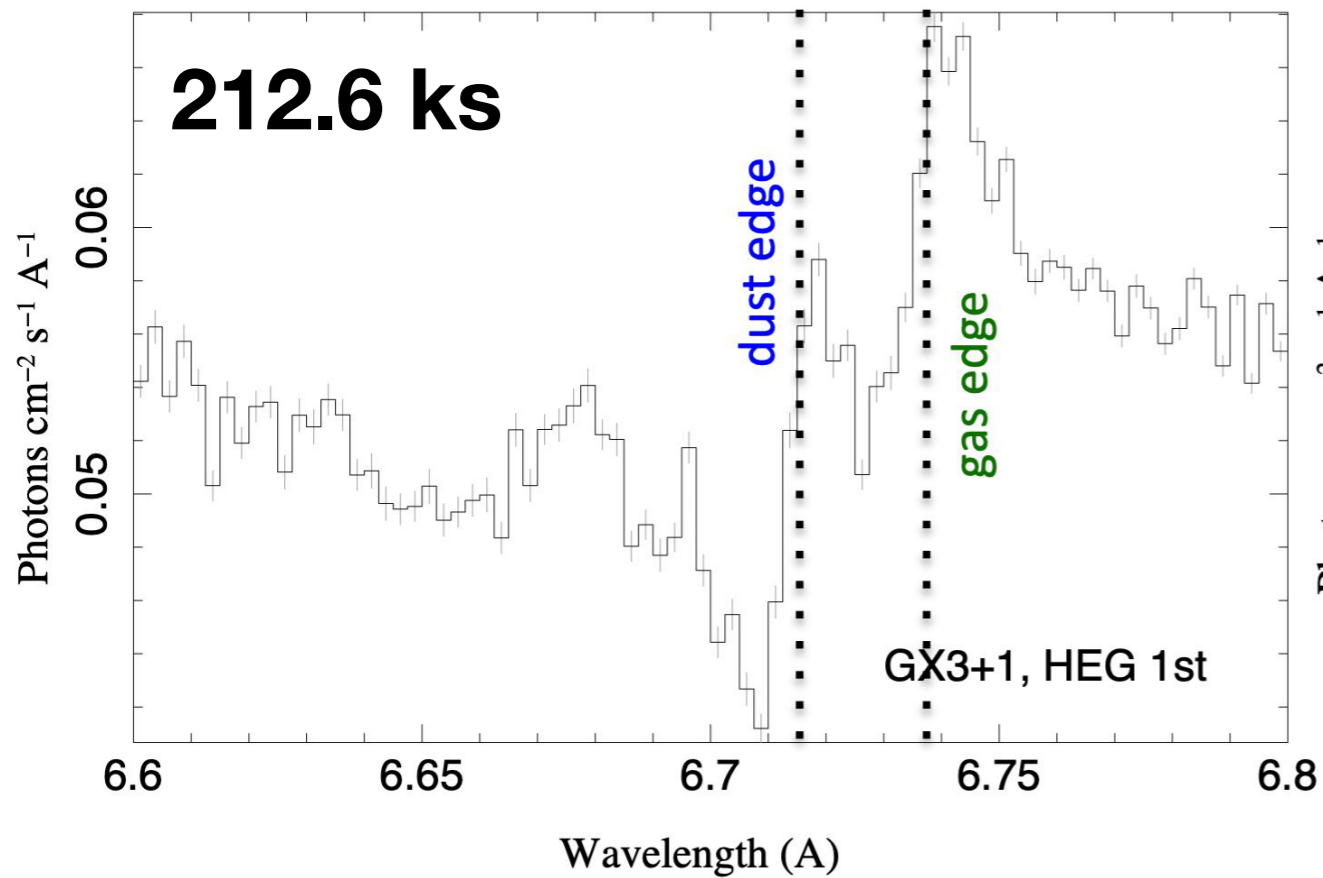


Only see this structure when look at the HETG grating data at the highest resolution.
2 eV resolution

