Neutron Star Astrophysics at the Crossroads: Magnetars and the Multimessenger Revolution
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Silicon K-edge Dust Properties of Neutron Star Low-mass X-ray Binaries

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Abstract. The dust properties of the line-of-sight materials in neutron star low-mass X-ray binaries (LMXBs) can be probed by X-ray observations and laboratory experiments. We use a Markov chain Monte Carlo (MCMC) method to conduct a spectral analysis of *Chandra* ACIS-S/HETG archival data of a sample of LMXBs, including GX 5-1 and GX 13+1. Our MCMC-based analysis puts constraints on the Si K-edge dust properties of the outflowing disk winds in this sample. Further X-ray observations of other LMXBs will help us better understand the grain features of dense outflows and accretion flows in neutron star binary systems.

Keywords. Stars: neutron – X-rays: binaries – ISM: dust – X-rays: ISM

The properties of silicate-based dusty materials in dense accretion disk and outflowing winds of low-mass X-ray binaries (LMXBs), such as grain and metallic content, can be determined from the K-edge absorption profile around 1.84 keV in the rest frame (Schulz et al. 2016; Rogantini et al. 2020). It has been found that photoelectric edges in the X-ray soft band can be utilized to explore the common features of dust grains of the interstellar medium (see e.g., Lee & Ravel 2005; Lee et al. 2009). In particular, silicon Kα edges might disclose the accreting properties of LMXBs, which allow us to assess better binary neutron star candidates for mergers.

We considered *Chandra* ACIS-S/HETG observations of a sample of LMXBs (GX 5-1 and GX 13+1 here). Cross-section data from various dust grains measured in laboratory experiments (shared by J. C. Lee) were fitted into the Si K-edge features in the *Chandra* ACIS-S/HETG observations to constrain the dust composition of LMXBs (see Fig. 1). The cross-sections include Fayalite, Enstatite Chondrite, Enstatite Fe-Free, Mg_2SiO_4, and Si_3N_4. Spectral MCMC modeling was performed with the S-Lang `emcee` module (developed by M. A. Nowak, 2017) in the Interactive Spectral Interpretation System (ISIS ; Houck & Denicola 2000). In particular, MCMC-based fitting methods have been found to be promising in determining the best-fitting model parameters of dense media around compact objects in X-ray astrophysics (e.g., Danehkar et al. 2018, 2021).

Our MCMC analysis suggests that the lines-of-sight dusty outflowing materials in GX 5-1 and GX 13+1 (see Fig. 2) are well fitted with Fayalite, Enstatite Chondrite, and Enstatite Fe-Free. We also get acceptable fits with Mg_2SiO_4. However, the Si_3N_4 model is unable to well reproduce the Si K-edge absorption characteristics in these LMXBs. As seen in Fig. 2, the cross-section models of Fayalite and Enstatite Fe-Free fitted to the Si K-edge absorption profile of GX 5-1 correspond to blueshifted outflow velocities of ≈ -390 and -350 km s^{-1}, respectively. Similarly, an MCMC-based spectral analysis of the silicon Kα edge in GX 13+1 yields ≈ -240 km s^{-1} with the Enstatite Chondrite and Enstatite Fe-Free cross-sections, while a mean Kα outflow velocity of ≈ -400 km s^{-1}

