Where is the X-ray Emission Coming from in the RT Cru Symbiotic System?

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Introduction: Symbiotics

Symbiotic systems belong to an important group of wind interacting binaries in which a white dwarf (WD) accretes from the wind of a red giant companion (e.g., Kenyon 1986, Karovska et al. 2007, de Val-Borro et al. 2009). They are likely progenitors of at least a fraction of asymmetric Planetary Nebulae (PN), and have been invoked as potential progenitors of a fraction of Supernovae type Ia (SNIa, a key cosmological distance indicator).

Understanding the characteristics of the accretion onto the white dwarf in symbiotic binaries, and of the characteristics of the accretion disk and the surrounding environment, are important first steps for determining the precursor conditions for formation of asymmetric PN, and the potential of a symbiotic channel toward a single degenerate origin for at least a fraction of SNIa.

Given the current debate regarding the possibility of a single- or double-degenerate origin of these important cosmic scale indicators (e.g., Meida et al. 2014), of a particular interest is the understanding of the accretion environment and dynamics, especially around accreting high mass white dwarfs.

The RT Cru Symbiotic System

The RT Cru system does contain a high-mass white dwarf (Mwd>1.3Ms) accreting from the wind of a mass-losing M5 III giant, likely via Roche Lobe-like overflow (RLOF-like, focused wind accretion, *vis* de Val-Borro , Karovska, & Sasselov 2009).

The white dwarf is surrounded by an accretion disk fed by the wind of the red giant (Luna & Sokoloski 2007). It was the first discovered of a new sub-class of symbiotic binaries showing a significant hard X-ray emission, when it was detected by INTEGRAL (Bird et al., 2007) and Swift/BAT (Kennea et al., 2009).

Currently this new sub-class of symbiotics with hard X-ray emission contains only a few members. Of these, RT Cru is the brightest and most variable in both soft and hard X-ray.

The hard X-ray emission of RT Cru has been studied in detail, with Swift, and Chandra HETGS +ACIS-S. The hard X-ray spectrum has been modeled as e.g., partially-covered cooling flow or as a multi-component thermal bremsstrahlung (e.g., Luna & Sokoloski 2007, Kennea et al., 2009).

Observations of the Soft Emission

The observations of RT Cru in the high-energy regime have been limited to high energies (>>1keV) since the effective areas of INTEGRAL, Swift/XRT and Chandra/ HETGS +ACIS-S all drop precipitously below ~1 keV (Luna & Sokoloski 2007, Kennea at al. 2009).

Even so, a definite low-energy signal is visible (in Swift/XRT spectra, in comparison between Swift and HRC-I, in soft flaring seen as early as HETG, e.g., Fig 2-Fig.4). The flares are soft; they show a definite softening of the spectrum, with most of the observed total intensity variations (over timescales of hours and days).

The same effect is also seen during the recent simultaneous observations of RT Cru made with Swift/XRT and Chandra/HRC-I carried out as part of the Chandra PSF calibration program (see Fig. 2). Chandra/HRC-I has a relatively large response at low energies, and is thus sensitive to the soft component. Chandra and Swift light curves are tightly correlated (Fig. 2). Differences between them can be attributed to the higher soft X-ray sensitivity of the HRC-I, although the HRC-I does not have the required spectral resolution for detailed spectral analysis.

