THE UNIQUE VARIABLE V725 SAGITTARII*

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Abstract

V725 Sagittarii is the only known variable star which has shown an important change in its period in an interval of a few years. Photographic observations of V725 Sgr began in 1889 and until 1926 it varied irregularly with a small amplitude, the maximum amplitude being 0.7 mag in 1898. In 1926 a regular pulsation began with a period of 12 days with an increase of one day per year until the period reached 21 days in 1935. During that decade the mean magnitude decreased by more than a magnitude. Photoelectric observations secured in 1968 and 1969 show that V725 Sgr is brighter than in 1935 and varies irregularly with an amplitude of 0.4 mag. The variation may have a period of about 45 to 50 days. An analysis of magnitude estimates over the last 70 years suggests that V725 Sgr is a single star, probably an RV Tauri or semi-regular variable.

Introduction. V725 Sagittarii, $\alpha = 18^h05^m$, $\delta = -36°07.'6$ (1900) was discovered to be variable by Miss H. H. Swope (1936). From measures of several plate series obtained by the Harvard southern telescopes Miss Swope was able to reconstruct the behaviour of this variable over 40 years. The variability of V725 Sgr from 1890 to 1935 can be summarized as follows: 1890–1900, more or less constant in brightness. 1900–1926, variations of nearly one magnitude in an irregular fashion were observed, although the observations are too few to establish a period. 1926, the variable exhibited a periodic variation with a period of 12 days. 1928–1935, the period increased by one day per year to reach 21 days in 1935. During this interval the amplitude reached nearly two magnitudes, while the mean brightness decreased by about one magnitude.

Since 1936 the star has shown small non-periodic light variations (Tzesevich 1964). During 1968 and 1969, the author, at that time resident astronomer at Cerro Tololo Observatory, monitored photoelectrically V725 Sgr to determine its present status and possibly to reveal new insight into the past performance of this unique variable.

Photoelectric Observations. V725 Sgr is a relatively faint reddish object V ~ 12.5, B ~ 13.7 and it is situated in a very crowded field of the Milky Way, $l = 356°$, $b = -8° 35'$ (new galactic coordinates). The field surrounding V725 Sgr is reproduced on figure 1, where the variable is identified by the two horizontal bars. Because of the nearby companion star, only 7″

*Based on observations made at Cerro Tololo Interamerican Observatory while the author was resident astronomer.

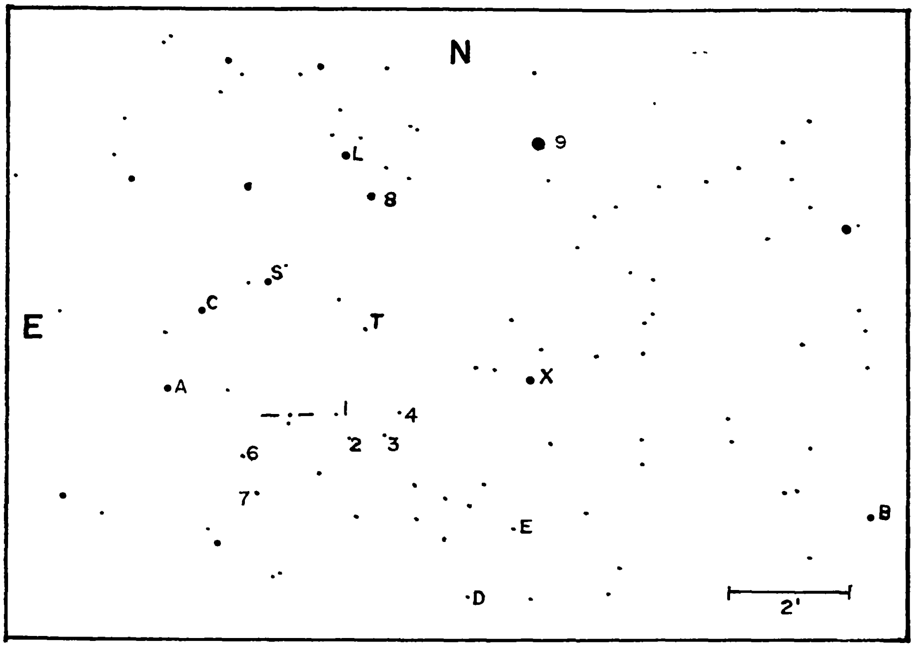

FIG. 1—Field of V725 Sgr, the variable is between the horizontal bars, and the companion is just south of it. 103aO without filter.

