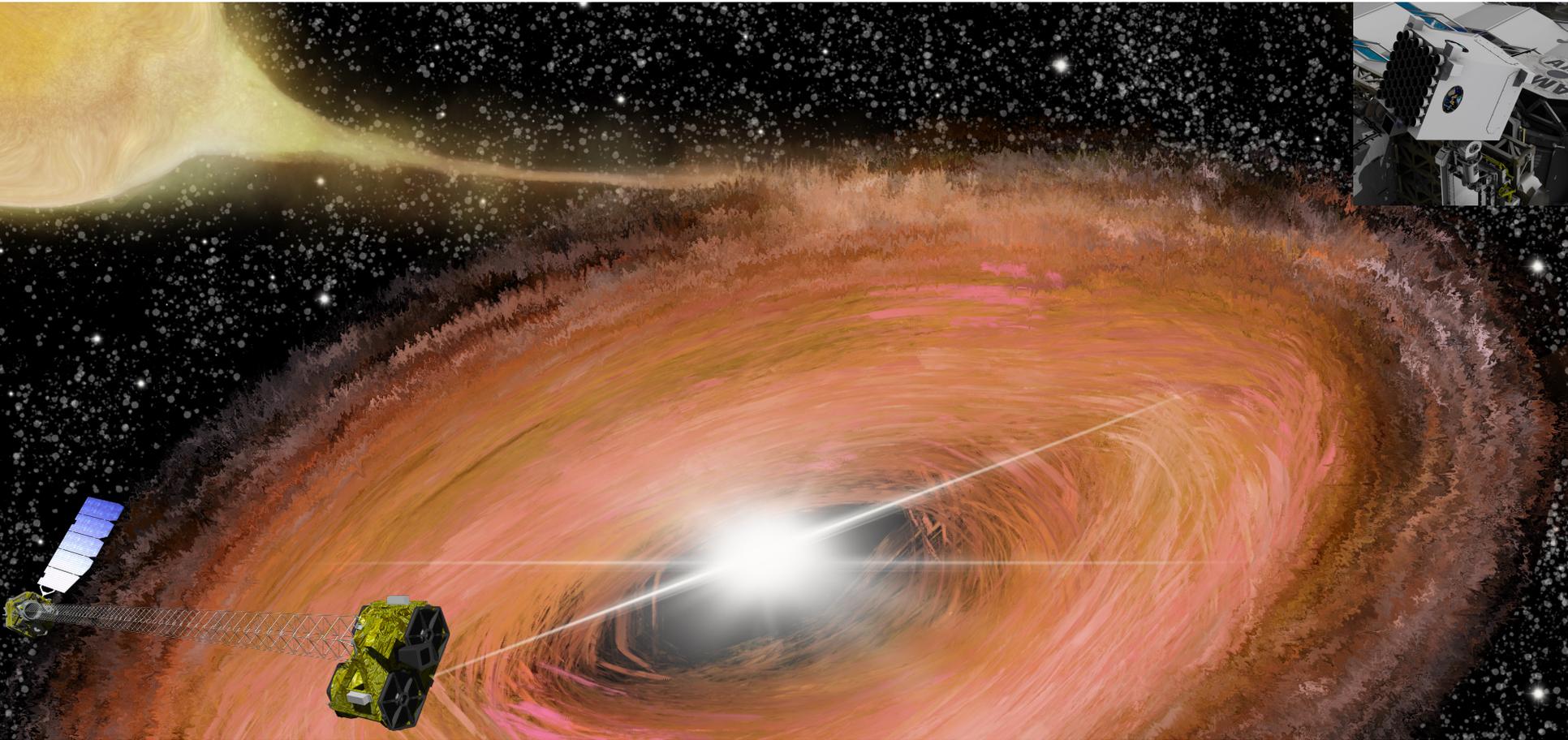


Utilizing NICER and NuSTAR for NS LMXBs

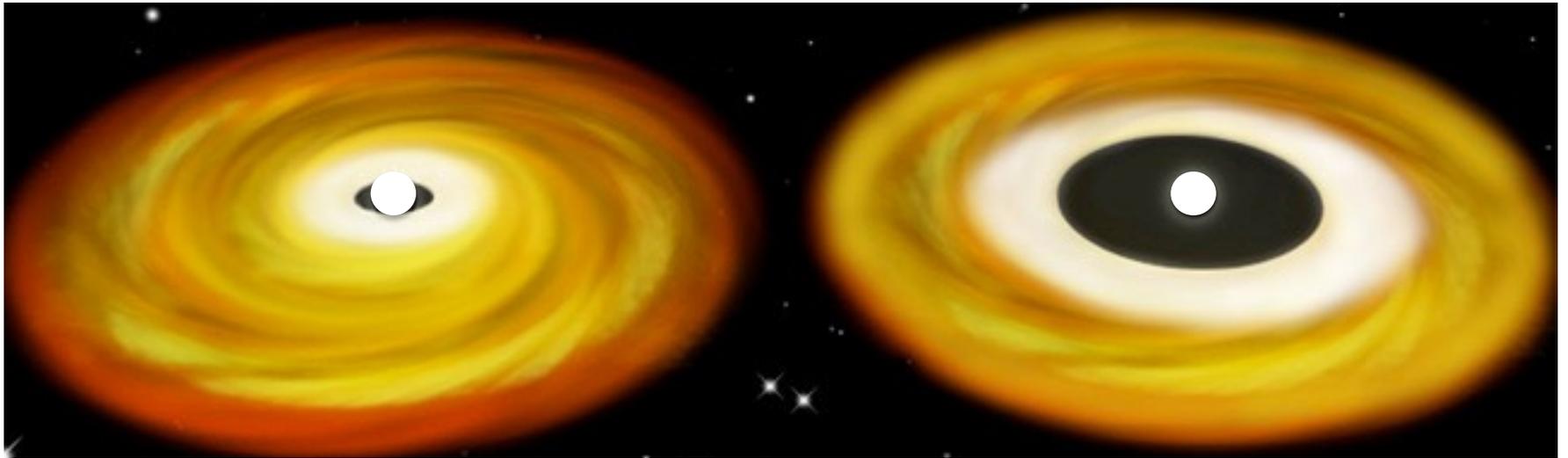


Dr. Renee Ludlam • rmludlam@caltech.edu



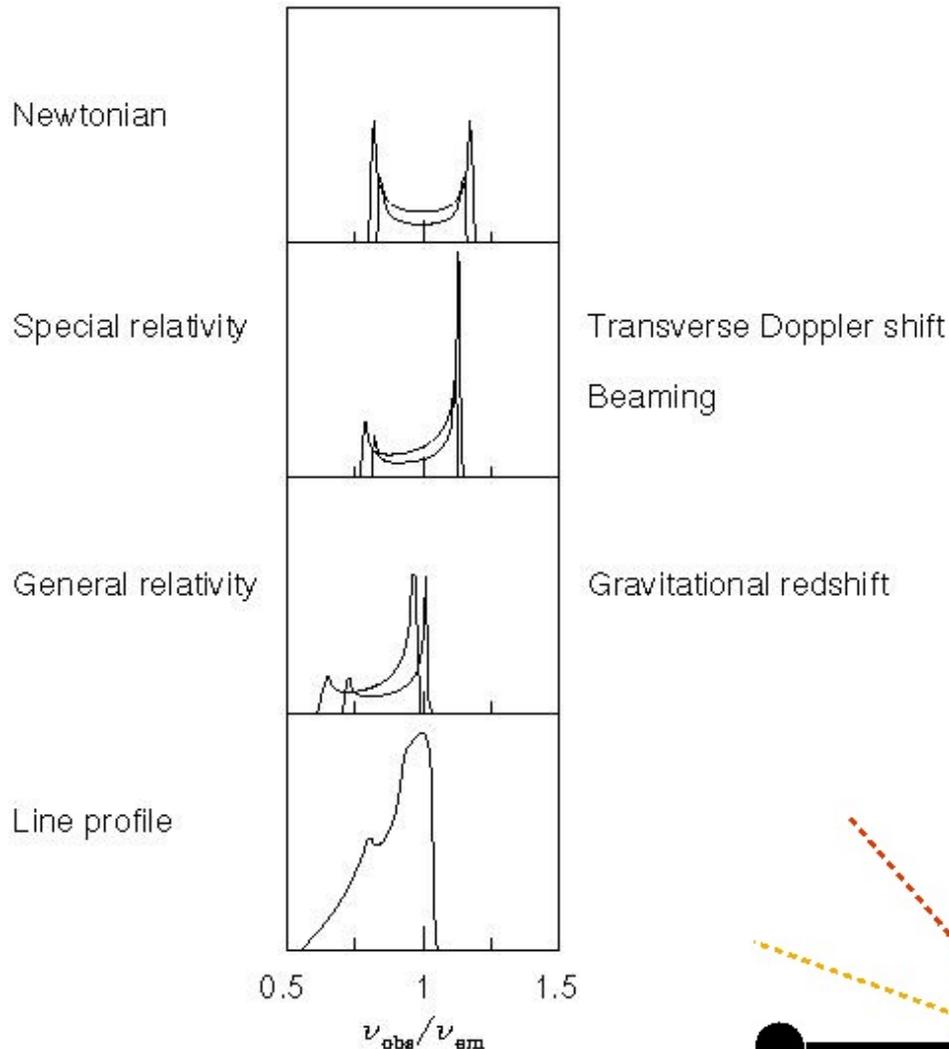
Why Study Disk Reflection in Neutron Stars?

- The equation of state (EoS) of ultradense, cold matter is still an open question (M-R)
