ISM analysis through high-resolution X-ray spectroscopy

Efrain Gatuzz

(MPA)

with

Tim Kallman (NASA/GSFC), Javier García (CfA),

Claudio Mendoza (IVIC), Tom Gorczyca (WMU),

Katherine Joachimi (UCV), Eugene Churazov (MPA)

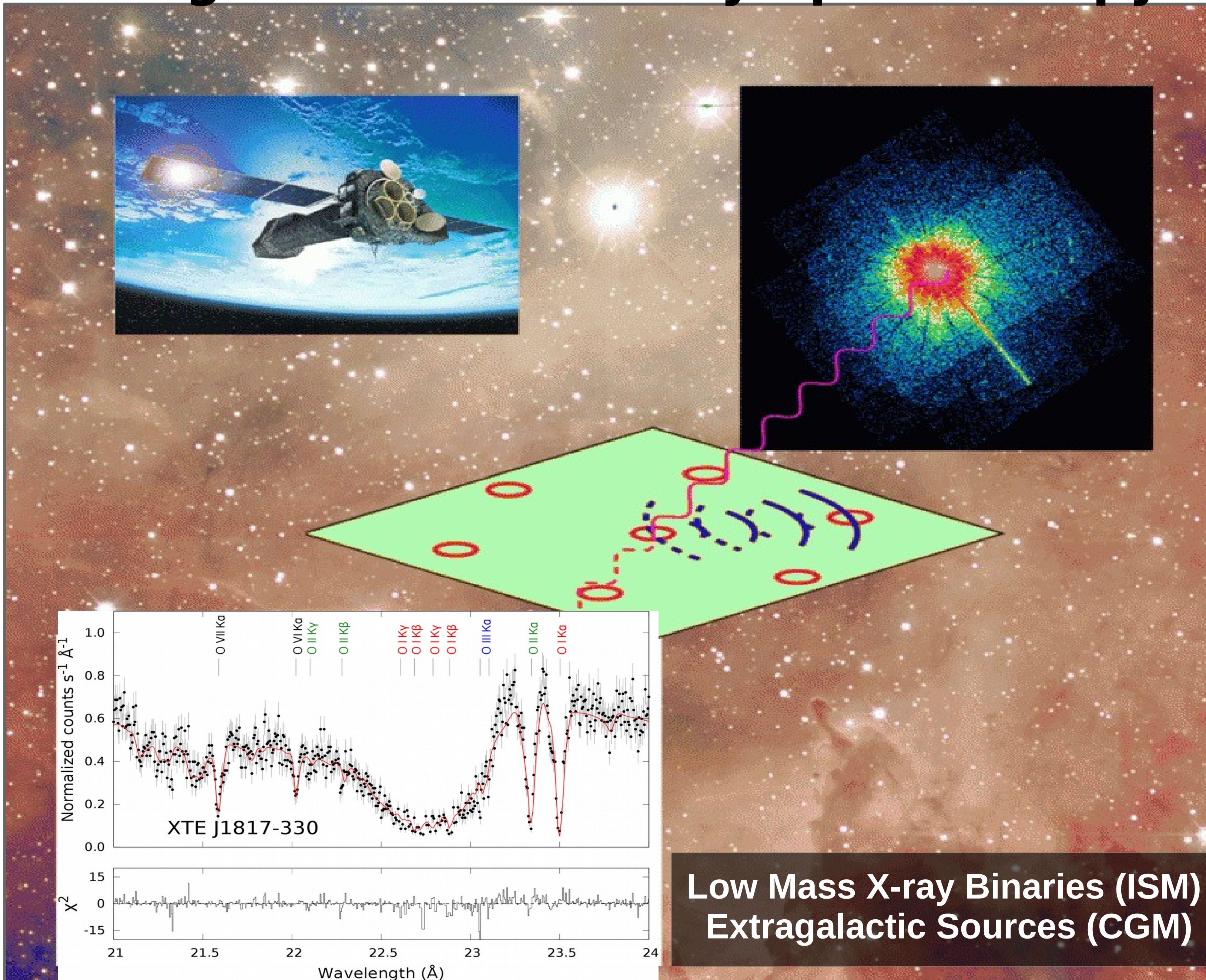
CHANDRA Science for the next decade

Cambridge, USA

16-19 August 2016

Max-Planck-Institut für Astrophysik

High-Resolution X-ray Spectroscopy

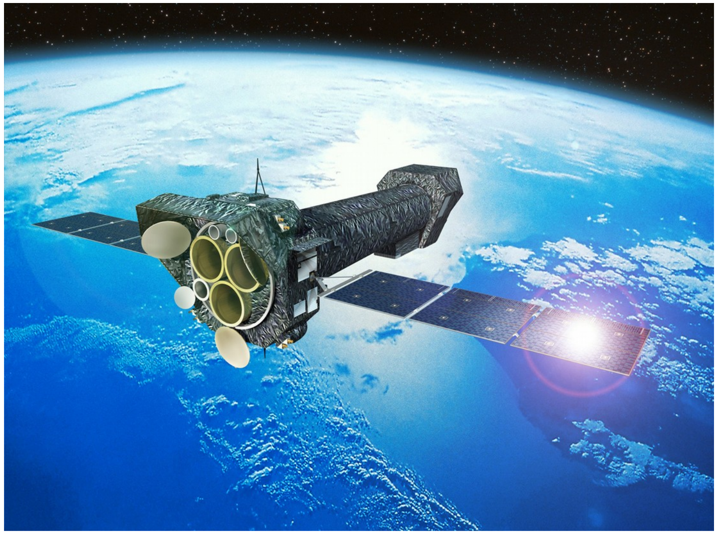


Chandra X-ray Observatory

HETG – MEG

Bandpass: 1.2 – 30 Å
Effective Area: 35 cm^2 (10 Å)
10 cm^2 (20 Å)
Resolution (ΔÅ): 0.012 Å FWHM

X-ray Multi-Mirror Mission (XMM-Newton)



RGS

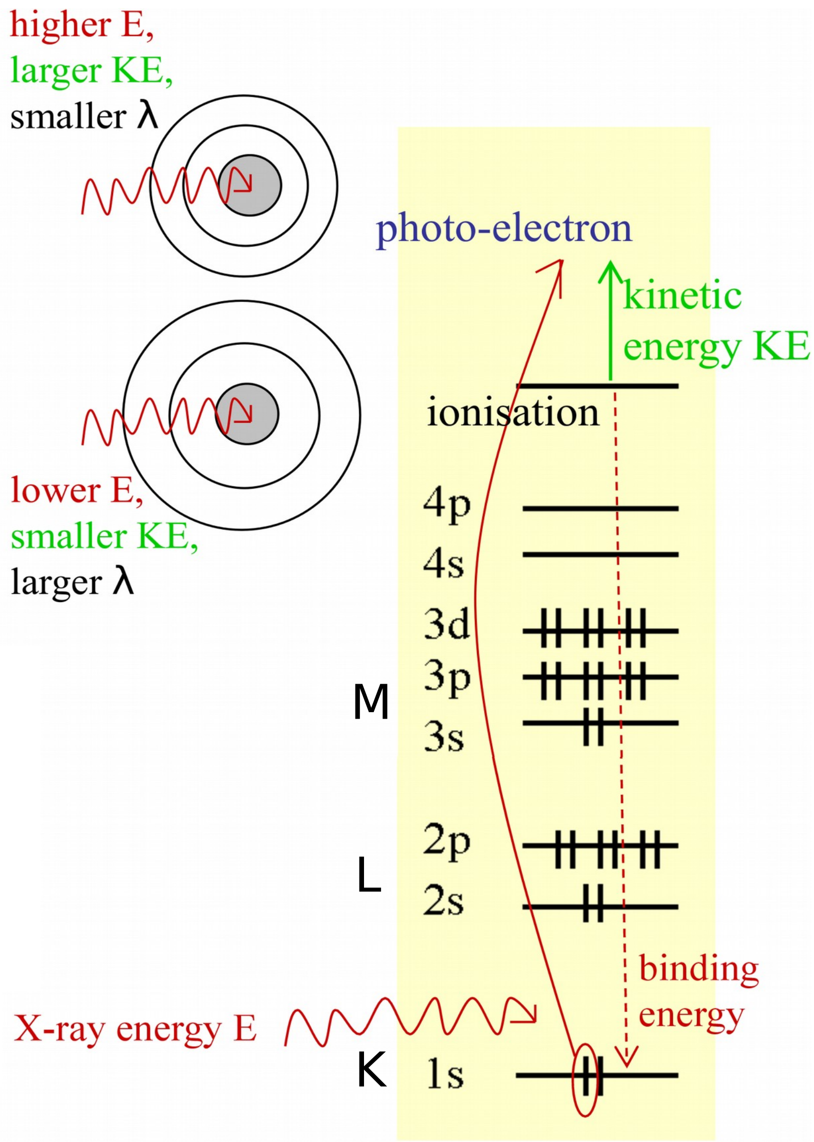
Bandpass: 10 – 35 Å
Effective Area: 59 cm^2 (10 Å)
50 cm^2 (20 Å)
70 cm^2 (30 Å)
Resolution (ΔÅ): 0.035 Å FWHM

X-Ray Photoabsorption

- The atom is excited by a photon.
- There is one **photoabsorption cross-section** for each ion.
- There are two decay processes:

  X-ray fluorescence

  Auger effect.



