



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-CONF-402889

High Spectral Resolution X-ray Observation of Magnetic CVs: EX Hya

G. Luna, N. S. Brickhouse, C. W. Mauche

April 11, 2008

HEAD 2008
Los Angeles, CA, United States
March 31, 2008 through April 3, 2008

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor Lawrence Livermore National Security, LLC, nor any of their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or Lawrence Livermore National Security, LLC. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Lawrence Livermore National Security, LLC, and shall not be used for advertising or product endorsement purposes.



High spectral resolution X-ray observation of magnetic CVs: EX Hya

Gerardo Luna (SAO/CFA), N. S. Brickhouse (SAO/CFA) and C. W. Mauche (LLNL)



In magnetic cataclysmic variables (CVs) the primary is a highly magnetized white dwarf (WD) whose field controls the accretion flow close to the WD, leading to a shock and accretion column that radiate chiefly in X-rays. We present preliminary results from a 500 ks Chandra HETG observation of the brightest magnetic CV EX Hya. From the observational dataset we are able to measure the temperature and density at different points of the cooling accretion column using sensitive line ratios. We also construct line-based light curves to search for rotational modulation of the X-ray emission.

EX Hya is an eclipsing, high inclination ($i \sim 78^\circ$) IP with an orbital period of 98 min and a WD spin period of 67 min. X-ray studies give a radial velocity amplitude of 58.2 ± 3.7 km/s associated with the WD, which can be used to infer the WD mass using additional optical information (Hoogerwerf et al. 2004, Beuermann & Reinsch 2008).

Beginning on 05-13-2007 we obtained a 500 ks ACIS/HETG observation of EX Hya, covering ~ 125 WD spin periods. These observations allow us to test models of the spin-phased modulation, including occultation of one shock column and absorption by the accretion curtain (see fig. 1). We present a progress report on the spectral analysis (fig. 2).

- Density diagnostic:

The high SNR obtained allows us to increase the accuracy of the density derived from the Fe XXII $I(11.92\text{\AA})/I(11.77\text{\AA})$ ratio (Mauche et al. 2003). In fig. 3 we show the measured value of this ratio using our data and compare it with results obtained from previous data. We find $\log n_e [\text{cm}^{-3}] \sim 13.7 \pm 0.2$. With this and other accurate measurements, we will be able to determine the density as a function of temperature in the cooling column and compare to model predictions.

- Line-based light curves:

For each ion, we extract photons from the HEG and MEG ($\pm 3, 2, 1$ orders) and construct light curves (fig. 4) using the ephemeris of Hellier et al. (1992). Fig. 4 shows features (e.g. $\phi \sim 0.9$) that are statistically significant, suggesting complex structures in the accretion flow.

- The Fe K α fluorescence line:

From the line-based periodogram and light curve (fig. 5) we can see that no modulation at the spin or orbital period is present. This suggests that Fe K α is not formed in the accretion curtain or column. Another spectral line with approximately the same flux shows strong modulation at the WD spin (see fig. 5, Ca XIX light curve), indicating that the lack of modulation in the Fe fluorescence line is not driven by a low SNR.

