UDC 524.354
IRSTI 41.27.29

https://doi.org/10.55452/1998-6688-2026-23-1-305-315

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COMPARATIVE ANALYSIS OF X-RAY LUMINOSITY OF PERSISTENT AND TRANSIENT HIGH-MASS X-RAY BINARIES

Abstract

High-mass X-ray binaries (HMXBs) are commonly divided into persistent sources, which emit X-rays steadily over long periods, and transient sources, which remain mostly in a quiescent state and exhibit episodic X-ray outbursts. The aim of this work is to statistically compare the X-ray luminosity properties of these two classes, focusing on the maximum luminosity $(L_{X,\max})$ and the luminosity variability range $(L_{X,\max})/(L_{X,\min})$. For this purpose, catalog data for Galactic HMXB pulsars were used, including 18 persistent and 64 transient systems. The distributions of $\log_{10} L_{X,\max}$ and $\log_{10}(L_{X,\max})/(L_{X,\min})$ were analyzed using histograms, box plots, cumulative distribution functions (CDFs), and the non-parametric Mann–Whitney test. It is shown that both classes reach similar values of $L_{X,\max}$ on the order of 10^{36}–10^{37} erg/s), with no statistically significant difference between their distributions. However, transient systems exhibit a much wider luminosity variability range, reaching increases of 4–5 orders of magnitude (up to 10^5), whereas persistent sources typically show lower variability. This difference is statistically confirmed, with transients demonstrating significantly higher variability p ≈ 0.05). Thus, the main distinction between persistent and transient HMXBs lies not in their peak X-ray luminosity, but in their accretion regime. In persistent systems, the compact object continuously accretes matter from a relatively stable stellar wind of an OB supergiant, resulting in steady X-ray emission. In contrast, transient systems are characterized by intermittent accretion (for example, episodic mass capture from a Be-star circumstellar disc), which leads to their extreme luminosity variability.

Keywords: high-mass X-ray binaries, HMXBs, transient sources, X-ray luminosity, accretion.

Received February 2, 2026; accepted: March 4, 2026

Introduction

High-mass X-ray binaries (HMXBs) are binary stellar systems in which a compact object–either a neutron star or a black hole–accretes matter from a massive stellar companion of spectral type O or B [1]. The X-ray emission in such systems is produced as the accreted material falls into the gravitational potential of the compact object, making HMXBs among the brightest X-ray sources in the Galaxy [2].

According to the nature of their X-ray emission, HMXBs are conventionally divided into two classes: persistent and transient systems. Persistent HMXBs emit almost continuously and are characterized by a relatively stable X-ray luminosity [3]. In contrast, transient HMXBs remain in a quiescent state most of the time and exhibit episodic outbursts, during which the X-ray luminosity can increase by several orders of magnitude compared to the quiescent level [4]. Thus, the key difference between the two classes lies not so much in the emission level itself as in the character of its temporal variability.

The physical differences between persistent and transient HMXBs are generally related to the type of donor star and the accretion regime. Most persistent HMXBs are systems with OB supergiant companions, from which the compact object continuously captures material from the stellar wind [5]. This mechanism produces a steady X-ray luminosity of about 10^{35} – 10^{36} erg s−1 and only moderate flux fluctuations [5]. In contrast, transient HMXBs often host a Be star–a rapidly rotating massive companion surrounded by a circumstellar disk [6]. In these systems, accretion is episodic: the neutron star interacts with the Be-star disk, typically during close passages along an eccentric orbit, leading to short-lived X-ray outbursts reaching 10^{37} – 10^{38} erg s−1 and above [7]. Outside the outburst phases, the luminosity of transient sources drops sharply and may reach values of 10^{32} –10^{33} erg s−1 or even become undetectable [8].

Despite a well-developed qualitative understanding of the differences in accretion regimes between persistent and transient HMXBs, a quantitative statistical comparison of their X-ray luminosities remains an important task. In particular, it is still not entirely clear whether the two classes differ in their limiting X-ray luminosities, or whether their main distinction lies in the degree and nature of variability.

The aim of this work is to identify statistical and physical differences in the X-ray luminosity behavior of persistent and transient HMXBs based on catalog data. We perform a comparative analysis of the distributions of maximum X-ray luminosity and the dynamic range of its variability for the two populations using visualization methods (histograms, box plots, and cumulative distribution functions), as well as non-parametric statistical tests. The results obtained help to clarify the role of the accretion regime in shaping the observed X-ray activity of HMXBs and can be used to classify new sources based on their temporal and energetic properties.