- The disk must truncate at or prior to the NS surface
- If $R_{NS} \leq R_{in}$, you obtain an angle on the EOS



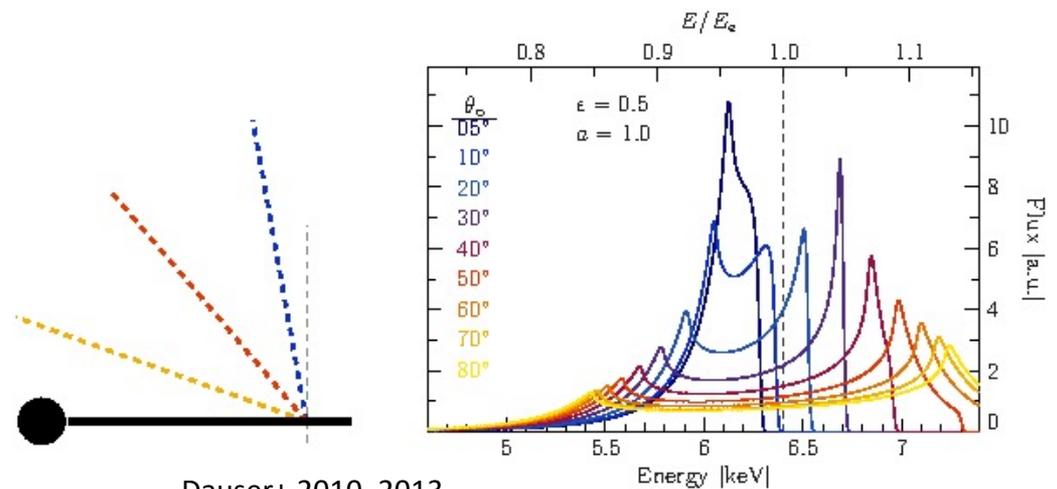
- Additionally, can constrain properties of the disk and NS itself

Emission Line Profile

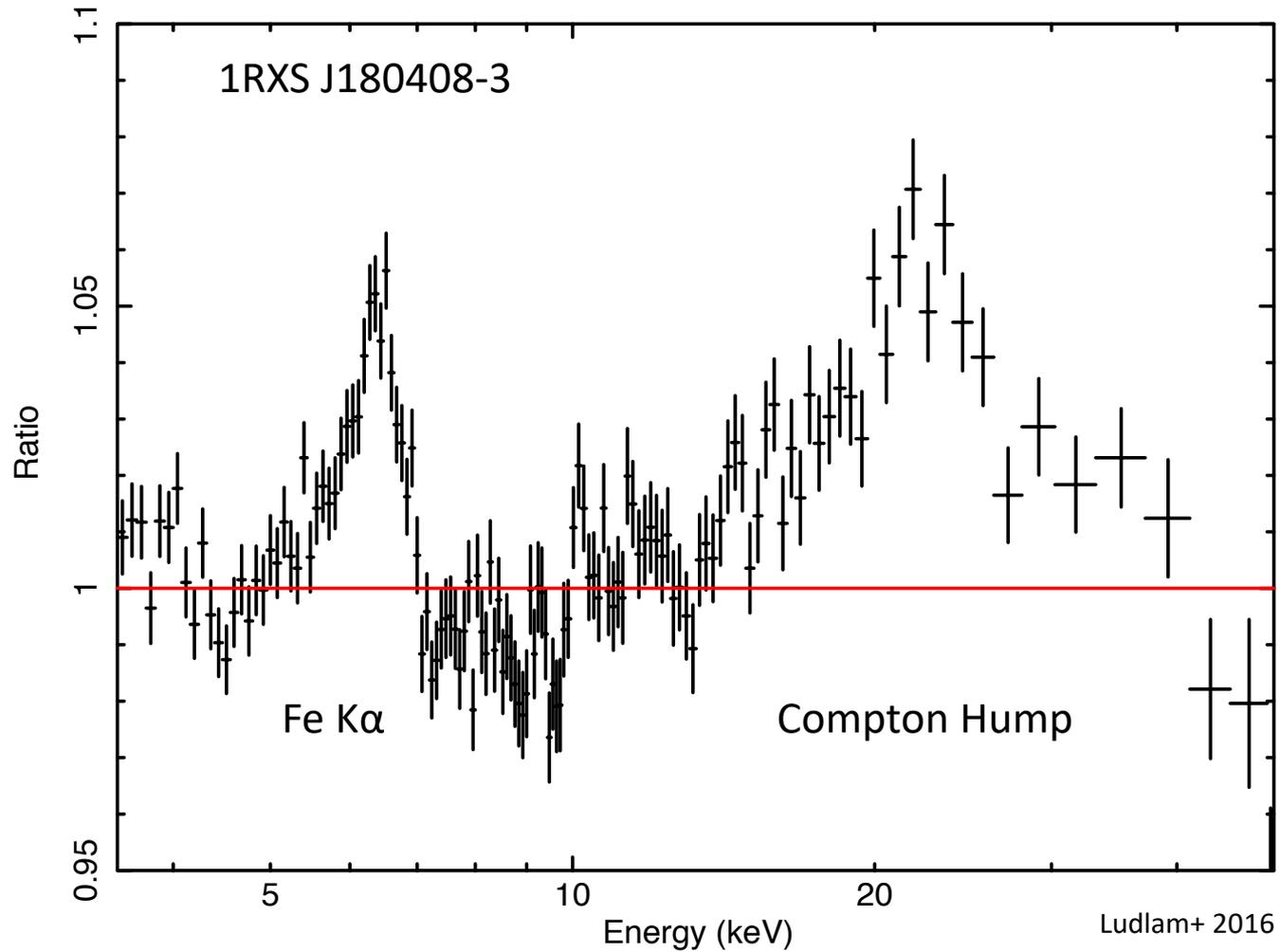


Degree of broadening in the red wing directly correlates with proximity to compact object.

