SPECTRAL AND TEMPORAL ANALYSIS OF SRG/ART-XC OBSERVATION OF SUPERGIANT FAST X-RAY TRANSIENT IGR 16195-4945

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Abstract

In this paper we present the results of the SRG/ART-XC observation of the transient X-ray source IGR J16195-4545 performed on March 3, 2021. This objects is classified as Supergiant Fast X-ray Transient (SFXT). During the observation, IGR J16195-4545 six bright flares during which it did not change the spectrum. Fitting the spectra with absorbed power law with high energy exponential cutoff showed the the source is strongly absorbed with $N_H = (12 \pm 2) \times 10^{22}$ cm^{-2}, $\Gamma = 0.56 \pm 0.15$ and $E_{cut} = 13 \pm 2$ keV. Adopting Bayesian block decomposition of light curve we measured the properties of observed flares, such as duration and released energy, that were compared with the expectations of the Rayleigh-Taylor instability model in accreting plasma near the neutron star magnetosphere.

Introduction

Supergiant Fast X-ray Transients (SFXT) are a sub-class of High Mass X-ray Binaries where the clumpy wind from blue supergiant is accreted onto a a neutron star. A distinctive feature of such systems is their X-ray variability - they demonstrate short sporadic flares, with duration of $\sim 10^3 - 10^4$ s, during which the X-ray luminosity exceeds 10^{35} erg s^{-1}, and in some cases even reaches 10^{37} erg s^{-1}. Herewith the X-ray luminosity between flares is $10^{32} - 10^{33}$ erg s^{-1}.

Transient X-ray source IGR J16195-4945 was discovered by INTEGRAL. On September 26, 2003 during the observation of the INTEGRAL observatory , the source showed a flare lasting ~1.5 h with F ~ 34 mCrab in 20 – 40 keV (Sguera et al. 2006), that made IGR J16195-4945 a SFXT candidate. The near-IR spectroscopy determined that the donor star is ON9.7Iab blue supergiant (Coleiro et al. 2013). This binary system is eclipsing with the orbital period of 3.945 d and an eclipse duration ~ 3.5% of orbital period (Cusumano et al. 2016).

Temporal Analysis

Figure 1 shows the light curve of the source with a time resolution of 500 s in the 4-20 keV energy range. The light curve clearly shows flares characteristic of SFXTs with duration of few thousand seconds. For further analysis we identified periods of time during which the source was in quiescent (A,C,G) , intermediate (E) and active (B,D,F) state. We have also generated light curves if soft (4-8 keV) and in hard (8-20) energy ranges. The hardness averaged over segments was estimated (the ration of count rats in soft and hard energy ranges). It is noticeable that the radiation becomes slightly harder during flares, but in general it could be concluded that the source demonstrates "colorless" variability known in other SFXTs. Using unbinned events we searched for the presence of periodicities in light curve in the range of 10-1000 s using Epoch Folding method (Leahy et al. 1983). No significant periodicities were found.

Spectral Analysis

The spectrum obtained ART-XC was fit with tbabs*cutoffpl model. Measured parameters - power law photon index and folding energy of exponential rolloff - turned out to be close to the values determined by Swift/XRT and Swift/BAT data (Cusumano et al. 2016). However, due to the low coverage of low-energy region, it was not possible to accurately measure absorption from ART-XC data. To obtain broad band energy spectrum we added to ART-XC spectrum the Swift/XRT spectrum of the source if bright states and the averaged source spectrum from the 105-month Swift/BAT catalog .