Materials and Methods

For the analysis, we used catalog tables of Galactic X-ray pulsars in HMXB systems, separated by source type into persistent and transient HMXBs [9]. Each table contains source parameters, including the estimated minimum and maximum values of their X-ray luminosity (columns LXLower and LXUpper) and the energy band of the measured luminosity (LXRange, indicating the energy range in keV for which the luminosity is reported). The luminosity is expressed in erg s−1. In addition, we calculated the relative luminosity variability range for each source, defined as the ratio $L_{X,\max}/L_{X,\min}$, where $L_{X,\max}$ = LXUpper, $L_{X,min}$ = LXLower.

In this work, we consider samples of N_p = persistent HMXB pulsars and N_t = 64 transient HMXB pulsars. For each group, we calculated the base-10 logarithms of the maximum luminosity, $\log_{10} L_{X,\max}$ and the luminosity ratio, $\log_{10}\ (L_{X,\max})/(L_{X,\min})$, which allows a consistent comparison of parameter distributions spanning several orders of magnitude.

The data were pre-cleaned: sources with missing $L_{X,\min}$ values (e.g., transient systems whose quiescent luminosity is not detected and is only given as an upper limit) were treated separately in the variability-range analysis. The main analysis was performed in a Python environment using the NumPy and Matplotlib libraries for calculations and visualization.

Visualization and distribution analysis

For a clear comparison of the two groups, the following types of plots were constructed:

- histograms of the $\log_{10} L_{X,\max}$ distributions for persistent and transient HMXBs (Figure 1), using identical bin widths along the X-axis, which allows us to assess the shape of the peak-luminosity distributions and the presence of extended tails;
- box plots for $\log_{10} L_{X,\max}$ for each group (Figure 2), showing the median, interquartile range, and outliers, which enables a visual comparison of the central tendencies and the spread of the parameters;
- histograms of $\log_{10} (L_{X,\max})/(L_{X,\min})$, characterizing the luminosity variability range (Figure 3), as well as the corresponding box plots for this parameter (Figure 4), were also constructed, allowing a direct comparison of the variability level in persistent and transient systems;
- cumulative distribution functions (CDFs) for $\log_{10} (L_{X,\max})/(L_{X,\min})$, (Figure 5), showing the fraction of sources with a luminosity variability range below a given threshold.

Statistical methods

To quantitatively assess differences between the samples, we applied the non-parametric Mann–Whitney U test, which allows testing the hypothesis of equality between the distributions of two independent samples without assuming normality of the data. The following hypotheses were tested separately:

1. differences in the distributions of $\log_{10} L_{X,\max}$ between persistent and transient HMXBs;
2. differences in the distributions of $\log_{10} (L_{X,\max})/(L_{X,\min})$ between the two groups.

In all cases, a two-sided null hypothesis of no difference between the distributions was formulated. The p-value obtained from the Mann–Whitney test was compared with the standard significance threshold $\alpha = 0.05$ (5%). Differences were considered statistically significant when $p < 0.05$. For the variability-range analysis, only sources with both luminosity values defined ($L_{X,\min}$ and $L_{X,\max}$), were used; therefore, the statistical analysis included 16 persistent and 49 transient HMXB systems.

Results

Distribution of the maximum X-ray luminosity $L_{X,max}$.

The histograms (Figure 1) and summary statistics show that persistent and transient HMXBs have peak X-ray luminosities of a similar order of magnitude. Both groups are mainly distributed within the range of $\sim 10^{35}$–10^{38} erg/s in $L_{X,\max}$. The median maximum luminosity of persistent sources is approximately 3×10^{36} erg/s ($\log_{10} L_{X,\max} \approx 36.5$), whereas for transient sources it is about 5×10^{36} erg/s ($\log_{10} L_{X,\max} \approx 36.7$). The difference between the medians is small (less than 0.2 dex). The box plots (Figure 2) show substantial overlap of the interquartile ranges: in both groups, the central 50% of $\log_{10} L_{X,\max}$ values lie approximately between 35.5 and 37.0. This indicates the absence of a strong luminosity shift between the two groups.