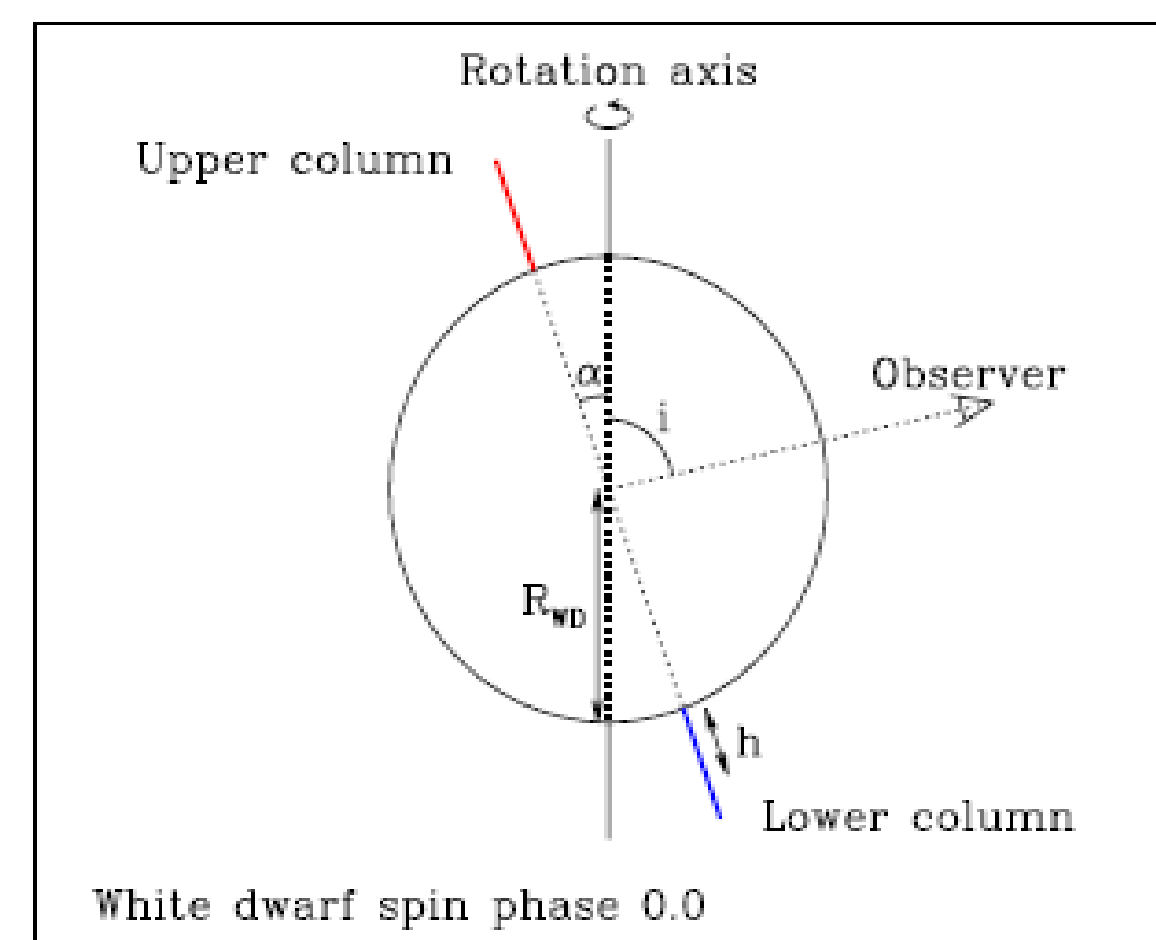


Fig. 1: Schematic of the EX Hya WD. The parameter h represent the height above the WD surface where the spectral line is formed.