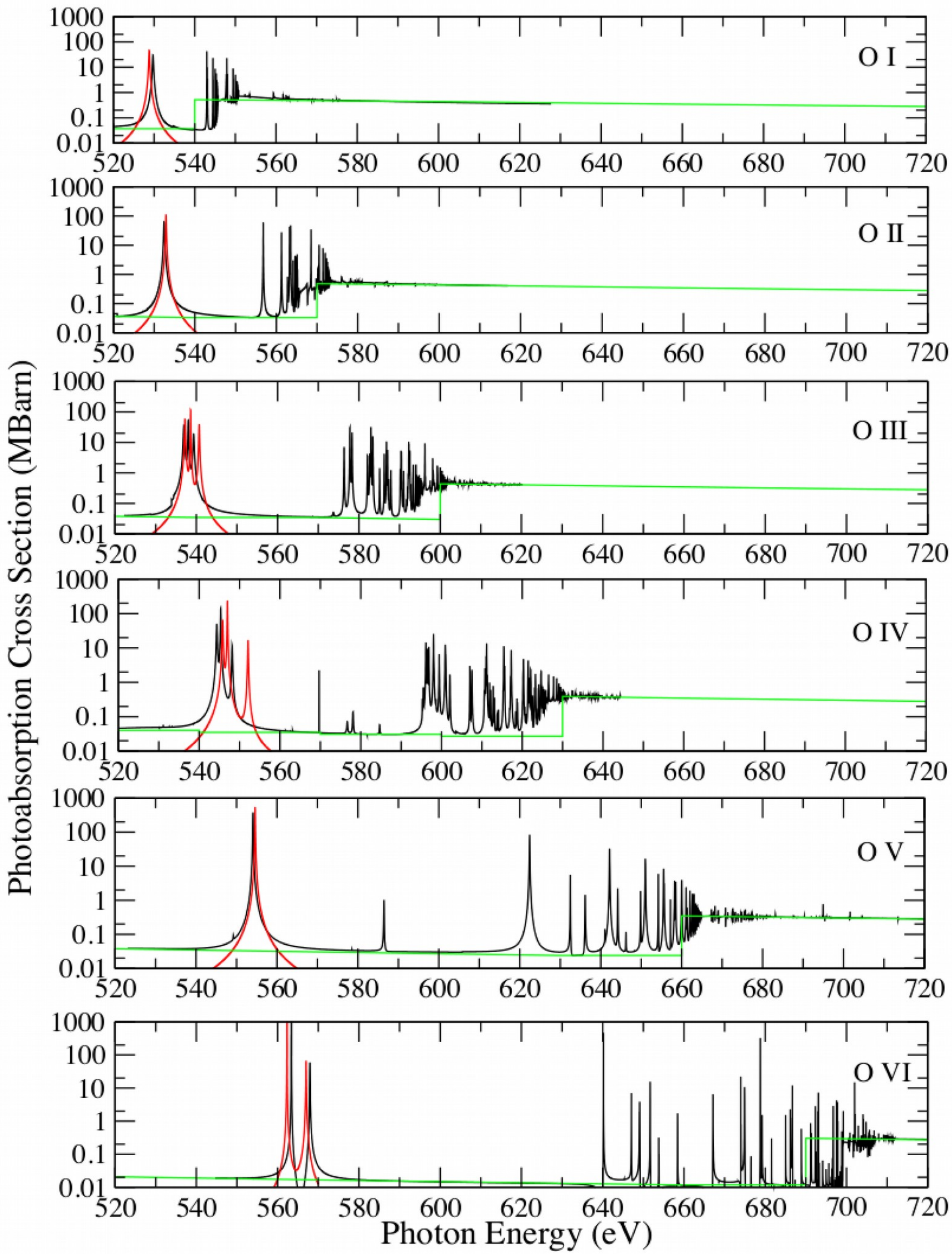
Atomic Data

High-energy photoabsorption cross-sections for O ions:

Black lines:
García+05

Red lines:
Pradhan+03

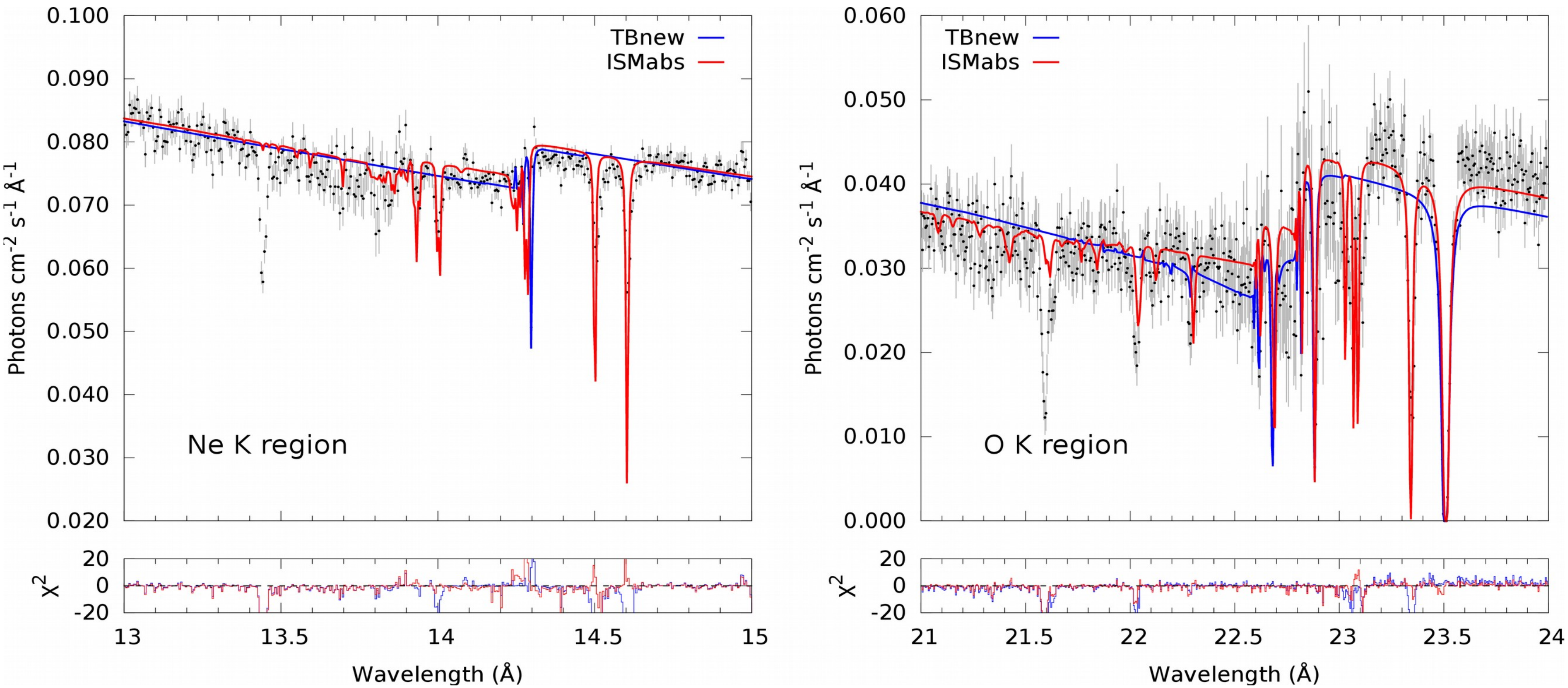
Green lines:
Reilman+Manson+79



ISMabs: A new X-ray absorption model

$$I_{obs}(E) = e^{-\tau} I_{source}(E)$$

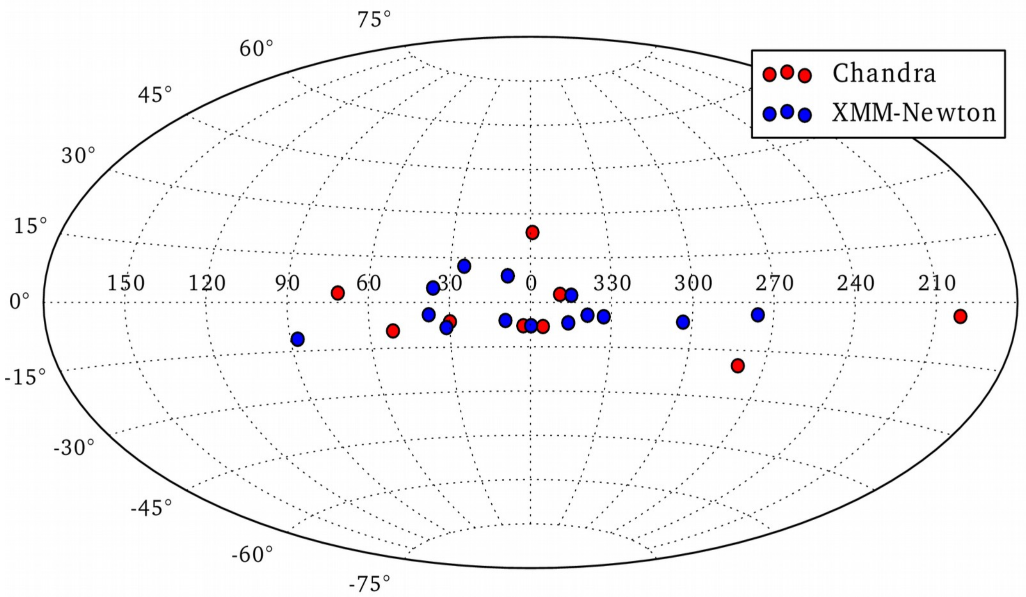
$$\tau = \sum_{i}^{k} \sigma_i \cdot N_i$$

