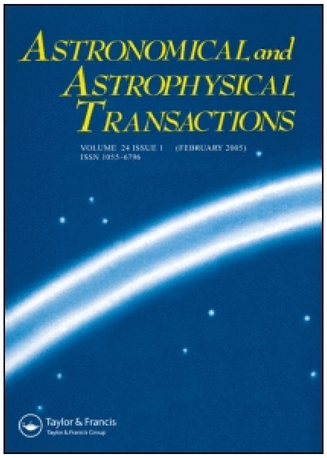

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Search for the periodicity in brightness and radial velocity variations of the runaway star HD 218915

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An analysis of the variations in the brightness and radial velocity of the high-velocity (runaway) star HD 218915 based on the author's ground-based Crimean observations and from Hipparcos data is presented. The analysis leads to the conclusion that there is a periodic component in the brightness and radial velocity variations of HD 218915. The period is estimated to be about 0.89 days.

Keywords: Runaway stars; Photometry; Radial velocity

1. Introduction

Most recent investigations have shown that about 10–30% of O stars and 5–10% of B stars have high spatial velocities, i.e. they belong to the so-called runaway stars. Objects of this class differ from ordinary O and B stars in a number of specific features, namely the high peculiar spatial velocities (up to hundreds of kilometres per second), the distance from the Galactic plane (tens or hundreds of parsecs), the chemical composition which is unusual for OB stars, the helium abundance in the atmosphere, the presence near to a star of 'bow shocks', the variations in the radial velocity and brightness variability related to the binary object, and others.

In order to explain the origins of this class of objects, two hypotheses or scenarios have been put forward. The first connects the runaway phenomenon among the early spectral class stars to a supernova explosion in a close binary system [1, 2]. Calculations show that such systems as a rule do not become disrupted by the explosion but acquire a high peculiar space velocity, i.e. this scenario means that the runaway stars are binary systems composed of a normal star and a relativistic satellite. However, single stars shot out of a binary system by a highly asymmetric supernova explosion may acquire a high spatial velocity as well. According to the second scenario [3, 4], the high velocities are the result of the dynamic interaction of binary

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and multiple stars in the centre of young star clusters. Single, binary and even multiple stars may be expelled from their parent cluster, because the most violent collisions occur between two massive binaries, producing in most cases binary and multiple runaway stars.

Both scenarios attribute the elevation of the runaway stars over the Galactic plane to their kinematic age. Other peculiar properties of this class of objects too find a sensible explanation in both scenarios. For a long time the two scenarios were looked at as alternatives. The advocates of one or the other used to put forward forcible arguments in support of the corresponding scenario. However, the newest astrophysical data allow us to state that both scenarios of the origin of OB runaway stars describe processes that really occur in the Universe [5]. So, currently, one of the main tasks is to verify which of the processes rules the birth of a particular runaway. To do this, intensive detailed observations are necessary.

In this paper, we analyse the brightness variations of HD 218915 (HIP 114704) on the basis of the new observations conducted by the present author at the Crimean Labortory combined with data from *The Hipparcos Catalogue* [6]. HD 218915 (O9.5 Iab, with a V magnitude of 7.2) is a well-known runaway star. Its peculiar space velocity $V_{\rm p}$ is $78.5\,{\rm km\,s^{-1}}$ [7]. Its elevation over the Galactic plane, which is believed to be the star's birthplace, is rather high, $z = -494$ pc [8]. If so, the star's kinematic age is $\tau = 6.0 \times 10^6$ years [7]. The star's mass is estimated to be $M = 45M_{\odot}$, its radius $R = 26R_{\odot}$, its luminosity $\log(L/L_{\odot}) = 5.62$ and the effective temperature $T_{\rm eff} = 30.0\,{\rm kK}$. The asymptotic velocity of the stellar wind reaches a value of $V_{\infty} = 2400\,{\rm km\,s^{-1}}$, and the mass loss rate is fairly high: $\log[\dot{M}(M_{\odot}\,{\rm year^{-1}})] = -5.94$ [9]. The star's distance is $d = 3530$ pc [7] from the Sun and $R = 11320$ pc from the Galaxy centre [10]. HD 218915 is considered to be a single star [11], although its radial velocity is known to vary with an amplitude of about $20\,{\rm km\,s^{-1}}$ [12]. Its rotational velocity is given by $V \sin i = 110\,{\rm km\,s^{-1}}$ [13]. Because of the unique localization of HD 218915 behind the gas associated with the Perseus arm, it may be used to probe the spiral matter up to approximately 300 pc away from the plane of the Perseus spiral arm along the line of sight. Consequently, HD 218915 is a doubly interesting and important target for a more sophisticated investigation.

2. Observations

Photometric observations of HD 218915 have been conducted since August 2000 up to August 2005 with the 60 cm reflector at the Crimean Laboratory of the Sternberg Astronomical Institute using an electrophotometer with a photon counter. HD 236068 (B9, with a V magnitude of 8.77) was used as the standard star. Each observational night, no fewer than three individual estimates of the star's brightness were made. A total of 93 brightness measurements in each of bands B, V and R were performed on 31 observational nights. To increase the accuracy of the light curves, all the one-night measurements were averaged for each band.