Broadening in the blue wing indicates inclination.



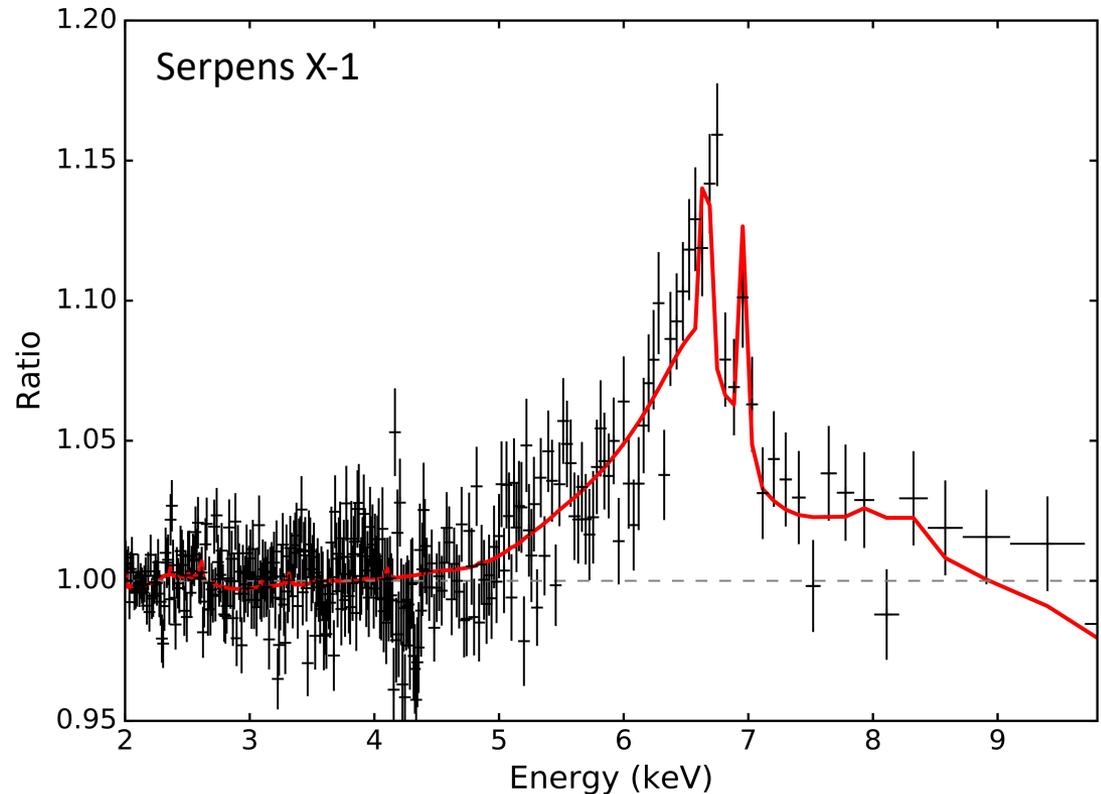
NuSTAR's high-energy passband



Fe K Line with *NICER*

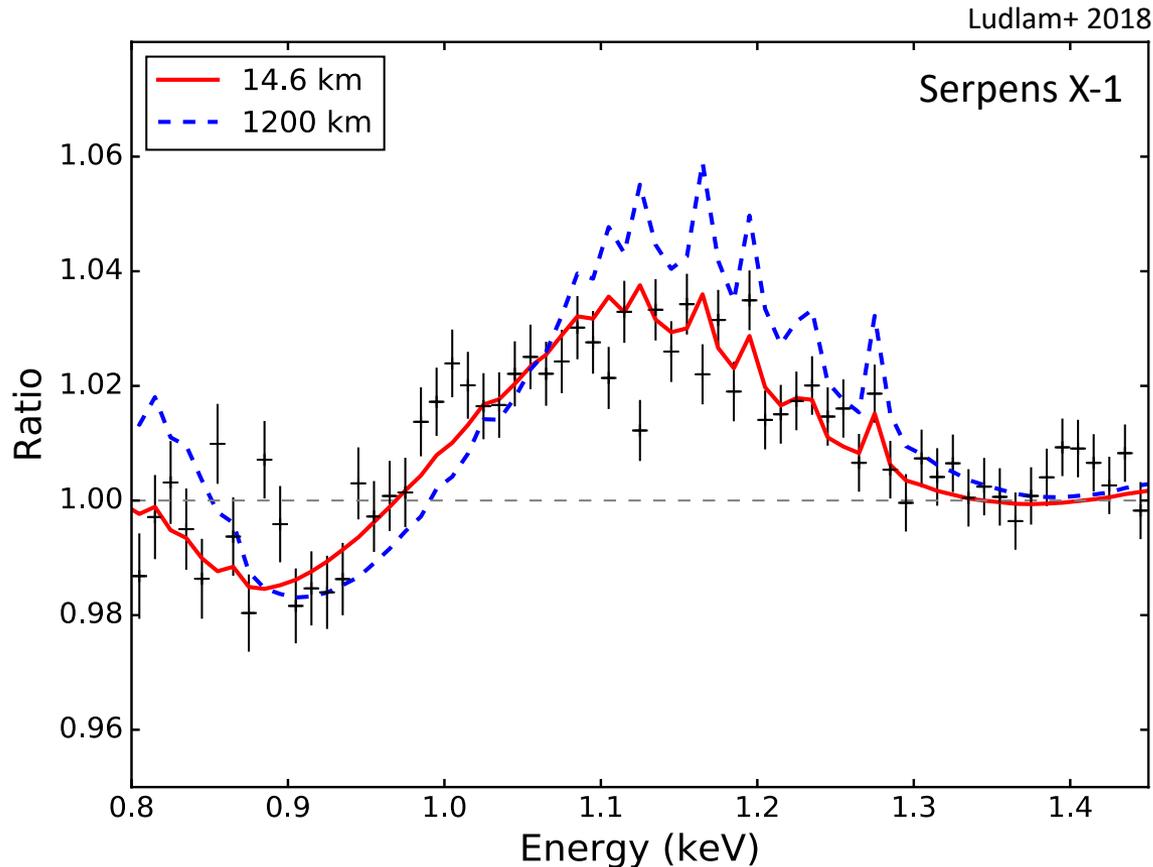
The predicted line profile (red) from the fully self-consistent reflection model RELXILLNS (García, Dauser, Ludlam+, *ApJ*, *submitted*).