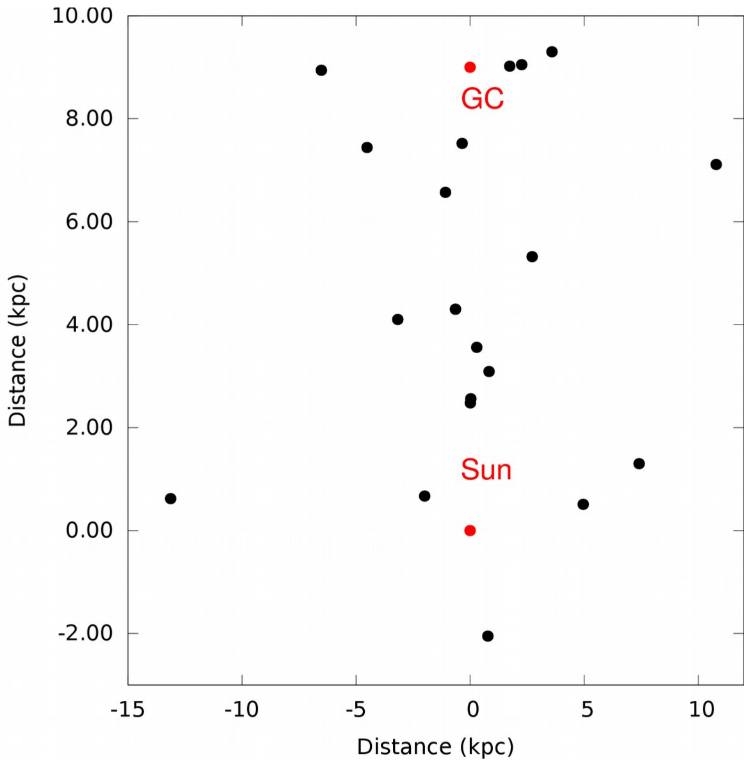


https://heasarc.gsfc.nasa.gov/xanadu/xspec/models/ismabs.html

Gatuzz+15

A detailed analysis of the ISM

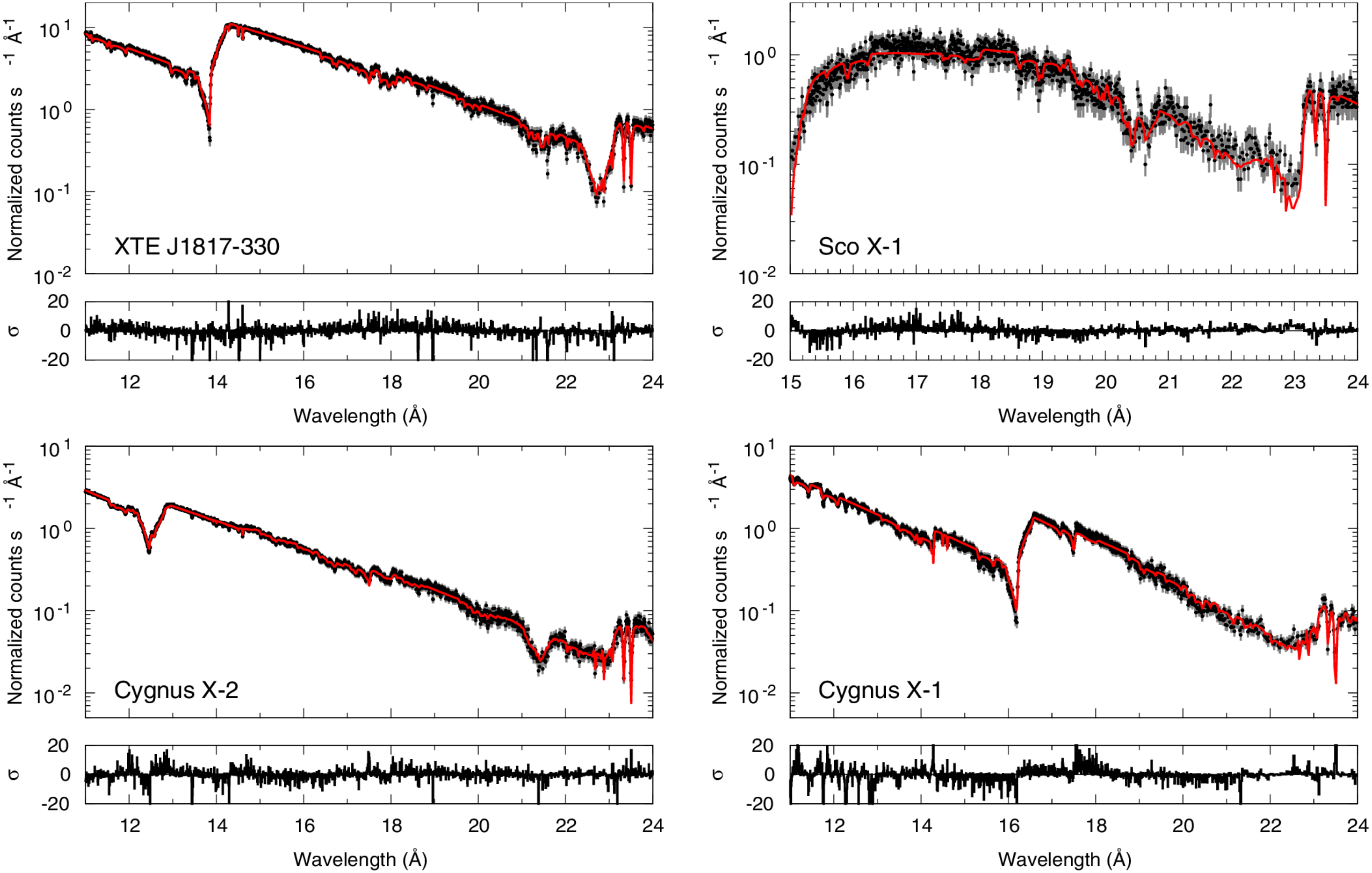




24 bright sources 17 from Chandra and 15 from XMM-Newton.
84 single observations were analyzed.