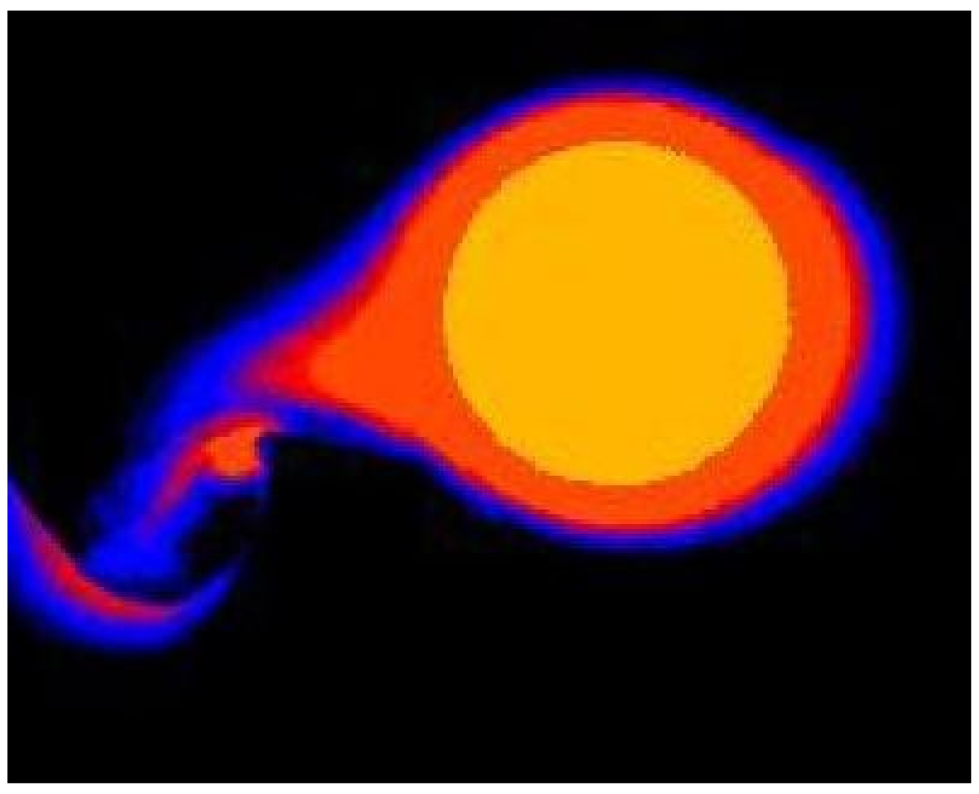

Fig. 1 - Accretion model showing RLOF-like accretion onto a WD due to gravitationally focused wind for a wind accelerating region in the extended dust envelope of the red giant (de Val-Borro et al., 2009).

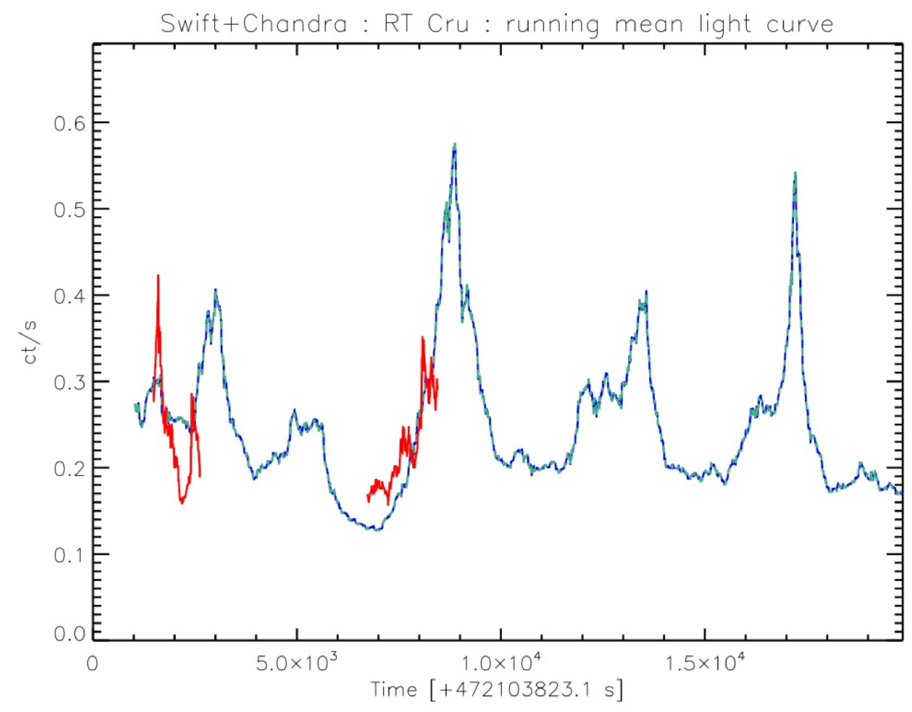

Fig. 2 - Chandra/HRC-I (blue) and Swift/XRT (red) running mean light curves of RT Cru observed in Dec. 2012. The rate is computed for a moving window with a fixed number of photons. The local uncertainty is 3% for Chandra and 10% for Swift. Swift and Chandra rates are generally correlated, but show some differences in detail. Notice the occasional large flare like events, roughly 4 ksec apart. No periodicity is evident in the data.