At the same time, the tail behavior shows a notable feature: transient systems exhibit a broader spread in their maximum brightness due to the presence of exceptionally luminous outbursts. For example, the histogram for transients displays an extended right-hand tail: the most extreme transient pulsar reached a luminosity of about 2×10^{39} erg/s ($\log_{10} L_{X,\max} \approx 39.3$), which is 1–2 orders of magnitude higher than that of any persistent source. This outlier corresponds to the observed super-Eddington outburst of the transient system Swift J0243.6+6124 (2017), during which an accreting neutron-star pulsar exceeded the typical luminosity limit for neutron stars [10,11]. For persistent HMXBs, the maximum luminosities are instead limited to $\sim 3 \times 10^{39}$ erg/s ($\log_{10} L_{X,\max} \approx 37.5$) – none of the persistent systems in our sample reached higher values. Nevertheless, if single extreme cases are excluded, the overall $L_{X,\max}$ distributions remain largely similar. The Mann–Whitney U test did not reveal a significant difference: for $\log_{10} L_{X,\max}$ we obtain p ≈ 0.39, which is well above 0.05. Therefore, at the 95% confidence level, we can conclude that the characteristic maximum luminosities of persistent and transient HMXBs are statistically indistinguishable. Both types can reach peak luminosities of a similar order (10^{36}– 10^{37} erg/s), although the brightest outbursts are observed specifically in transient systems [12].

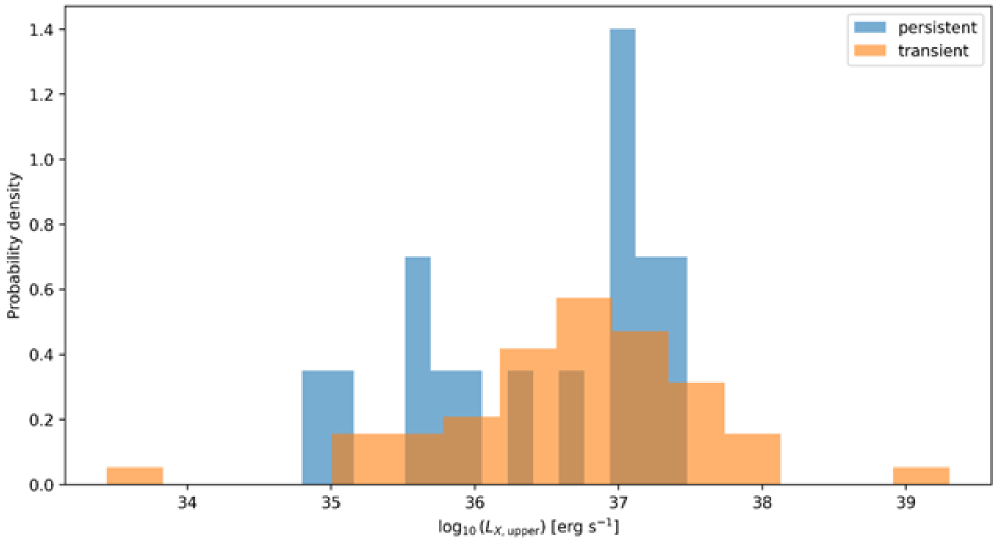

Figure 1 – Histograms of the $\log_{10} L_{X,\max}$ distribution for persistent and transient HMXBs

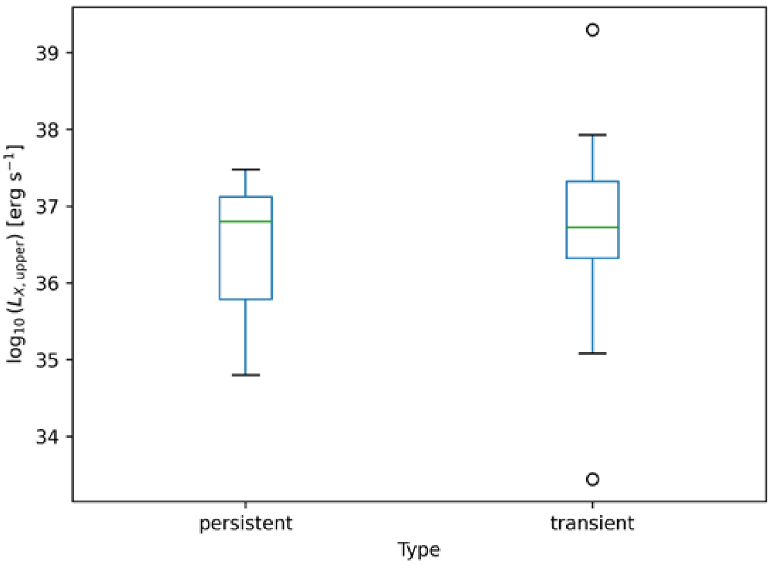

Figure 2 – Box plots of the $\log_{10}(L_{X,\max})$ distribution for persistent and transient HMXBs

Luminosity variability range $L_{X,max}/L_{X,min}$.