south of V725 Sgr it is preferable to use a telescope with a scale large enough to measure the variable alone and exclude the companion. All photoelectric measures reported in this article were done with the 36-inch or 60-inch telescopes on Cerro Tololo in Chile. Refrigerated 1P21's were used, with integration times of 10 or 20 seconds depending on the brightness of the objects. Extinction coefficients on each night were computed by iteration from the average extinction coefficients. V725 Sgr and a certain number of stars in its vicinity were often observed during regular photoelectric observations. On many nights only differential measures were obtained, relative to star 1. A typical observation would then consist of the following measures: V (star 1), V (V725), V (star 1), V (725), V (star 1). Table I lists the observations of V725 Sgr taken during the observing seasons of 1968 and 1969. The ΔV's are relative to star 1, $\Delta V = V$ (V725) $-$ V (star 1). When V725 Sgr and star 1 were observed independently the V (star 1) of that particular night is used to compute the ΔV. On a few nights the yellow magnitude of star 1 differed by a few hundredths of a magnitude from its adopted value of 12.235. On one occasion V725 Sgr was monitored continuously for three hours, and showed no variation larger than 0.02 mag from the mean value. All observations made during one night are therefore averaged. A typical entry in Table I represents the average of two observations. Table II gives magnitudes and colours of a few stars in a field surrounding V725 Sgr, these stars are identified in figure 1. The fifth column indicates the number of nights that each star was observed and compared with UBV standards.

TABLE I

PHOTOELECTRIC MEASURES OF V725 SGR

J.D. 2440000+	V	ΔV	B-V	U-B
6.85		0.31		
35.78		0.46	1.55	(1.56)
69.83	12.55	0.30	1.35	1.28
70.65	12.58	0.295	1.345	1.285
91.58	12.685	0.375	1.31	1.21
137.52	12.675	0.385	1.33	
138.54	12.56	0.35	1.375	1.24:
139.53	12.54	0.31	1.29	1.16
140.55	12.53	0.29	1.31	1.10
141.51	12.495	0.255	1.245	1.135
142.52			1.32	1.10
143.52	12.46	0.22		
148.52		0.31		
149.53	12.615	0.34	1.41	1.36
150.54	12.685	0.395	1.405	
164.51		0.46		
165.52		0.49		
166.52		0.46		
168.52		0.43		
169.52		0.45		
283.88	12.46	0.34	1.28	1.14
284.86		0.31	1.33	
286.86	12.44	0.34	1.315	1.15
287.87	12.49	0.34	1.34	1.18
292.88	12.50	0.28	1.30	1.12
294.88	12.42	0.22	1.305	1.16
302.89		0.22		
306.86		0.28		
307.86		0.27		
368.78	12.725	0.53	1.405	1.36
369.66	12.71	0.49	1.365	
370.77	12.68	0.44	1.38	
371.64	12.695	0.425	1.35	
401.56	12.33	0.17	1.26	
403.56	12.42	0.13	1.225	
434.70	12.49	0.22	1.31	
435.70	12.48	0.23	1.31	
439.70	12.54	0.31	1.28	1.13
441.99	12.47	0.32	1.38	

The last column gives the adopted photographic magnitudes of Swope. Figure 2 shows the ΔV's plotted as a function of the Julian Date. Table III presents the yearly averages of magnitudes and colours. V725 Sgr is brightening.

TABLE II

PHOTOELECTRIC MAGNITUDES AND COLOURS OF STARS IN THE FIELD OF V725 SGR

Star	V	B-V	U-B	n	Swope m_{pg}
1	12.235	1.623	1.56	26	
2	13.70	0.695	0.22	6	14.4
3	14.05	0.564	0.04	4	14.5
4	13.045	1.58	2.07	4	
6	14.42	0.81	0.36	1	
7	13.01	1.24	1.29	2	
8	10.835	0.15	0.07	6	
9*	9.375	−0.04	−0.17	14	
comp.	13.63	1.257	(1.16)	13	
A	12.20	0.37	0.03	2	12.2
B	12.71	0.38	0.12	5	12.8
C	13.03	0.47	0.05:	2	13.3
D	13.30	0.59	0.08	5	13.8
E	13.635	0.45	0.06:	6	14.0
L	10.75	1.05	0.94	5	
S	12.24	0.11	0.13:	3	
T	12.86	0.55	0.06:	5	
X	10.64	0.98	0.80:	8	