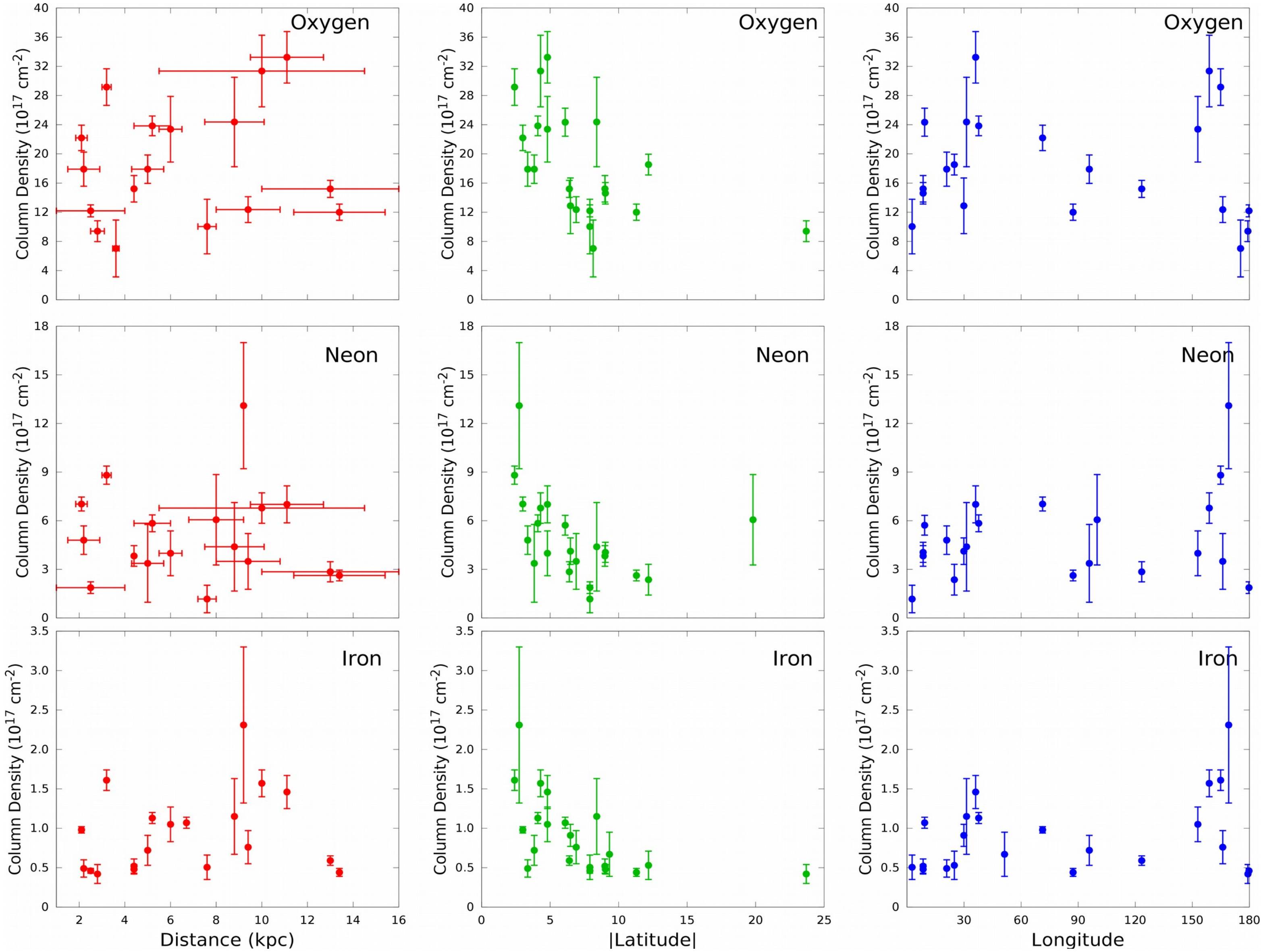
Gatuzz+16

A detailed analysis of the ISM



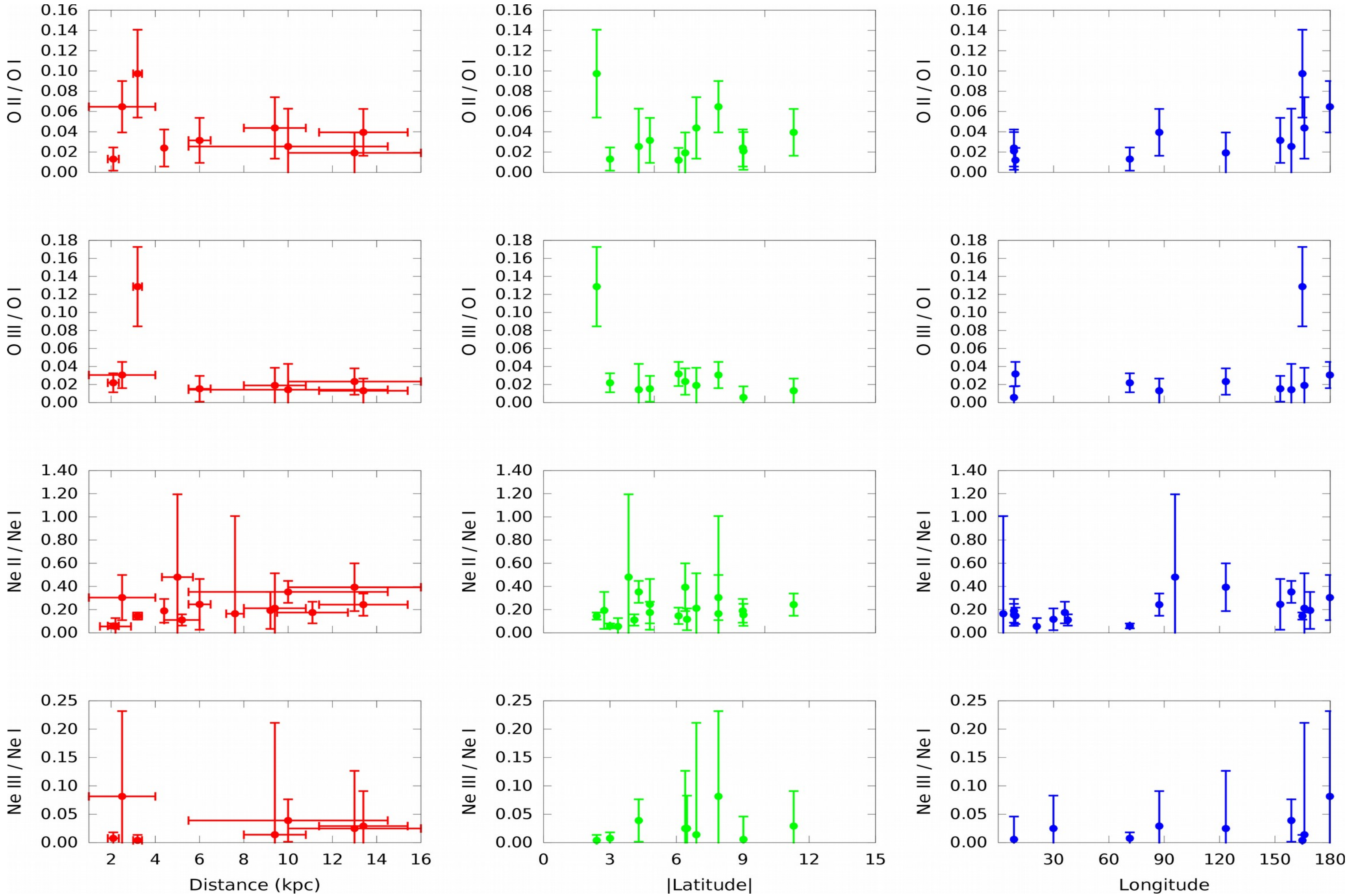
Gatuzz+16

Spatial variations of the columns



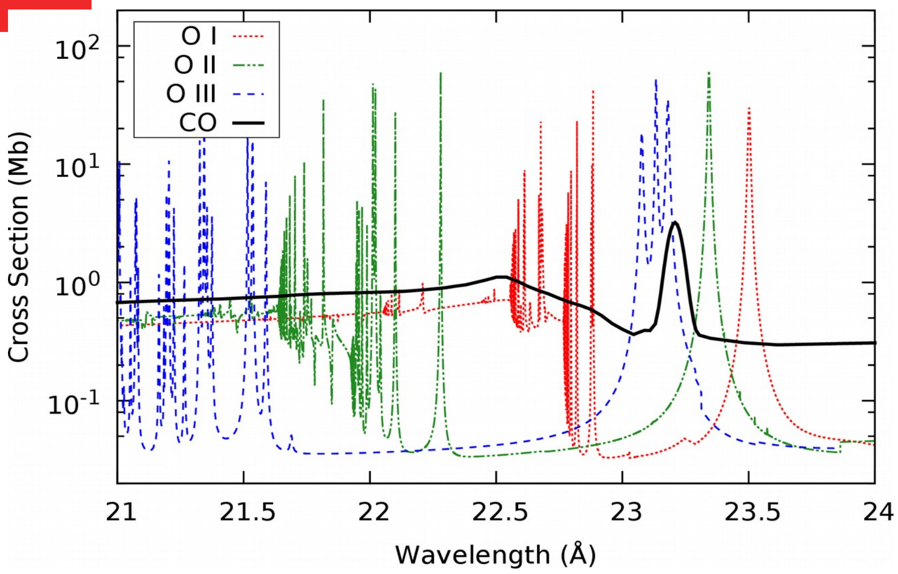
Gatuzz+16

ISM Ion fractions



Gatuzz+16

CO X-ray absorption



O I → Gorczyca et al. (2014)
O II, O III → García et al. (2005)
CO → Barrus et al. (1979)

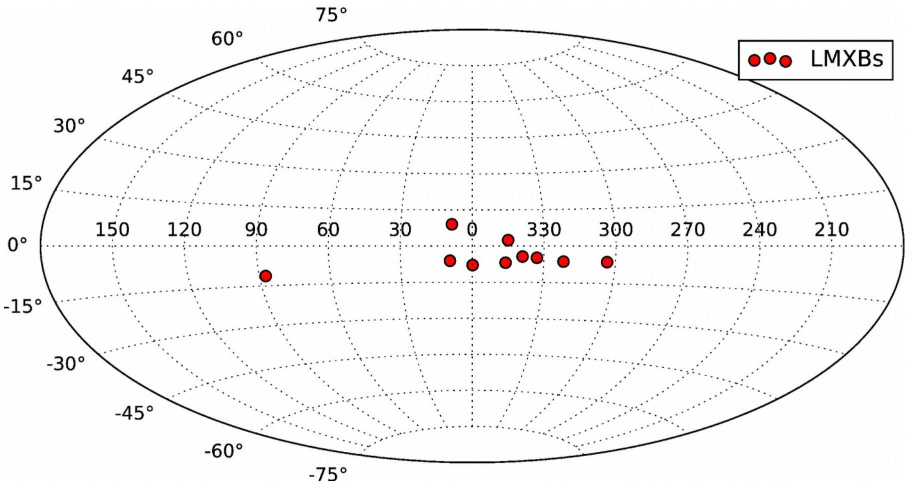
The high width of the ~23.2 Å resonance is due to vibrational level excitation.

