# The Large Observatory For X-ray Timing (LOFT)

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We present the contribution of Polish researchers to the science which can be done using the planned X-ray satellite - *LOFT*. In this article we address two topics: time-resolved studies of dipping in X-ray Binaries and simulations of the radiation-driven disc instability, which can be applied for microquasar IGR J17091-3264. A short description of the mission is given in the introduction.

## 1 Introduction

The Large Observatory For X-ray Timing (*LOFT*) is specifically designed to investigate "matter under extreme conditions". The very large collecting area and fine spectral resolution of its instruments will allow detailed X-ray timing and spectral analysis. Thanks to an innovative design and the development of large-area monolithic silicon drift detectors, the Large Area Detector (*LAD*) on board *LOFT* will provide an effective area of 12 $m^2$, more than an order of magnitude larger than any spaceborne predecessor in the 2 - 50 keV range, yet still is a conventional platform requiring a small/medium-class launch vehicle. With this large area and resolving better than 260 eV at 6 keV, *LOFT/LAD* will yield unprecedented information on matter under extreme conditions of pressure and magnetic field strength.

The second detector on board *LOFT*, is the Wide Field Monitor (*WFM*), with a large field of view, high sensitivity, and good spectral resolution, making the satellite a discovery machine for objects of a variable and transient nature in the X-ray sky.

Objects that will be monitored by *LOFT* in multiwavelength campaigns will reveal phenomena such as flares in magnetized white dwarfs; the physical properties of neutron stars and black holes; blazar outbursts and tidal disruption events in supermassive black holes in AGN.

## 2 Time resolved spectral studies of the extended corona in X-ray binaries

The occurrence of absorption phenomena in high energy astrophysics has been shown to be critically important in revealing not only the properties of the absorber, but more important the nature, location and properties of the X-ray emitting regions. Absorption occurs in many systems, both Galactic and extragalactic and in particular the X-ray dipping phenomenon is seen universally in accreting black hole and neutron star systems as decreases in X-ray intensity. In Galactic black holes such as Cygnus X-1, dipping is cause by blobs of matter in the wind of the companion star. In neutron star binaries, dips are seen on every binary orbit due to absorption in the outer accretion disc around the compact object. Dipping studies are critical in revealing the fundamental physical nature of the systems. The major X-ray emitter in neutron star system was shown to be non-thermal Comptonized emission in a region of hot electrons with plasma temperature of up to 50 keV. The location of this region is not around the compact object as originally thought but in a hot coronal skin of the accretion disc (the Accretion Disc Corona). Studies of the evolution of dipping have proven its extended nature (Church & Bałucińska-Church, 2004) and have led to a unified model of Low Mass X-ray Binaries explaining in a self-consistent way the nature of the brightest super-Eddington sources (the Z-track sources) in all their states (Bałucińska-Church et al., 2010; Church et al., 2012) and of the less luminous Atoll sources in all their states (Church et al., 2014).

It is not known whether the corona is isothermal, or whether there is a radial distribution of temperature. It is not clear how absorption can take place within the corona, as is sometimes seen, dipping primarily taking place in the outer accretion disc. Dipping reveals that the size of the corona varies with the luminosity of the source, i.e. the mass accretion rate, allowing comparison with the theory of ADC formation by illumination from the central object.

Dipping shows that the absorbing material is clustered in the bulge in the outer part of the disc where the stream from the companion star hits the rim. The period of dipping reveals immediately the orbital period of the binary, otherwise difficult to obtain. The variation of the X-ray intensity with time provides the size and structure of the matter causing absorption. The spectral changes in dipping provide the integrated density of absorber along the line-of-sight allowing plasma density to be determined as a function of position in the absorber.

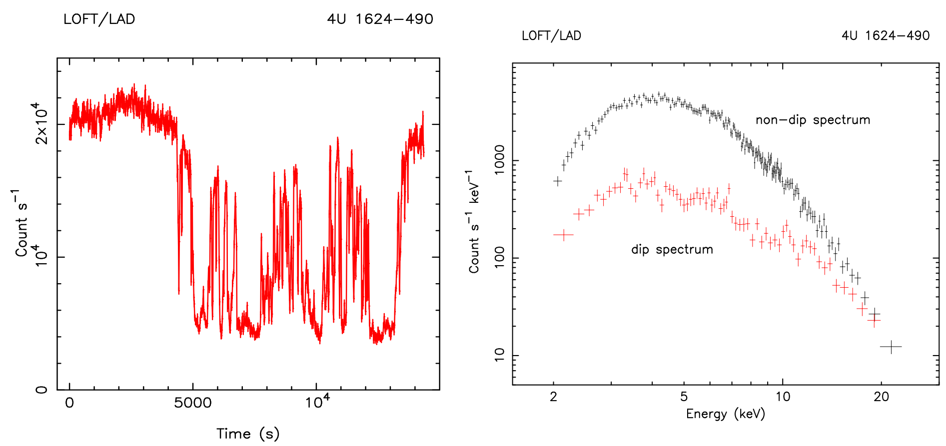


Fig. 1: Left: a simulated *LOFT/LAD* light curve of 4U 1624-490 with 16 s time bins in the 2 – 20 keV energy band based on real data from *Rossi-XTE*; right: 4U 1624-490 1-second non-dip and dip spectra from the simulated observation.

