SIGNATURES OF SMALL-SCALE BRIGHTNESS VARIABILITY OF THE BINARY STAR SYSTEM NQ GEM

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Abstract: *We present the results, obtained from online observational databases of the binary star system NQ Gem (Gemini). The constructed light curves of this binary manifest variation in its brightness. Small-scale magnitude fluctuations are detected for short and long time-scales during the different periods of observations. It is most likely the signatures of irregular non-periodic flares, according to their life-time of activity. The energy spectrum of NQ Gem shows the maximum counts during its X-Ray activity and their distribution through the energy band. An occurrence of single, sporadic gamma flare is also observed at the generated gamma-ray light curve.*

ИНДИКАЦИИ ЗА ПРОМЕНЛИВОСТИ В БЛЯСЪКА НА ДВОЙНАТА ЗВЕЗДНА СИСТЕМА NQ GEM

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Ключови думи: *Звезди: Двойни звезди; Акреция; Криви на блясъка;*

Резюме: *В тази статия са представени резултати за двойната звездна система NQ Gem (Gemini), получени от източници с наблюдателни база данни и онлайн ресурси - генератори. Чрез построените криви на блясъка са детектирани променливости в светимостта на звездата. Флуктуации в звездната величина с малка амплитуда се проявяват и в кратка, и в дълга времева скала, по време на различни периоди на наблюдение. В съответствие с продължителността на тяхната активност, се предполага, че това най-вероятно са индикации за неправилни, непериодични проблясвания. Енергийният спектър на NQ Gem показва в коя част на обхвата: мек, среден или твърд, звездата проявява максимум на рентгенова активност. От генерираната крива на блясъка, вследствие на гама-излъчването в района на координатите на двойната звезда, се наблюдава единичен гама-проблясък.*

Introduction

The stars variability is usually defined as the changes in their brightness. The variable stars investigation is important, because it gives the way and methods to obtain information about stellar masses, radius, temperatures, luminosity, as well as the properties of their structure and evolution.

Observing and detecting the brightness variability in stars require a long time monitoring of the objects. In this purpose, many Earth-based and space-based telescopes implement this observational mission. The large packages of observational data are collected in the International Astronomical data bases. In this way they make a useful contribution to the scientific activity of the professional astronomers worldwide. More of them enable free access of data usage to scientific researcher or educators.

American Association of Variable Star Observers (AAVSO) is the largest digital star database. They collect data from amateur and professional astronomers for thousands of variable stars objects. The AAVSO International Database has an archive by the sources, such as: visual magnitude

estimates made from digital images; photographic plate estimates and plate measurements; CCD or photoelectric photometry. Their online light curve generator is updated after every new data are submitted to the database.

The other online data light curve generator is based on the Swift - XRT web site. The data are received from the X-Ray telescope (XRT), loaded at the Swift satellite. It has been created a catalogue, which consists of analyzed data of Swift – XRT [7]. Light curves have been produced and the variability for each source in this database catalogue is estimated [6].

Searching for the gamma (γ)-ray emission or transient gamma-ray events is possible by employing the Fermi All-sky Variability Analysis (FAVA) – based on the data of Large Area Telescope (LAT). FAVA comparing the number of counts observed in a given time interval for every direction in the sky [1]. From the submitted coordinates, into the online generator, it could be selected those produced from the regions of binary stars. Gamma-flares are then detected, from the area enclosed by the coordinates.

In this paper we present the brightness variability of the binary star NQ Gem. The object's description is given in the next section (II). It is followed by the results obtained from the three online databases (Section III).

Target's details

NQ Gem is a type of Semi-regular variables, which are giants or supergiants of intermediate and late spectral types. This star shows periodicity in its light changes for a long period of observations and accompanied or sometimes interrupted by various irregularities. Periods lie in the range from 20 to > 2000 days, while the shapes of the light curves are rather different and variable, and the amplitudes may be from several hundredths to several magnitudes (usually 1–2 mag. in V).

NQ Gem belongs to the family of Symbiotic variables of the Z Andromedae type. They are close binaries that consist of a hot star, a star of late type, and the existence of extended envelope is very possible, which is influenced by the hot star's radiation. Their brightness usually displays irregular variations with amplitudes up to 4 mag. in V. It is a inhomogeneous group of objects. The star is previously attached to the group of X-Ray symbiotic binaries, as well [8].

On the other hand, the Spectral types of those objects are usually C6 or CH3. They are known as "carbon stars" with an excess of carbon in their atmosphere [3], usually red giants. Their average magnitude range is about 7.4 ÷ 8.18 V. The period of their rotation is calculated as 58.2 days.

The light curves of NQ Gem show pulsations, with a pulsation period: P_{pul} ~ 58 ± 1 d, received by Gromadzki et al. (2013) [4] in their periodic light curve analysis of symbiotic stars.