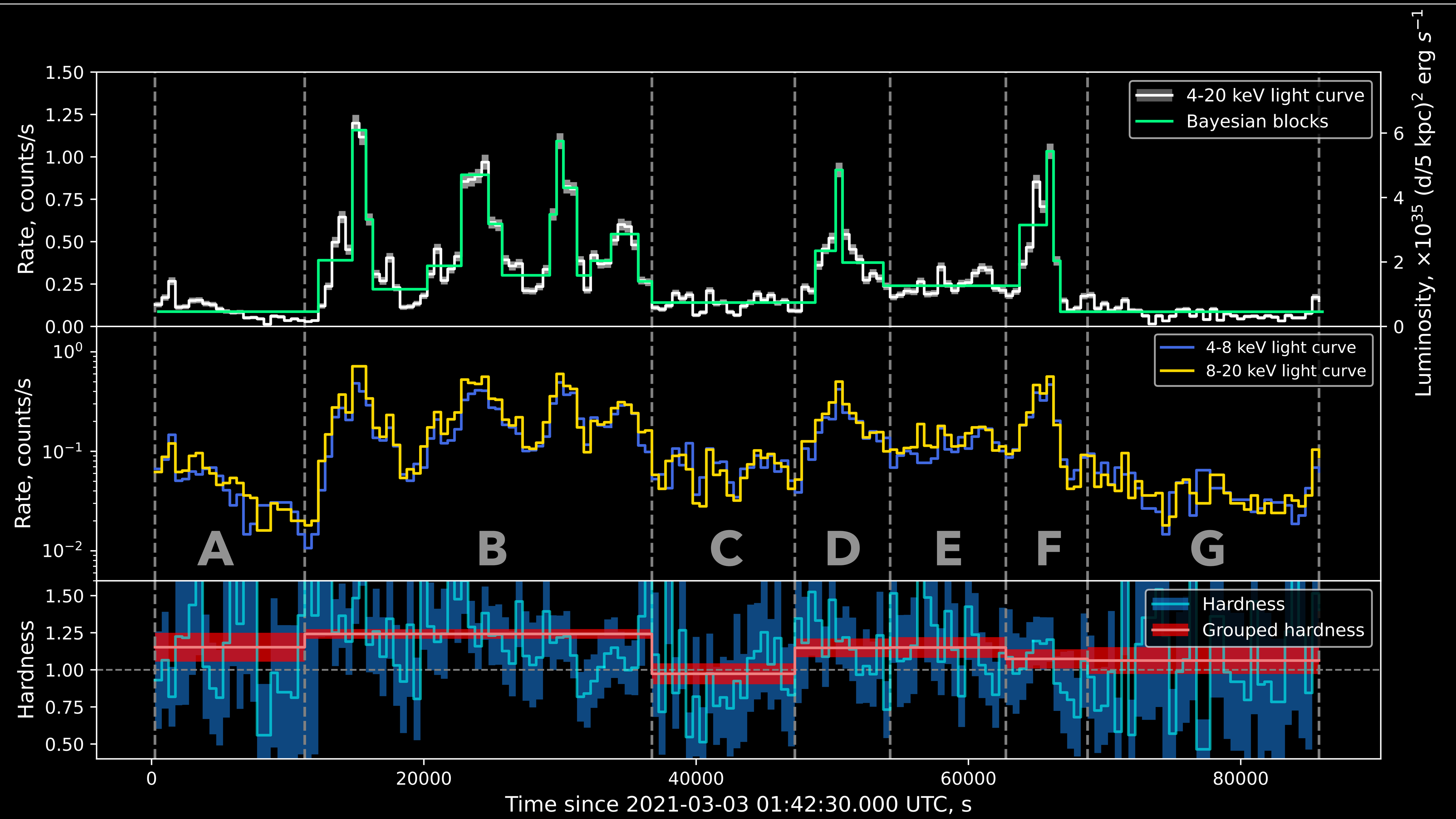

Figure 1. *Top panel:* light curve (4-20 keV) and its Bayesian block segmentation.
Middle panel: light curves in soft (4-8 keV) and hard (8-20 keV) energy ranges.
Bottom panel: hardness (blue),
hardness averaged over segments corresponding to different states of the source (red).

