PROCEEDINGS OF SCIENCE

Scanning the Egress of Vela X-1

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We have observed the high mass X-ray binary Vela X-1 shortly after its egress from eclipse on two different occasions: in May 2006 with *XMM-Newton* and in December 2007 with *RossiXTE*. Both data sets show a similar behaviour for the earliest observed phases, dominated by the influence of the extended atmosphere of the supergiant, but then marked differences. The *XMM-Newton* observation was characterized by a strong flare and related dramatic changes in the spectral features, while the *RossiXTE* observations present a much smoother picture

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1. Introduction

Vela X-1 (4U 0900-40) is an eclipsing high mass X-ray binary (HMXB) consisting of the B0.5Ib super giant HD77581 and a neutron star with an orbital period of 8.964 days [1] at a distance of $\sim$2.0 kpc [2]. The optical companion has a mass of $\sim 23\,M_\odot$ and a radius of$\sim 30\,R_\odot$ [1]. Due to the small separation of the binary system with an orbital radius of just $1.7R_\star$, the massive $1.9\,M_\odot$ neutron star [3, 4] is deeply embedded in the dense stellar wind of the optical companion ($\dot{M} = 4 \times 10^{-6} M_\odot yr^{-1}$ [5]). X-ray lines show that this wind is inhomogeneous with many dense clumps [6] being embedded in a much thinner, highly ionized component [7].

Significant random variations in the X-ray pulsar's luminosity – including large flares and sudden drops in luminosity [8, 9, 10] – indicate rather inhomogenous, clumpy accretion, consistent with this picture.

In order to study the B0Ia supergiant's extended atmosphere and strongly ionized stellar wind we have observed the early part of the orbit on two different occasions with *XMM-Newton* and *RossiXTE* (Figure 1).

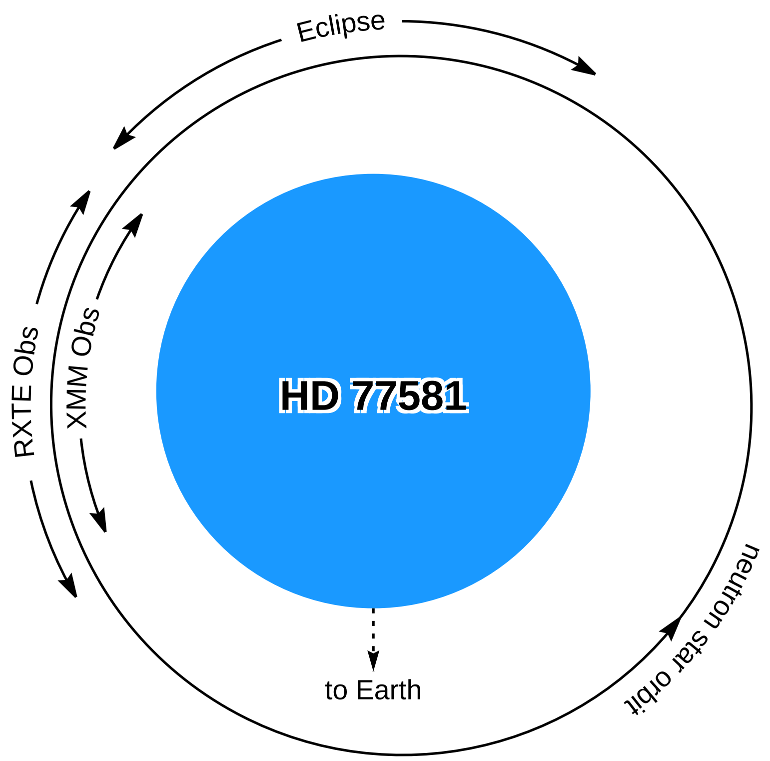

Figure 1: Sketch of the Vela X-1 system indicating the orbital phases covered by the *XMM-Newton* and *RossiXTE* observations discussed here.

