X-ray spectral evolution during the 2006 Outburst of RS Oph

Kim Page, Julian Osborne, Andy Beardmore, Mike Goad, Graham Wynn (U. Leicester),
Mike Bode (LJMU), Tim O'Brien (Jodrell Bank)

In February 2006, RS Oph entered its latest outburst. X-ray observations with Swift began rapidly, only 3.17 days later, and continued for more than a year, with the most recent dataset being obtained on 11th March 2007. During this time, the X-ray spectrum was seen to evolve from relatively hard, optically thin emission (shock systems caused by the ejecta interacting with the red giant wind; RS Oph was also detected in hard X-rays, by the Swift Burst Alert Telescope, during the first 3 days of the actual outburst. See [1] for more details), to a very much brighter super-soft source (SSS) state ~29 days after the outburst. Around day 58, the X-ray emission began to decay, with the SSS component no longer evident from around day 90.

Here we report preliminary results on the X-ray spectral evolution during the SSS emission.

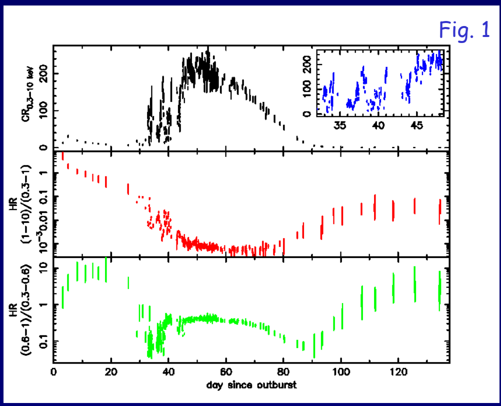
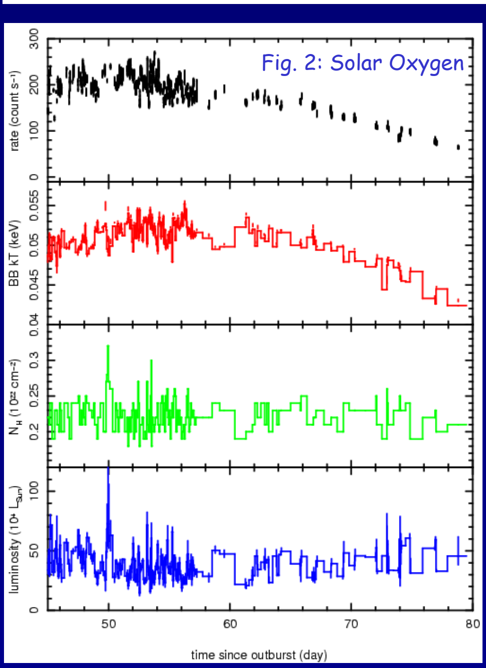


Fig. 1. Light-curve and two hardness ratios (over the full band-pass and for the soft component alone), showing the significant spectral evolution prior to, and during, the SSS phase. The top right panel (plotted in blue) zooms in on the most variable part of the emission.

The model fitted to the SSS phase spectra consisted of two optically thin components (parameterising emission above ~1 keV), a blackbody component (for soft emission), four lines (H- and He-like oxygen and nitrogen), a H-like oxygen absorption edge and two absorption systems – the interstellar column density set at 2.4×10^{21} cm^{-2} [2], together with a variable column due to the unshocked red giant wind [1]. Oxygen abundance has been taken first as Solar, and then reduced, in the circumstellar medium (~30% Solar until day 54, then at 0%, based on grating observations discussed in [3]).



Figs. 2&3.

Data from days 45-80 after outburst (peak and decline of the SSS state): light-curve, blackbody temperature, wind column density and associated luminosity of the soft component. Solar oxygen abundance is shown in Figure 2 (left); under-abundant oxygen in Figure 3 (right).

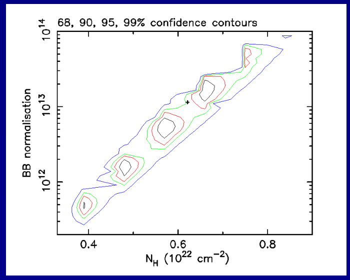
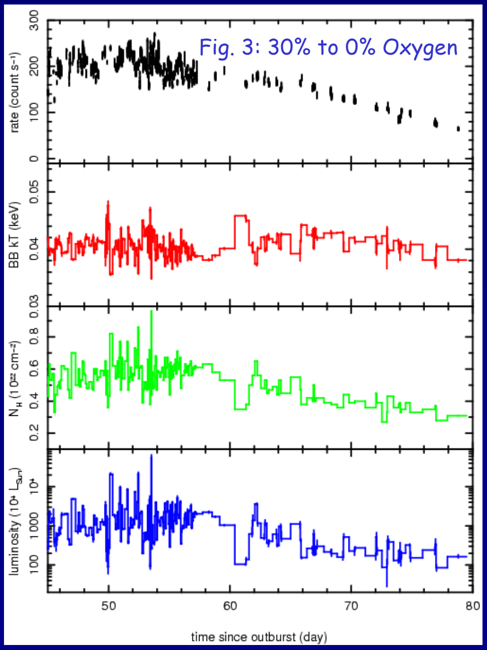


Fig. 4. N_H and normalisation (hence luminosity) are strongly correlated.



The trends seen are apparently very much dependent on the oxygen abundance. If the abundance is kept at Solar (Fig. 2), then the decrease in count rate after ~day 58 appears to be due to the cooling of the blackbody; the luminosity stays constant, meaning the effective radius would be increasing. If, however, oxygen is set to be under-abundant (Fig. 3), then the blackbody temperature remains close to constant (~40 eV), while the luminosity (and, hence, effective radius) decreases. Theoretically, one might expect the blackbody temperature to increase until the end of nuclear burning and then start to fall, at which time the luminosity would also decrease [4,5]. Fig. 2 (Solar oxygen) is consistent with this prediction during the nuclear burning phase, though the luminosity doesn't seem to decrease at later times. Note that the calculated luminosities for the reduced oxygen abundance fits are very large, possibly unphysically so. However, there is a correlation between the luminosity and N_H in the models applied (see Fig. 4), so more constrained fits are clearly required.

[1] Bode, M.F. et al., 2006, ApJ, 652, 629 [2] Hjellming, R.M. et al., 1986, ApJ, 305, L71 [3] Ness, J.-U. et al., 2007, ApJ, in press (arXiv:0705.1206) [4] Starrfield et al., 1991, in Extreme UV Astronomy, p168 [5] Balman et al., 1998, ApJ, 499, 395