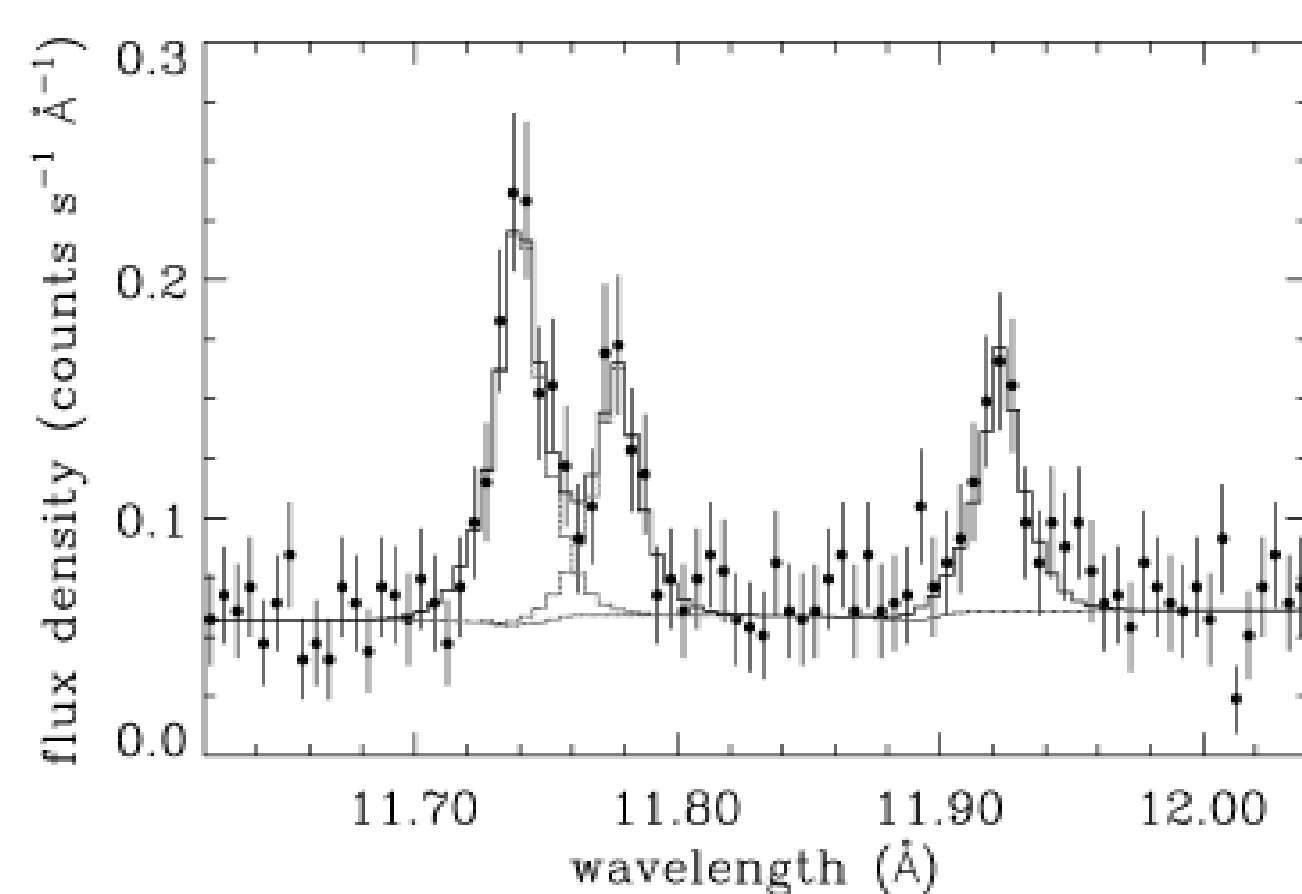