- High density disk near 10^{19} cm^{-3}
- Both the Fe XXV and Fe XXVI K alpha lines are produced at similar strength



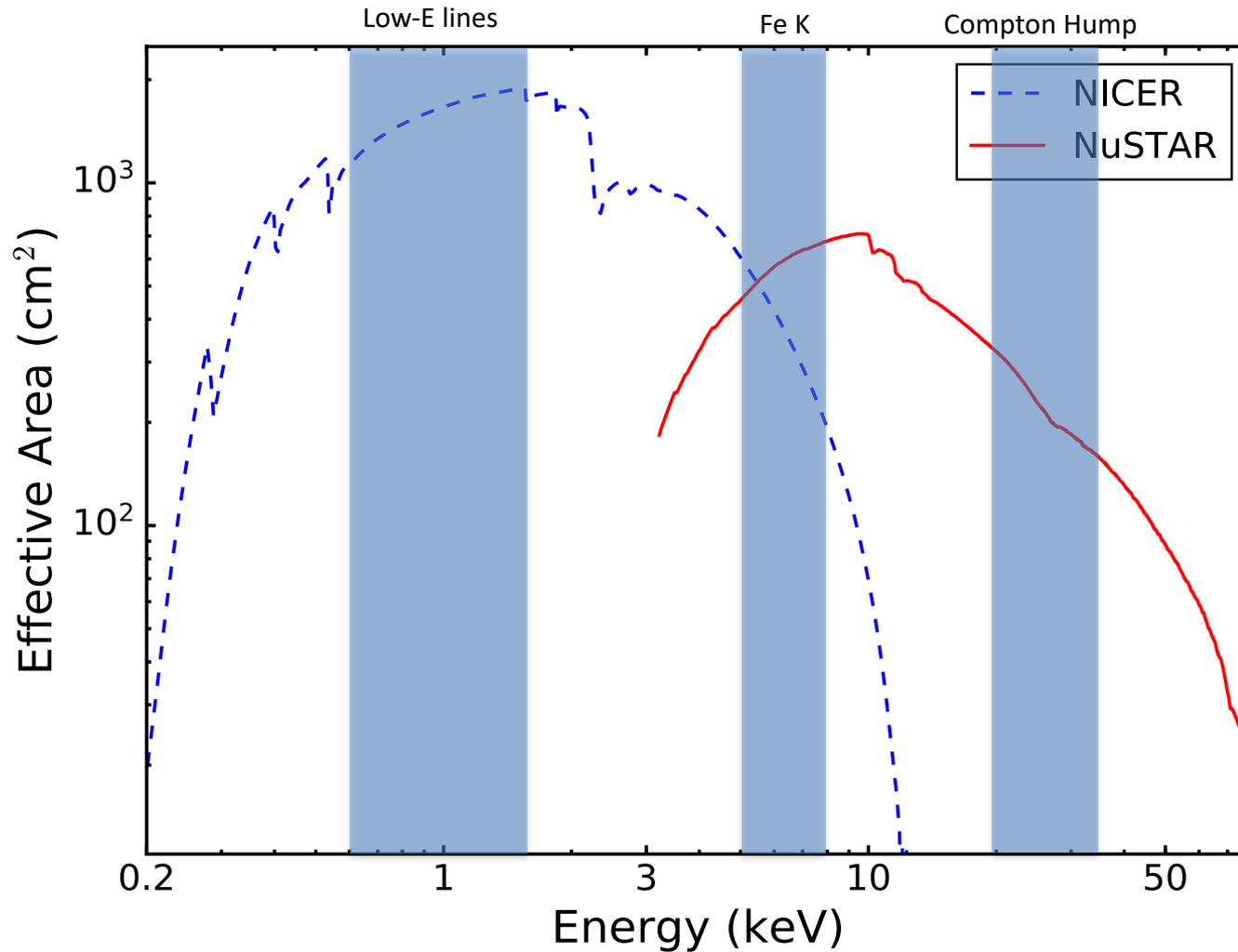
- This highlights energy resolution of *NICER* and the need to fit a reflection spectrum.

Fe L Complex



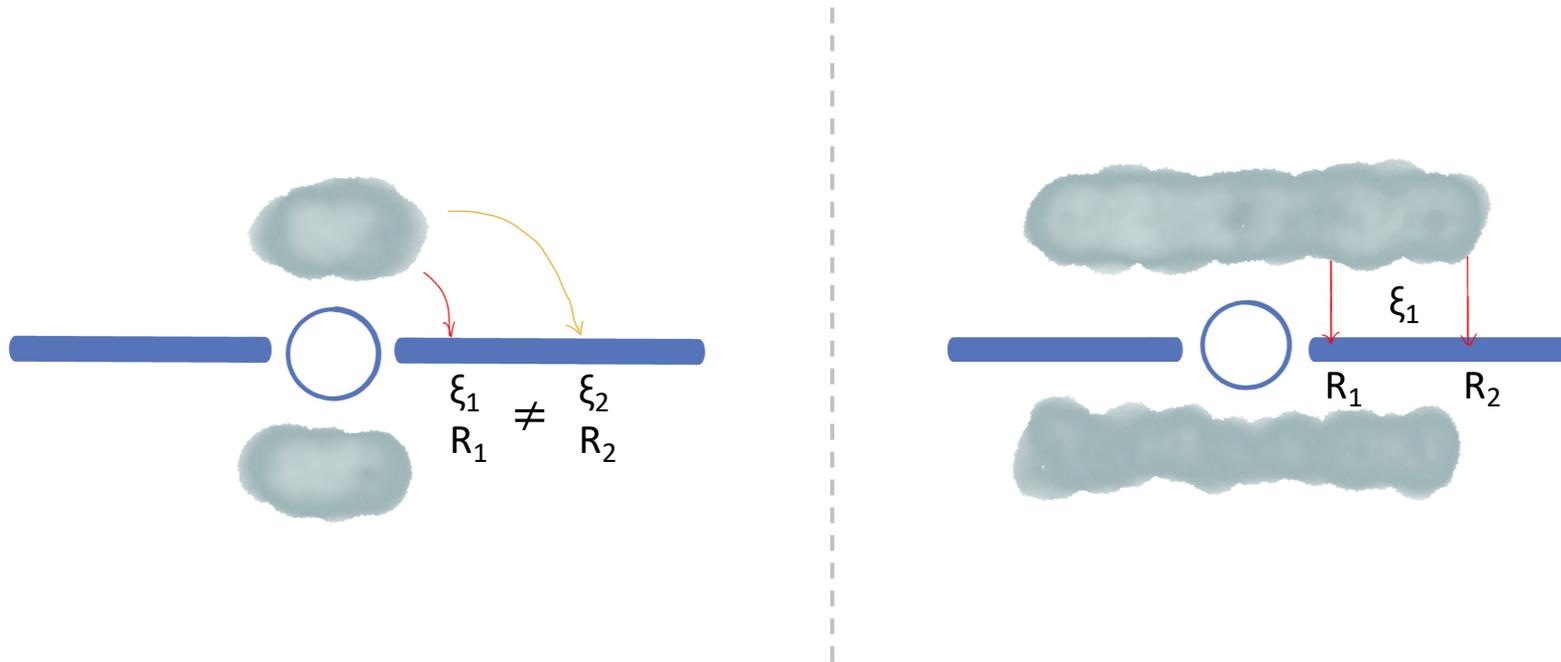
- The Fe L complex with the best fit model predicted line profile (**red**) and the local-frame emission (**blue**) for comparison.
- Narrow emission lines in the broad Fe L region likely due to a lower-Z element such as Mg III-VII.