*9 = HD 166315 = CD −36°12311

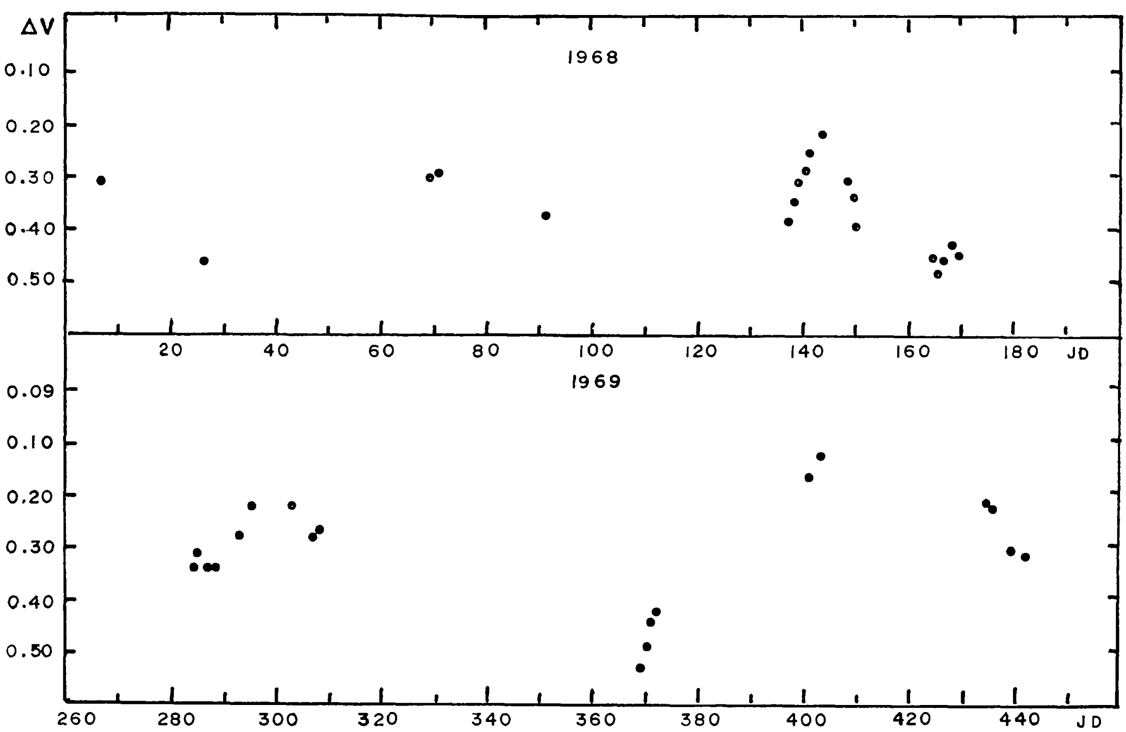

FIG. 2—Variation of brightness of V725 Sgr during 1968 and 1969. ΔV = V(725) − V(Star 1).

TABLE III

SUMMARY OF PHOTOELECTRIC OBSERVATIONS OF V725 SGR

Year	V	Average B-V	U-B	Amplitude V
1968	12.59	1.36	1.19	0.27
1969	12.52	1.32	1.18	0.40

Colour Excess of V725 Sgr. V725 Sgr is situated in the direction of the galactic centre. The interstellar absorption in this region is known to be non-uniform. Six globular clusters within 6 degrees of V725 Sgr have known colour excesses (van den Bergh 1967). Their E_{V-B} range from 0.17 to 0.68 magnitude, the average being 0.33 magnitude. The colours of stars in Table II can be used to estimate the colour excess of V725 Sgr. We can, in principle, determine the colour excess of a normal star from its observed (B−V) and (U−B) but without its spectral type we have to assume its luminosity class. We assume here that all stars are main sequence stars, unless their colours fall below the curve defined by main sequence stars on the U−B, B−V plane. In these cases we assume the stars are red giants. We use $E_{U-B} = 0.72\ E_{B-V}$ and $A_V = 3.0\ E_{B-V}$. These assumptions yield two solutions for the variation of E_{B-V} with distances. This is because the reddening line may intercept the locus of intrinsic colours more than once. For example, a star may be a slightly reddened F star or a heavily reddened B star. With only (U−B) and (B−V) we cannot estimate unambiguously the colour excess of all stars. Figure 3 shows the variation of the colour excess with distance in the direction of V725 Sgr. In the upper part we assume that stars are slightly reddened (solution 1) while in the lower graph we assume that stars are generally heavily reddened (solution 2). Solution 2 implies that along the line of sight we encounter heavily reddened B stars, up to distances of 2000 parsecs or more. These stars would be at least 300 parsecs above the plane of the Galaxy. At such distances Population II giants should predominate, hence for this reason solution 2 could be rejected.