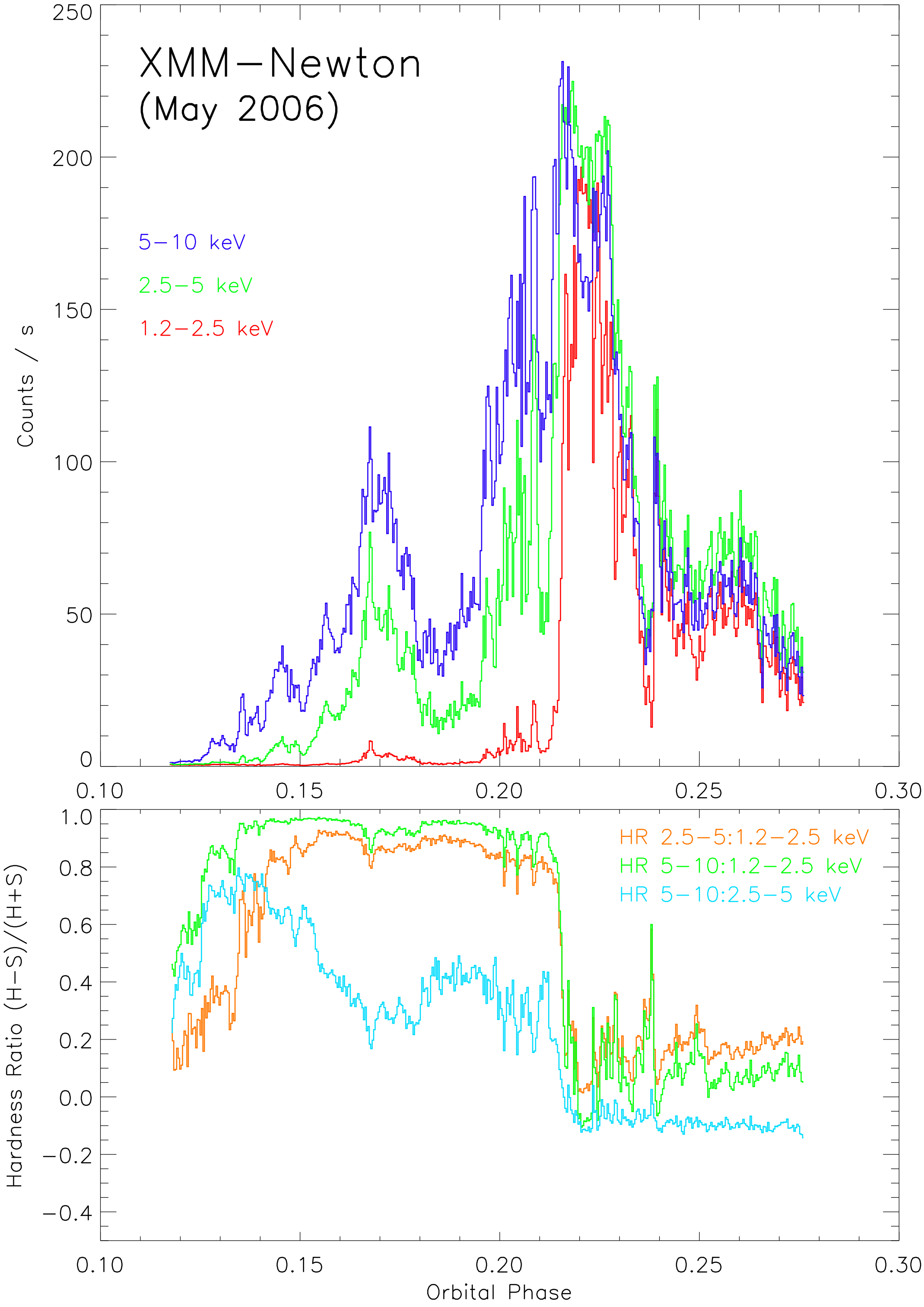

Figure 2: Fluxes in three energy bands and hardness ratios from our *XMM-Newton* observation in May 2006. At the beginning a hardening is visible related to a slowly diminishing soft excess. During the strong flare after phase 0.2 the spectral hardness changes drastically.