The light curves of symbiotic binaries manifest a complex behavior. If we are tracing out the long period light curve of such systems, we could see their light curves are compound of alternated activity stages. It is observed small and large scale events, such as flickerings and bursts, lasting for short and long terms during the period of their observation.

Results

In this section, we present the online generated light curves of NQ Gem, by using the online data centers: AAVSO, Swift – XRT and FAVA (see the details in the Introduction). Therefore, the obtained light curves of NQ Gem are in different bands: BVRI, Vis. (Visual), X-ray and gamma. We compare the brightness variability and behavior of this star for different periods, according to the existing data. The energy spectrum is also obtained by the XRT generator.

The light curves time in this paper is given in: MET (Mission Elapsed Time (s)); JD (Julian date); MJD (Modified Julian date).

1. Results from AAVSO

The irregular variability of NQ Gem requires monitoring of its light curve for a longer observational period (> 1 year). The first observational period is for ~ 1 year, between JD (Julian date): 2453179.5 (MET: 109641600.0) and JD: 2453569.5 (MET: 143337600.000). It shows very small amplitude fluctuations in the brightness in all five bands (Fig.1). As the detection period is longer than a day, these fluctuations could be a particular manifestation of flares activity.

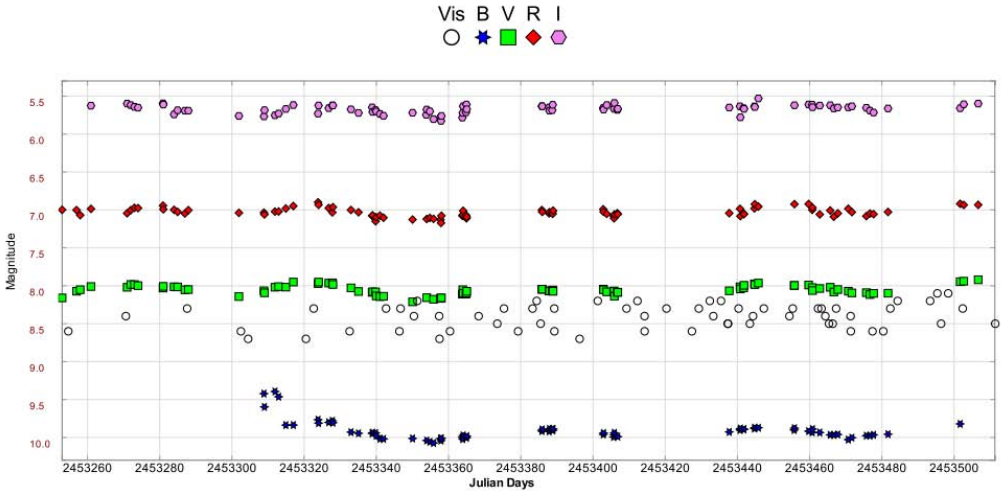

Fig. 1. One year light curve of NQ Gem in BVRI and Visual bands (AAVSO data generator). Small scale variations in the magnitude are observed, with a maximum value: 0.2 ÷ 0.5.

The next observational period of NQ Gem spans over 2 years, which include the dates between: JD: 2454672.5 (MET: 238636801) and JD: 2455402.5 (MET: 301708802). The light curve for this period is created from 211 observations with available data in the Vis. (Visual) band only. It is averaged with bin size of 3 Julian days and its final shape - form is seen in the Fig. 2 below.

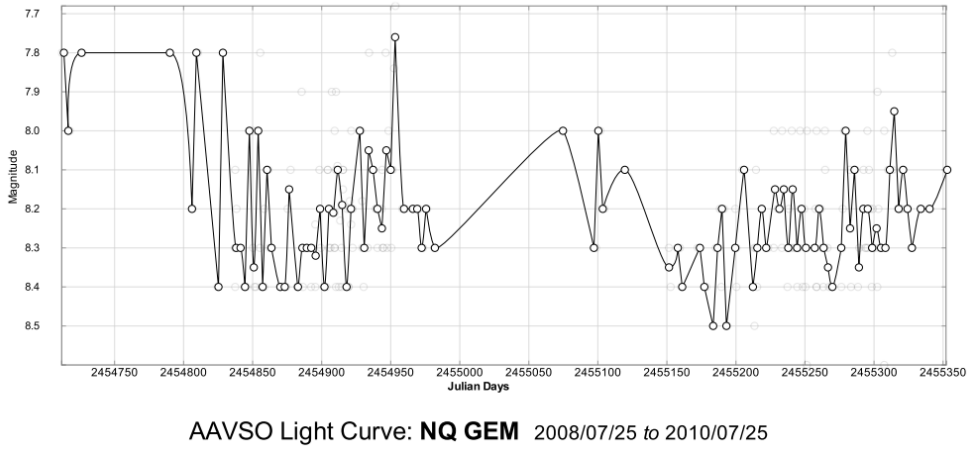

Fig. 2. Two years light curve of NQ Gem in Visual band (AAVSO data base). The magnitude variations with amplitude in a range 0.1 ÷ 0.6 are observed.

