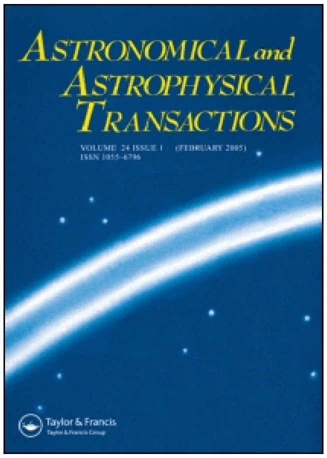

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

X-ray emission properties from Circinus X-1

V. V. Fidelis [a]
[a] Scientific Research Institute, Crimean Astrophysical Observatory, Nauchny, Crimea, Ukraine

Online Publication Date: 01 August 2007
To cite this Article: Fidelis, V. V. (2007) 'X-ray emission properties from Circinus X-1', Astronomical & Astrophysical Transactions, 26:4, 235 - 239
To link to this article: DOI: 10.1080/10556790601156709
URL: http://dx.doi.org/10.1080/10556790601156709

Astronomical and Astrophysical Transactions
Vol. 26, Nos. 4–5, August–October 2007, 235–239

X-ray emission properties from Circinus X-1

V. V. FIDELIS*

Scientific Research Institute, Crimean Astrophysical Observatory,
Nauchny, Crimea 98409, Ukraine

(Received 10 November 2006)

The X-ray activity of Circinus X-1, a periodically flaring source, was studied using observational data from the all-sky monitor onboard the Rossi X-ray Timing Explorer orbital observatory in the 2–12 keV energy band. The cross-correlation analysis of the 1 day averaged data set obtained in 2001 has confirmed the fundamental 16.6 day orbital period. The variability pattern of source emission in September–November 2005 has a complicated structure that may be explained by X-ray emission pressure on the accretion disc and periodically ejected matter. The spectral analysis of X-ray emission has revealed the source behaviour in high- and low-activity states that may be caused by differential absorption of emission by the dynamically changed environment in a close binary system.

Keywords: X-ray binaries; Microquasars; Observations; Circinus X-1

1. Introduction

X-ray binary sources are powered by matter accreted in conditions of strong gravitation in close binary systems. When particles from the accretion disc that fills the Roche lobes fall on the neutron star or black-hole (BH) solar mass, they have an energy of about $0.1\,mc^2$ at a velocity of up to $0.3c$. The emission spectra in this case may reach the hard-X-ray region (77 keV).

A small fraction of these sources, which emit at radio frequencies, contained a selected class of microquasars, which ejected collimated plasma clouds. In the microquasar population the prototypes are the galactic X-ray binaries GRS 1915 + 105 and GRO J1655-40 [1, 2]. Both objects contain BHs of 14 solar masses and 1 solar mass, respectively. They are relativistic synchrotron radio sources; the ejection velocities from these objects may be close to the velocity of light. Jets in these transient sources are ejected in some periods of source activity; the lifetime of radio jets is from a few days to a few weeks. In active states the X-ray emission is essentially higher. In the inner parts around the BH in these objects, relativistic particles are accelerated and collimated; at the moment of relativistic rejection, infrared synchrotron emission is seen. It is worth mentioning that GRS 1915 + 105 exhibited variability properties that have never been seen in galactic black-hole binaries (BHBs) before this discovery. Thus, in the burst period the flux from GRS 1915 + 105 on May 20 1996 (modified Julian date

*Email: fidelis@crao.crimea.ua

Astronomical and Astrophysical Transactions
ISSN 1055-6796 print/ISSN 1476-3540 online © 2007 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/10556790601156709

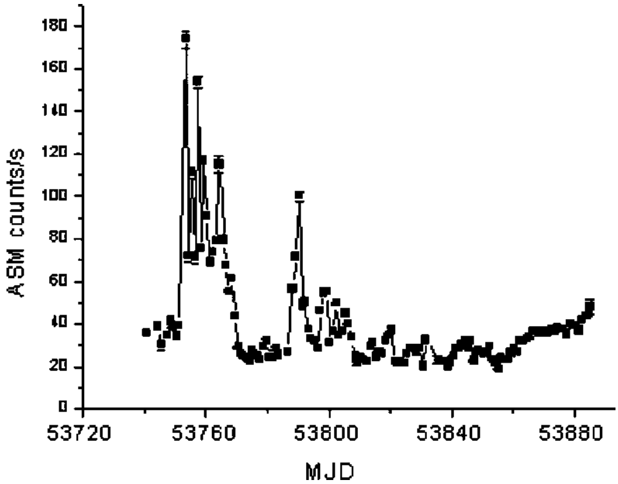

Figure 1. ASM RXTE light curve in the 2–12 keV energy band showing the quasiperiodic flares of GRS 1915 + 105 on 1 January–31 May 2006.