Collecting Area of *NICER* & *NuSTAR*

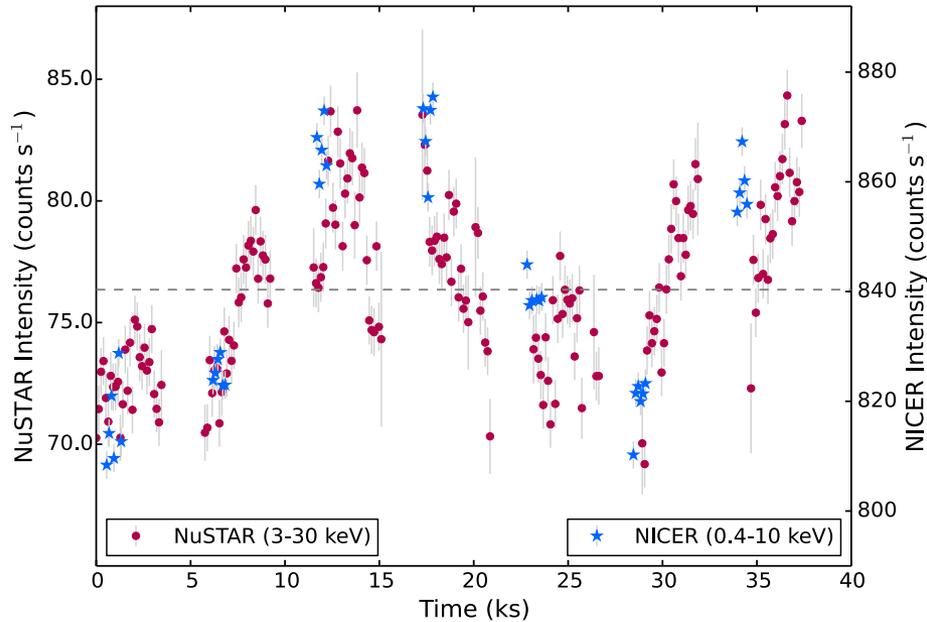


Probes w/ Multiple Emission Lines

- Additional constraint on the position of the inner disk
- Disk structure
 - Ionization (ξ) with radius (R)
 - Illumination source geometry

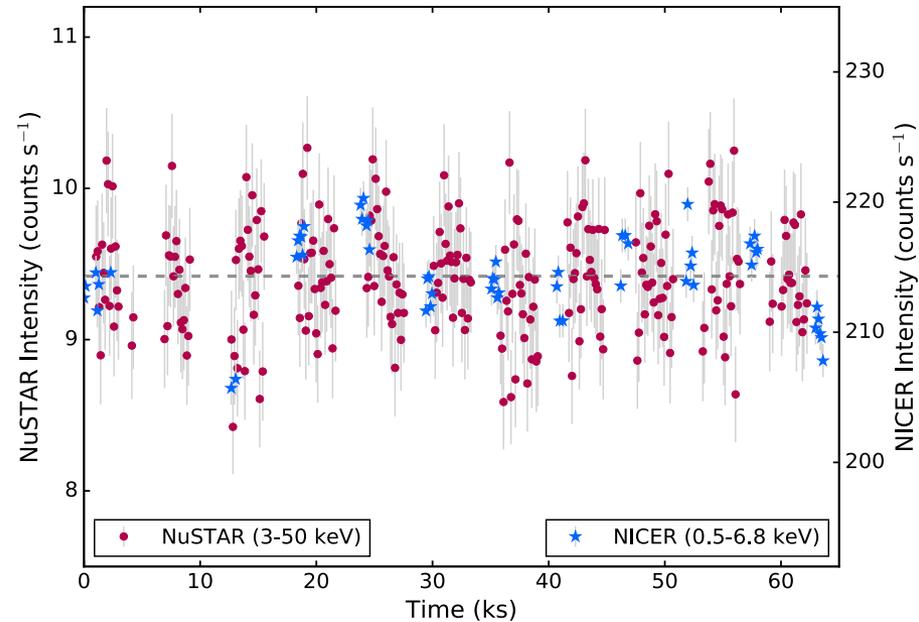


NICER-NuSTAR Lightcurves



4U 1735-44

- Atoll Source
- 2018 August
 - 20 ks NuSTAR
 - 10 ks NICER



4U 1543-624

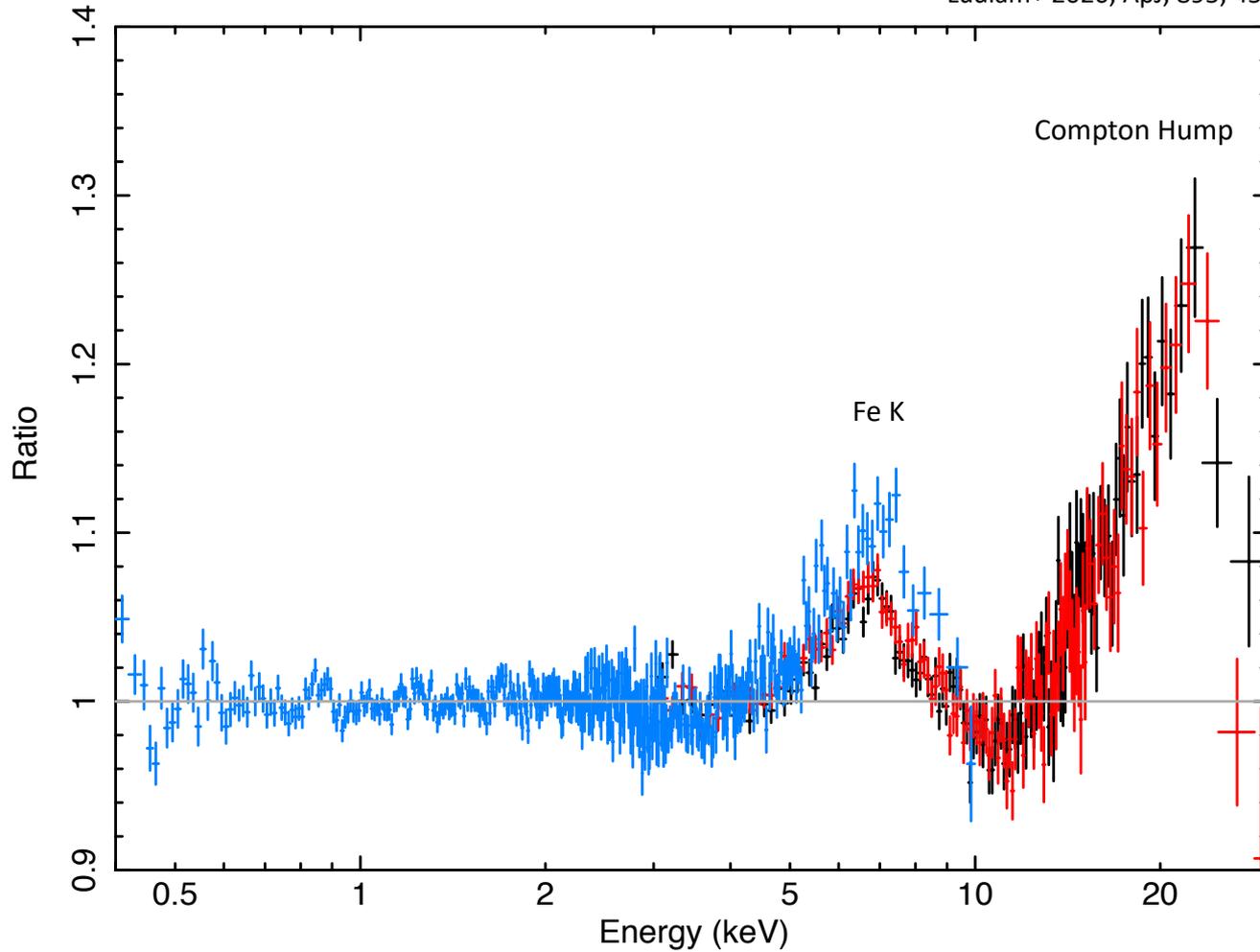
- Ultra-Compact X-ray Binary
- 2020 April
 - 30 ks NuSTAR
 - 10 ks NICER