In contrast to the absolute luminosity values, the comparison of variability amplitude reveals clear differences between the two groups. The histograms of $\log_{10}(L_{X,\max})/(L_{X,\min})$ (Figure 3) show that transient HMXBs have a substantially broader variability range. For persistent systems, $\log_{10}(L_{X,\max})/(L_{X,\min})$ values in most cases lie between 0 and ~ 2, corresponding to luminosity changes by at most tens to a hundred times [13]. For transient sources, however, the histogram extends up to ~ 5 and higher in logarithmic units, meaning that some objects vary by 4–5 orders of magnitude (i.e., by tens of thousands). The box plots (Figure 4) quantitatively confirm this contrast: the median decimal logarithm of the variability range for persistent systems is about 0.7 (corresponding to an ~ 5-fold increase in luminosity from minimum to maximum), whereas for transients the median is around 1.0 (an ~10-fold increase). The whiskers of the box plots show that almost all persistent sources have $\log_{10}(L_{X,\max})/(L_{X,\min}) < 2.5$ (i.e., no more than a factor of ~ 300 between minimum and maximum luminosity). For transients, the upper quartile is significantly higher: about one quarter of transient HMXBs have log10 ranges above ~ 2 (i.e., >100 times), and roughly 10% exceed even a 10^3 - fold change ($\log_{10} > 3$). The maximum observed value is 5.52, corresponding to a record luminosity increase of ~ 3.3×10^5 times (again, the case of Swift J0243.6+6124).

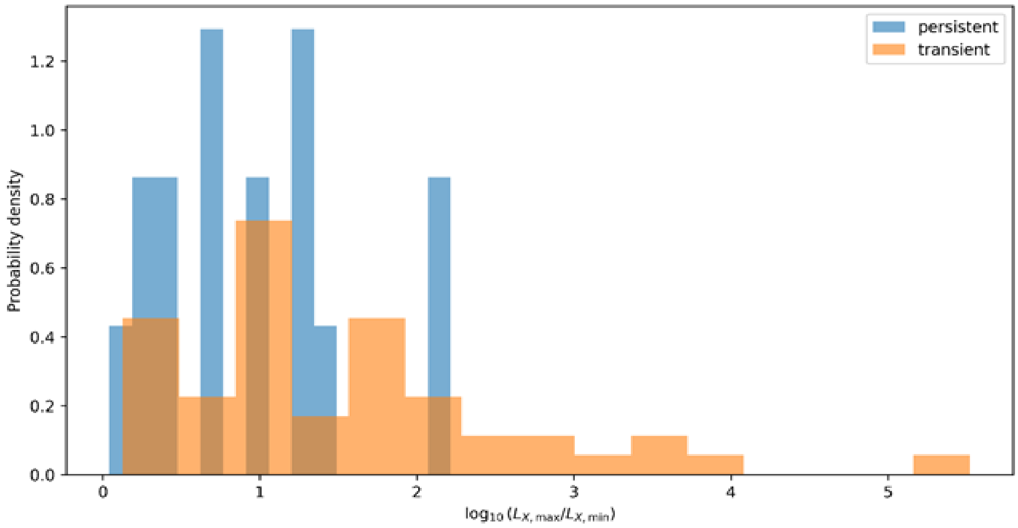

Figure 3 – Histograms of the $\log_{10}(L_{X,\max})/(L_{X,\min})$ distribution for persistent and transient HMXBs

