АСТРОФИЗИКА

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ON THE DUPLICITY OF COOL GIANT AND SUPERGIANT VARIABLE STARS

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From the analysis of photometric, colorimetric and polarimetric data it follows that high luminosity red variable stars are divided into two groups: group I - double stars with brightness variation periods more than 480 days, group II - single stars with period less than 480 days. Moreover, double stars possess: a) high coefficients of correlation between brightness *V* and *U-B; B-V* colours. b) relatively low values of *U-B* ($< 1^m.5$) and high infrared excess. c) strong variations of parameters of polarization ($\overline{S}_{P,\theta} > 1.5$) and often those are associated with maser sources.

1. *Introduction.* The variations of stellar polarization with time were first discovered in 1958 in Byurakan by Grigorian [1] for the red supergiant star μ Cep. The intrinsic polarization was discovered during observations of T Tau, RY Tau in 1964 by Vardanian [2]. A variable intrinsic polarization of T Tau type stars [2] and a dozen of red giants and supergiants was discovered in 1965 - 1985 by Vardanian [3-4] and Abrahamian [5-6].

For the stars with intrinsic polarization we have found a dependence of the degree of polarization on the variability of brightness and the spectral range [3,4].

These polarimetric, photometric and statistical investigations allowed us to find a criterrium of duplicity of cool giant and supergiant variable stars.

2. *Some polarimetric and photometric peculiarities of high luminosity red variable stars.* The analysis of observational data of red variables shows that:

a) About 10% of them possess of high degree of intrinsic light polarization (P>1.5%) and many of them exhibit variations of polarization parameters (p,θ).

b) With the decreasing of the brightness and wavelength the percentage of the intrinsic polarization increases.

c) The percentage of stars which are associated with maser sources and exhibit intrinsic light polarization increases when the period of light variations are larger or the spectral class of stars is later.

d) Most of them shows infrared excess: $I\text{-}K>0.65K+4.0$; $V\text{-}K>5.^{m}0$, when $I\text{-}K$ increases the polarization degree increases as well up to 5-6%.

e) For most of the stars, with periods greater than 400 days and exibiting a high polarization, the period is a decreasing function of time.

f) The intrinsic polarization of cool variable stars is caused by the scattering of light by solid particles in the atmospheres or in the envelopes of these stars.

Now we shall consider the relations between the degree of variability of polarization, position angle, brightness and colours of high luminosity red variable stars and parameters of duplicity.

3. *The identification of high luminosity double red variable stars from the character of brightness, colours and variations of parameters of polarization.* In Abrahamian's paper [6] the polarimetric and photometric data for 79 red variable supergiant stars are given, namely, the values of variations of polarization parameters (S_p, S_θ), their dispersions (σ_p, σ_θ), coefficients of correlation between V magnitude and $(B\text{-}V)$ and $(U\text{-}B)$ colours [$r_v(B\text{-}V)$; $r_v(U\text{-}B)$], the errors of correlation coefficient are presented ($r_{0.05}$-for the absence of correlations [6]).

Using these data the mean values of $(U\text{-}B)$, relative coefficients of correlation $K=\left|r_v(B-V)/r_{0.05}\right|$; the dates S_p/σ_p, S_θ/σ_θ and their mean values $S_{p,\theta}=1/2(S_p/\sigma_p+S_\theta/\sigma_\theta)$ were calculated. These data are presented in Table 1.

We obtained the dependences of K parameter on $(U\text{-}B)$ colours as well as on the mean value $S_{p,\theta}$. One can see from Fig . 1, that the double stars are separated from single ones. Moreover the obtained results show that for the double stars $(U\text{-}B)<1^{m}.5$ and the value of the coefficient of relative correlation $K>1^{m}.5$ [7]. It means that for double stars a tight correlation between the variation of brightness (V) and colours $(U\text{-}B)$; $(B\text{-}V)$ exists.

The obtained small values of colours $(U\text{-}B)<1^{m}.5$ are due to a hot component of these binaries. The relation presented in Fig.1 shows that for double stars the mean value of variations of polarization parameters ($\overline{S}_{p,\theta}$) exceeds 1.5 and their periods are larger than 450 days. The last result allows to propose that the periods of light variations for double stars are longer than for single stars.

We see that most of high luminosity red variable stars, with periods more than 500 days, are double stars [8]. And on the other hand almost all stars with periods smaller than 400 days are single stars.