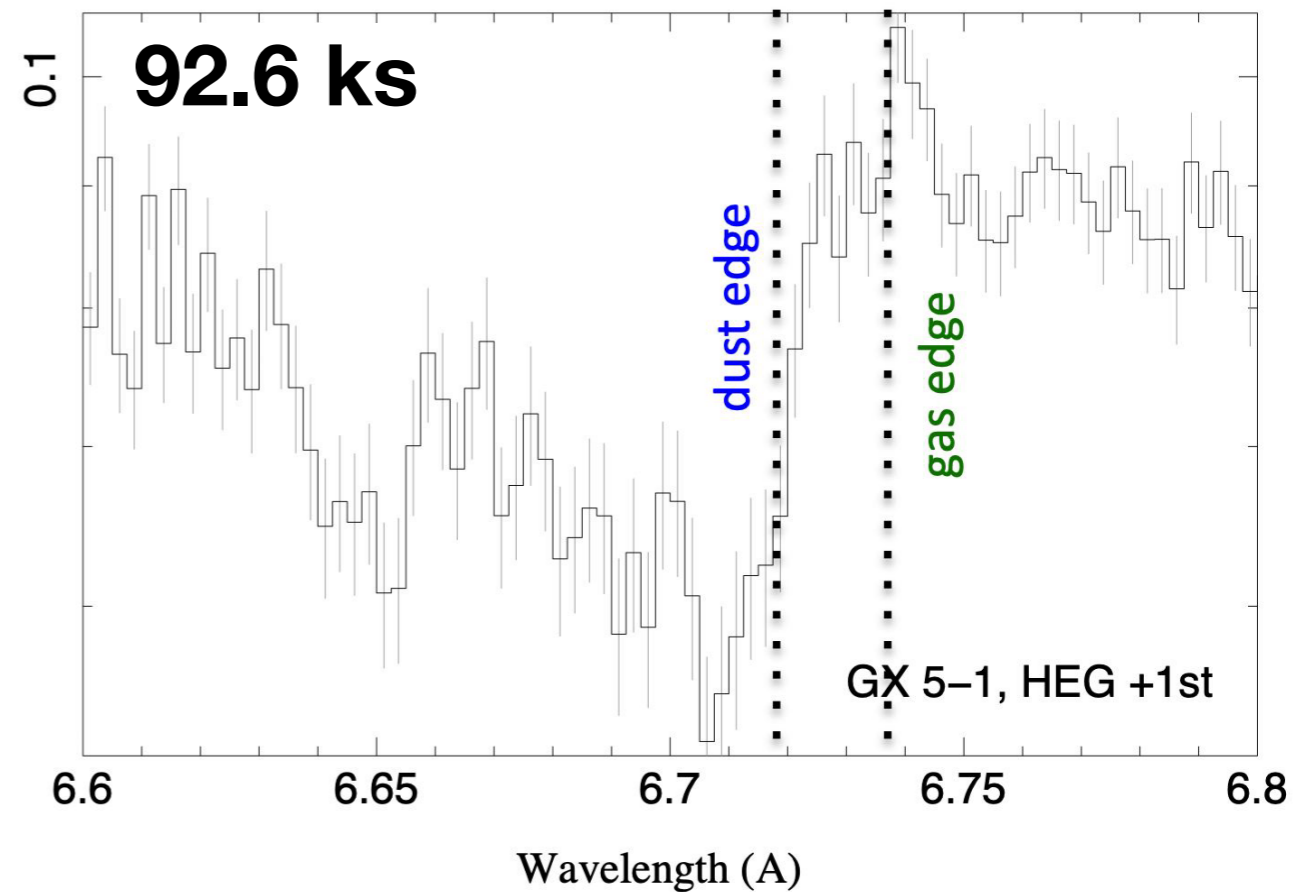
Two extreme cases of High resolution structure in Si edges

