

PHOTOMETRIC OBSERVATIONS OF SYMBIOTIC STAR AG PEG

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In the article, using the AAVSO (American Association of Variable Star Observers) photometric database of the AG Pegasi symbiotic star, a light curve was constructed in the Vis filter for a period of 68 (1954-2022) years. During this period, the brightness of the Ag Peg star changed by approximately 2 magnitudes, reaching from 7.5^m to 9.5^m. Using the Scargle method, the possible periodicities in the light curve were investigated by applying statistical spectral Fourier analysis. Two P=17857^d long and P=815^d short periodic variations were detected in the light curve.

Keywords: Symbiotic star; AG Peg; Photometric variable; Light curve; Photometry; Period; Observation

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1. INTRODUCTION

Symbiotic stars are interacting binary systems surrounded by cover. They consist of an advanced Red Giant and a hot component – White Dwarf. The material source of the cloud is Red Giant, which loses its substance by stellar wind and pulsation, and the energy source is the hot White Dwarf. Red Giants are stars that have reached the necessary temperature for helium fusion in their cores. White Dwarfs, on the other hand, are stars nearing the end of their life cycle and are highly compressed. These stars are so dense that, despite having nearly the same mass as the Sun, their size is comparable to that of Earth. [1, 2, 3, 4].

AG Pegasi (HD 207757, BD +11°4673) is a symbiotic star which is situated in the constellation Pegasus. This star is a dense binary system consisting of a red giant and a white dwarf [5]. The entire system is surrounded by a gas-dust nebula. The orbital period of the star is assumed to be ~818 days [1, 6]. The mass of the red giant: $M_g=2.6M_\odot$, the mass of the white dwarf: $M_d=0.6M_\odot$, the ratio of the masses of the components $M_g/M_d = 4.33$. Kenyon et al. (1993) estimated a distance of 800 pc to AG Peg from the calibration of absolute bolometric magnitudes, assuming the M3 giant has a luminosity class III [7]. In 1967-1972, work was published by Boyarchuk et al. and by Hutchings et al. The spectroscopic studies have been interpreted as corresponding to a binary whose components can be approximated as an WN 6 and an M3 III, with a period of around 800 days [8, 9].

AG Peg belongs to the symbiotic new group. Currently, only 8 nova-like symbiotic stars are known. When stars ignite, the representatives of this class reach very high brightness and remain in this state for tens, sometimes hundreds of years. The strong shock waves that occur during ignition heat the surrounding plasma to 10⁶ K and serve as a source of emission lines at various degrees of ionization [10]. In the spectrum of the star, coronal lines such as FeX, FeXI, [NiXV] are observed as well as [NII], [OII], and lines with low excitation potential, such as the Balmer series of hydrogen. AG Peg can confidently be an example of "symbiotic new".

Symbiotic stars can show 'classical' outbursts lasting weeks to years where they brighten by ~1–3 mag [11, 12]. AG Peg has been studying since the middle of the 19th century. The fact that the AG Peg symbiotic star is bright enough ($V \approx 8.5^m$) allowed it to be well studied both photometrically and spectrally. Allen, who analyzed the light curve starting in the 1850s, called the AG Peg star a symbiotic nova. Burning in the star began in 1850. Then its star size increased from 9^m to 6^m. It reached its maximum luminosity of ~ 6^m in about 1885. Later, the gradual decrease in the star's brightness, to the level observed before ignition, continued for about 130 years [13]. Second-best, AG Peg continued to weaken until 2000 and showed variations in the V filter in the stellar size interval 8.5^m ÷ 9.0^m by June 2015. Along with other spectrophotometric parameters, this evolution of the light curve (LC-light curve) is characteristic of the slowest nova ever recorded [10, 11].

Despite the well-studied AG Peg symbiotic star, the daily acquisition of new observational data and new approaches allows for obtaining more reliable results about the star, as well as refining previously obtained values of the star's parameters.

The main purpose of our work is to investigate the periodic changes in the light curve of the symbiotic star AG Peg. For this, using the AAVSO photometric database, the light curve of the AG Peg symbiotic star was constructed in

the Vis filter over 68 years, and possible periodic variations in luminosity were investigated using Fourier analysis. Photometric observations of the AG Peg symbiotic star were taken from the AAVSO (American Association of Variable Star Observers) database [14].

2. RESEARCH METHOD

We constructed a light curve in the Vis filter for a period of 68 years based on the AAVSO database of the AG Peg nova-like symbiotic star (Figure 1) [14].