The *LOFT* mission with its huge effective area will allow us detailed study of these issues, as spectral studies on a timescale of seconds will be possible, previously impossible. The more accurate time resolved spectral studies will provide information on the column density of each part of the absorbing structure during a complex dip. Analysis of a sequence of the spectra during dip ingress or egress will allow us to map the temperature of the extended emission region by investigation of the high energy cut-off of the spectra, while measurement of dip ingress/egress times provides the size of the corona and the absorber.

Fig. 1 left shows a *LOFT/LAD* light curve of 4U 1624−490 with 16 s bins based on our Nov. 1999 *XTE/PCA* observation during which the total luminosity in the $1 - 30$ keV band was $1.47 \times 10^{38}$ erg$^{-1}$ for this source at a distance of 15 kpc. The *XTE/PCA* count rate was scaled up to allow for the larger effective area of the *LAD*. A single dip episode demonstrates the wealth of detail accessible to study by *LOFT* but not fully exploited by previous missions due to the lack of count statistics. The non-dip *LAD* count rate is a staggering 20,000 counts per second, while the deep dip rate is about 5000 counts per second, easily allowing spectral analysis on a timescale of 1 second.

Fig. 1 right shows an example of the dip and non-dip spectra with a 1-second exposure time for the simulated observation. Even this 1-second non-dip spectrum is of reasonable quality. Increasing the integration to 10 seconds allows determination of the column density and the cut-off energy with an accuracy of 6% and 20%, respectively, while the cut-off energy of the spectrum with the same exposure time during a deep dip can be determined with 25% accuracy (for $N_{\rm H} = 7 \times 10^{22}$ H atom cm$^{-2}$ and a cut-off energy $E_c = 11$ keV). Therefore, mapping the temperature of extended emission region by investigation of the high energy cut-off of a sequence of spectra between non-dip and deep dip becomes possible with the *LAD* instrument.

## 3 Simulations of the radiation-driven disc instability

We have simulated an X-ray light curve for the radiation-driven disc instability which can be applied to the newly discovered microquasar IGR J17091-3264.

An accretion disc around a black hole will be a bright source of X-ray emission. The newly discovered microquasar IGR J17091-3264 most probably hosts a black hole of 6 Solar masses (Rebusco et al., 2012) at a distance of 11 - 17 kpc (Rodriguez et al., 2011). Most recent observations show that IGR J17091-3264 exhibits many outbursts of different shapes thought to be related to different accretion disc instabilities (Capitanio et al., 2012). The radiation pressure disc instability is well studied theoretically by Janiuk & Czerny (2011). It is responsible for disc outbursts of the order of several thousand seconds for a Galactic black hole. Such outbursts are clearly observed in the X-ray light curves of Galactic black hole binaries.

Therefore, we have performed numerical calculations of such an instability driven by radiation pressure in a standard Shakura-Sunayev disc by using the known parameters of IGR J17091-3264. Simulations of outbursts are done only for the basic one set of parameters. Total grid should be computed in the aim to fit model with observations. More detailed theoretical studies of this phenomenon for the case of IGR J17091-3264 is presented in Janiuk et al. (2014). For the purpose of this paper, we show the one example of light curve caused by radiation pressure disk instability to show the excellent observing possibilities of the mission for further research done in this subject. After the model is computed, we then run simulations using publicly available software SIXTE[1] (Simulation of X-ray Telescope) to produce the observed light curve that would be seen by the *LAD* detector with its very good time resolution.

In Fig. 2 we present a simulated 1 ksec light curve for the case of microquasar IGR J17091-3264, assuming an unabsorbed flux $F_{\rm X}$(2 - 10 keV) of $1.9 \times 10^{-9}$ ergs cm$^{-2}$ s$^{-1}$. With this flux regular disc outbursts driven by the radiation pressure

[1] http://www.sternwarte.uni-erlangen.de/research/sixte/index.php

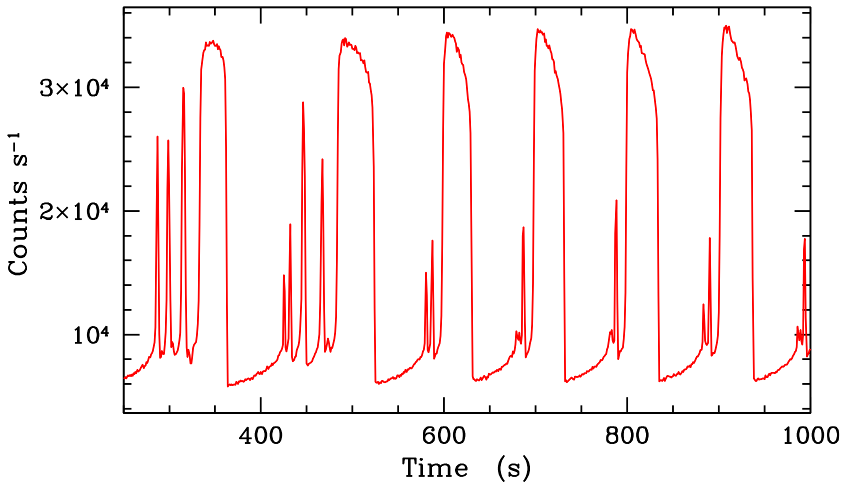


Fig. 2: Simulated light curve of the radiation pressure disc instability with 1-second binning. The detailed shape of outbursts will be detected by *LOFT/LAD* instrument.

disc instability are seen every hundred seconds. Additionally pre-burst flickering of the order of several seconds may be observed. The 1 second binned light curve from many X-ray binaries will be easily observed by *LOFT/LAD*, collecting $10^4$ counts per second and giving an opportunity to study disc instabilities in this kind of source.

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