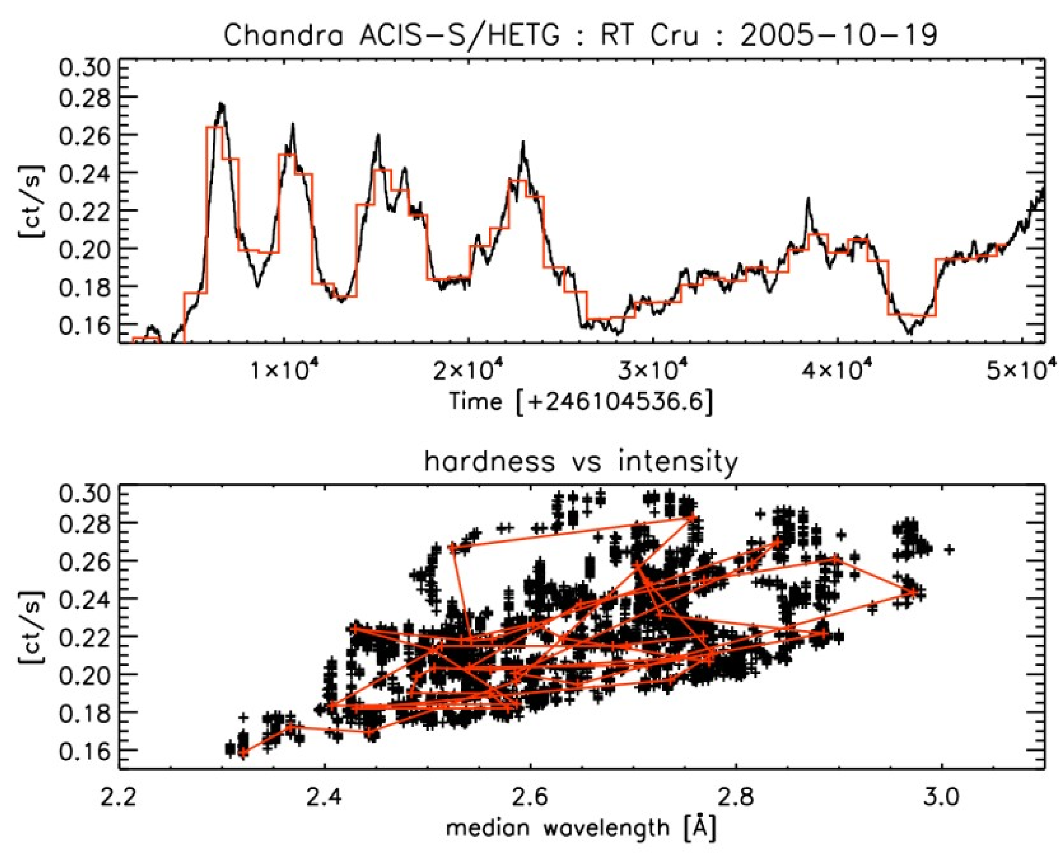

Fig. 3 – A similar behavior as in Fig. 2 is seen in an older Chandra ACIS-S/HETG observation from Oct 2005 (upper panel). The running mean light curve (black) is shown, along with statistically independent data points (red histogram). The spectral hardness increases as intensity decreases (bottom panel; independent points are shown connected by red line segments). Whether this is due to changes in the spectral model, or because of variations in the absorption column is not known. In either case, a significant soft component is present.

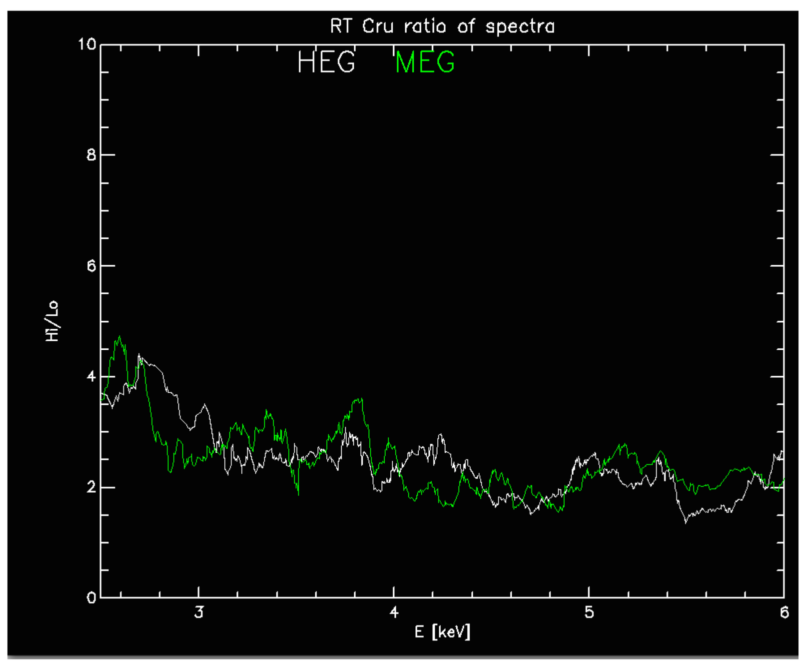

Fig. 4 - The ratio of the soft/high-count-rate to hard/low-count-rate spectra for HEG (green) and MEG (white). If the change in spectra are due to changes in absorption column, we should see an exponential increase in the ratio towards low energies. If the change is due to emission mechanism, the ratio should increase linearly as energy decreases. These two scenarios cannot be distinguished based on available data.
The HRC-S/LETG, with significantly better sensitivity at lower energies, will be able to determine the trend in this ratio.

Results and Conclusions

- Strong evidence for a soft component to which Chandra is sensitive
- Highly variable emission, showing intermittent flare-like events separated by ~4 ksec
- Spectrum softens during flares
- Current data-sets are insufficient to distinguish between competing spectral models:
  - are the soft flares due to clumpy absorbing material moving in and out of LOS?
  - are the flares due to fluctuations in accretion boundary layer due to variation of wind mass deposition from the RLOF-like flow?

Determining origin of the soft emission is a crucial piece of the puzzle to understand the accretion characteristics in the environment around the accreting white dwarfs in this new class of symbiotic systems. We are on the doorstep of separating competing models of the nature of the soft source in RT Cru.

The upcoming Chandra/HRC-S/LETG observations should pin down the origin of the soft emission and its variability.

References

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