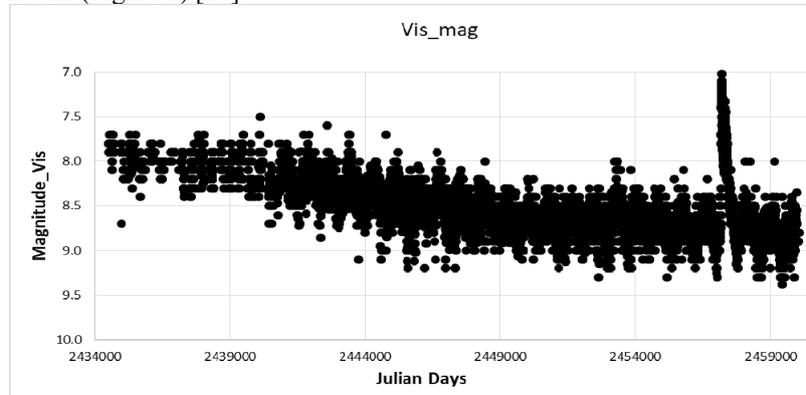


Figure 1. The light curve of the symbiotic star AG Peg for the period 1954-2022. Each point in the figure is the average value of measurements for one day

As can be seen from the picture, the brightness of the star was 8^m stars in the years 1954-1970. After 1970, the star's brightness gradually decreased. The star AG Peg had one strong flare in 2015 (between 2457050 and 2457400 Julian date). At this time, the magnitude of the star increased from 8.7^m to 6.9^m. That is, it has changed by 1.8^m stars. In the rest of the time, as can be seen from the light curve of the star, small modulations, i.e., changes, happened in the star in the interval of 1^m star size. Currently, the magnitude of the star is 8.5^m.

We have divided the light curve in Figure 1 into two parts to better illustrate the periodic variations in the symbiotic star AG Peg. The first part covers the period 1954-1990, and the second part covers the period 1990-2022 (Figure 2) [14]. From Figure 2, certain periodic changes are visible in the light curve.

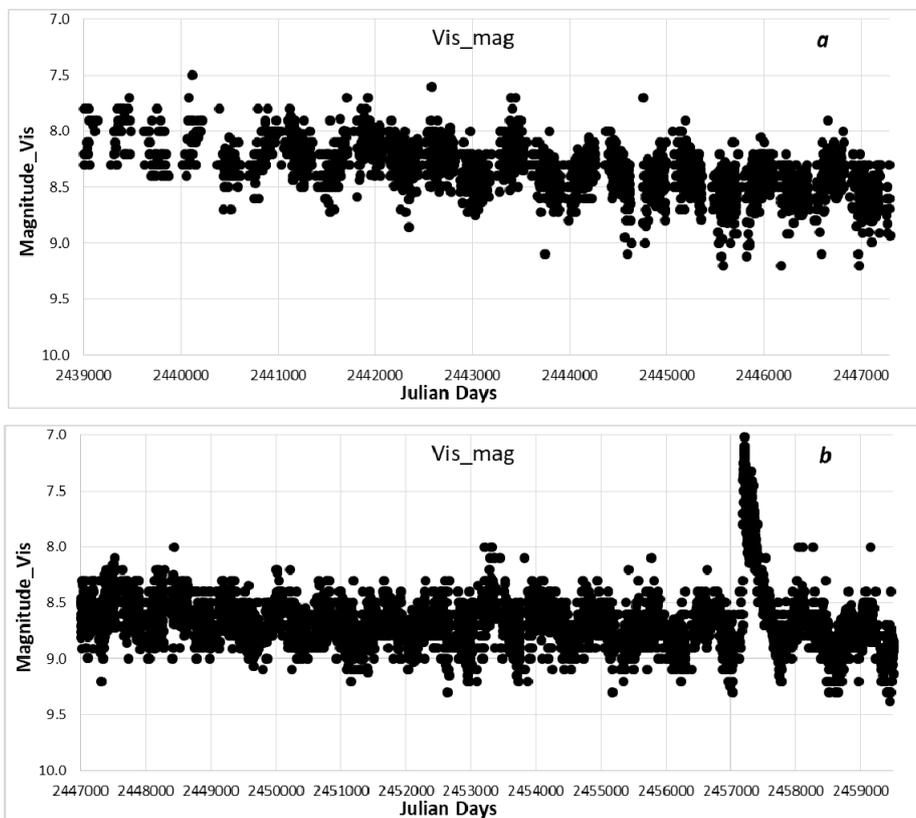


Figure 2. Age of the symbiotic star AG Peg 1954-2022 based on AAVSO datalight curve for the period a) 1954-1990; b) 1990-2022

In figure 3, we have plotted the light curve for the JD 2440000-JD 2460000 interval. The time interval is taken as 10 days. On the flipside, each point is the average value of 10 days of measurements [15]. As can be seen from the picture, in this case, period-periodic changes in the brightness of the star are better seen.