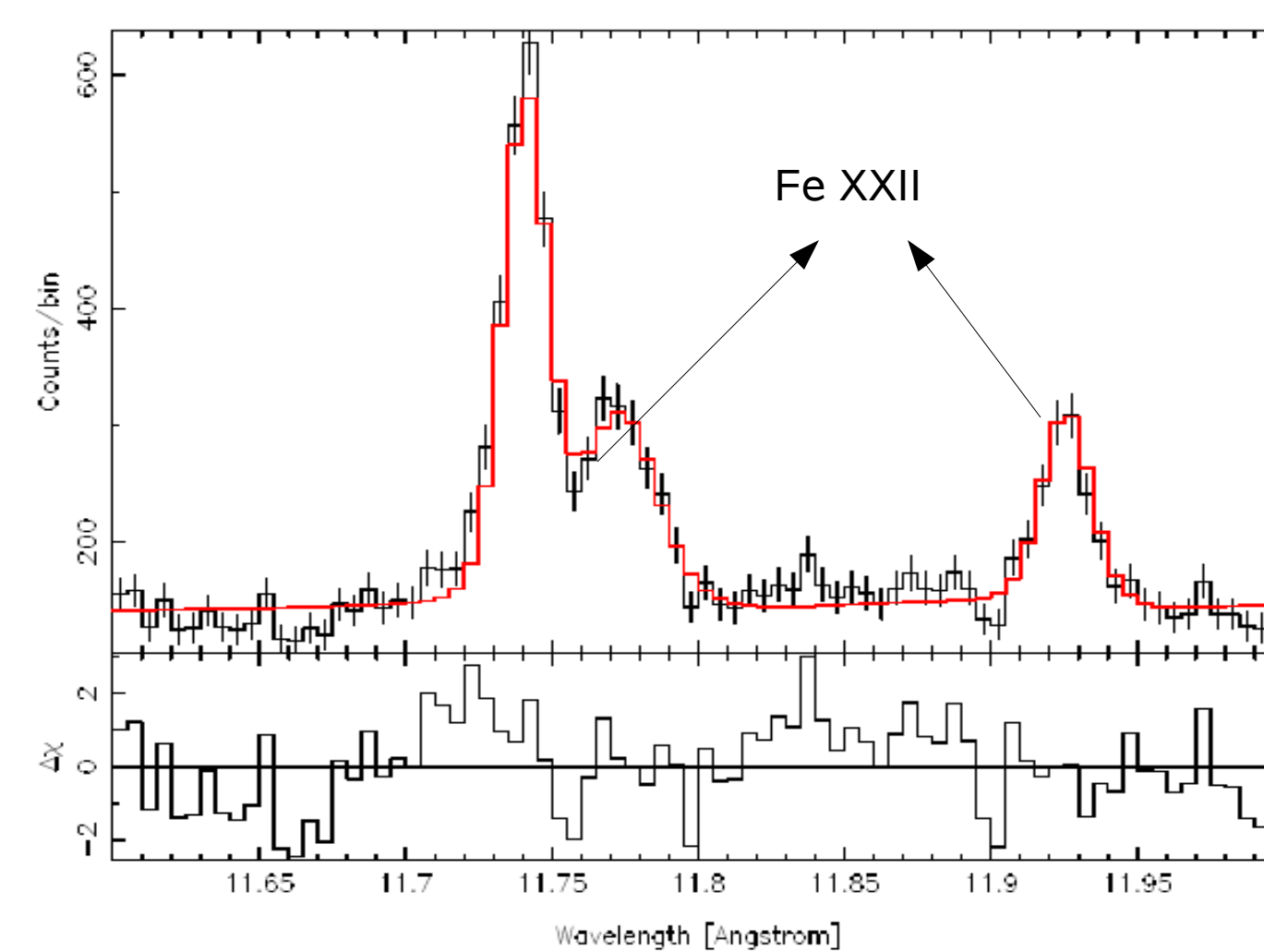


