CHARACTERIZATION OF THE X-RAY ABSORPTION IN THE GALACTIC ISM

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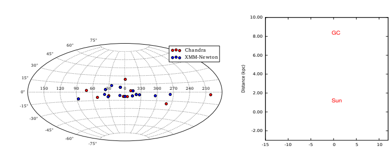
INTRODUCTION

The analysis of the Interstellar Medium (ISM) is crucial to understand stellar formation and evolutionary processes, which may be performed by means high-resolution X-ray spectroscopy, providing the opportunity to study physical properties such as column densities, ionization fractions, and abundances for astrophysical relevant elements in both the gas and grain(Pinto et al., 2010, 2013; Nicastro et al., 2016a,b). In this work we present an extensive analysis of the ISM using *XMM-Newton* and *Chandra* high-resolution X-ray spectra

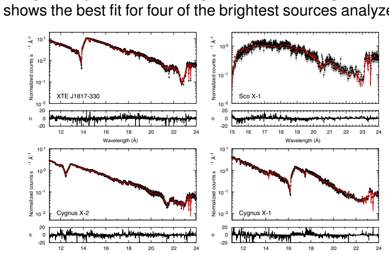
OBSERVATIONS AND DATA REDUCTION

A total of 24 bright sources have been reduced, 15 from the XMM- Newton Science Archive (XSA) and 17 from the Chandra Source Catalog (CSC), some of which have been observed with both telescopes. As shown in the figure below, the source locations allow an analysis of the ISM along different lines of sight. The figure also shows the source position projected in the galactic plane.



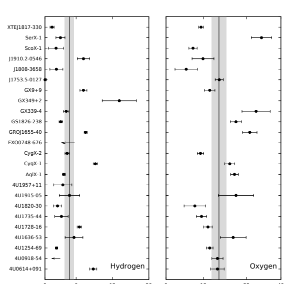
SPECTRAL FITTING PROCEDURE

In order to estimate the O, Ne, and Fe column densities we have carried out a broadband fit (11-24 Å) for each source using a simple **ISMabs*Bknpower** model[1]. Figure below shows the best fit for four of the brightest sources analyzed.



ISM STRUCTURE

Figures below show the distribution of the column densities obtained for each source. The hydrogen and neon column densities are mostly consistent, and are homogeneously distributed along their average value. Oxygen and iron column densities, on the other hand, tend to be more dispersed probably due to depletion to diverse compounds that reduce the atomic abundances along the different lines of sight.



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

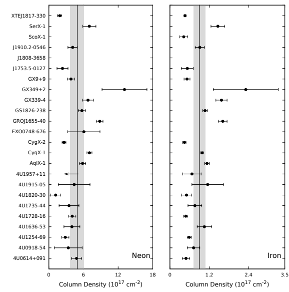
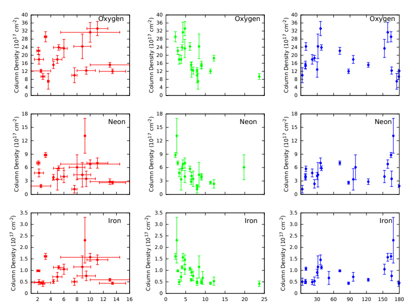
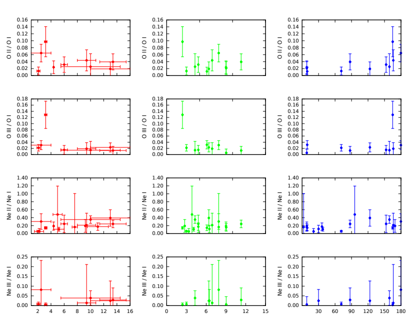


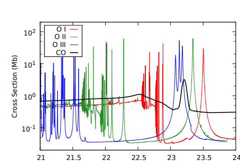
Figure below shows a comparison of the oxygen, neon, and iron total column densities from the **ISMabs** model as function of multiple geometric parameters. We have found that the column densities tend to increase with distance, the slope being steeper in the case of oxygen, and the general trend is to decrease with galactic latitude.



Unlike the column densities, the ionization fractions tend to be approximately constant with the geometric parameters (see Figure below). This result agrees with previous findings regarding the dominance of the ISM cold phase characterized by a low ionization degree (Gatuzz et al., 2013a,b, 2014, 2015).

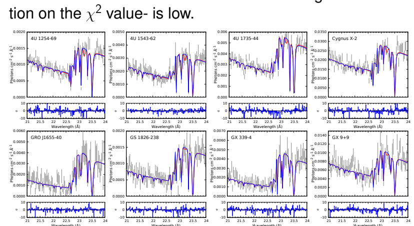


CO X-RAY ABSORPTION



In order to model the CO molecular absorption, we use the cross-section measured experimentally by Barrus et al. (1979). Figure shows the cross-sections included on **ISMabs** in order to model the O K-edge. The principal CO resonance (~23.20 Å) is partially embedded in the O III Kα triplet, making difficult its detection.

Figures below show the best fit of our model to the O K-edge region for 10 sources selected with CO (red lines) and without CO (blue lines) For sources in which the inclusion of CO yielded to some improvement in the fit statistics, the presence of the CO resonance at 23.20 Å can be appreciated in the models fit as well as the residuals. However, in most cases the statistical inference -referring to the variation on the χ^2 value- is low.



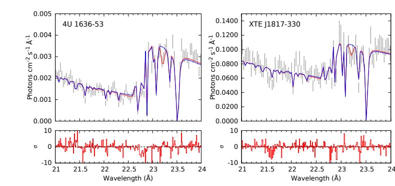
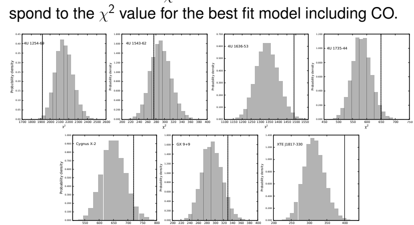


Figure below shows a Monte-Carlo (MC) statistical analysis for the sources with $\Delta\chi^2 > 2$. Vertical dashed lines correspond to the χ^2 value for the best fit model including CO.



The MC analysis prevents from a significant detection of CO molecular X-ray absorption features in all sources analyzed, except for 4U 1636–53 and XTE J1817-330, for which we obtained a significant detection with at least 95% confidence. The column density values measured are $N(\mathrm{CO}) = (7.22 \pm 0.57) \times 10^{16}\mathrm{cm}^{-2}$ (for XTE J1817-330) and $N(\mathrm{CO}) = (7.08 \pm 3.45) \times 10^{16}\mathrm{cm}^{-2}$ (for 4U 1636–53).

CONCLUSIONS

This is the most complete study to date using a physical model and considering O and Ne charge states. We derive column densities for multiple line-of-sights. We find that the ionization fractions tend to be constant with distance and latitude reinforcing previous conclusions regarding the dominance of the neutral ISM component.
We include the CO experimental photo-absorption cross section measured by Barrus et al. (1979) in order to model the contribution of CO to the absorption spectra. We performed Monte-Carlo simulations to obtain a rigorous estimate of the statistical significance of possible CO detection. We measure CO column density values for XTE–J1817-330 and 4U 1636-53 line-of-sights.

References

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