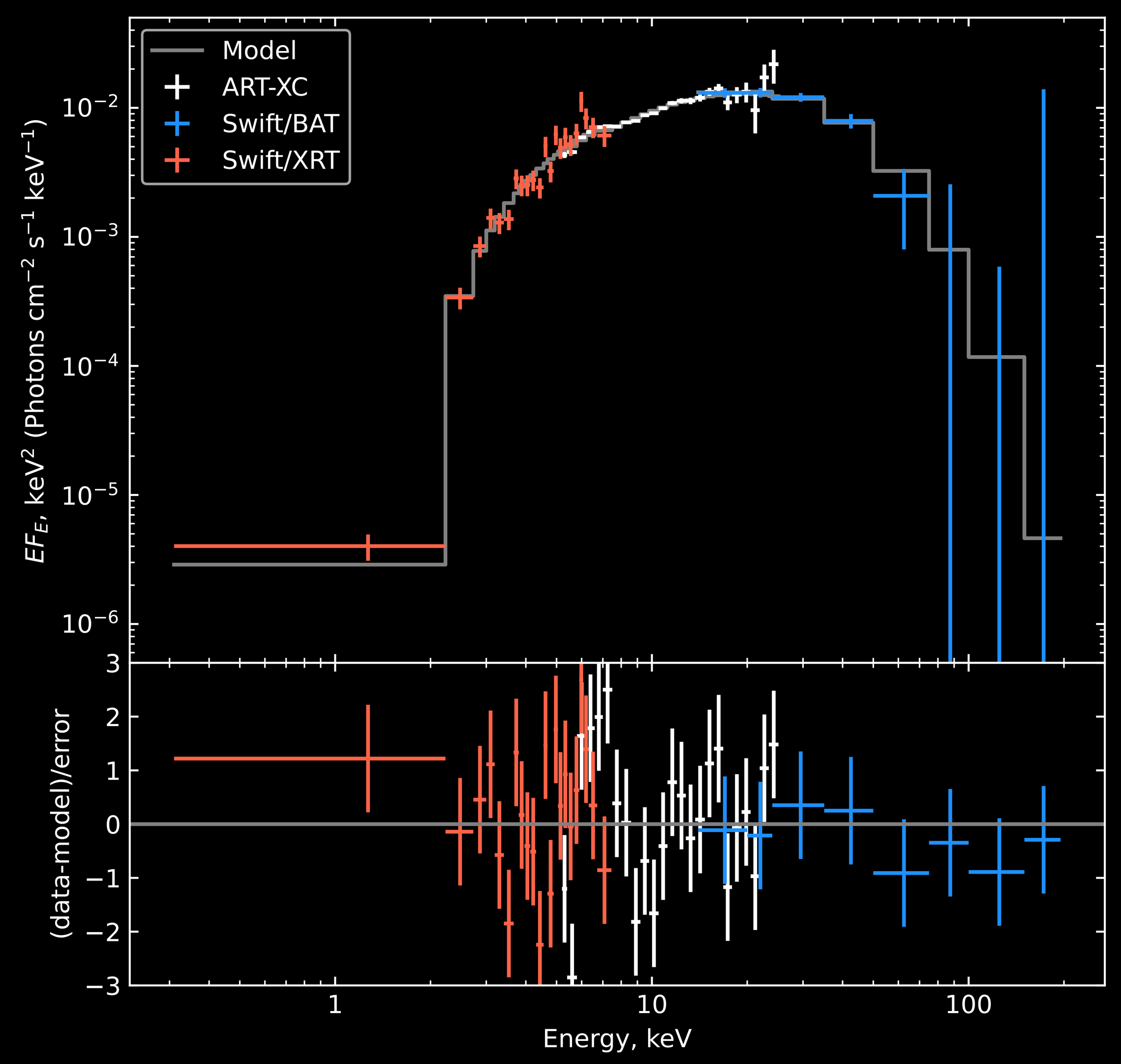

Figure 2. IRG J16195-4945 spectrum on ART-XC (white), Swift/BAT (blue) and Swift-XRT (red) data and tbabs*cutoffpl model (gray).