Table 1

SOME PHOTOMETRIC AND POLARIMETRIC PARAMETERS OF COOL SUPERGIANT VARIABLE STARS

Name of stars	$K = \lvert r_v(B-V) / r_{0.05} \rvert$	*U-B*	$\bar{S}_{P,\theta}$	Periods	Sp
KN Cas	1.69	0.50	1.29	-	M1EPIB+B2.6V
V466 Cas	1.95	2.29	1.41	-	M1.5IB
AZ Cas	2.23	0.56	2.50	3402	MOEIB+BO-B1V
EZ Per	1.13	2.44	0.83	184	M0.5IAB-M2OIAB
XX Per	2.10	1.31	2.33	415	M4IAB+B
KK Per	0.49	2.39	1.00	-	M1.0IAB-M3.5IAB
BU Per	1.62	2.57	1.33	367	M3.5IB
PR Per	0.66	2.6	1.33	-	M1IAB-IB
SU Per	0.21	2.08	0.83	533	M3.5IAB
RS Per	1.56	2.08	1.16	244.5	M4IAB
T Per	1.25	2.41	1.50	379	M2IAB
BD+58°445	1.10	2.57	1.00	-	K5.7IAB
BD+56°609	0.40	2.24	1.00	-	M3.1IAB
BD+29°897	0.44	2.45	0.84	-	M1.7IAB
NO Aur	1.50	2.18	1.00	-	M2.5IAB
TV Gem	1.71	1.70	1.00	-	K5.5-M1.3IAB
WY Gem	1.64	0.19	1.25	-	M2EPIAB+B2V-B3V
ψ Aur	1.18	2.26	1.40	-	K5-M0IAB-IB
Y Lyn	0.92	0.89	0.85	110	M6.5IAB-II
RS Cnc	0.46	1.03	-	120:	M6EIB-II(S)
YY Lyr	1.61	1.34	0.94	-	M4-5IAB-II
AZ Cyg	1.86	2.73	2.00	459	M2-4IAB
μ Cep	2.07	2.57	8.00	730	M2EIA
VV Cep	2.21	0.56	1.41	7430	M2EPIA-IAB+B8:EV
ST Cep	1.61	2.43	1.35	-	M2IA-IAB
U Lac	2.85	1.29	2.12	550-690	M4EPIAB+B
PZ Cas	2.70	0.91	2.50	925	M2-4IA

This evidence gives us a basis to conclude that luminous red variables are dievided into two groups:

I - the group of double stars with greater periods and II - the group of single stars with smaller periods.

To confirm this conclusion, we have analyzed the IRAS [9] data of objects belonging to the bulge of the Galaxy. Using the data given in [9] we worked out a histogram exhibiting the distribution of *H-K* colours of stars (mainely Mira stars). There are two maxima in this distribution: at $H-K = 0^m.75$, and the other at $H-K = 1^m.45$.

Minimum value is observed between the maxima at $H-K = 1^m.25$. (It is of interest to mention, that a similar maximum is observed also for red variable stars of the LMC at $H-K = 0^m.75$.)

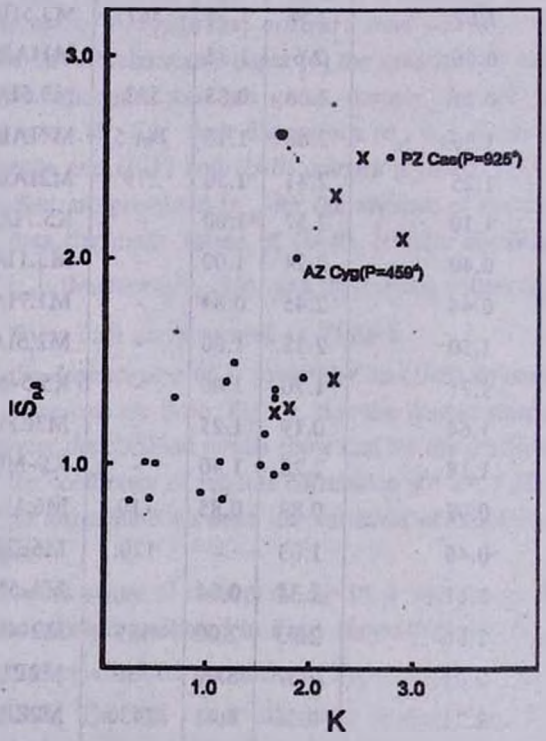

Fig. 1. Dependence of variation of polarization parameters from the K parameter x - double stars, • - single stars.

To determine the periods which have the red stars with $H-K = 1^m.25$ we considered another relation, namely, the relation between $H-K$ colours and amplitudes of brightenss variations of (ΔK) in the K spectral range [9]. For this analysis the stars with $K<5^m.0$ and with doubtful periods were not considered. The mentioned relation between K and $H-K$ shows that red variable stars with $H-K>1^m.2$ (≈80%) have periods larger than 480 days, and the overwhelming majority of stars (93%) with $H-K \leq 1.2^m$ have periods smaller than 480 days [7].

4. *Conclusion.* From the analysis of photometric, polarimetric and colorimetric data of high luminosity red variable stars follows that these stars are divided into two groups:

I group - stars with periods $P > 480^d$, colours $H-K>1^m.2$, variations of polarization parameters $S_{p,\theta} > 1.5$, and high coefficient of relative correlation $K>1^m.5$ are double, II group- stars with smaller periods $P < 480^d$, colours $H-K < 1^m.2$, and parameters $S_{p,\theta} < 1.5$, $K<1^m.5$ are single ones.

О ДВОЙСТВЕННОСТИ КРАСНЫХ ПЕРЕМЕННЫХ ЗВЕЗД ГИГАНТОВ И СВЕРХГИГАНТОВ

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Из анализа фотометрических, колориметрических и поляриметрических данных получено, что красные переменные звезды высокой светимости делятся на две группы: группа I-двойные звезды с периодами изменения блеска больше 480 дней: группа II-одиночные звезды с периодами меньше 480 дней. Более того, двойные звезды характеризуются: а) большими коэффициентами корреляции между изменениями блеска V и цветами $U-B$, $B-V$: б) относительно меньшими значениями цвета $U-B$ ($<1^m.5$): и большими инфракрасными избытками. в) сильными изменениями параметров поляризации ($\overline{S}_{p,\theta}>1.5$), притом они часто ассоциированы с мазерными источниками.

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