An Ionised Accretion Disc Wind in Hercules X-1

P. Kosec⋆, A. Fabian, C. Pinto, S. Dyda, D. Walton, C. Reynolds

Institute of Astronomy, Cambridge, UK

⋆pk394@cam.ac.uk

Introduction

Hercules X-1 is one of the best studied accreting neutron star X-ray binaries. It is famous for the various time periods observed in the system: a 35-day period of high, low and short-on flux states caused by a precessing warped accretion disc, a 1.7 day orbital period of the binary and a 1.2 sec pulsation period of a neutron star with a $\sim 10^{12}$ G magnetic field. Here we present the discovery of a highly ionised disc wind in its high state X-ray spectrum.

Results

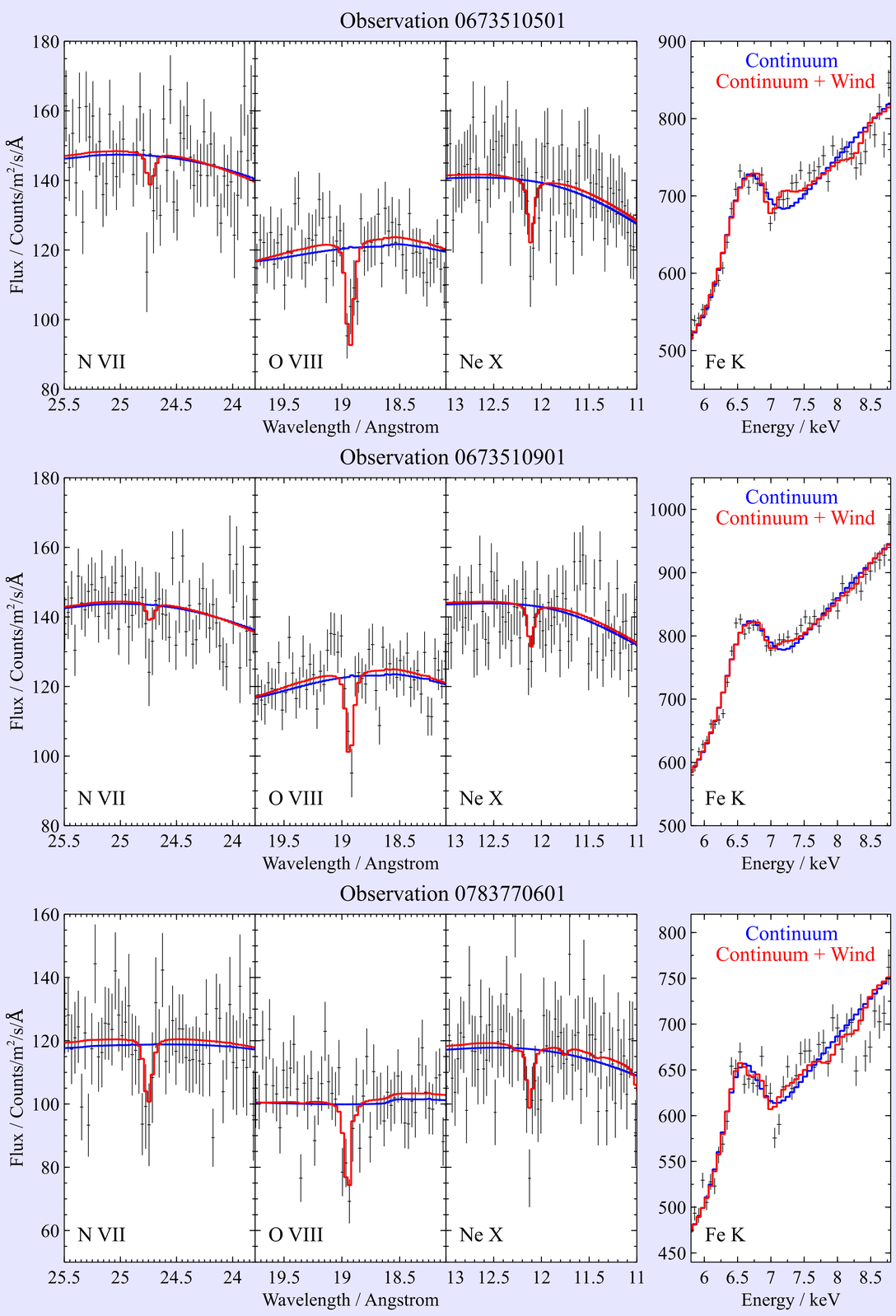

Figure 1: 3 out of 9 high state XMM-Newton observations of Her X-1. The wind is significantly detected in most of these observations. Only narrow energy bands containing the strong absorption lines of N VII, O VIII, Ne X and Fe XXV/XXVI are shown. The left panels show RGS data (stacked for plotting purposes) and the right panels show pn data for each observation.