Selection Criteria

- In addition to standard filtering:
 - $\text{SUN_ANGLE} > 60$
 - $\text{COR_SAX} > 4.0$
 - $\text{KP} < 5$
- Backgrounds:
 - 4U 1735-44 used Space Weather background
 - 4U 1543-624 used 3C50 background model
- Added systematic errors:
 - 5% systematics added below 2 keV
 - 1% systematics added above 2 keV

Joint NICER-NuSTAR Spectra of 4U 1735-44

Ludlam+ 2020, ApJ, 895, 45



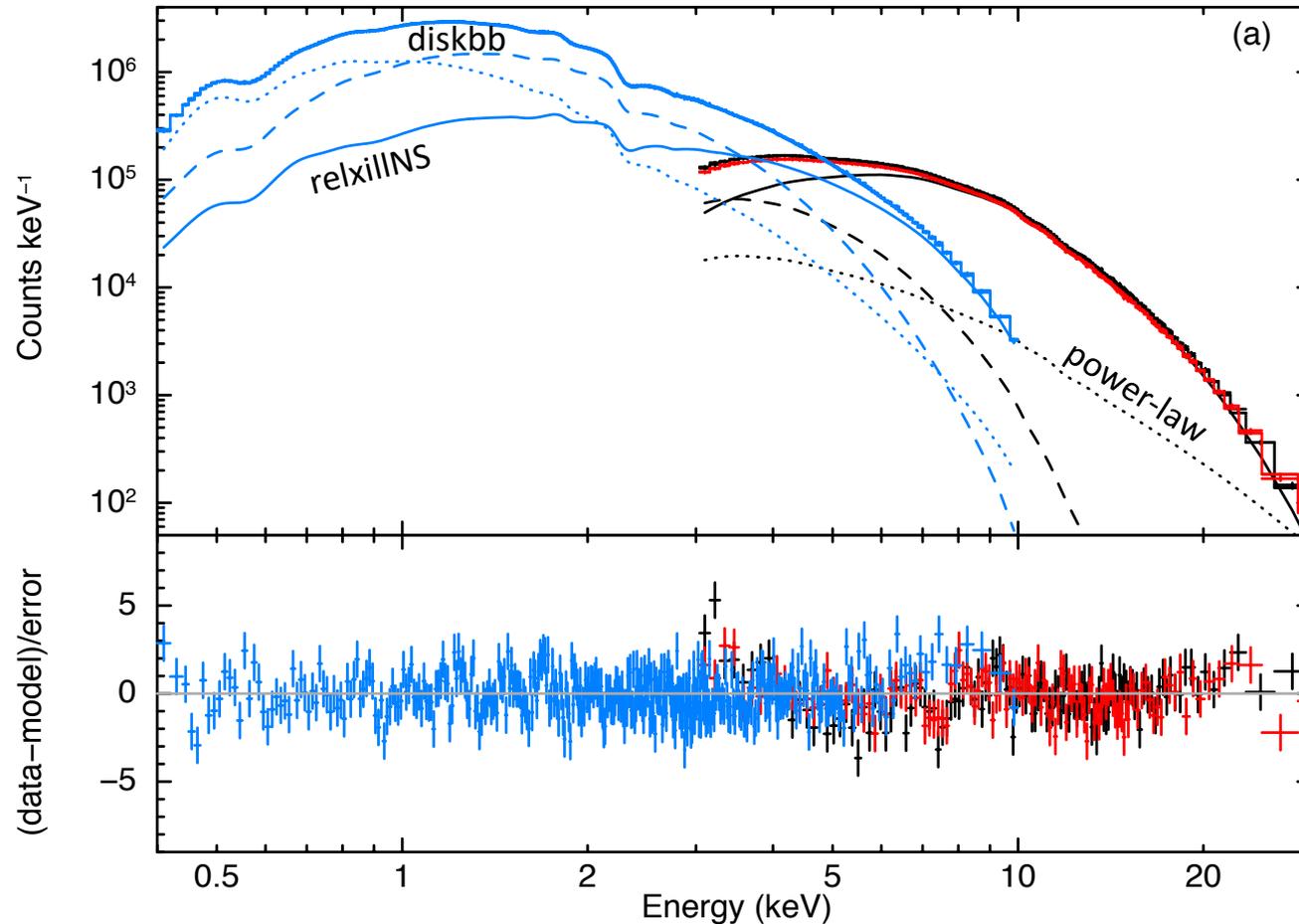
CALDB release 20200202

$C_{\text{FPMA}} = 1.0$ (Fixed)