Fig. 2: Chandra/HETG spectra of EX Hya. Top panel shows the spectrum from a 500 ks (05-13-2007) observation in the Fe XXII region. Bottom panel shows previous 60 ks (05-18-2000) observation of the same object (from Mauche et al 2003). The significant improvement in the SNR will allow us to model the density and temperature distribution of the accretion column in detail.

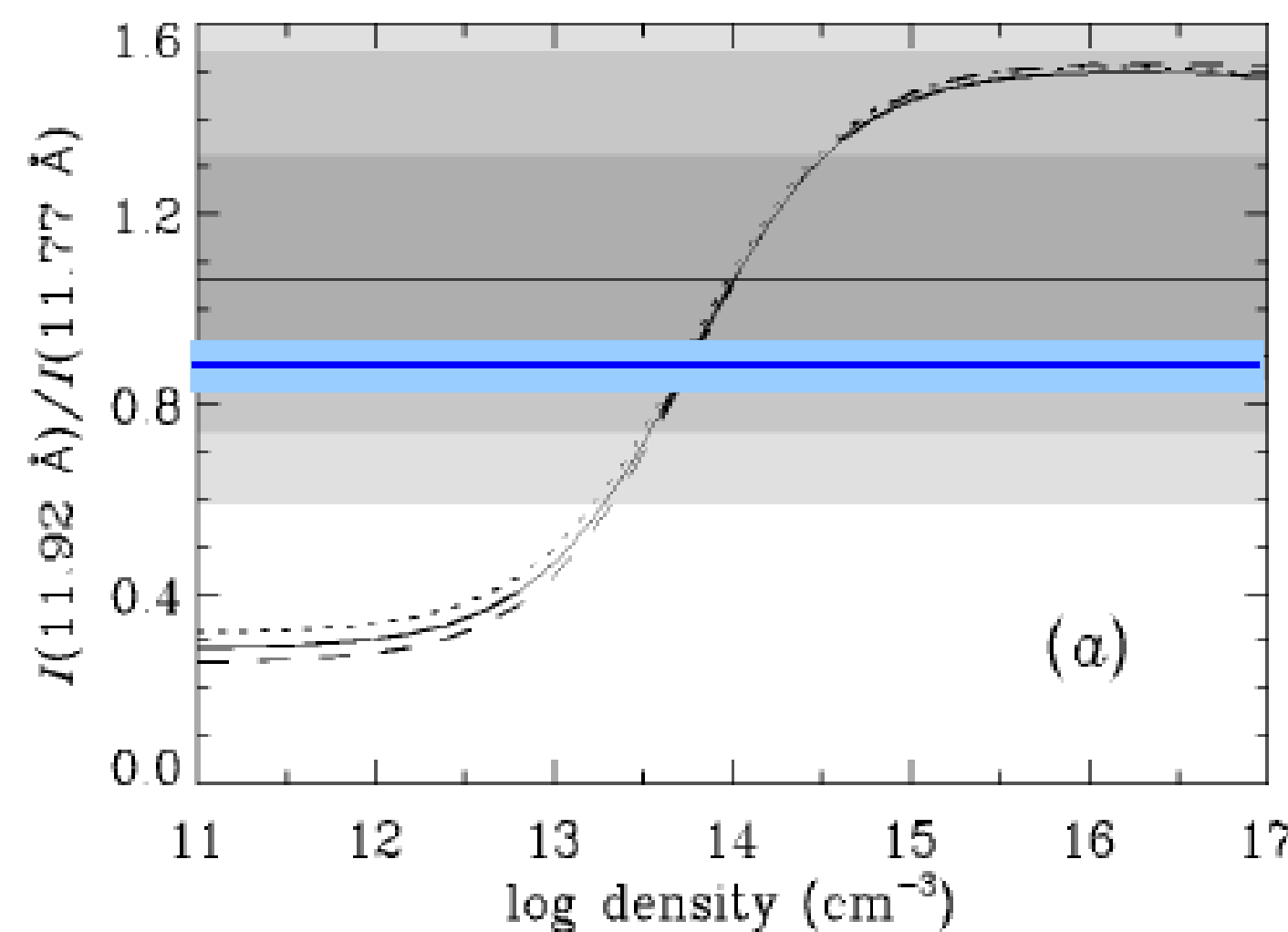


Fig. 3: Fe XXII density diagnostic line ratio applied to EX Hya. Gray shaded region represent 68%, 90% and 99% confidence error envelopes calculated from previous ACIS/HETG observations (see Mauche et al. 2003 for details). Blue line and light blue strip represent measured value and its 90% confidence error from our data.