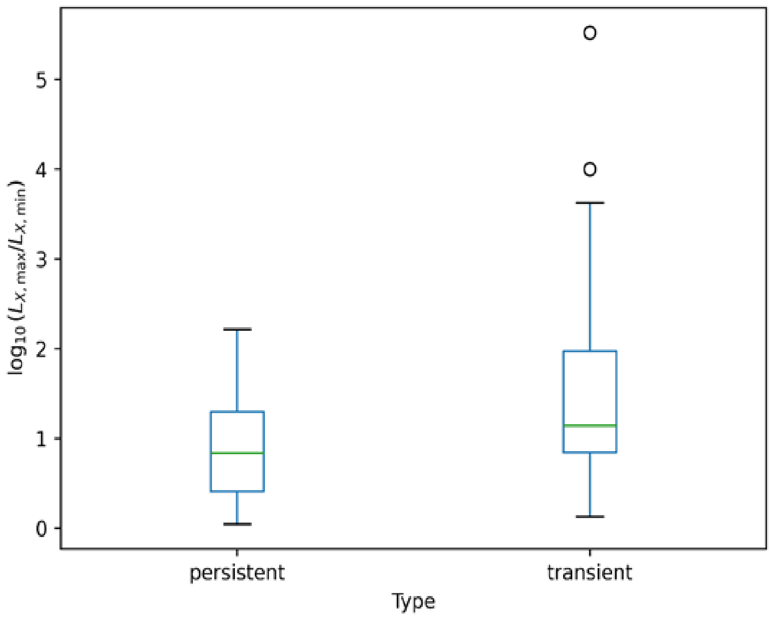

Figure 4 – Box plots of the $\log_{10}(L_{X,\max})/(L_{X,\min})$ distribution for persistent and transient HMXBs

On the cumulative distribution curve (Figure 5), this appears as a pronounced divergence between the two groups: the curve for persistent HMXBs rapidly reaches a plateau at $\log_{10}\,(L_{X,\max})/(L_{X,\min})$ ~ 2.2 (about a factor of 100–160, beyond which no additional objects are present), whereas for transients the curve must be extended to ~ 5 along the x-axis to cover all sources. For example, about ~ 90% of persistent systems have a variability range of less than a factor of 100, while nearly 25% of transient systems exceed this level of variability.

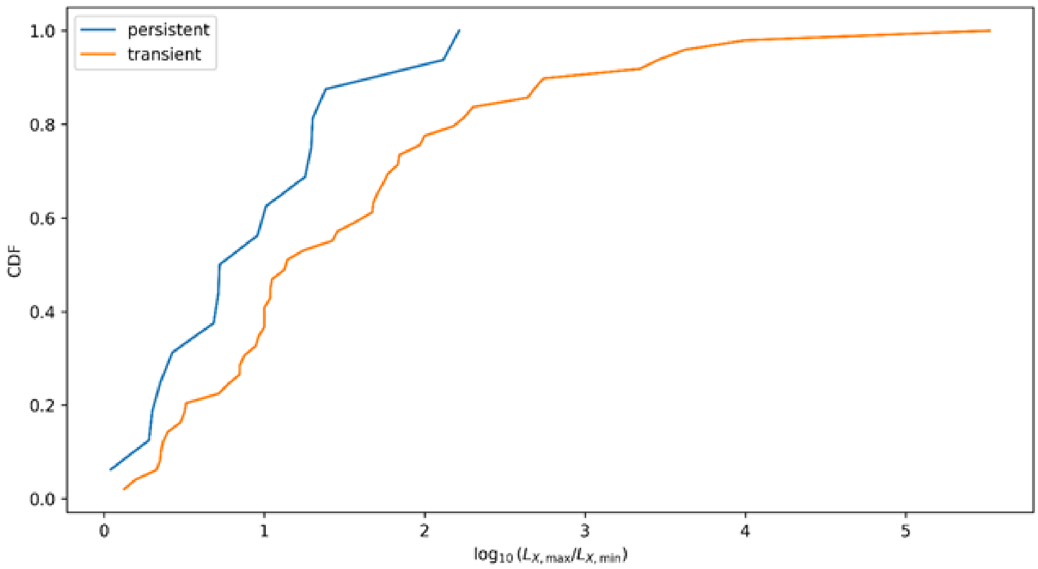

Figure 5 – Cumulative distribution functions (CDFs) of $\log_{10}\,(L_{X,\max})/(L_{X,\min})$ for persistent and transient HMXBs

The Mann–Whitney U test indicates a difference in the variability distributions, although with borderline statistical significance. The computed p-value for the $\log_{10}\,(L_{X,\max})/(L_{X,\min})$ samples is ≈ 0.05, which lies exactly at the adopted significance threshold. This suggests that, with a confidence level of about 95%, transient HMXBs can be considered more variable than persistent ones; however, the result should be interpreted with caution due to the limited sample size and the presence of censored data for some transients, whose minimum luminosity is only constrained by an upper limit. Nevertheless, the trend is clear: transient systems are, on average, capable of changing their luminosity by larger orders of magnitude than persistent systems. Even when the extreme source is excluded, transients still show a much larger dispersion in $L_{X,\max}/L_{X,\min}$ values. They often exhibit phases of nearly complete "switching off" of X-ray emission, followed by episodes of intense accretion and outbursts, whereas persistent sources maintain a more stable level of accretion and emission.