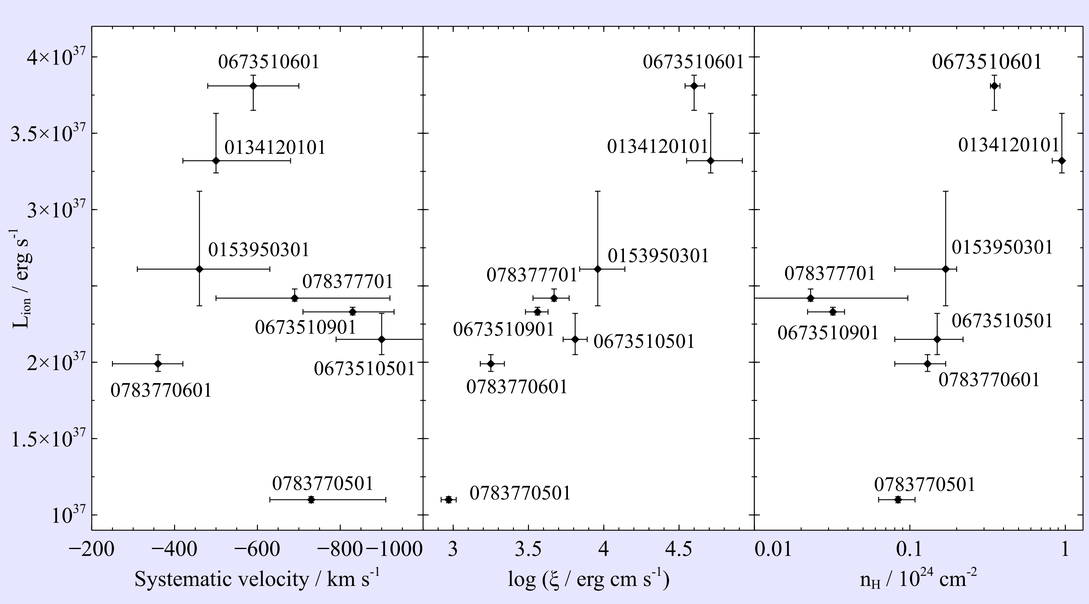

Figure 2: Best-fitting wind parameters for each of the high state XMM-Newton observations versus the unabsorbed ionising luminosity of Her X-1. We do not find any significant correlation between the outflow velocity and the luminosity (left subplot). There is a clear correlation between the wind ionisation parameter and the luminosity (middle subplot), suggesting that the wind observes changes in the ionising continuum. A possible correlation is also observed between the luminosity and the column density of the wind, but with clear outliers.

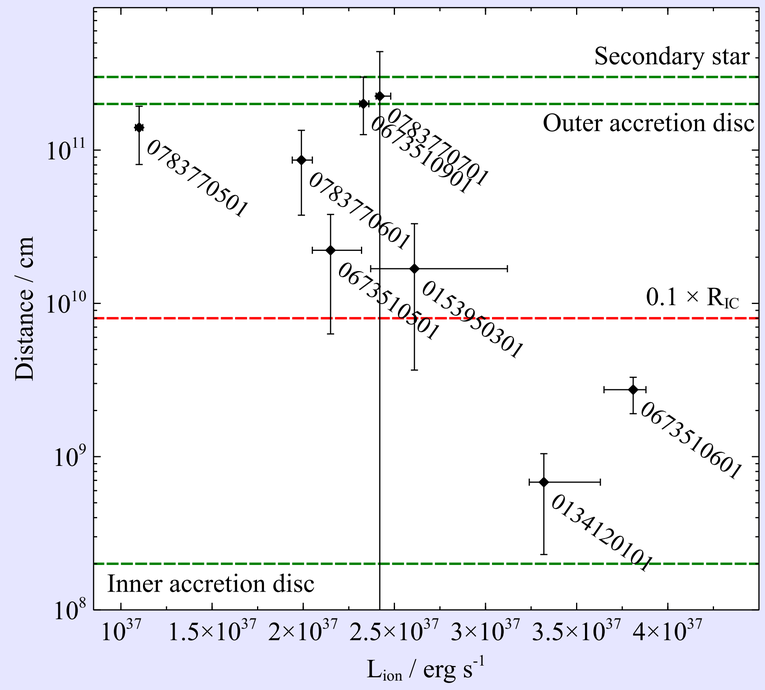

Figure 3: Estimates of the wind absorption distance from the ionising source for each observation where the wind is detected. The distance is estimated from the ionising luminosity of Her X-1, the column density and the ionisation parameter of the wind. Various scales in the system are shown by green dashed lines. Our results show that the wind must be launched from the accretion disc but likely not from its inner edge. The red dashed line shows the approximate minimum launching radius of a Compton-heating driven wind [1], with which most of our distance estimates agree very well.