$C_{\text{NICER}} = 1.04 \pm 0.01$

4U 1735-44: Spectral Modeling

Ludlam+ 2020, ApJ, 895, 45

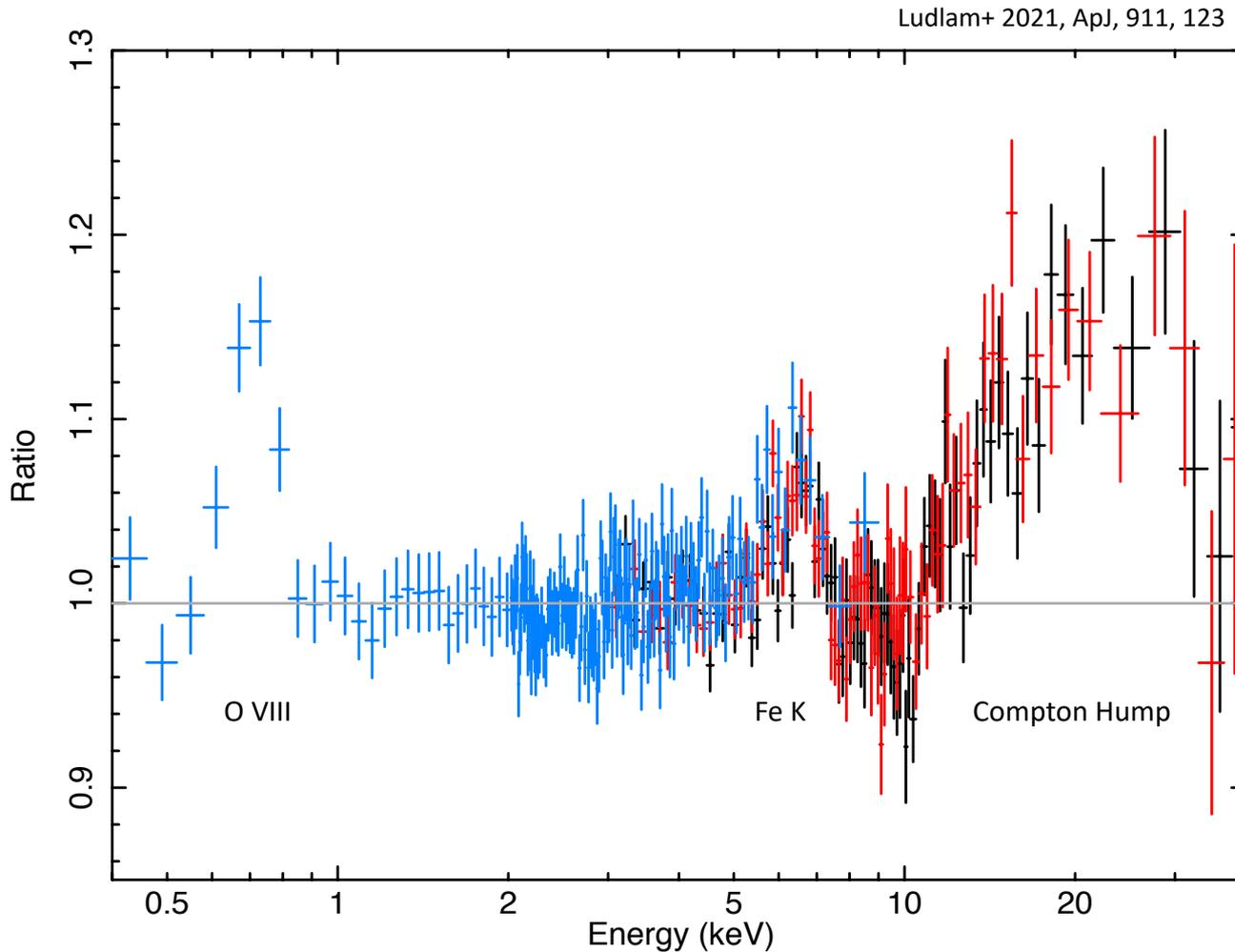


(a) $\text{tbabs} * \text{edge} * \text{edge} * (\text{diskbb} + \text{pow} + \text{relxillNS})$

$$R_{in} = 12.52^{+7.07}_{-0.12} \text{ km}$$

$$i = 42^{+2}_{-4} \text{ degrees}$$

Joint NICER-NuSTAR Spectra of 4U 1543-624



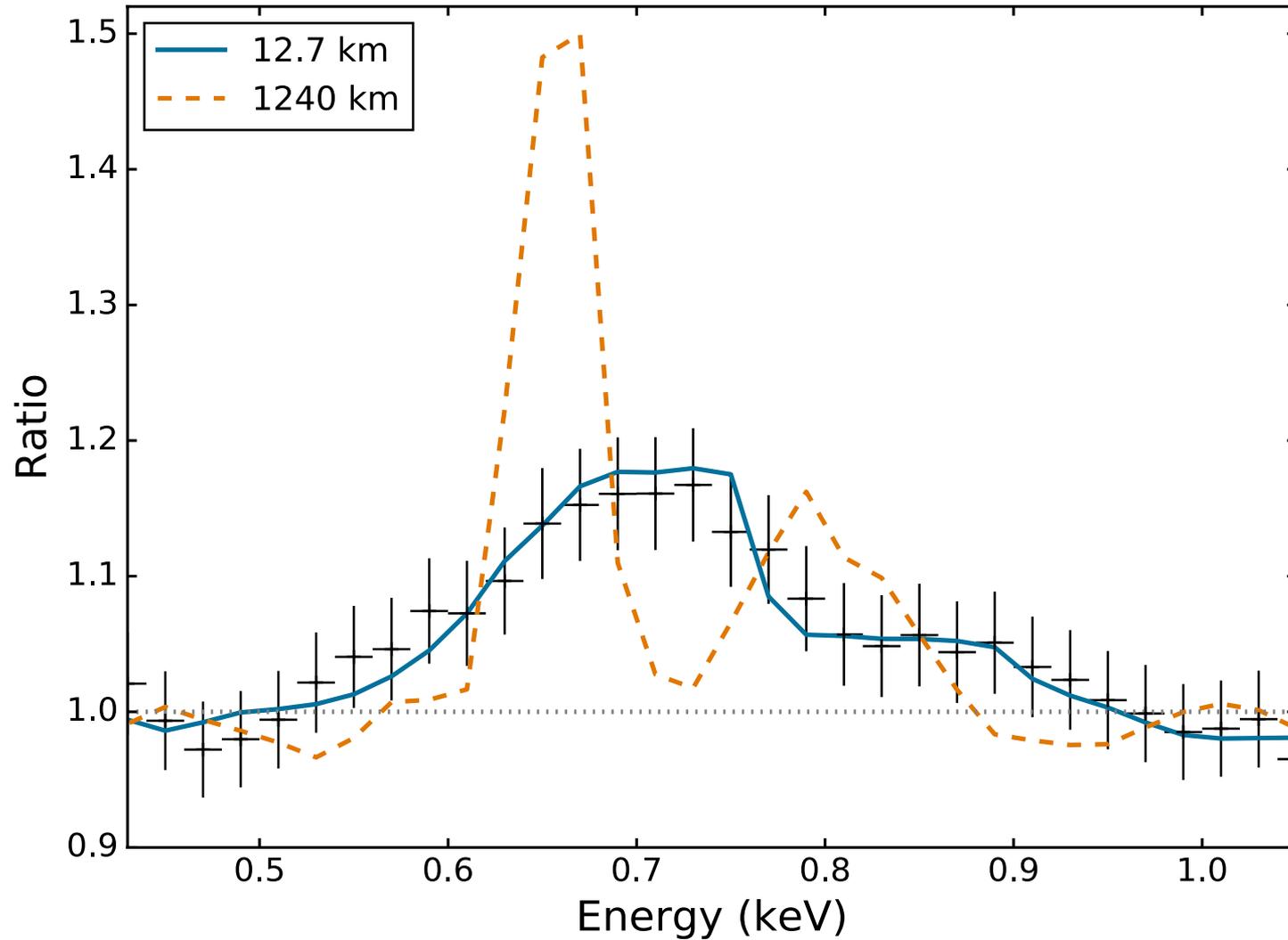
CALDB release 20200722

$C_{\text{FPMA}}=1.0$ (Fixed)