Discussion

The obtained results confirm and quantitatively refine the well-known picture of the differences between persistent and transient high-mass X-ray binaries. First, both populations exhibit comparable ranges of absolute peak X-ray luminosities. This means that the presence of a persistent or transient accretion regime does not impose a strict upper luminosity limit: persistent HMXBs can be as bright as transient systems during outbursts (for example, some persistent sources reach several 10^{37} erg/s, which is comparable to the luminosities of typical transient outbursts). This finding is consistent with the fact that the maximum luminosity in both cases is limited approximately by the Eddington luminosity of an accreting neutron star (of order 10^{38} erg/s for a mass ~ 1.4$M_\odot$), and both classes of systems are in principle capable of approaching this limit. The difference is that persistent sources maintain a near-maximum level continuously, whereas transients reach it only episodically. In addition, the extreme transient system Swift J0243.6+6124, which exceeded the Eddington limit during an outburst, stands out separately [14]. Its existence demonstrates that the transient accretion regime can temporarily produce supercritical accretion flows, possibly due to radiation beaming or other exotic mechanisms. In persistent systems, such a strong excess above the Eddington limit is not observed, likely because long-term stable accretion self-regulates through the balance of radiation pressure.

Second, a fundamental difference is revealed in the variability behavior. Persistent HMXBs show limited fluctuations in the X-ray flux–typically within no more than two orders of magnitude–which may be caused, for example, by wind inhomogeneities in the supergiant donor or by transitions between different accretion regimes, such as disk-like and sporadic accretion. In contrast, transient systems exhibit an extremely wide range of states: from deep quiescence, when the luminosity can drop to 10^{32}–10^{33} erg/s (effectively “switching off”), to the brightest outburst phases, comparable to the most powerful X-ray sources known in the Galaxy. Such variability is explained by the specific accretion mechanism. In most transient HMXBs, the compact object interacts with the disk surrounding a Be star. During a substantial part of the orbit, the neutron star may remain outside the dense disk layers and accrete only at a minimal level (from a tenuous stellar wind or even with almost no mass supply), which accounts for the low $L_{X,\min}$. However, during close passages through the disk or during episodes of enhanced mass ejection from the Be star, a sudden increase in mass inflow occurs, producing an outburst. The dynamic nature of accretion in these systems–depending on orbital phase, disk density, and other stochastic factors–leads to a large spread in energy output: some outbursts can be relatively weak, while others reach record-high levels.

In contrast, persistent HMXBs (e.g., systems consisting of an OB supergiant and a neutron star) are predominantly fed by a steady stellar wind. Although the wind density may fluctuate, it still provides continuous accretion. As a result, the X-ray luminosity of such systems is more stable: even if temporary obscuration events or accretion instabilities occur, the baseline flux does not drop to zero. Many persistent HMXBs (for example, Vela X–1 and Cen X–3) exhibit X-ray eclipses and moderate flares, but they almost always remain detectable at a level of 10^{35}–10^{36} erg/s. The relatively low dynamic range of their luminosity is consistent with the idea that the accretion rate in these systems varies within a relatively narrow range around a mean value determined by a stable mass supply from the donor star.

It should be noted that the class of transient HMXBs also includes the so-called supergiant fast X-ray transients (SFXTs)–systems with OB supergiant donors that nevertheless exhibit short, impulsive outbursts and long quiescent phases. These objects (for example, IGR J17544–2619, included in our sample) occupy an intermediate position: their donors are similar to those in persistent systems, but their accretion mechanisms may involve periodic interruptions, possibly related to magnetospheric inhibition of the accretion flow or a “gating” mechanism. This leads to transient behavior even in the presence of a supergiant donor. In our analysis, SFXTs also show high values of $L_{X,\max}/L_{X,\min}$, comparable to those of Be/X-ray transient binaries. This indicates that the decisive factor behind transient behavior is not only the nature of the donor star, but also the accretion regime: intermittent mass capture–driven either by orbital geometry or by physical “switch-on/switch-off” accretion mechanisms–determines the extreme variability of the system.