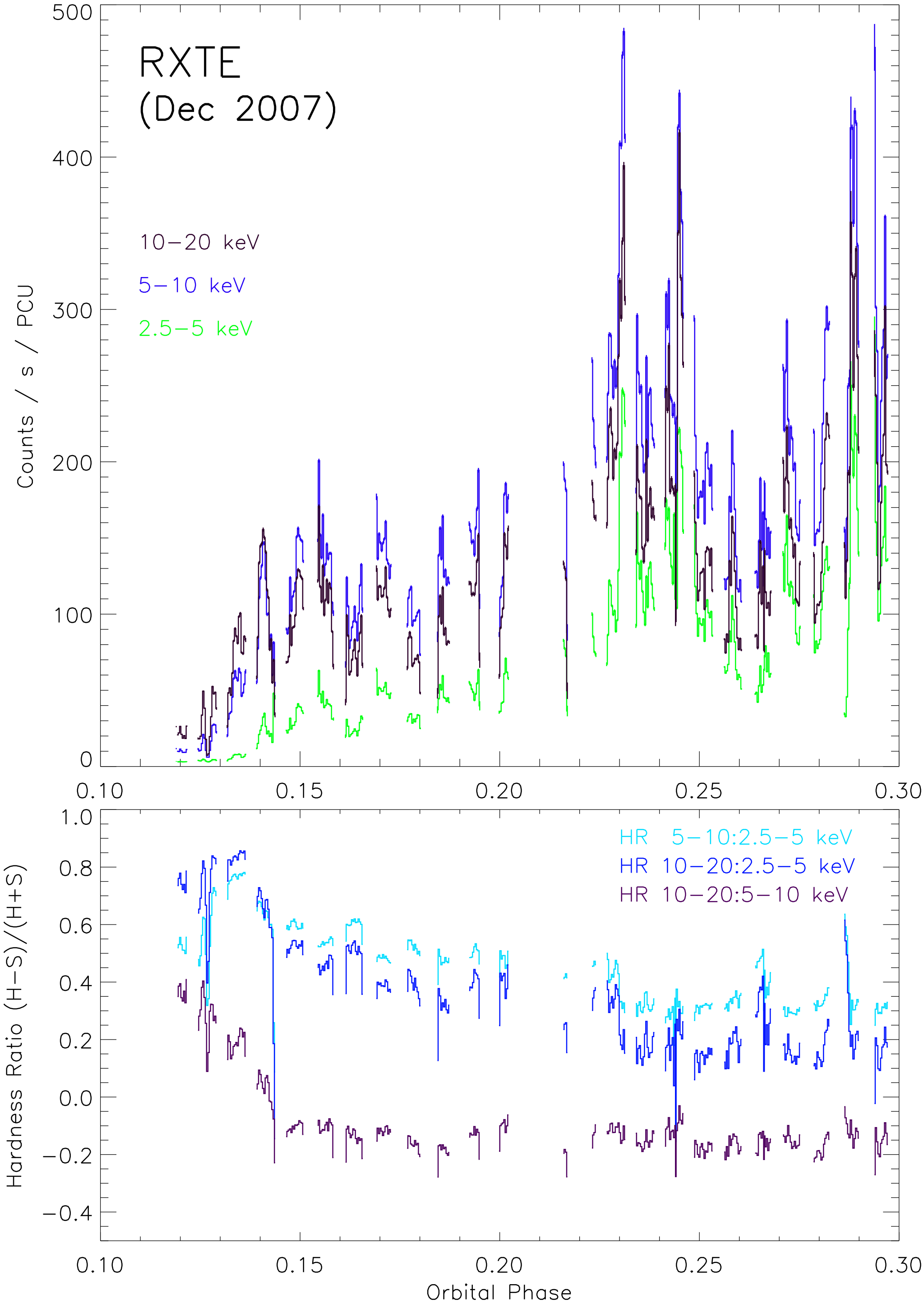

Figure 3: Fluxes in three energy bands and hardness ratios from our *RossiXTE* observation in Dec 2007. Due to observational constraints the coverage is not continuous and variable in its density. Some flaring activity is also evident in this observation. A soft excess is present before phase 0.14, after that the spectral hardness evolves relatively smoothly towards a softer spectrum.