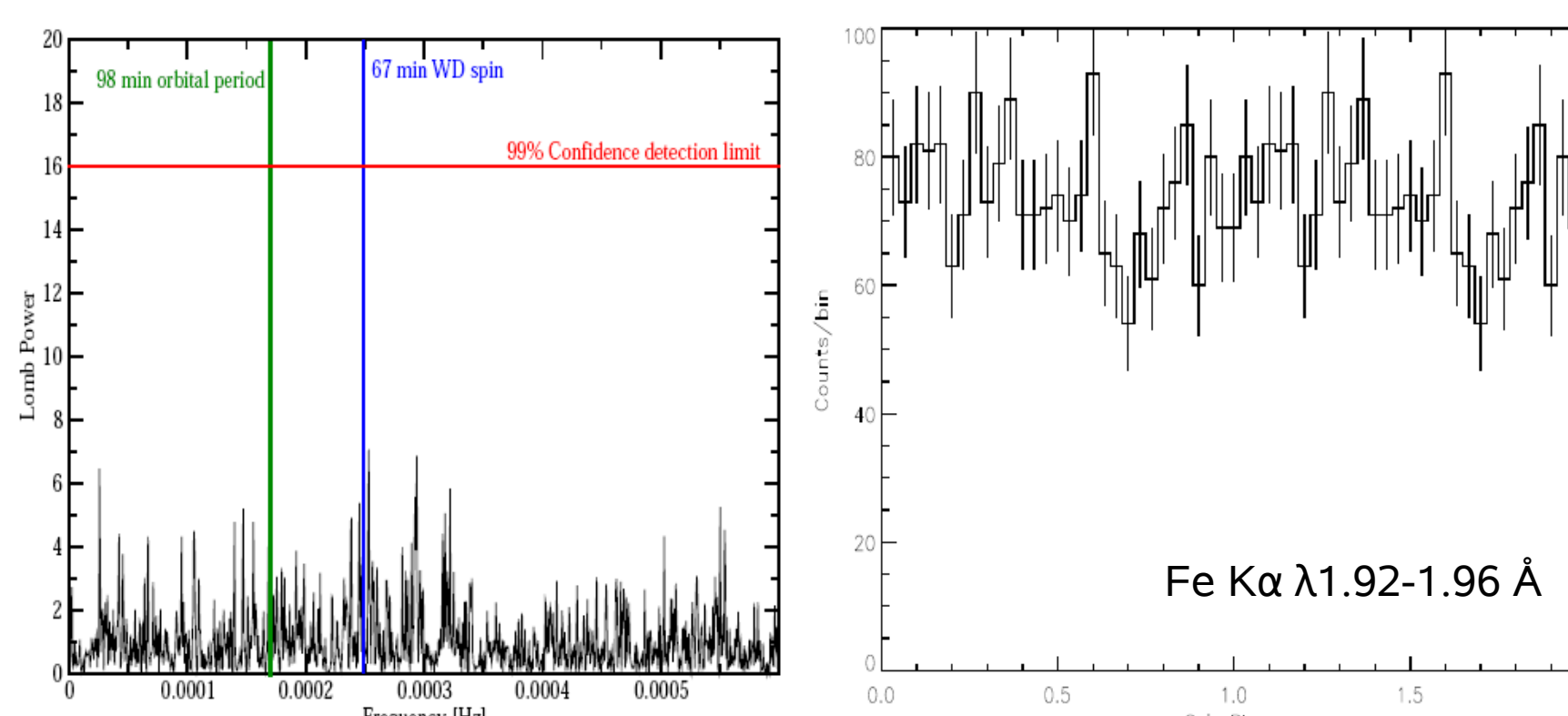


Fig. 5: Left Panel: Lomb periodogram of the Fe K α line region (6.4 keV). The red line show the 99% confidence detection limit. Blue and green lines indicates the frequencies where the WD spin and orbital periods are located. Right panel: ACIS/HETG light curve, folded at a 67 min WD spin period of EX Hya. The bin size is 0.0334 spin period, error bars represent 1σ errors.