(MJD) 50 223.5) reached 2.5 Crab [3]. For comparison with the studied microquasar Circinus X-1 we show in figure 1 the light curve for GRS 1915 + 105, which characterizes the basic properties of this object.

Cir X-1 is a periodically flaring source embedded in a synchrotron structure with associated radio jets [4]. The electrons emitting synchrotron radiation are supposedly accelerated at the fronts of shock waves, produced under supercritical accretion on the compact component in the periastron passage. The compact component in this system is a neutron star of about 1.4 solar masses; the optical component has a mass approximately equal to a few solar masses [5]. The distance to Cir X-1 is 8–10 kpc.

There are striking similarities in the behaviours of the galactic BHBs and active galactic nuclei (AGNs). Both systems exhibit rapid intensity fluctuations and the fundamental physics may be common to both systems, despite the difference of many orders of magnitude in the system scales and masses. So, by investigating BHBs, we may gain insight into the high-energy physics of the AGN environment.

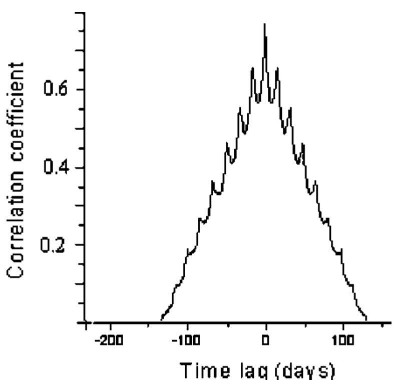

Figure 2. X-ray periodicity properties of Cir X-1 as a function of the time delay during the period from 13 February to 2 October 2001 (MJD 51954–52185).

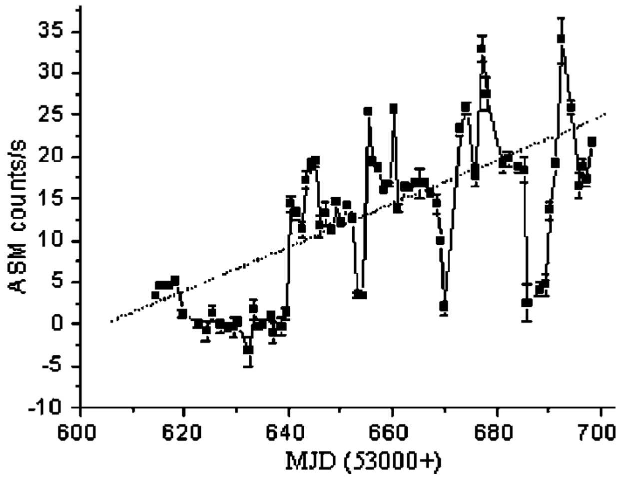

Figure 3. ASM count rates in the 2–12 keV band for Cir X-1 in the period from 1 September to 27 November 2005. The dashed line is the average squared value. There is a tendency to increasing activity in the observing period after the prolonged dip.

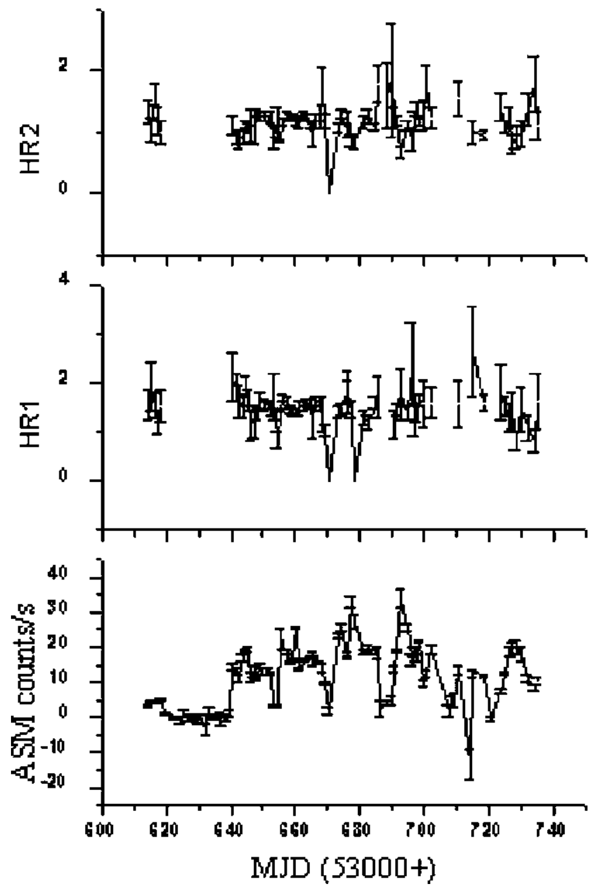

Figure 4. ASM count rates and the hardness ratios HR1 and HR2 seen in Cir X-1.