It is partially embedded in the O III Kα triplet, **making difficult** its detection.

– 10 bright LMXB spectra obtained with XMM-Newton.

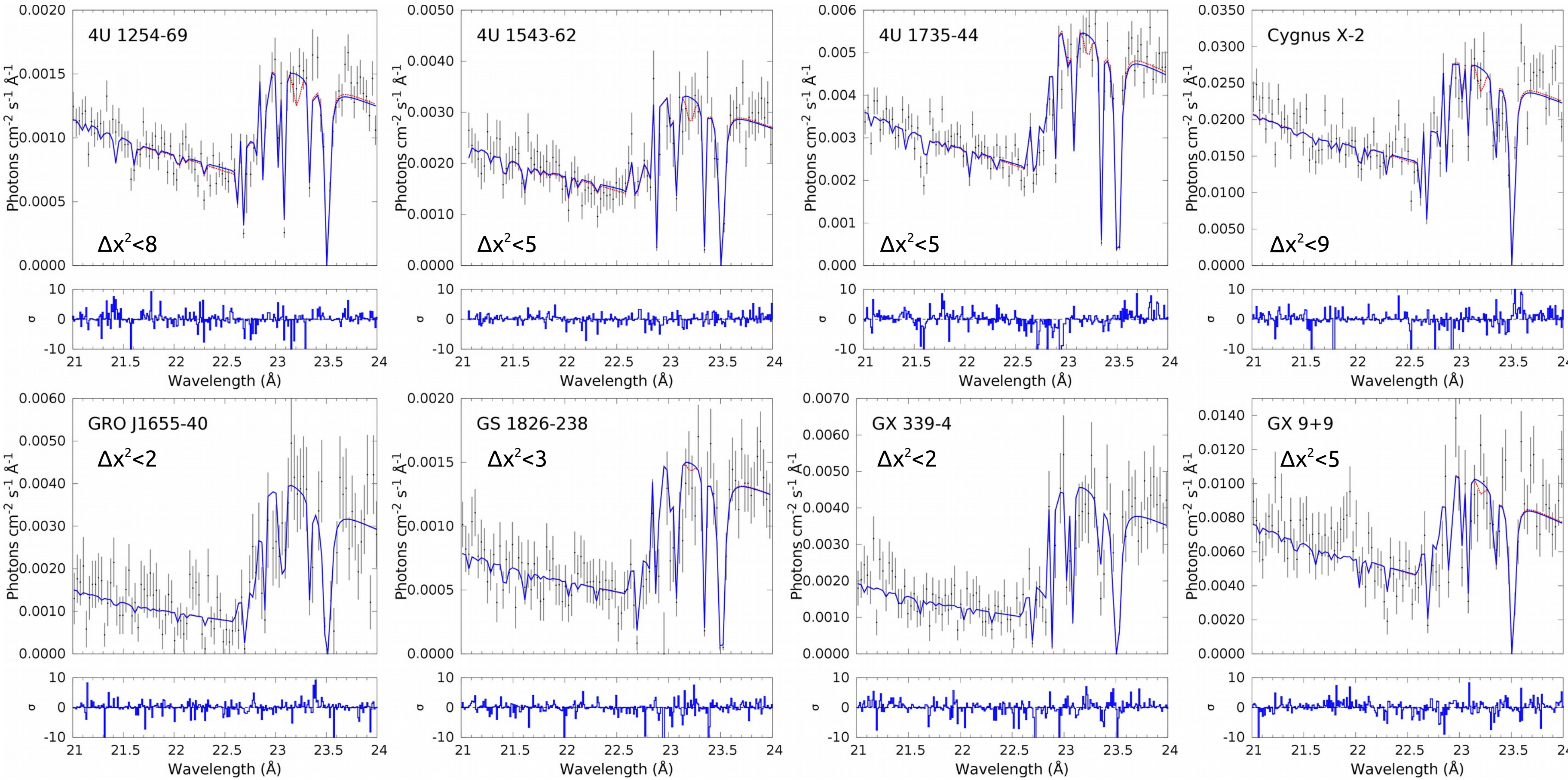
– Galactic center line-of-sight.

– Enough statistic to solve O I, O II and O III Kα resonances.