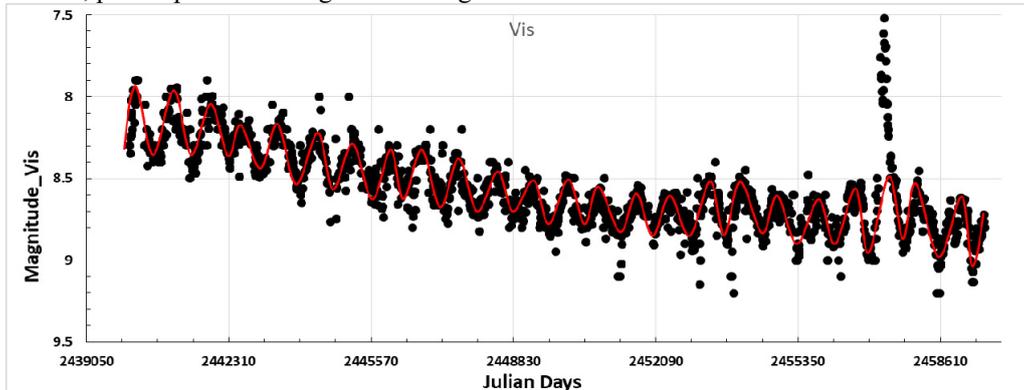


Figure 3. The light curve of the star AG Peg for 1968-2022 (JD 2440000-2459000). Each point in the figure is the average value of 10 days of measurements.

As you can see from the figure, periodic changes are thorough seen during quiet periods. The wrinkled curve shown in red corresponds to a period of about 815 days. This curve fits very well on the points.

Fourier analysis was performed using Scargle software to find the period [16]. Classic Scargle can only work on Norton. We used the version developed by Kh. Mikailov and H. Mikailov for Windows [15]. The sequence of finding the period is as follows: 1. We add the file about the size of the star depending on time to the program. 2. Click the calculate button. 3. We enter the maximum frequency and step. 4. We consider the trend.

Figure 4 shows the power spectrum for the period 1994-2005.

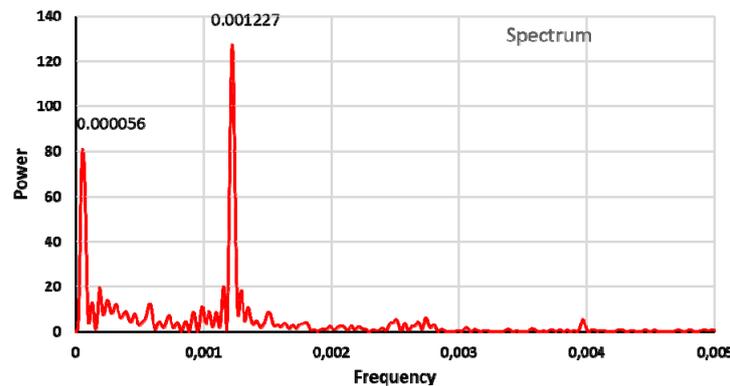


Figure 4. Power spectrum for the selected interval JD 2449400-JD2453400 (1994-2005).

As it is shown in the figure, there are two maxima in the power spectrum: **0.000056** and **0.001227**. Knowing that the period is inversely proportional to the frequency, we get the subsequent values of the period: **1.** Short period $P=814.99$ days, **2.** Long period $P=17857.148$ days. As you can see, mainly 2 periods are taken.

A phase diagram for the light curve of the symbiotic star AG Peg in the selected interval (1968-2012, and for the Julian date range $2440014 \div 2455953$, i.e. for a period of 44 years) was constructed (Figure 5).