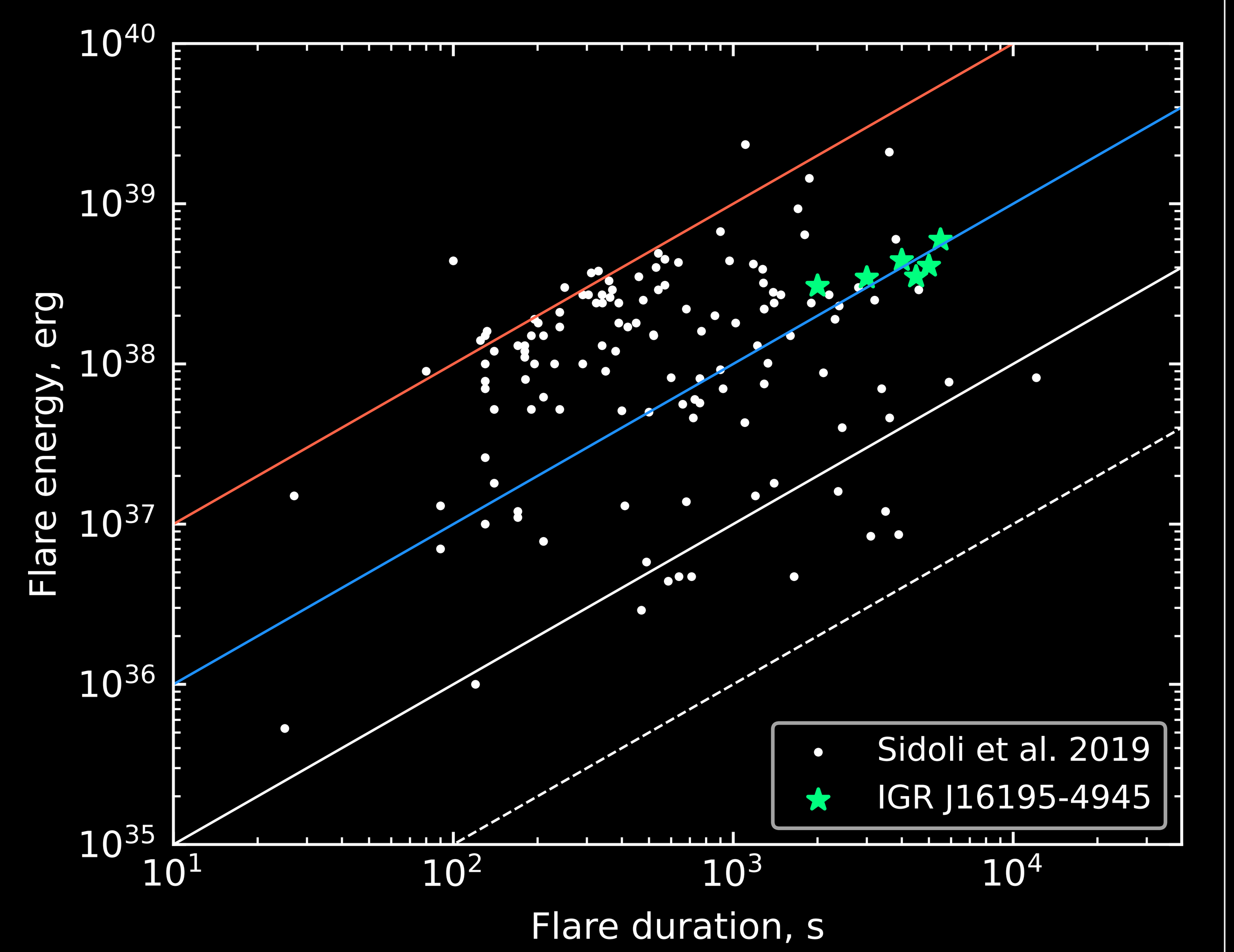

Figure 3. Dependence of the energy released during the flare on its duration for IGR J16195-4945 (green), for different SFXT from Sidoli et al. 2019 (black) and the predicted values of the "settling" accretion model ($\Delta E = 10^{33-36}$[erg s^{-1}]Δt)

The expansion of the energy range made it possible to reliably measure the absorption ($N_H = (12 \pm 2) \times 10^{22}$ cm^{-2}) and the exponential rolloff energy (13 ± 2 keV). The spectra in different states (B, D, F and A, C, G) did not differ significantly. The resulting spectrum made it possible to obtain the conversion coefficient on the light curve from counts per second to bolometric luminosity, assuming the distance to the source to be 5 kpc.

const*tbabs*cflux*cutoffpl

Сегмент	N_H, cm^{-2}	Γ	E_{cut}, keV	χ^2 / d.o.f.	F[4-20 keV], erg s^{-1} cm^{-2}
Full ART-XC + XRT + BAT	$(12 \pm 2) \times 10^{22}$	0.56 ± 0.15	13 ± 2	231.29 / 185	$(2.5 \pm 0.1) \times 10^{-11}$
Full ART-XC	$(16 \pm 8) \times 10^{22}$	0.87 ± 0.35	15^{+13}_{-5}	193.51 / 157	$(2.8 \pm 0.3) \times 10^{-11}$
Full ART-XC (fixed N_H)	12×10^{22}	0.67 ± 0.27	15^{+12}_{-5}	196.49 / 158	$(2.4 \pm 0.3) \times 10^{-11}$
ART-XC: ACG (fixed N_H)	12×10^{22}	$0.58^{+0.84}_{-0.97}$	10^{+88}_{-5}	187.16 / 158	$(0.9 \pm 0.1) \times 10^{-11}$
ART-XC: BDF (fixed N_H)	12×10^{22}	0.59 ± 0.27	15^{+9}_{-5}	184.15 / 158	$(4.1 \pm 0.2) \times 10^{-11}$

Таблица 1. Параметры спектра

Properties of Flares

The average bolometric luminosity turned out to be less than $\sim 4 \times 10^{36}$ erg s^{-1}, therefore, Rayleigh-Taylor instability model in accreting plasma near the neutron star magnetosphere ("settling" accretion) can occur in the system (Shakura et al. 2012). This model predicts characteristic properties of flares, such as total energy release and duration. According to the method proposed by Sidoli et al. 2019, the parameters of observed outbursts can be estimated using Bayesian block segmentation of the light curve. These characteristics can be compared with model predictions, for example, the energy released during a flare depends on its duration as $\Delta E \sim 10^{35}$[эрг с$^{-1}$]Δt. On Figure. 3, the measured properties lie in the region described by the model; therefore, the observed flares in this system can be explained by the "settling" accretion model.

Results

Based on long-term, continuous ART-XC observation of IGR J16195-4945, a light curve was extracted, which shows bursts characteristic of SFXT. When changing states, the source did not demonstrate a significant change in the spectrum. An analysis of the observed bursts has shown that their characteristics, such as the energy released during the burst and its duration, are in good agreement with the model of "settling" accretion.