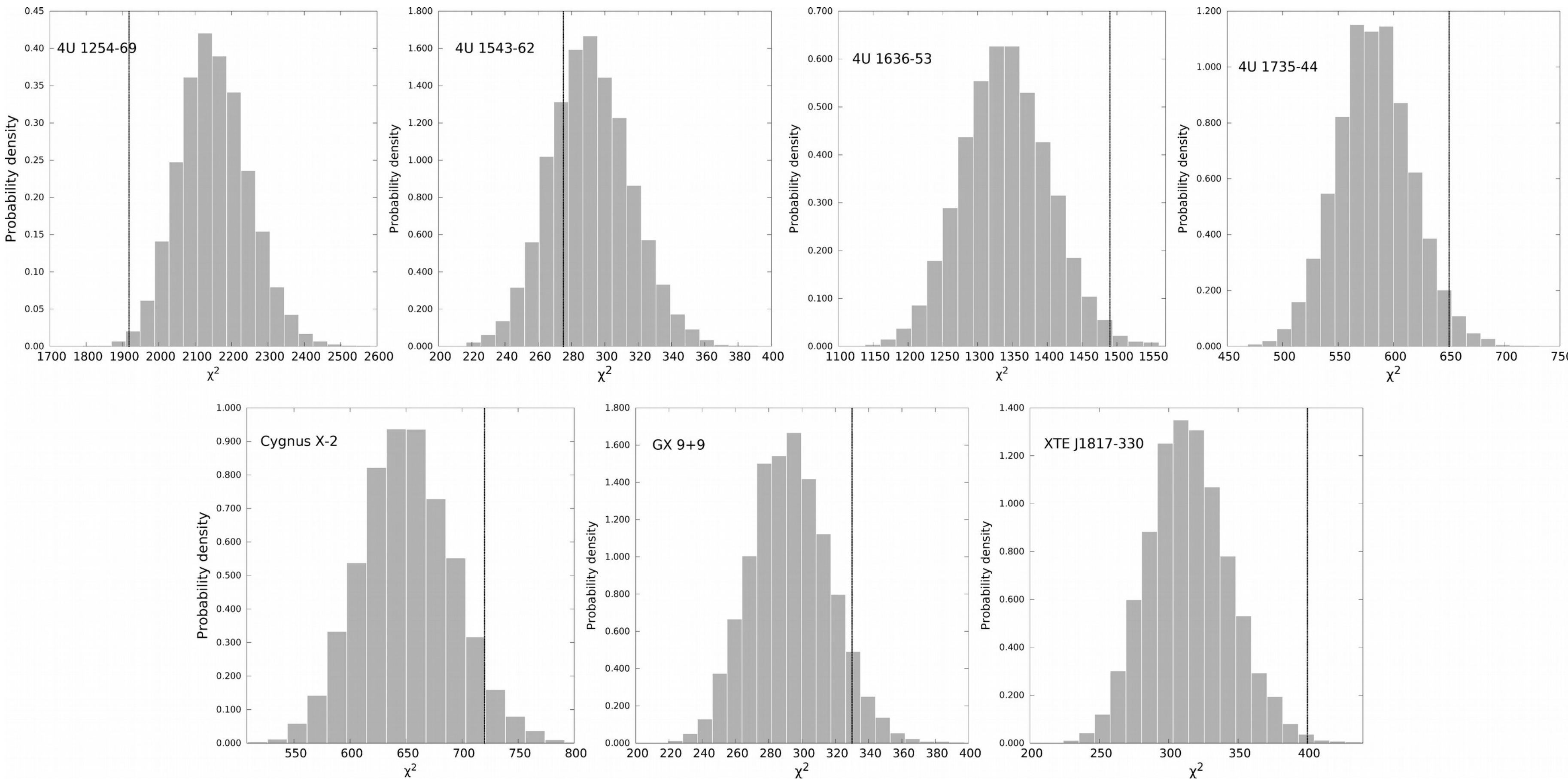
JOACHIMI+16

CO X-ray absorption



JOACHIMI+16

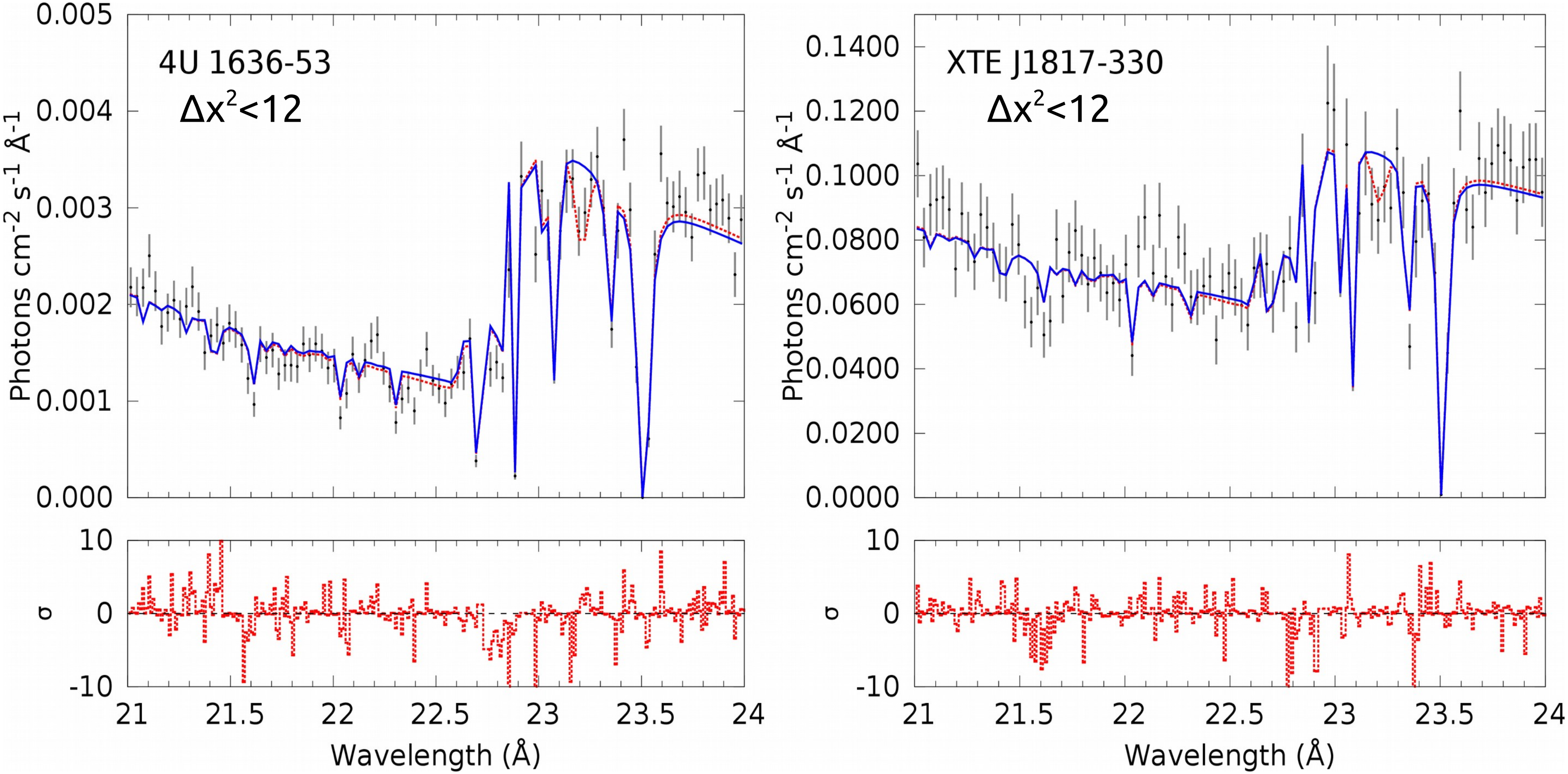
CO X-ray absorption



Vertical dashed lines correspond to the best χ^2 obtained for each source

JOACHIMI+16

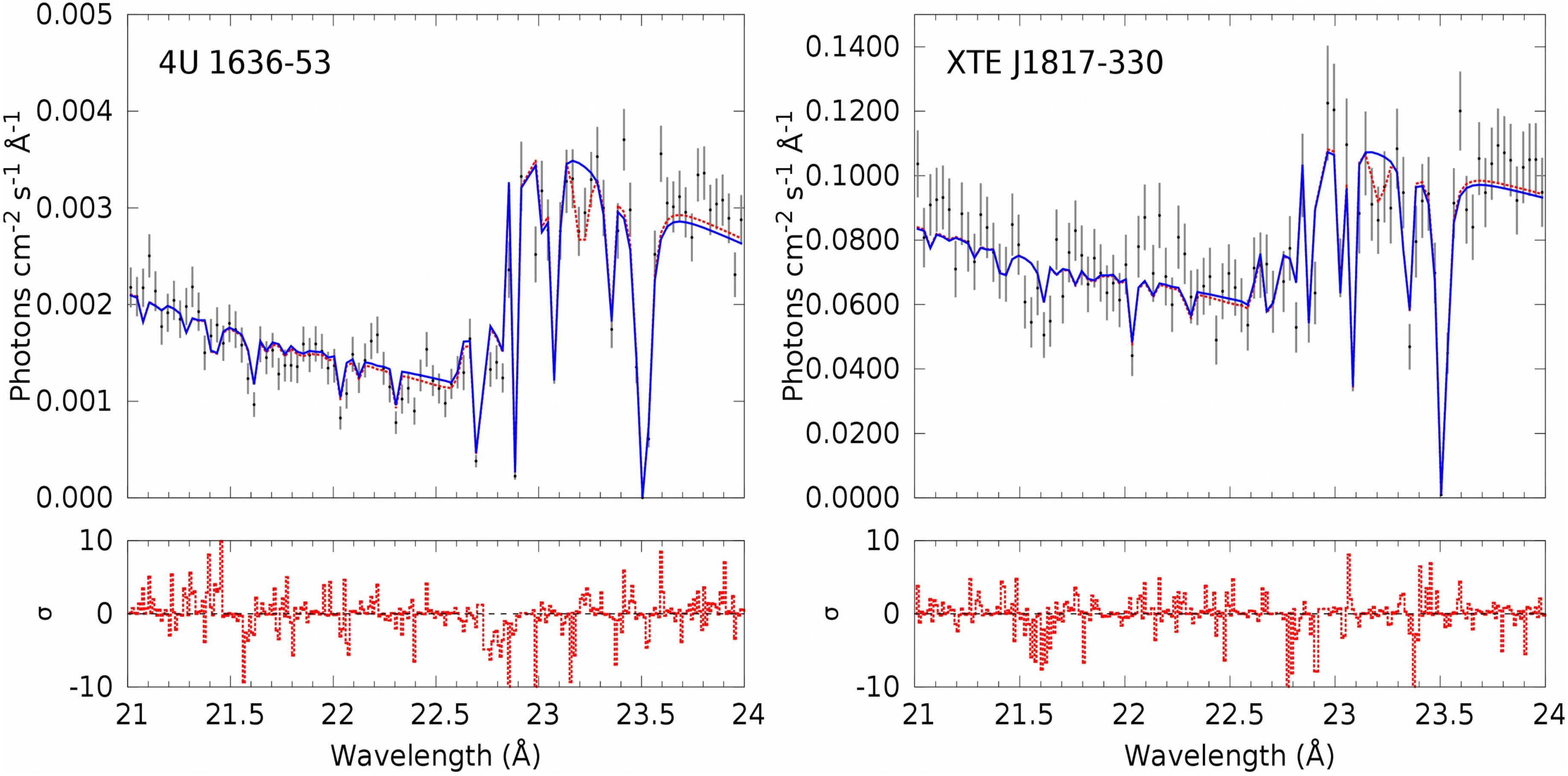
CO X-ray absorption



ISMabs best fit of the oxygen K-edge region without CO and including CO

JOACHIMI+16

CO X-ray absorption