2. Observations

The *XMM-Newton* observation took place during orbital phase 0.12–0.27 for a total of 123 ks of continuous coverage. The observation was marked by a very dynamic source. During the first half it presented a moderate count rate with smooth variability and several distinct peaks. After phase 0.2 the source flared to such an extent that it saturated the maximum possible telemetry rate of the pn instrument (Figure 2). Going through a narrow minimum at orbital phase ∼0.24 the source returned to roughly its pre-flare level.

With *RossiXTE* a sequence of observations of varying length was scheduled spanning orbital phases 0.05–0.30 for a total of 105 ks. In this preliminary analysis we only used observations with a clearly visible source, covering phases 0.12-0.30 (Figure 3). The source evolution was less dramatic than during the earlier *XMM-Newton* observation, but again some flaring activity is visible after orbital phase ∼0.23.

3. Results

For the whole *XMM-Newton* observation, the spectra above ∼2 keV are well described by an absorbed power law component plus Fe-line emission. In addition, a soft excess was present at lower energies especially for the earlier orbital phases. Before the major flare, several emission line features of Si, Mg and Ne were detected.

Besides the overall countrate, the *XMM-Newton* observations also presented a peculiar and dramatic evolution of the absorption column density N_H. After an initial fall-off it remained roughly constant for ∼half a day and then dropped rapidly by roughly one order of magnitude (see Figure 5).

Also the absolute and relative strength of the Fe-K fluorescence line varied significantly over this observation (see Figure 4). Around orbital phase 0.18, coinciding with a drop in overall flux and a rise in N_H, it increased by a factor ∼3. Between phases 0.21 and 0.22 the relative line intensity dropped sharply to the previous level, at about the same time as the overall flux peaked and N_H dropped to its minimum.

In contrast to these dramatic changes, the *RossiXTE* observations show a much smoother evolution. The spectra are well described in the range 3–20 keV by an absorbed power law with a cutoff towards higher energies plus Fe-line emission. The well known cyclotron line features with a harmonic at ∼25 keV are visible, but not the topic of this work. Again a soft excess is visible in the early phases, though less clearly than with *XMM-Newton*, due to the energy range covered.

Spectral hardness (Figure 3) and N_H (Figure 5) show a much smoother evolution than during the earlier observation, with a small rapid change at orbital phase 0.23, coincident with the onset of flaring.

