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)

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High-Resolution X-ray Spectroscopy

Low Mass X-ray Binaries (ISM)
Extragalactic Sources (CGM)
**Chandra X-ray Observatory**

**HETG – MEG**

- **Bandpass:** 1.2 – 30 Å
- **Effective Area:** 35 cm² (10 Å), 10 cm² (20 Å)
- **Resolution (ΔÅ):** 0.012 Å FWHM

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

**RGS**

- **Bandpass:** 10 – 35 Å
- **Effective Area:** 59 cm² (10 Å), 50 cm² (20 Å), 70 cm² (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.**
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

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Spatial variations of the columns

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ISM Ion fractions

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CO X-ray absorption

- 10 bright LMXB spectra obtained with XMM-Newton.
- Galactic center line-of-sight.
- Enough statistic to solve $\text{O I}$, $\text{O II}$ and $\text{O III}$ $\text{K}_\alpha$ resonances.

$\text{O I} \rightarrow$ Gorczyca et al. (2014)
$\text{O II}, \text{O III} \rightarrow$ García et al. (2005)
$\text{CO} \rightarrow$ Barrus et al. (1979)

The high width of the $\sim 23.2$ Å resonance is due to vibrational level excitation.

It is partially embedded in the $\text{O III}$ $\text{K}_\alpha$ triplet, making difficult its detection.
CO X-ray absorption

Δχ² < 8

Δχ² < 5

Δχ² < 5

Δχ² < 9

Δχ² < 2

Δχ² < 3

Δχ² < 2

Δχ² < 5
CO X-ray absorption

Vertical dashed lines correspond to the best $\chi^2$ 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

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

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