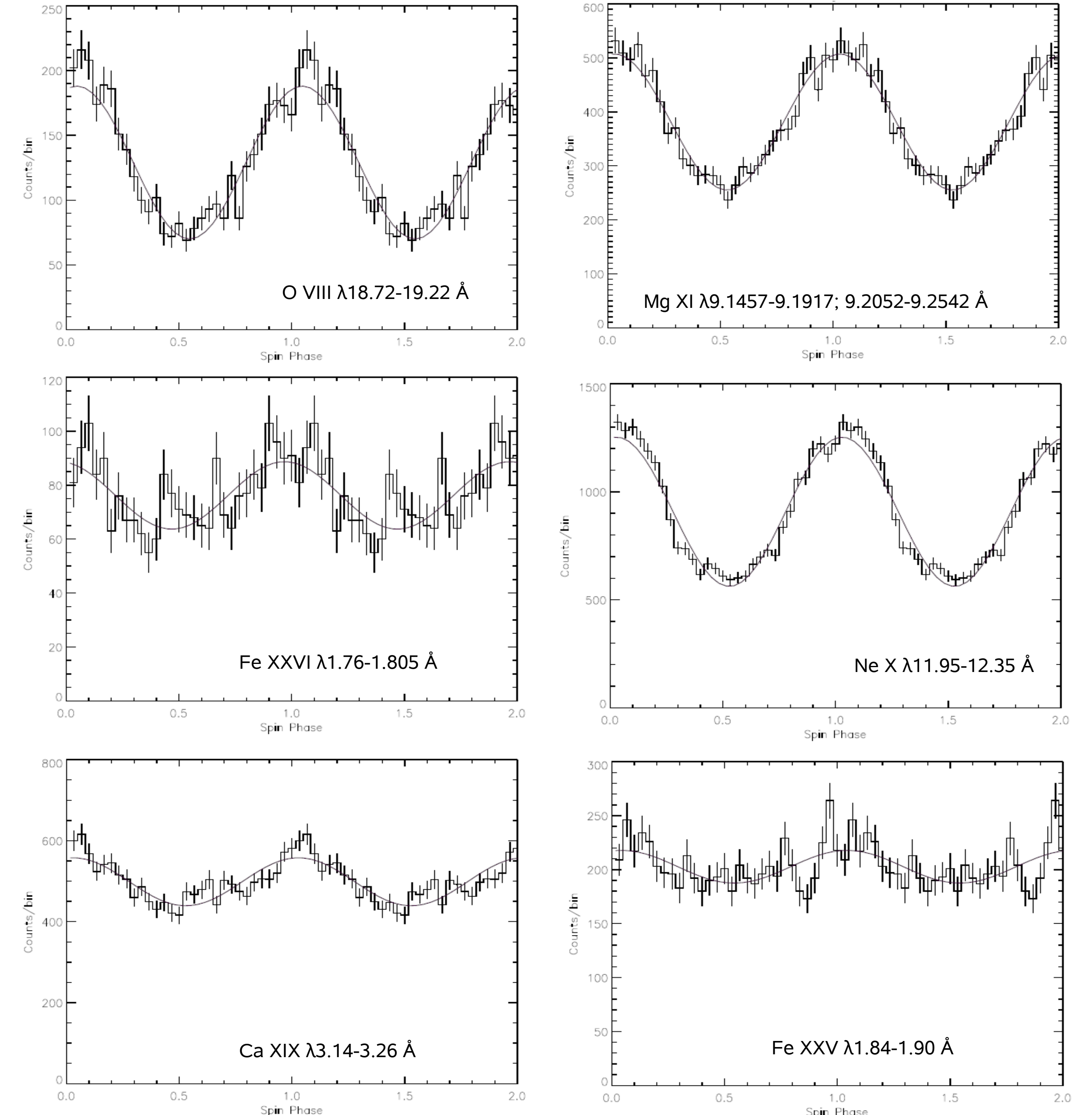


Fig. 4: Line-based light curves folded at a 67 min WD spin period of EX Hya. The bin size represent 0.0334 spin period, error bars represent 1σ . Each plot contains the best fit of a sinusoidal curve (except Fe K α where no satisfactory fit was found).

-Changes in the structure of the accretion columns?:

ACIS/HETG observations in May 2000 showed two remarkable features in the Mg XI light curves, which are explained as emission from the accretion columns (see fig. 1 and 6).

During our observation, those features are not reproduced in any line-based light curves, probably due to changes in the accretion rate (i.e. shock height), asymmetries between both accretion columns or some other effect to be investigated.