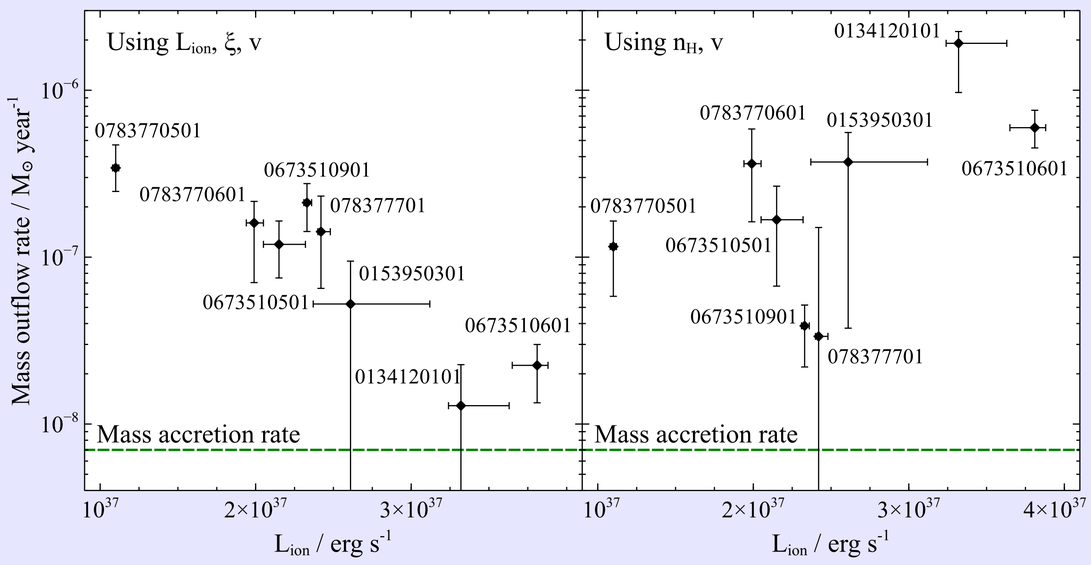

Figure 4: The wind mass outflow rates for each of the XMM-Newton observations. The left subplot contains estimates made using the ionising luminosity of Her X-1, the ionisation parameter and the outflow velocity of the wind. The right subplot shows estimates made using the column density and the outflow velocity of the wind. The green horizontal dashed line shows the measured mass accretion rate [2]. These estimates do not take into account the wind launching solid angle and volume filling factor of the wind. Even if the solid angle is small (~ 0.1) and the wind is clumpy, the wind mass outflow rates can still easily be of the same order as the mass accretion onto the neutron star.

Conclusions

- We detect a highly ionised blueshifted absorber in the high state of Her X-1. The detection is statistically significant in most of the *XMM-Newton* observations. The wind has a projected outflow velocity of 300 to 1000 km/s, varying between different observations, and the ionisation parameter $\log \xi$ is in the range of 3.0 to 5.0.
- We find a clear correlation between the luminosity of Her X-1 and the ionisation parameter of the wind, suggesting that the material in the outflow observes a similar X-ray flux as we do. We do not observe such clear correlations between the luminosity and the outflow velocity or the column density of gas.
- The wind parameters suggest that the wind is launched from the accretion disc of the neutron star. The X-ray outflow could be the progenitor of the blueshifted UV absorption [3], but the latter likely only occurs at larger, circumbinary distances from the system.
- We find that the mass outflow rate in the wind can easily be of the same order as the mass accretion onto Her X-1. We conclude that the wind is driven either by Compton heating of the outer accretion disc or by magnetic fields.
- Our analysis of elemental abundances in the outflow finds a strong over-abundance of iron compared to oxygen. We also confirm the previous results which found an over-abundance of nitrogen and neon compared to oxygen.
- None of the low state or short-on *XMM-Newton* observations of Her X-1 are of high enough quality to detect a similarly ionised wind. We stack all the available low state data but do not find significant evidence of blueshifted absorption.

References

[1] - Begelman M. C., McKee C. F., Shields G. A., 1983, ApJ, 271, 70; [2] - Boroson B. S., Vrtilek S. D., Raymond J. C., Still M., 2007, ApJ, 667, 1087; [3] - Boroson B., Kallman T., Vrtilek S. D., 2001, ApJ, 562, 925;