Thus, it is statistically confirmed that the main difference between the two classes of HMXBs lies in the degree of temporal variability of their X-ray luminosity rather than in their limiting brightness values [15]. Earlier qualitative estimates suggested that transient Be/neutron-star binaries can exceed persistent systems by 2–3 orders of magnitude in luminosity at maximum, and the results obtained in this work are consistent with these conclusions. More generally, variability can serve as a diagnostic indicator: if a source is capable of changing its brightness by several tens of thousands of times, it most likely belongs to the transient class, most often with a Be companion. In contrast, a relatively stable X-ray pulsar with only small flux variations is likely a system with a supergiant donor. These conclusions are consistent with modern accretion theories, in which a steady mass supply from a stellar wind and episodic mass capture from a disk lead to fundamentally different X-ray behavior of the accreting compact object.

Conclusion and future research directions

In this work, we performed a comprehensive analysis of the differences between persistent and transient high-mass X-ray binaries based on their X-ray luminosities. The main conclusions can be summarized as follows.

1. Maximum luminosity ($L_{X,\max}$). Persistent and transient systems reach peak X-ray luminosities of a similar order of magnitude (several 10^{36} erg/s). The statistical analysis did not reveal a significant difference between the $L_{X,\max}$ distributions of the two populations. This indicates that belonging to either the transient or persistent class does not limit a system's ability to be a bright X-ray source; both types can approach the Eddington limit for a neutron star, either in a steady state or during outbursts.

2. Variability range ($L_{X,\max}/L_{X,\min}$). Transient HMXBs exhibit a significantly broader luminosity variability range. While persistent sources typically vary by no more than ~ 10^2, transient systems can increase their luminosity by $10^3 - 10^5$ times. This difference has borderline statistical significance (p ~ 0.05) and is clearly visible in the distribution plots, allowing variability to be considered a key diagnostic feature of transient systems.

Physical interpretation. The observed differences are driven by distinct accretion regimes. Persistent HMXBs are typically powered by the steady stellar wind of a supergiant donor, resulting in moderately stable accretion and X-ray emission. In contrast, transient systems experience episodic accretion flows associated with interactions with a Be-star disk or with specific "switch-on/switch-off" accretion mechanisms in supergiant systems, leading to sharp outbursts and long quiescent phases.

The quantitative estimates obtained support the classification of HMXBs commonly used in astrophysics and may be useful for diagnosing newly discovered sources. For example, if future X-ray observations (eROSITA, Athena) detect a source showing luminosity variability of more than 10^3 times, it is highly likely to belong to the class of transient Be/X-ray binaries. At the same time, persistently detected sources with relatively small flux fluctuations are most likely systems with a supergiant donor.

The present study is limited to the analysis of X-ray luminosity parameters. In the future, it would be promising to extend the comparison by including the distributions of neutron-star spin periods, orbital parameters, and evolutionary properties of the donor stars. Of particular interest is the identification and separate analysis of the SFXT subclass, as well as a comparison between Galactic HMXBs and extragalactic systems, for example in the Magellanic Clouds, where metallicity and star-formation conditions differ significantly. Combining statistical studies with physical modeling of accretion will make it possible to deepen our understanding of HMXB evolution and the transitions between persistent and transient regimes.

Funding. This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP23489541).

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ТҰРАҚТЫ ЖӘНЕ ТРАНЗИЕНТТІ ЖОҒАРЫ МАССАЛЫ РЕНТГЕНДІК ҚОС ЖҮЙЕЛЕРДІҢ РЕНТГЕНДІК ЖАРЫҚЫРАУЫН САЛЫСТЫРМАЛЫ ТАЛДАУ