The light curve of NQ Gem for this 2 years period manifests the irregular variability in brightness of this type of stars, mentioned in the previous section. It is observed the drop in the magnitude by the value of 0.6 as a whole for the period of less than 3 months ~75 days (2008-11-29; JD:2454800 ÷ 2009-02-12; JD: 2454875), accompanied with quasy-periodic oscillations (or pulsations) with small-scale amplitudes. After that the star's magnitude increases to the initial value for the same duration of less than 3 months or ~ 80 days. Further, this is followed by periods of irregular brightness variations with small-scale amplitude again.

2. Results from Swift - XRT

By using the Swift – XRT data, we check the energy spectrum of NQ Gem and the behavior of X-ray light curve for the same period, as the non-periodic brightness variabilities are observed.

The X-ray light curve shows (Fig.3a) that its maximum counts per second take values between 0.2 – 0.4 c/s, with exceptions at 1.5 c/s. They appear at the hard part of the energy band: 3 – 7 keV.

Following the separation of the energy band by Evans (2014) [7], we delimit the next 3 bands: Total = 0.3 ≤ E ≤ 10 keV; Soft = 0.3 ≤ E < 1 keV; Medium = 1 ≤ E < 2 KeV; Hard 2 ≤ E < 10 keV. The maximum activity of the star is concentrated in the hard band part of the energy spectrum, where most of the normalized counts are detected (Fig. 3b): $2.10^{-4} \div 10^{-2}$ s^{-1} keV^{-1} . There is a weak activity in the soft energy band, but with higher values of the normalized counts ≥ 5.10^{-2} s^{-1} keV^{-1}. The lower panel of the Fig. 3b gives the ratio between the detected counts in both energy bands. The automatically chosen reading-out mode here is PC (Photon counter) mode, because of the low source intensity.

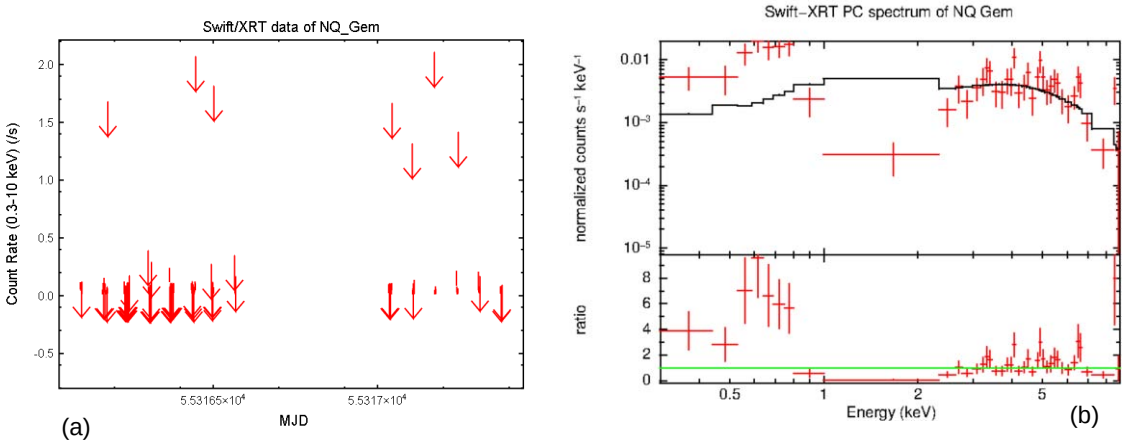

Fig. 3. Swift X-ray light curve (3a, left) and energy spectrum (3b, right) of NQ Gem. The count rates, seen in the light curve, are given for soft and hard energy bands separately. The normalized counts have their highest values at the hard band of the energy spectrum (2 – 10 keV), in PC mode. (by Swift-XRT generator [5])

We chose the option for the light curves data to be binned by time. This means that the using method set the bins in a specified duration. It is inserted into the generating form the significance “minimum sigma” and its value is pointed to be 3σ. The duration of light curve bins, known as “bin length” is specified for WT (Windowed Timing) and PC mode separately and could be changed in every light curve or spectrum generation. In current calculations, they take the values of: WT – 20; PC – 200.

3. Results from FAVA

Authors of the online FAVA catalog Ackermann et al. (2013) [1] and Abdolahi et al. (2017) [2] apply the units of Gaussian sigmas to visualize the significance that is the probabilities the observed counts are a statistical fluctuation of the expected one.