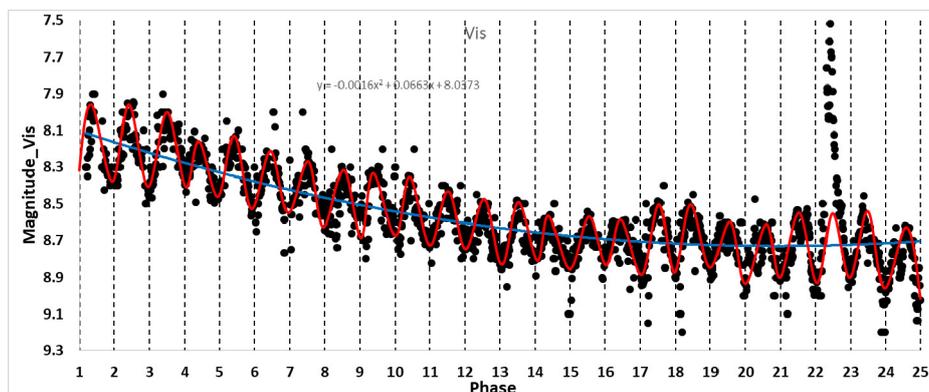


Figure 5. Phase diagram for the 44-year period 1968-2012. The phase diagram spans 25 full cycles. Each period is 814.99 days.

We have drawn the trend curve for the selected time interval. The function of the curve:

$$y = -0.0016x^2 + 0.0663x + 8.0373$$

Using this function, the deviation value of the Vis star size from the mean (O-C, Observed-Calculated) for each time was calculated. On the flipside, the value in the trend curve for that time was subtracted from each value of the star size of the AG Peg (figure 6).

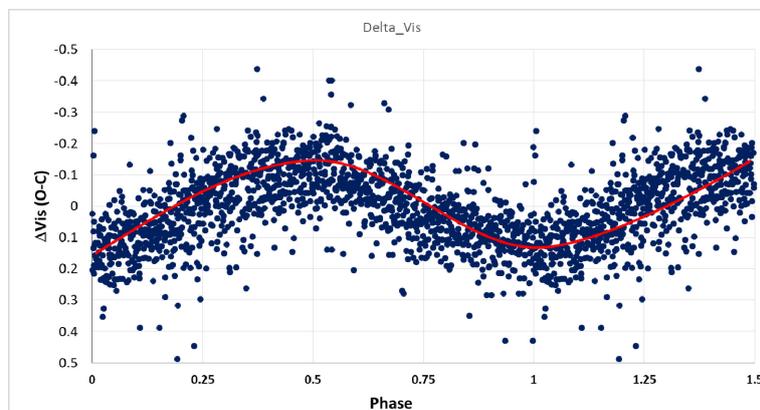


Figure 6. Total phase diagram of the Vis star size of the symbiotic star AG Peg

As shown in the figure, the points for the 44-year period fit the phase diagram very well. Thus, we assume that the Vis stellar magnitude of the AG Peg symbiotic star varies with a period of $P = 814.99^d$. Epoch start $T_0 = 2439050$. The minimum phase is calculated as: $\text{Min} = \text{JD}2439050 + 814.99E$.

3. CONCLUSIONS

A light curve of the symbiotic star AG Peg has been constructed for a period of 68 years (1954-2022). The long-term light curve of AG Peg shows two types of optical variability. One of them is a large-amplitude change, and the second is regular periodic modulations. Modulations with small amplitude are better seen in the interval 1968-2012. Using Fourier analysis, the problem of finding periods in the light curve of a star was considered. 2 periodic changes were found in the light curve: 1. $P=17857.148$ days for a long period. 2. For a short period, $P=814.99$ days.

It is believed that the short period is related to the binary system's orbital motion. That is, it is connected to the orbital motion of this system around the common center of mass of the red giant and the white dwarf. The long period can be revealed by the accretion (i.e., collection) of material lost by the red giant through its stellar wind onto the white dwarf.

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ФОТОМЕТРИЧНІ СПОСТЕРЕЖЕННЯ СИМБІОТИЧНОЇ ЗІРКИ AG PEG

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У статті, використовуючи фотометричну базу даних AAVSO (Американської асоціації спостерігачів змінних зірок) симбіотичної зірки AG Pegasi, у фільтрі Vis було побудовано криву блиску за період 68 (1954-2022) років. Протягом цього періоду яскравість зірки Ag Peg змінилася приблизно на 2 зоряні величини, досягнувши від 7.5^m до 9.5^m. За допомогою методу Скаргла було досліджено можливі значення періодичних змін кривої блиску шляхом застосування статистичного спектрального Фур'є-аналізу. На кривій блиску було виявлено дві періодичні варіації тривалістю P=17857 днів та короткочасну варіацію P=815 днів.

Ключові слова: симбіотична зірка; AG Peg; фотометрична змінна; крива блиску; фотометрія; період; спостереження