3. Brightness variability analysis

All the observational data were analysed using Scargle's [14] method as modified by Horne and Baliunas [15]. Of all the most pronounced peaks, the peak corresponding to the period $P \approx 0.89$ days seems to be the most interesting and important. The interesting fact is that the dominant peak appears at the frequency corresponding to the same period in periodograms constructed on the basis of absolutely independent space- and ground-based observations. To highlight this fact, we present here separately periodograms and light curves constructed from both types of datum. Figure 1 shows the periodogram derived from the Hp data from

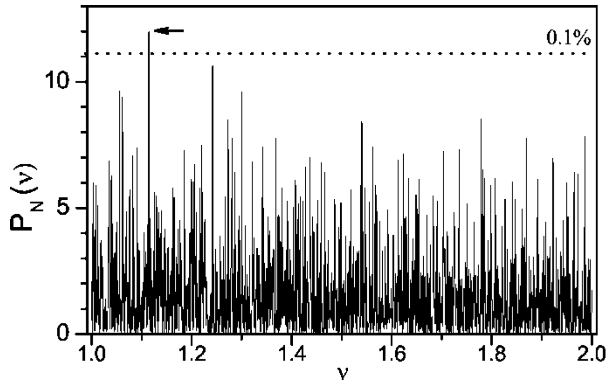

Figure 1. Periodogram (obtained using Scargle's method) of the Hipparcos *Hp* data. The highest peak is indicated by the arrow. The false alarm probability level 0.1% is marked.

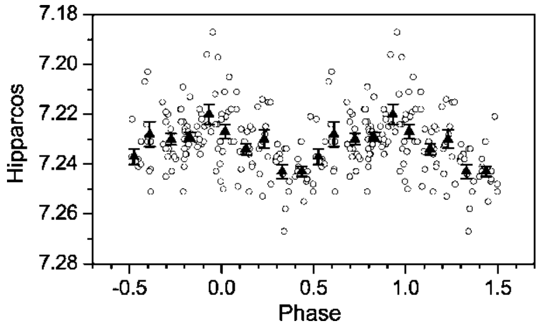

Figure 2. The Hipparcos light curve with elements of period $P = 0.897$ days: ▲, data averaging in bins of 0.1 cycles. The first data point JD 2447884.25158 of the Hipparcos observations was arbitrarily set to phase zero.

The Hipparcos Catalogue. The peak $P = 0.897$ days is very pronounced and its degree of reliability is rather high; the false alarm probability is 0.04%. Figure 2 shows the light curve drawn from the Hipparcos data points and computed with the period phase. Figure 3 shows the periodogram for the present author's Crimean observations in the *B* band. The arrow indicates the peak at the frequency that corresponds to the period $P = 0.899$ days. The low-order variation in amplitude and relatively small number of points reduce the authenticity

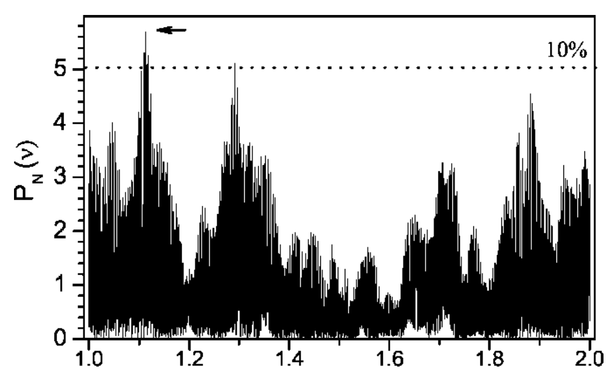

Figure 3. Periodogram (obtained using Scargle's method) of the present author's Crimean observations in the *B* band. The higest peak is indicated by the arrow. The false alarm probability level 10% is marked.

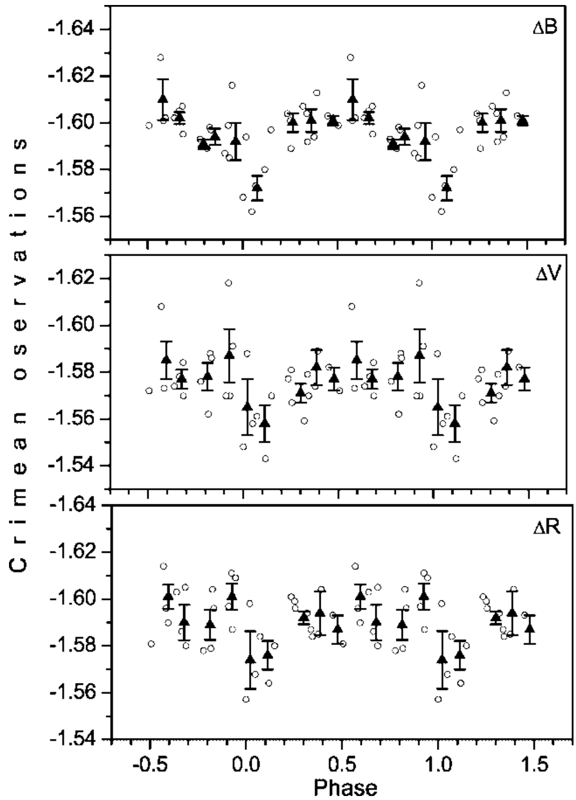

Figure 4. Crimean light curve with elements of period $P = 0.899$ days: ▲, data averaging in bins of 0.1 cycles. The first data point JD 2451766.508 of the Crimean observations was arbitrarily set to phase zero.