Significant gas and dust optical depths

Dominant dust, weak gas edge depths



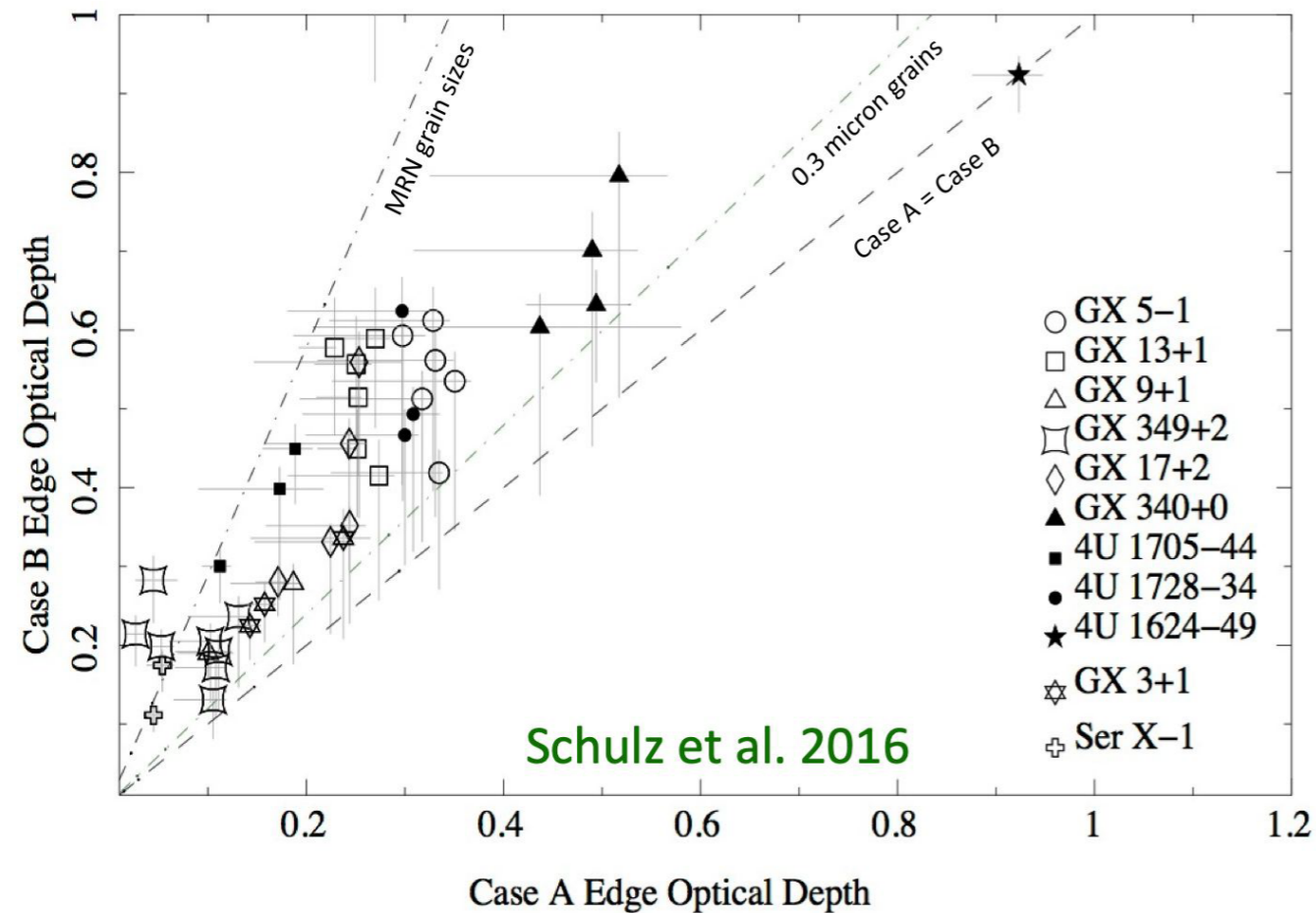
GX 3+1



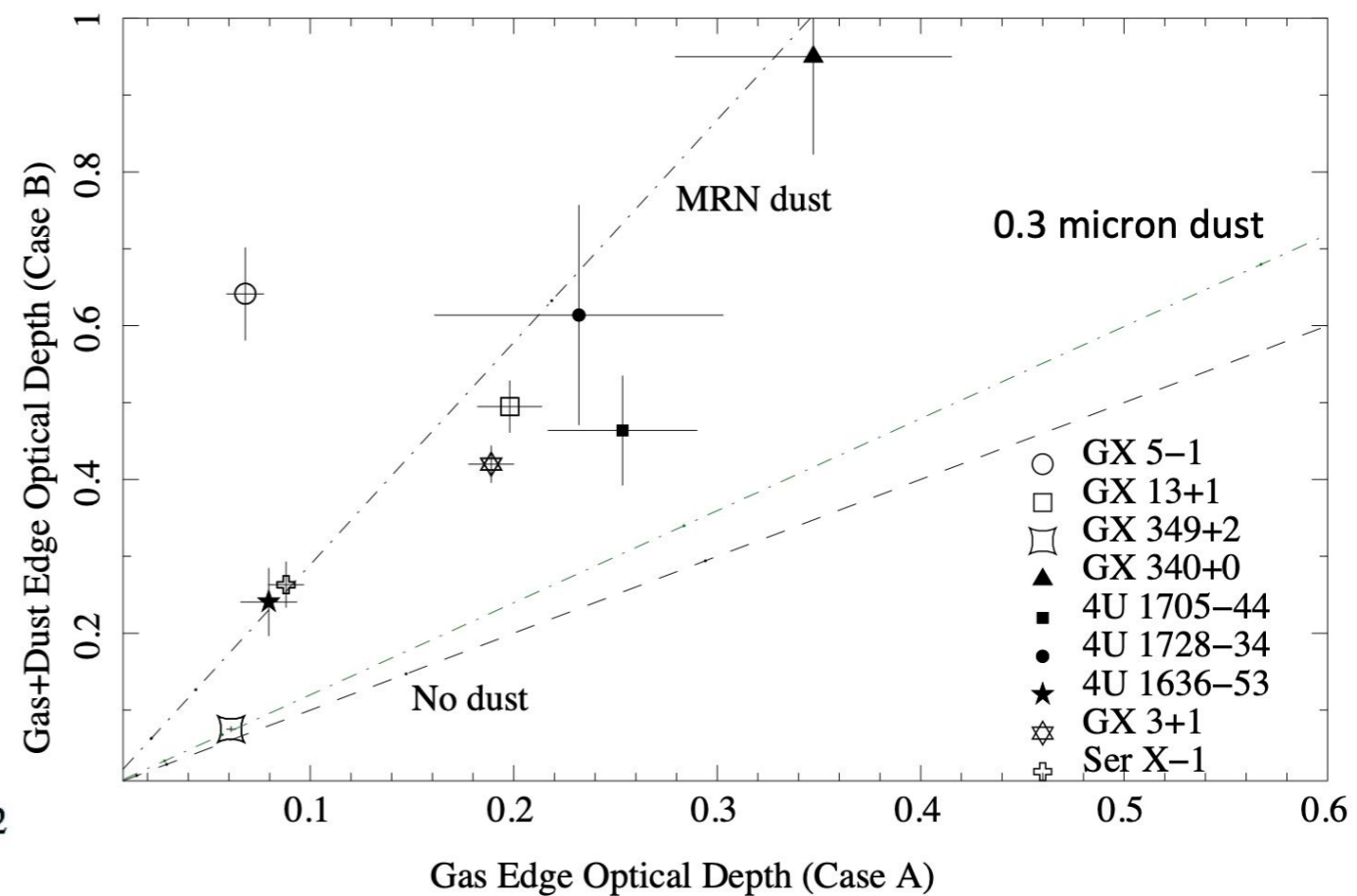
GX 5-1

Optical depth Gas v.s. dust

Old data



New data



Case A: gas

Case B: gas + dust

Summary and Outlook

We obtained **gas to dust optical depth ratios** for X-ray sources in the Galactic Bulge

- These ratios are data reliant, **independent** of any **edge modeling**
- The data show a variety of possibilities ranging from very **dusty edges** as for GX 5-1, several edges that are compatible with the MRN dust size distribution, to some edges indicating either larger grain sizes or **little dust contribution**
- we now focus on using **silicate models** (i.e. Zeegers et al. 2017) to determine mass column densities, abundance, and possibly modified cross sections
- We also will include **ionized Si models** (Gatuzz et al. 2020) in our final fits to account for possible variabilities.