According to their papers the events with sigma ≥ 5.5σ (and ≤ –5.5σ) should be considered only. To limit the false flares, they eliminated those by this threshold in advance.

We chose to examine the flares in the low energy band with FAVA detections of the significance threshold: > 5σ.

We have received the light curves of NQ Gem (Fig. 4), by employing the FAVA light curve generator. The light curves of this object manifest individual gamma – flare during the period of observations. It is a sporadic event with magnitudes 2 to 3 values above the average ones.

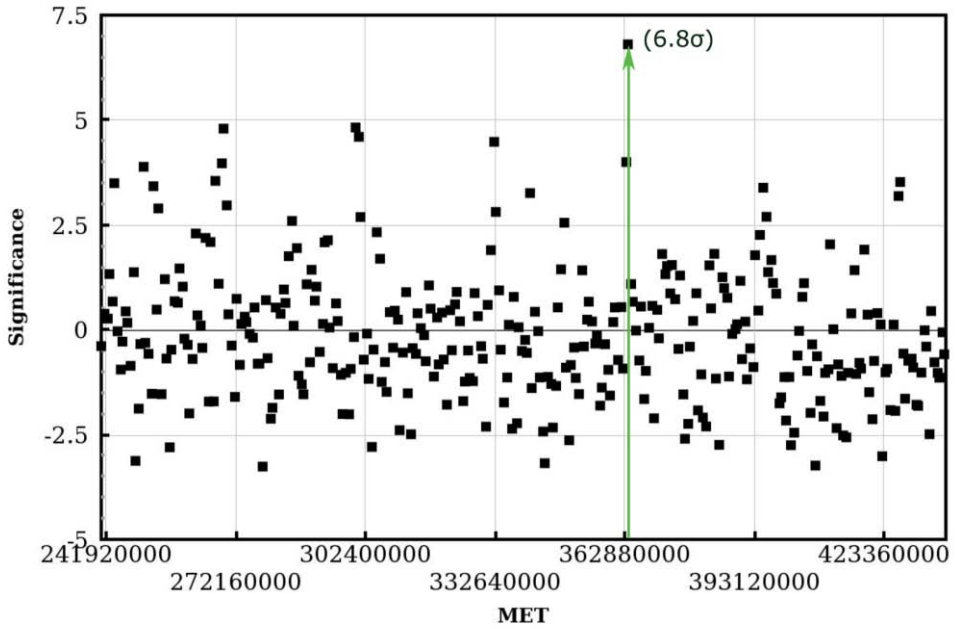

Fig. 4. Gamma-ray LC, at the coordinates of NQ Gem. The green vertical arrow marks the occurrence of highest flares with maximum variation = 6.80σ at MET=363843818 (JD: 2456121.65).

The whole period of monitoring is chosen automatically by the light curve generator and it reaches approximately 10 years of observations. Fig. 4 presents only part of this period, where the highest σ value is detected. The input time format for the light curve generator is MET (Mission Elapsed Time) - Fermi seconds since 2001.0 UTC (decimal). The corresponding dates in JD (Julian Date) are calculated as: T_1 = MET: 241920000 (JD: 2454710.49) to Tf = MET: 438480000 (JD: 2456985.49).

The gamma light curve shows the maximum value of sigma is 6.80**σ**. It appears at MET: 363843818 (JD: 2456121.65)

Discussion and conclusion

We have traced out the behavior and brightness variability of symbiotic irregular binary star NQ Gem. In this aim the light curves and energy spectrum are constructed, by applying data and by use of three online databases: AAVSO, Swift – XRT, FAVA.

The variability in stars exhibits in many ways. As an example: they could pulsate by internal forces; they could be binaries that eclipse each other; or due to the mass transfer processes in contact binaries.

We could not find any periodicity in the magnitude variations of NQ Gem and correspondingly its brightness in the selected periods, according to the AAVSO data observations. If the light changes in the time period of Figure 2, the variations are probably related to the orbital period. They could be also caused by some eclipses or fluctuations in the accretion rate, or appearance of a dense formation, which is moving and interacting with the surrounding flow. If the light curve variations are related to the pulsation periods, then the stellar pulsations are with a different amplitude, related to the results. As a symbiotic binary, NQ Gem is an intrinsic variable star and the most probable source of its variability is coming from the physical changes in the stellar system.

We have detected two main periods of activity in the X-ray light curve and the corresponding energy spectrum of NQ Gem, received by Swift – XRT observations. The dates with highest values of the normalized flux don't coincide with those of maximum flare detected by FAVA. This could lead us to the particular conclusion that there isn't any similarity in the detected activity in BVRI, Vis, X-Ray or gamma - rays.

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