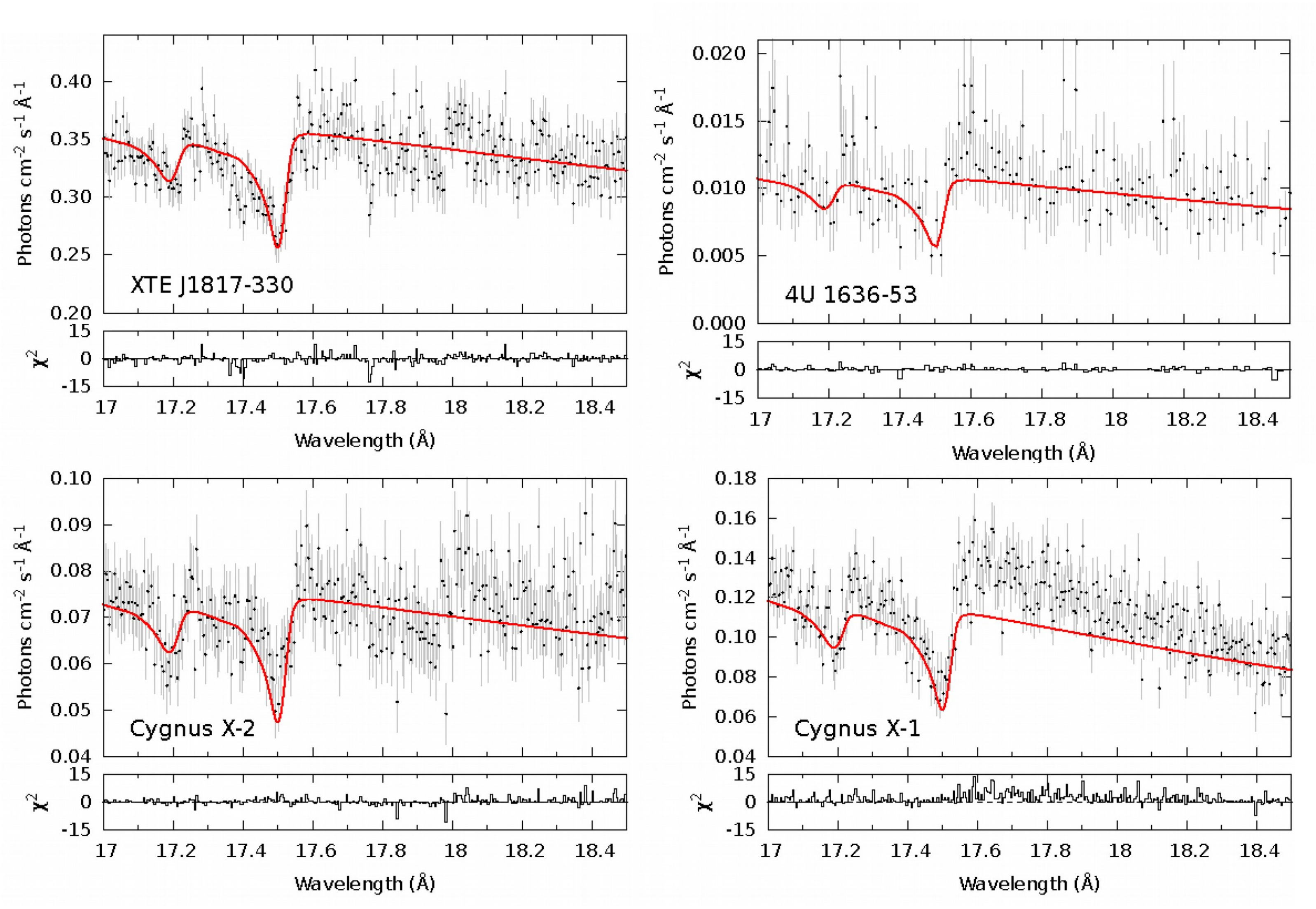


N(CO) = $(7.22 \pm 0.57) \times 10^{16}$ cm^{-2} (XTE J1817-330)

N(CO) = $(7.08 \pm 3.45) \times 10^{16}$ cm^{-2} (4U 1636-53)

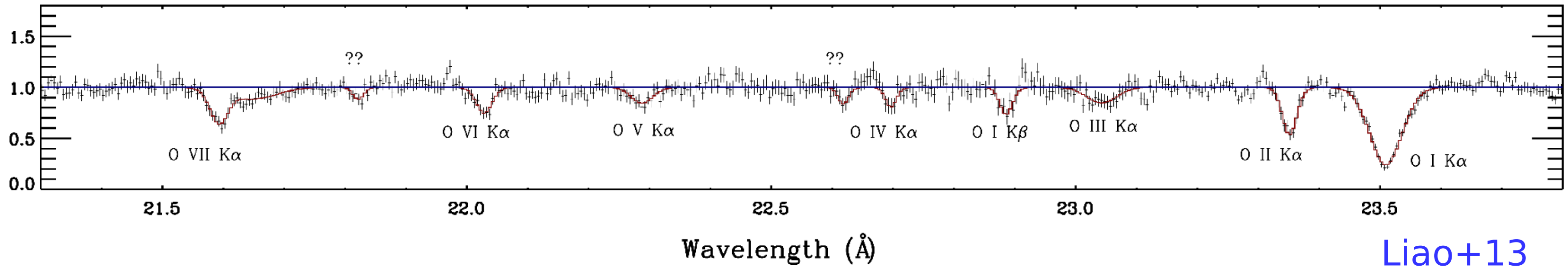
Joachimi+16

Iron L-edge: solid + atomic?

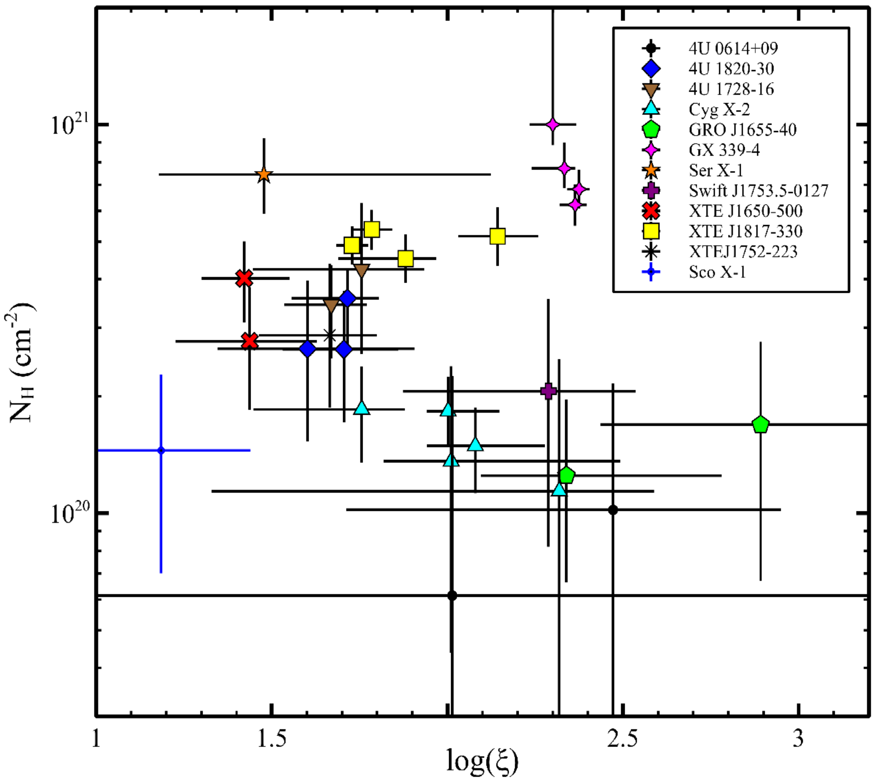


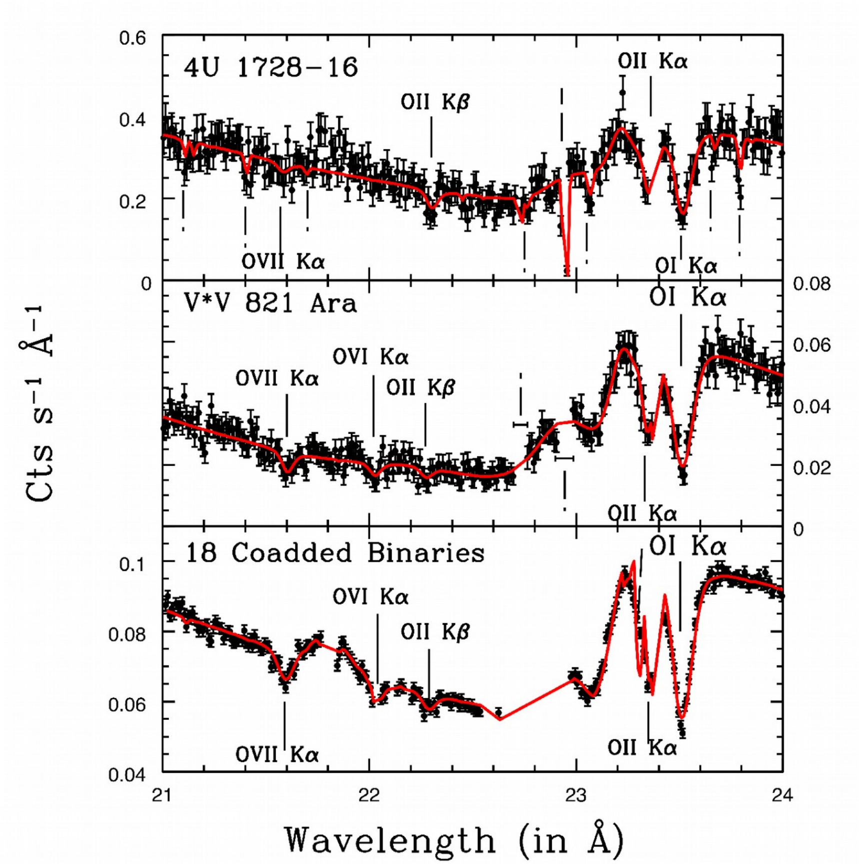
Metallic Fe experimental measurements by Kortright&Kim+00

Hot component?