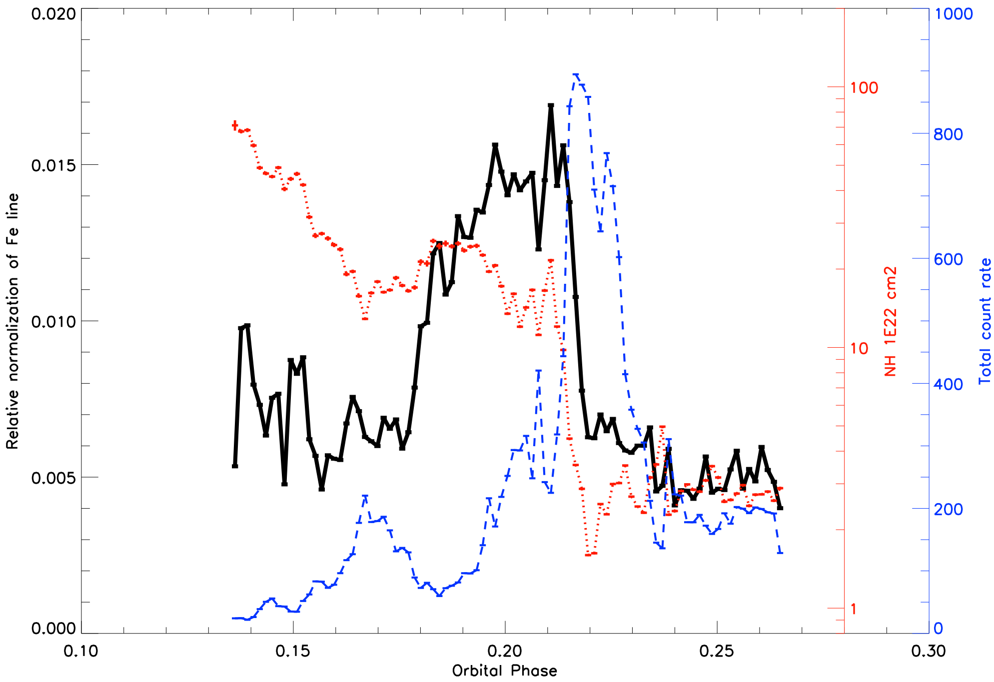

Figure 4: Relative strength of the Fe-K line over orbital phase, based on the *XMM-Newton* observation. For comparison, the evolution of N_H and the best fit normalization are also shown.

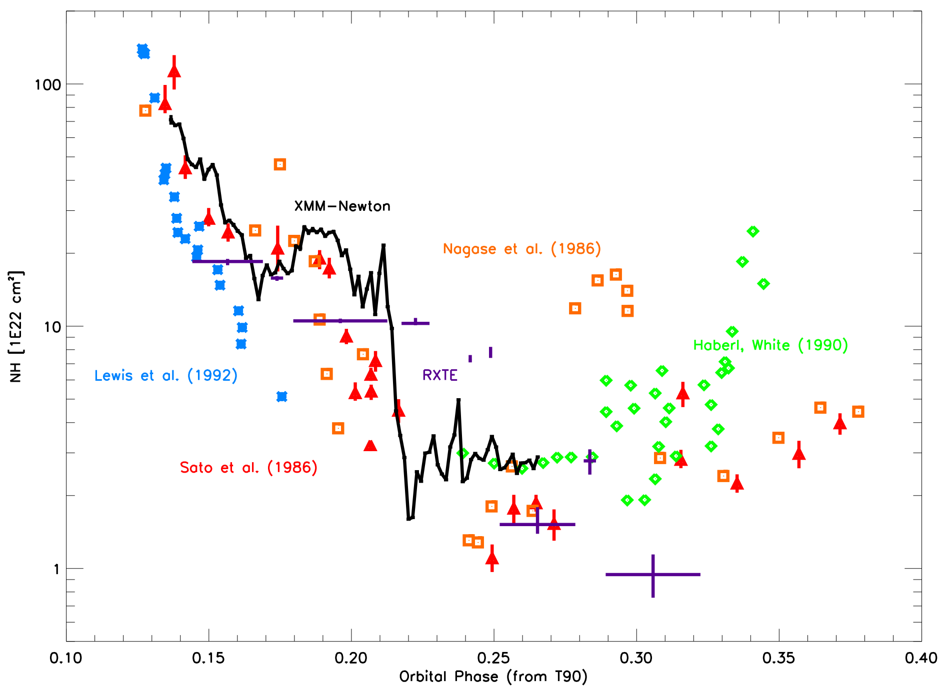

Figure 5: Comparison of historical measurements of N_H with the values obtained from our observations. The historical data have been corrected for differences in zero phase definition as far as possible.

4. Discussion

The comparison of these two detailed observations demonstrates again the well-known large variability in the behaviour of Vela X-1 [9], but also some common features, e.g., the early steep fall in N_{H} and the soft excess.

A comparison with historical measurements (Figure 5) underlines the variability and sometimes rapid N_{H} variations, with a tempting indication of a trend to increased N_{H} values around phase 0.2, which would need confirmation.

The dramatic flare and associated spectral evolution observed with *XMM-Newton* might be understood by the capture of a dense cloud of material which first enshrouds the X-ray source and scatters its light and then gets rapidly accreted fueling the main flare.

Work is ongoing for a more detailed analysis of the spectral evolution in both data sets, preparing the ground for a comparison with the predictions of hydrodynamical simulation models [11].

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