of the main peak to a false alarm probability of 6.2%, although figure 3 shows the obvious predominance of the peak over all the other peaks with a probability level not exceeding 90%. Figure 4 shows the *B–V–R* light curves for our observations.

The variation in the radial velocity from [12, 16, 17] was also analysed using Scargle's technique. One interesting result is that one of the most substantial peaks coincides with the peak derived from the photometric data analysis. Figure 5 shows the periodogram for the joint sequence of the observed radial velocities. The second most important peak (indicated by the

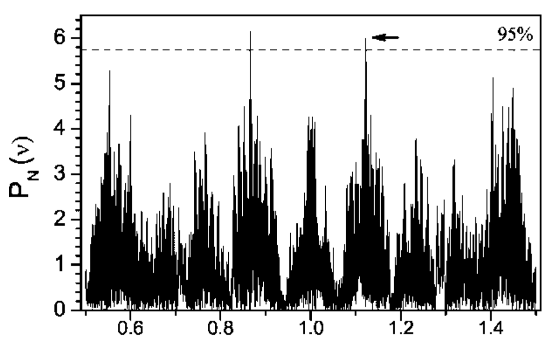

Figure 5. Periodogram (obtained using Scargle's method) of the joint sequence of the observed radial velocities. The second most important peak is marked by the arrow. The probability level 95% is marked.

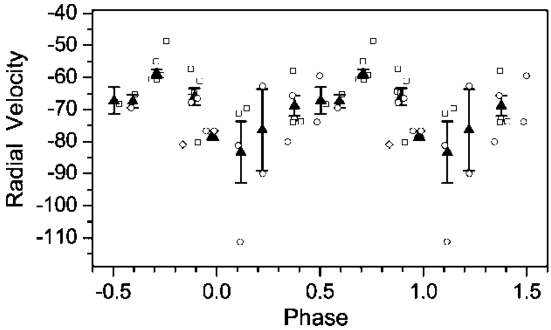

Figure 6. The combined radial velocity curve with elements of period $P = 0.8909$ days: □, observations from [12]; ○, observations from [16]; ◇, observations from [17]; ▲, data averaging in bins of 0.1 cycles. The only data point JD 2440074.866 from observations reported in [17] was arbitrarily set to phase zero.

arrow) is clearly pronounced at the frequency corresponding to the period $P = 0.8909$ days with a probability level of 100 – false alarm probability = 96%. The joint radial velocity curve convoluted with the obtained period phase is shown in figure 6.

Underhill [18] has pointed out that, very probably, almost all the bright supergiants would be proved to vary in brightness and/or colour, and/or radial velocity. Further research confirmed that statement, connecting the variation with changes in the supergiant atmosphere occurring on different timescales, from subdiurnal to several years. The detected variations in brightness and radial velocity are most probably due to changes in the atmosphere of the supergiant HD 218915. Any relation of such fast variations (1 day) to the possible binary nature of the star is hardly credible. The fact that HD 218915 could be a binary with a period $P = 9$ days was suspected on the basis of 13 radial velocity measurements [16]. We have analysed 31 radial velocity data points, including the 13 mentioned above. The expanded data series does not confirm the period of 9 days. So the hypothesis that the star is a binary suggested in [16] becomes doubtful.

4. Conclusions

In this paper, the variability of HD 218915 was explored for the first time on the basis of a prolonged time series of photometric data points. Our results may be looked at as the first step towards a deeper investigation of the star, first of all, because of the rather poor amount of observational material. Even the data from *The Hipparcos Catalogue*, representative as it might look (145 data points), has really been collected during 37 calendar dates spread over many years. The data on radial velocities are inhomogeneous. In [12], for instance, the radial velocities were computed by averaging V_r over different numbers of lines (from eight to 14). In [16], on the contrary, the mean values were obtained for each spectrum by averaging over exactly eight lines. In spite of the fact that the star does not show any substantial Balmer velocity progress, the V_r average value may be considerably shifted (affected) by including or excluding even one single extra line. In fact, according to [12], the mean radial velocity calculated over the line H9 equals –76.8 km s^{-1}, while averaging over Hδ yields a value of –36.6 km s^{-1}, which is comparable with the amplitude of the radial velocity variation.

All this leads to the conclusion that extensive observations of HD 218915 should be continued; the available data are not sufficient. Unfortunately, the star as a rule used to interest the observers not in itself but as a standard or as a probe for the interstellar medium. The search for the possible compact component of this runaway on a highly eccentric long-period orbit would also be interesting and promising.

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