Liao+13



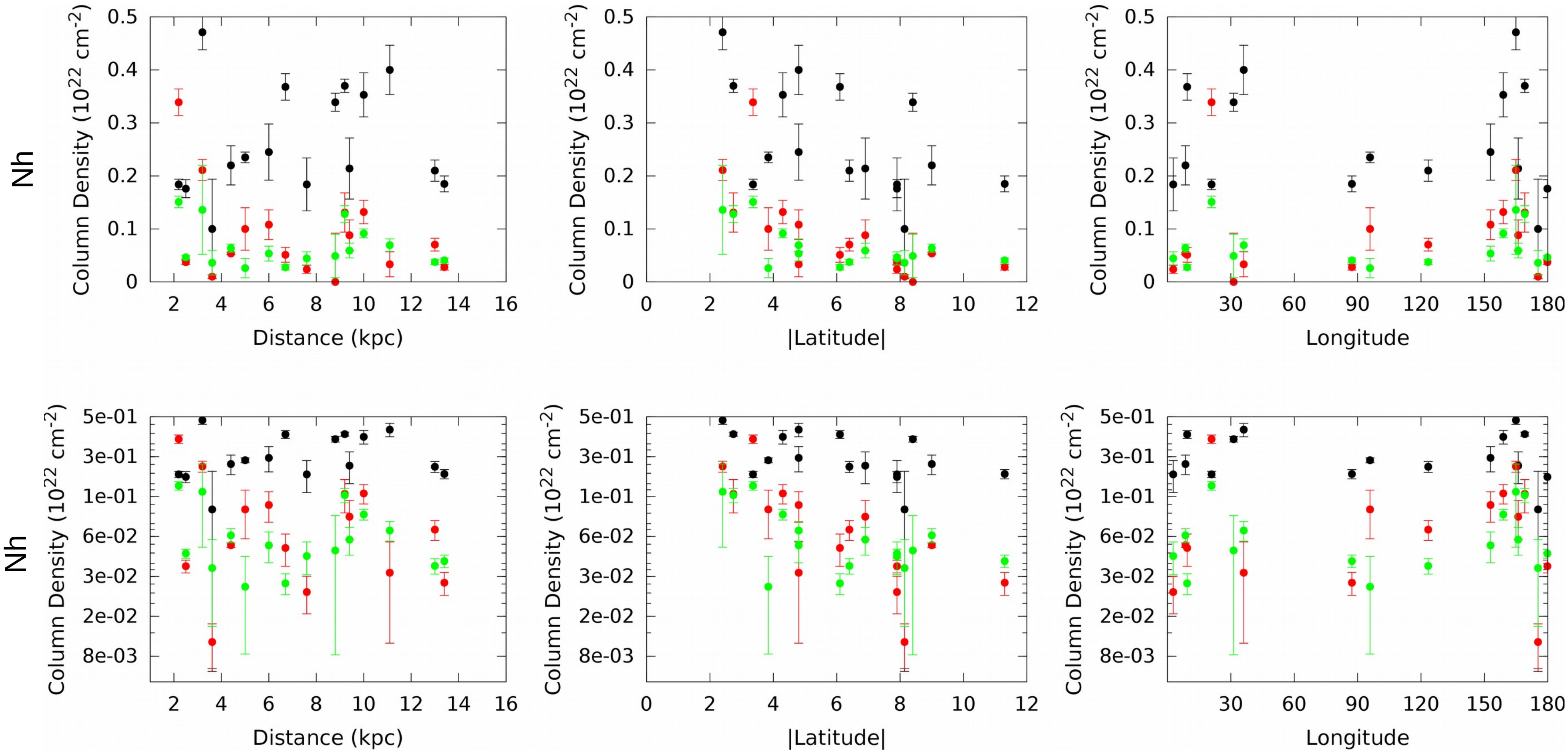


Luo+14

Nicastro+16

Ionization Equilibrium

$$\tau = \sum_{i}^{k} \sigma_i \cdot N_h \cdot A_i \cdot \xi_i$$



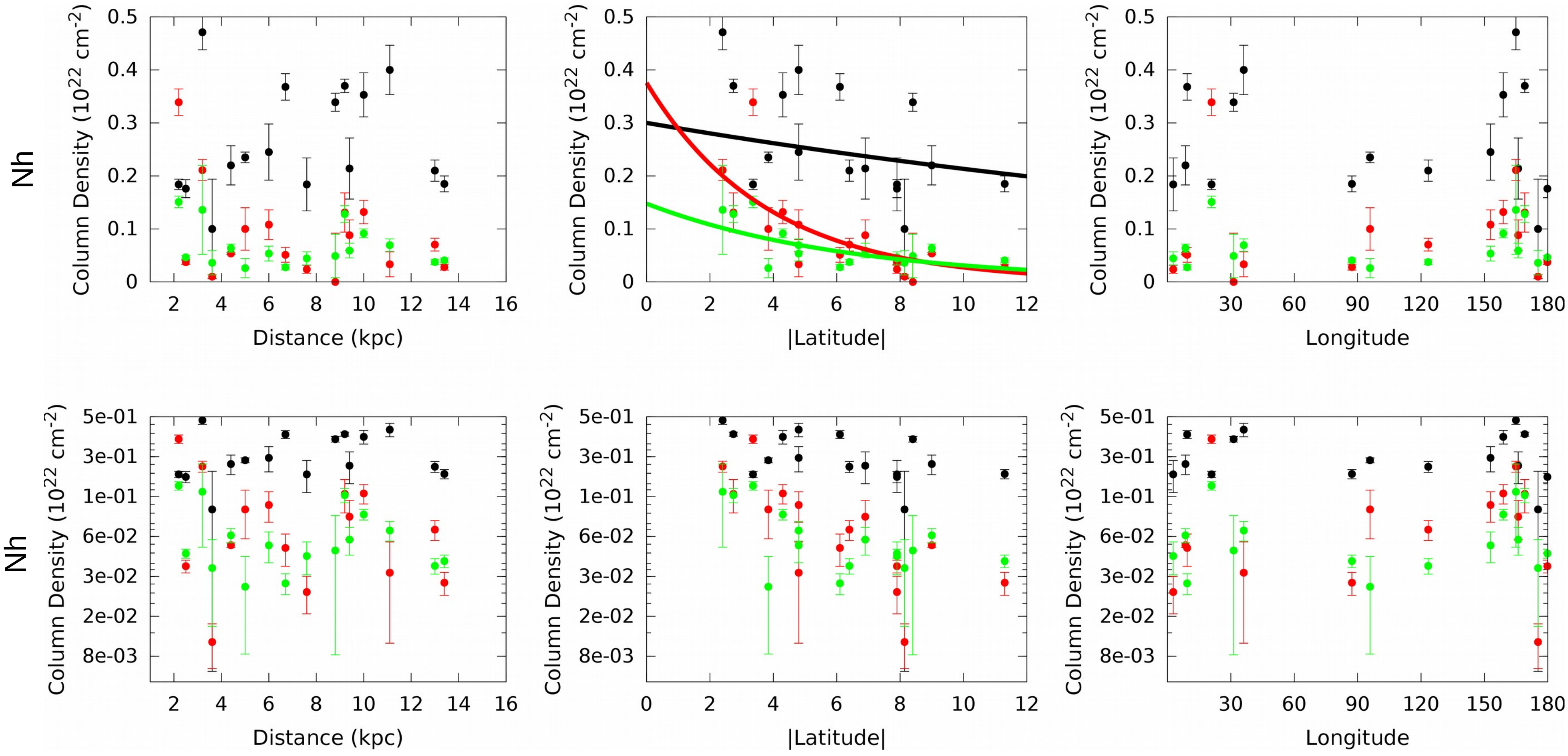
COLD COMPONENT: O I, Ne I, Fe I, Metallic Fe, CO

WARM COMPONENT: O II, O III, Ne II, Ne III

HOT COMPONENT: Ne IX, O VII, O VIII

Ionization Equilibrium

$$\tau = \sum_{i}^{k} \sigma_i \cdot N_h \cdot A_i \cdot \xi_i$$



COLD COMPONENT: O I, Ne I, Fe I, Metallic Fe, CO
WARM COMPONENT: O II, O III, Ne II, Ne III
HOT COMPONENT: Ne IX, O VII, O VIII

Conclusions

- A detailed analysis of the ISM absorption has been performed through high-resolution X-ray spectroscopy.
- Although the predominant ISM component is a cold gas, the inclusion of low ionization states leads to a better modeling of the spectra.
- An accurate analysis of the cold ISM absorption is crucial in order to study high-ionization states and molecular features.
- We measured CO column densities along the line of sight through XTE J1817-330 and 4U 1636-53.
- There is a hot component which can be part of the ISM instead of intrinsic to the sources.

THANK YOU!