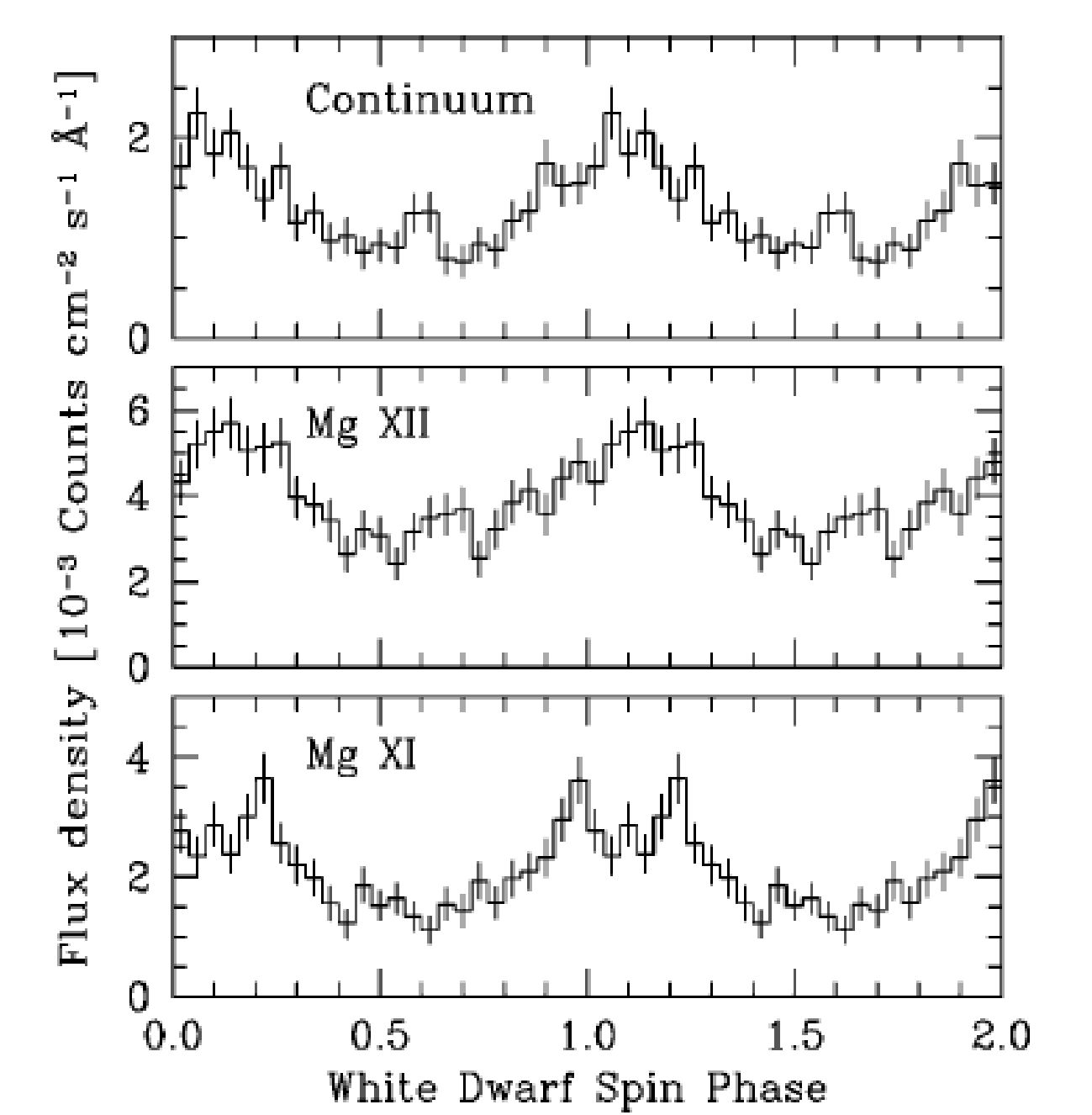


Fig. 6: Line-based light curves folded at a 67 min WD spin period of EX Hya from previous ACIS/HETG observations (from Hoogerwerf et al. 2006). The bin size represent 0.04 spin period, error bars represent 1σ errors.

References

- Hoogerwerf R., Brickhouse N. S. & Mauche C. W., 2004, ApJ, 610, 411
- Beuermann K. and Reinsch K., 2008, A&A, 480, 199
- Hellier C. and Sproats L.N., 1992, IBVS, 3724, 1
- Mauche C. W., Liedahl D. A. and Fournier K. B., 2003, ApJ, 588, 101
- Hoogerwerf R., Brickhouse N. S. & Mauche C. W., 2006, ApJ, 643, 45