Аңдатпа

Жоғары массалы рентгендік қос жүйелер (HMXB) рентген сәулесін дерлік үздіксіз әрі салыстырмалы түрде тұрақты шығаратын тұрақты көздерге, сондай-ақ уақыттың басым бөлігінде тыныш күйде болып, тек белгілі бір кезеңдерде ғана қуатты рентгендік жарқылдар көрсететін транзиентті көздерге бөлінеді. Бұл жұмыстың мақсаты – HMXB жүйелерінің аталған екі класының рентгендік жарықырау қасиеттерін статистикалық тұрғыдан салыстыру. Атап айтқанда, ең жоғарғы рентгендік жарықырау мәні $L_{X,max}$ және оның өзгергіштік диапазоны $L_{X,max}/L_{X,min}$ қарастырылды. Зерттеу барысында Галактикадағы HMXB-пульсарлар туралы каталогтық деректер пайдаланылды (18 тұрақты және 64 транзиентті жүйе). $\log_{10} L_{X,max}$ және $\log_{10}(L_{X,max}/L_{X,min})$ шамаларының үлестірімдері гистограммалар, қораптық диаграммалар (boxplot), жинақталған үлестірім функциялары (CDF) және Манн–Уитнидің параметрлік емес критерийі көмегімен талданды. Зерттеу нәтижелері екі класс үшін де $L_{X,max}$ мәндері ұқсас диапазонда орналасқанын көрсетті (шамамен 10^{36}–10^{37} эрг/с) және олардың үлестірімдері арасында статистикалық тұрғыдан мәнді айырмашылық байқалмайды. Сонымен қатар транзиентті жүйелер рентгендік жарықыраудың әлдеқайда кең өзгергіштік диапазонына ие екені анықталды. Тұрақты жүйелерде бұл көрсеткіш әдетте 10^5 еседен аспайды, ал транзиентті жүйелерде өзгергіштік 4–5 реттік шамада, яғни 10^5 есеге дейін артуы мүмкін. Бұл айырмашылық статистикалық тұрғыдан расталды (транзиентті жүйелерде вариабельділік жоғары, $p \approx 0.05$). Осылайша, тұрақты және транзиентті HMXB жүйелері арасындағы негізгі айырмашылық олардың шектік рентгендік жарықырауында емес, аккреция режимінде екені анықталды. Тұрақты жүйелерде ықшам объект OB-супергигант жұлдыздың тұрақты жұлдыздық желінен үздіксіз зат аккретациялап, салыстырмалы түрде тұрақты рентгендік сәуле шығарады. Ал транзиентті жүйелер үзік-үзік аккрециямен сипатталады (мысалы, Be-жұлдыздың дискінен заттың эпизодтық түрде қармап алынуы), бұл олардың жоғары вариабельділігіне алып келеді.

Тірек сөздер: жоғары массалы рентгендік қос жүйелер, HMXB, транзиентті көздер, рентгендік жарқырау, аккреция.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ РЕНТГЕНОВСКОЙ СВЕТИМОСТИ ПОСТОЯННЫХ И ТРАНЗИЕНТНЫХ ВЫСОКОМАССИВНЫХ РЕНТГЕНОВСКИХ ДВОЙНЫХ СИСТЕМ

Аннотация

Высокомассивные рентгеновские двойные системы (HMXB) делятся на постоянные (персистентные) источники, которые излучают практически непрерывно и относительно стабильно, и транзиентные (переменные) источники, большую часть времени пребывающие в тихом состоянии и лишь эпизодически переживающие мощные рентгеновские вспышки. Цель данной работы – статистически сравнить свойства рентгеновской светимости этих двух классов HMXB, в частности максимальную светимость $(L_{X,\max})$ и диапазон ее изменчивости $(L_{X,\max})/(L_{X,\min})$. Для этого использованы каталожные данные по галактическим HMXB-пульсарам (18 постоянных и 64 транзиентных систем). Проанализированы распределения $\log_{10} L_{X,\max}$ и $\log_{10}(L_{X,\max})/(L_{X,\min})$ с помощью гистограмм, коробчатых диаграмм (boxplot), кумулятивных кривых (CDF) и непараметрического критерия Манна–Уитни. Показано, что оба класса достигают сходных значений $L_{X,\max}$ (порядка 10^{36}–10^{37} эрг/с), без статистически значимого расхождения распределений. Однако транзиентные системы демонстрируют значительно более широкий диапазон изменчивости светимости: увеличение на 4–5 порядков (до 10^5 раз) против обычно менее 10^5 раз у постоянных. Это отличие подтверждается статистически (для транзиентов выявлена более высокая вариабельность, $p \approx 0.05$). Таким образом, основное различие между постоянными и транзиентными HMXB заключается не в предельной рентгеновской светимости, а в режиме аккреции. В постоянных системах компактный объект непрерывно аккрецирует вещество из устойчивого звездного ветра OB-сверхгиганта, обеспечивая относительно стабильное излучение. Напротив, транзиенты характеризуются прерывистой аккрецией (например, эпизодическим захватом материи из диска Be-звезды), что приводит к их экстремальной вариабельности.

Ключевые слова: высокомассивные рентгеновские двойные, HMXB, транзиентные источники, рентгеновская светимость, аккреция.