$C_{\text{NICER}}=1.04 \pm 0.01$

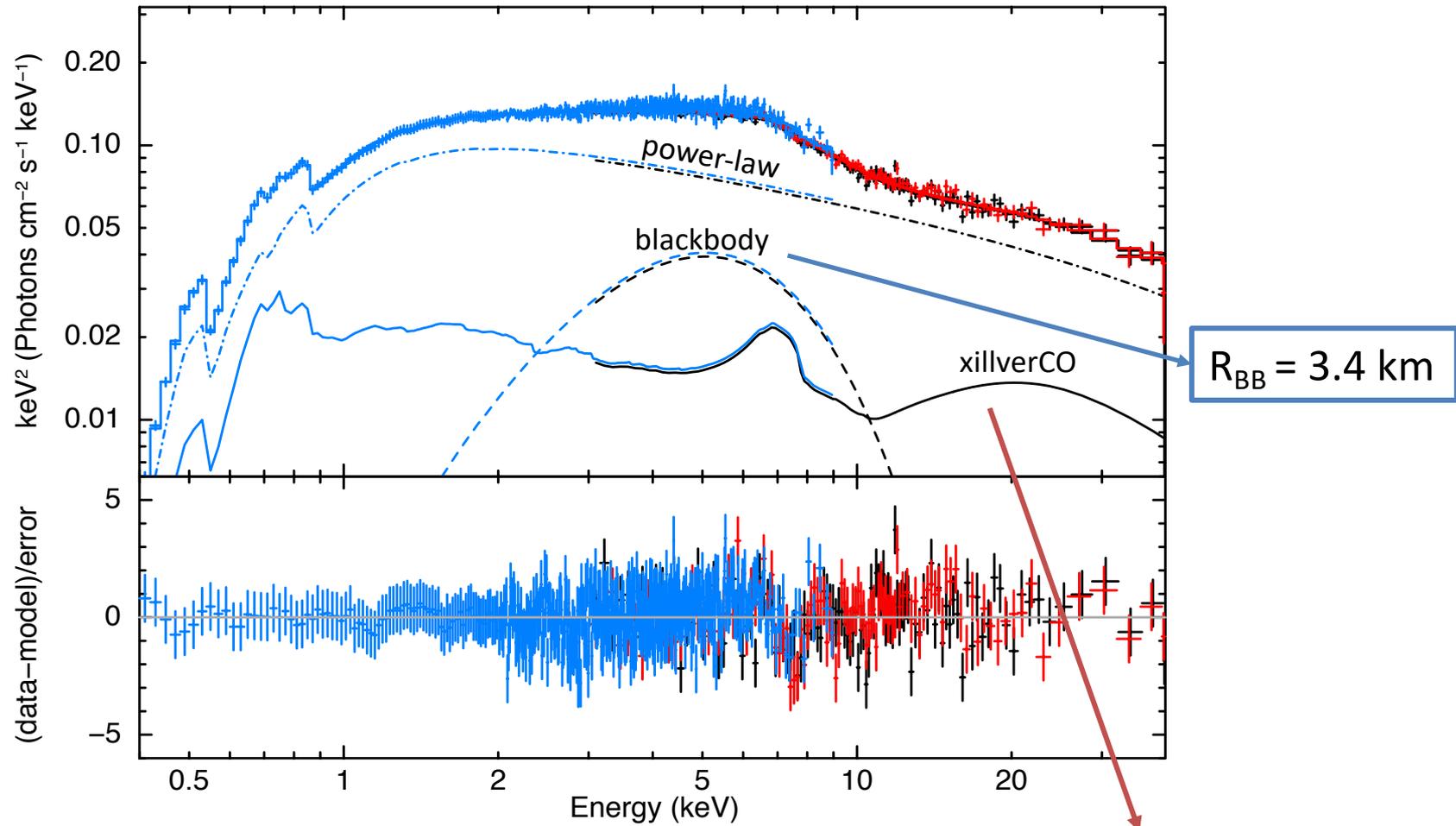
O VIII line broadening

Ludlam+ 2021, ApJ, 911, 123



4U 1543-624: Spectral Modeling

Ludlam+ 2021, ApJ, 911, 123

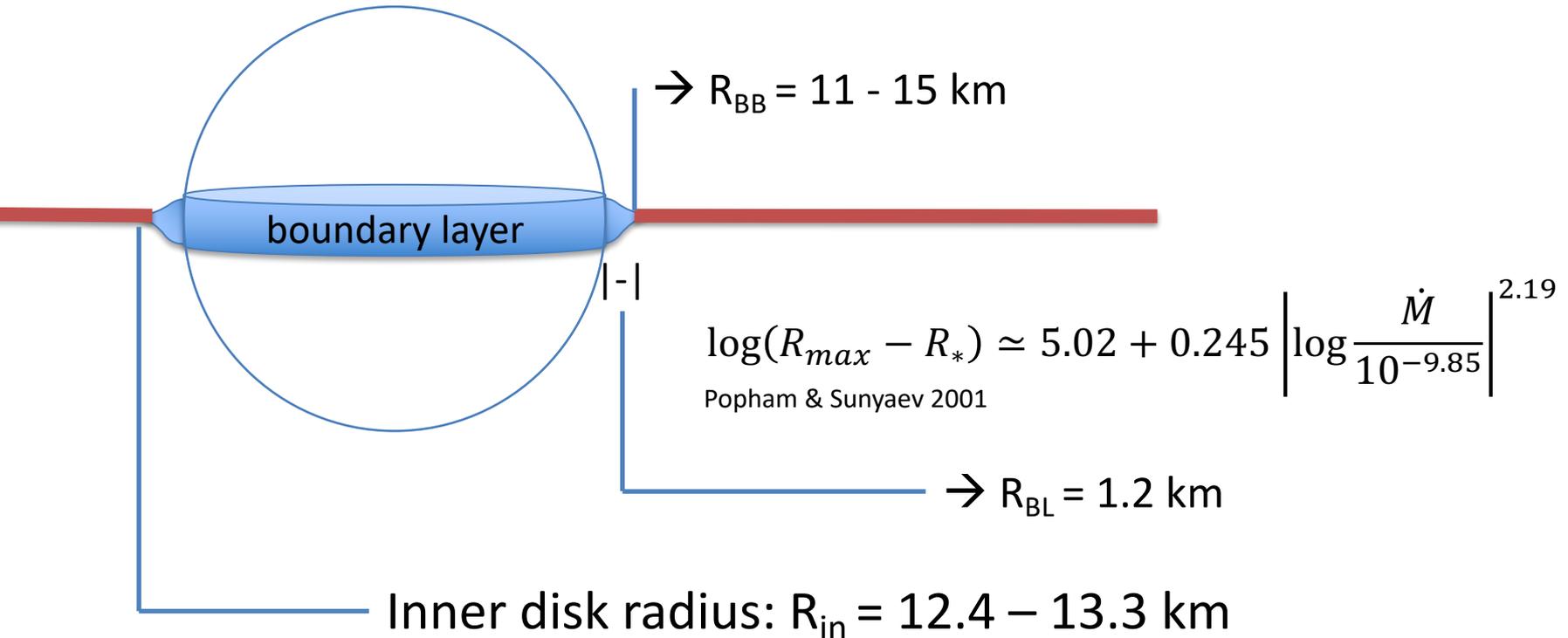


`tbabs*edge*edge*(bbody+pow+relconv*xillverCO)`

$R_{\text{in}} = 12.4 - 13.3 \text{ km}$

Blackbody Emission Radius

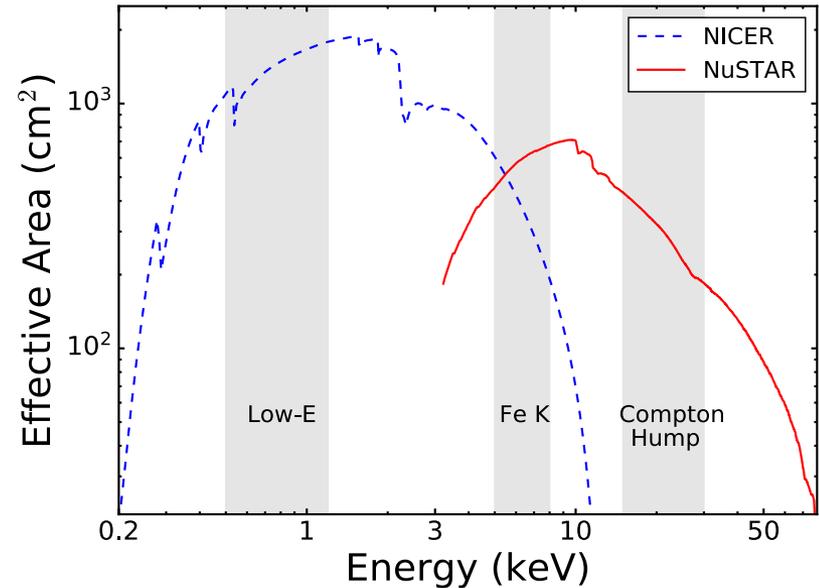
→ Narrow banded emission with a height 5%-10% the radial extent



$$R_{NS} \leq 12.1 \text{ km}$$

Summary

Combined passband of *NICER* and *NuSTAR* can reveal the entire reflection spectrum and shed light on accretion disk properties



NICER +
NuSTAR

Cross-cal

The *NICER* and *NuSTAR* cross-calibration constant within 5%

Thank you!

Email: rmludlam@caltech.edu