Circinus X-1: The return of the bursts

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We report the detection of 15 X-ray bursts with RXTE and Swift observations of the peculiar X-ray binary Circinus X-1 during May 2010. These are the first X-ray bursts observed from the source after the initial discovery by Tennant and collaborators, twenty-five years ago. By studying their spectral evolution, we firmly identify nine of the bursts as type I (thermonuclear) X-ray bursts. We obtain an arcsecond location of the bursts that confirms the identification of Cir X-1 as a type I X-ray burst source, and therefore as a low magnetic field accreting neutron star. We find a change in burst properties during May 2010, and discuss its possible origin. Finally, we explore a scenario to explain why Cir X-1 shows thermonuclear bursts now but not in the past, which it was extensively observed and accreting at a similar rate, that invokes crust cooling during the past two decades of very low activity.

DISCUSSION:

The early bursts were short, low-luminosity events with recurrence times as short as 20 minutes and no evidence for cooling. Later bursts were longer and brighter, with cooling times much longer than could clearly identify them as thermonuclear bursts. The general trend in persistent flux was downward (Figure 2). The abundance of variability in burst properties may be associated to the transition from stable thermonuclear burning of Helium at high accretion rates to unstable burning at lower rates (Bildsten 1998).

This transition region permits some interesting behavior, as outlined by Meyer et al. (2006). In particular, these authors showed that one should expect mainly marginally stable quasi-periodic burning (mHz QPOs), then low-luminosity short recurrence time bursts, before the eventual establishment of brighter bursts with longer recurrence times. If this is the case then Cir X-1 would be a valuable probe of this transition, since very short recurrence time bursts at high accretion rates are extremely rare (Keek et al. 2010).

From 1985 to 2003 the source was observed almost exclusively at persistent luminosities much higher than those measured during May 2010 (Parkinson et al. 2003, Figure 1). However, between April 2003 and April 2010, Cir X-1 was observed by the Swift XRT probe (Evans et al. 2008), which detected several X-ray bursts in a range of 1.2–1.8 keV; we argue that they are most likely of thermonuclear nature (Linares et al. 2010).

We asked for Swift ToO observations of the source to confirm the location of the bursts. We report the detection of three X-ray bursts with Swift-XRT, and we find evidence of cooling in two bursts. We obtain follow-up UVOT (Swift) enhanced XRT position (Evans et al. 2009): RA = 15° 20′ 40.84″, Dec = −57° 10′ 00.9″ (2000.0). An arcsec resolution UVOT light curve is consistent with the Chandra position given by Iaria et al. (2008). We therefore conclude that Cir X-1 is the origin of the Swift bursts and, in all likelihood, the ones detected by RXTE.

REFERENCES:


INTRODUCTION:

Discovered during the early years of X-ray astronomy (Mar{on et al. 1971) and frequently observed ever since, the peculiar X-ray binary Cir X-1 was initially classified as a black hole candidate (BHC), due to spectral and variability similarities to Cyg X-1 (Toor 1977). In 1984–1985, 11 X-ray bursts were discovered in EXOSAT observations of Cir X-1 (Tennant et al. 1986a,b). Three of these could be identified as type I X-ray bursts based on their cooling tails. The discovery of type I X-ray bursts led to the conclusion that the compact object in Cir X-1 is a NS (Tennant et al. 1986b). Since then many X-ray missions have observed Cir X-1 but no X-ray bursts were detected (see, e.g., Galloway et al. 2008, for a search of 2.7 Msec of Cir X-1 data from RXTE).

RESULTS:

A total of 15 bursts were recorded during May 15–30, 2010. Detailed inspection of their properties reveals two clearly distinct flavors: the ‘early bursts’ have long rise times (7.3–10 s), moderate energy output (total energy of (1.3–3.7)×10^38 erg), and show approximately symmetric profiles. After May 20, bursts feature shorter rise times (1.8–5.3 s), are more energetic (1.3–3.1)×10^39 erg and present prototypical type I X-ray burst (FRED-like) light curves (Figure 3). The peak luminosities of the early bursts were systematically lower than those of the bursts that followed, and the persistent pre-burst luminosities were higher on average in the early bursts (Figure 2). Besides the well-mentioned FRED like profile, bursts after May 20 all show clear cooling trends along their decays, and we therefore classify them unequivocally as type I (thermonuclear) X-ray bursts. The early bursts showed little or no signs of cooling along the tail, with black body temperature approximately constant in the range 1.2–1.8 keV; we argue that they are most likely of thermonuclear nature (Linares et al. 2010).

We asked for Swift ToO observations of the source to confirm the location of the bursts. We report the detection of three X-ray bursts with Swift-XRT, and we find evidence of cooling in two bursts. We obtain follow-up UVOT (Swift) enhanced XRT position (Evans et al. 2009): RA = 15° 20′ 40.84″, Dec = −57° 10′ 00.9″ (2000.0). An arcsec resolution UVOT light curve is consistent with the Chandra position given by Iaria et al. (2008). We therefore conclude that Cir X-1 is the origin of the Swift bursts and, in all likelihood, the ones detected by RXTE.