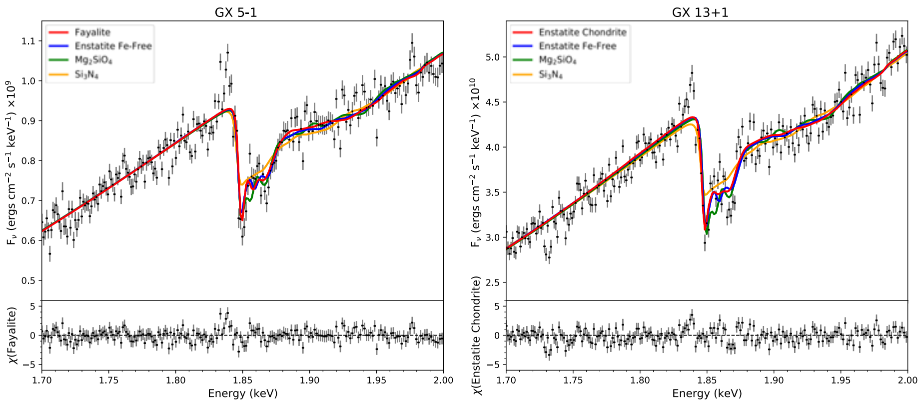

Figure 1. Si K-edge absorption profiles of GX 5-1 (left panel) and GX 13+1 (right) in the combined MEG and HEG, ACIS-S/HETG *Chandra* observations, fitted by various dust models, including Fayalite, Enstatite Chondrite, Enstatite Fe-Free, Mg_2SiO_4, and Si_3N_4.

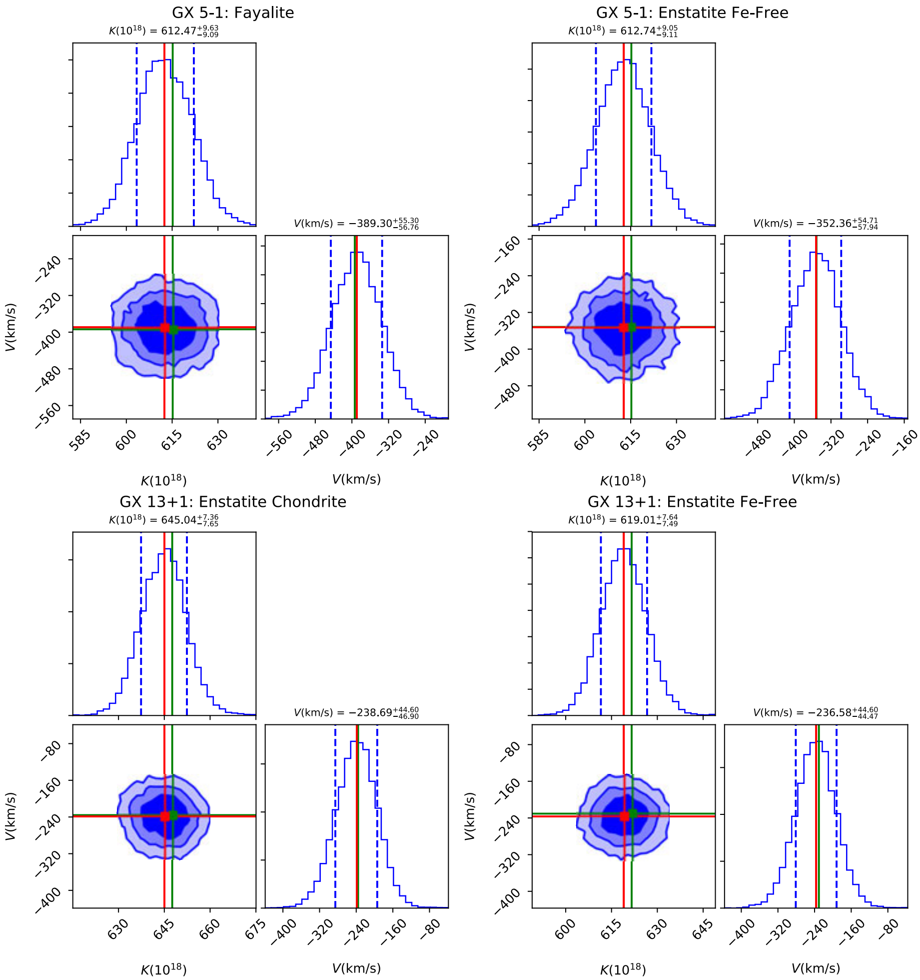

Figure 2. Posterior probability distributions of the normalization factor K and outflow velocity V for the dust models fitted to Si K-edge absorption features of GX 5-1 (top panels; Fayalite and Enstatite Fe-Free) and GX 13+1 (bottom; Enstatite Chondrite and Enstatite Fe-Free).

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was found by Allen et al. (2018). The blueshifted Si K-edge absorption features could be associated with outflowing disk winds along the line of sight in these LMXBs.

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