2. Observations and data in use

In the present research, we used X-ray observations of Cir X-1 by the all-sky monitor (ASM) onboard the Rossi X-ray Timing Explorer (RXTE) observatory in the 2–12 keV energy band [3]. The cross-correlation analysis of the 1 day averaged uninterrupted data set, obtained at the epoch on 13 February–2 October 2001, for a duration of 132 days, has shown a fundamental 16.6 day period (figure 2).

So, this object may not have stable long-term periodicity, although longer, evenly sampled monitoring is required. The light curve from the object (figure 3) demonstrates four groups of measurements, which show a two-peak structure in each burst. The presence of large dips between these peaks may be attributed to the photosphere expansion under the pressure of Eddington emission. There is a tendency to an increasing luminosity maximum with a corresponding permanency of its minimum. As a whole the light curve patterns are different from those for GRS 1915 + 105. The presence of a continuous quiescent period at the beginning of the observations emphasizes the transient character of the source. The maximum X-ray flux from this object in the 2–12 keV range in the burst periods approached 0.5 Crab.

To understand the X-ray spectral properties of Cir X-1 we give the light curve and hardness ratios obtained from the RXTE archives in figure 4. The whole ASM energy range may be divided into three bands: energy band A (1.5–3 keV), energy band B (3–5 keV) and energy

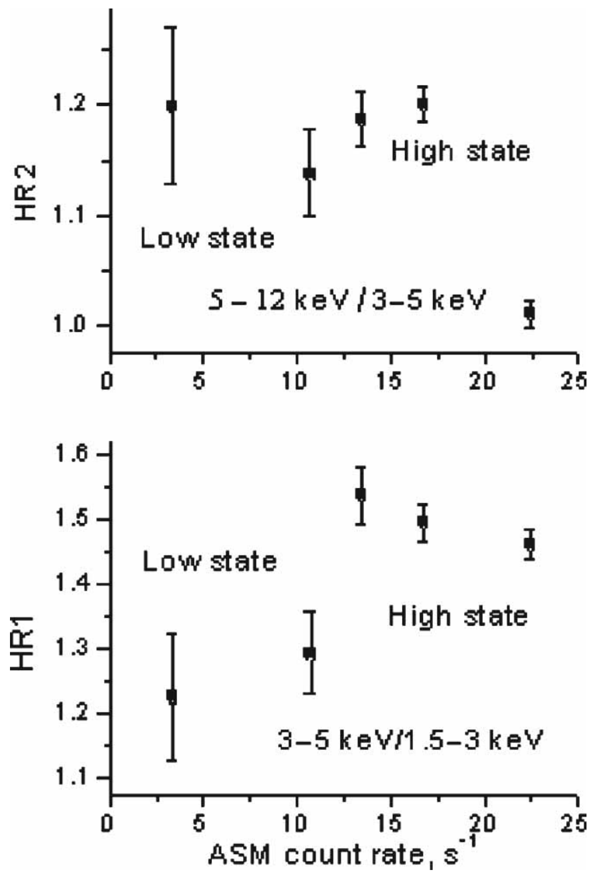

Figure 5. Hardness ratios HR1 and HR2 of Cir X-1 in the low-activity state (quiescent) and high-activity state (with flares dominating).

band C (5–12 keV). The first hardness ratio (HR1) is defined as the ratio of the count rate in energy band B to that in energy band A; the second hardness ratio (HR2) is defined as the ratio of the count rate in energy band C to that in energy band B. Both hardness ratios of X-ray emission from this object are negatively correlated with the intensity in all ASM bands. The explanation for this may be instability of the accretion disc in the low-mass binary system or modulation of the accretion rate on the neutron star by X-ray emission.

The increase in the absorption of emission in the low-intensity phase causes increases in the hardness ratios when the soft component of X-ray emission will be absorbed more strongly. Before each burst the X-ray flux was reduced and the X-ray spectrum became harder. Soon high isolated X-ray bursts appeared; this is the time when jet ejection occurred and furthemore we saw oscillations. The X-ray behaviour may be interpreted as the rapid destruction and subsequent restoration of the inner accretion disc. The jet ejection takes place at the moment that the hardness ratios increase.

The behaviours of the two hardness ratios are different (figure 5). While in the relatively stable state, no pronounced spectral changes are seen; in the high-activity state, there is a tendency for HR1 to decrease with increasing flux and for HR2 to increase with increasing flux.

3. Conclusion

The behaviour of X-ray emission in Cir X-1 in bursts may be determined by synchrotron and inverse Compton radiation from the domain of relativistic jets and also destruction of the inner parts of the accretion disc. So the results of this work show that the spectral variations in X-ray emission from Cir X-1 are in accordance with the scenarios of emission pressure, the appearance of instability of the accretion disc and also differential absorption of emission depending on its energy.

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