The intrinsic colours of V725 Sgr may then be estimated from its observed (B−V) and (U−B), the averages of all colour observations. We assume that the absolute magnitude of V725 Sgr is $M_V \sim -2$, appropriate for a Population II giant. Table IV summarizes results of the two solutions. The intrinsic colours of V725 Sgr according to solution 1 and solution 2 are shown on a colour-colour diagram in figure 4. The line represents the locus of type Ib supergiants. Solution 2 yields colours much too blue and too violet. Solution 1, on the other hand, gives colours quite compatible with colours of RV Tauri stars (Preston *et al.* 1963). We adopt solution 1, keeping in mind that globular clusters in this area have an average colour excess of 0.33.

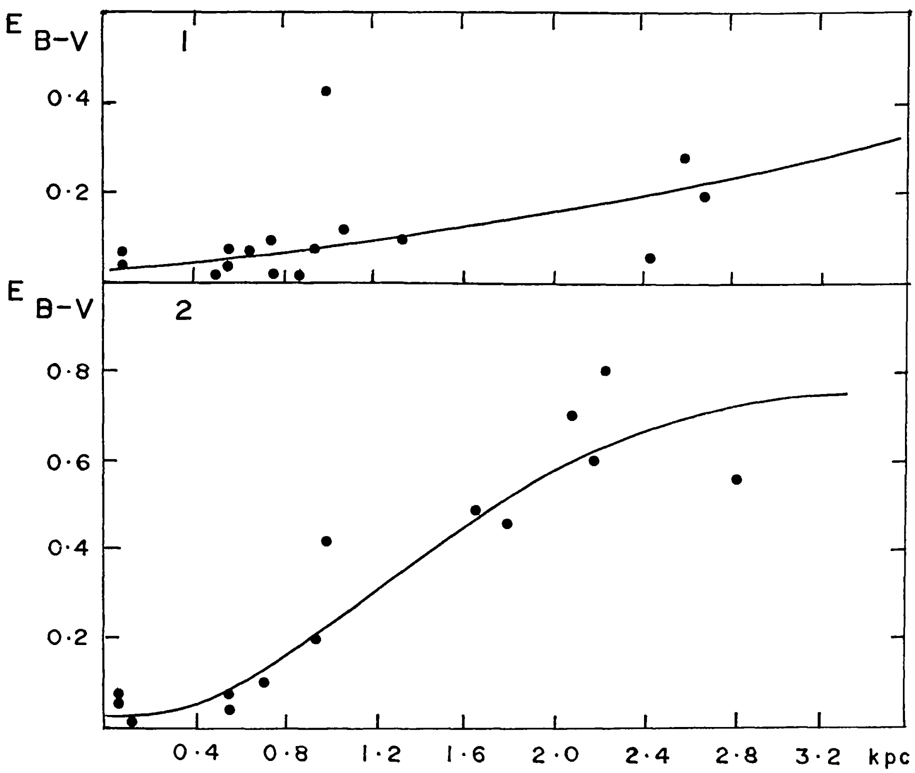

FIG. 3—Variation of the colour excess in the direction of V725 Sgr: 1 – Solution 1, 2 – Solution 2.

With $M_V = -2$ and $E_{B-V} = 0.3$, V725 Sgr would then be at a distance of 5.4 kpc, 800 parsecs above the plane of the Galaxy. By adopting $E_{B-V} = 0.3$, we assume that for a distance larger than 2.8 kpc the interstellar absorption remains essentially constant. This is a reasonable assumption, since at 2.8 kpc we are some 400 parsecs above the plane. If, on the other hand, we suppose that the colour excess continues to increase linearly, according to solution 1, well above the plane of the Galaxy, we find with $M_V = -2$ that V725 Sgr would be at a distance of 4.9 kpc and would have a colour excess of 0.42 mag. This value represents a maximum colour excess for V725 Sgr.

TABLE IV

COLOUR EXCESS OF V725 SGR

	E_{B-V}	$(B-V)_0$	$(U-B)_0$	Distance ($M_v = -2$)	z
Solution 1*	0.3	1.04	0.97	5.4 kpc	0.8 kpc
Solution 2	0.7	0.64	0.69	3.0 kpc	0.45 kpc

*Adopted

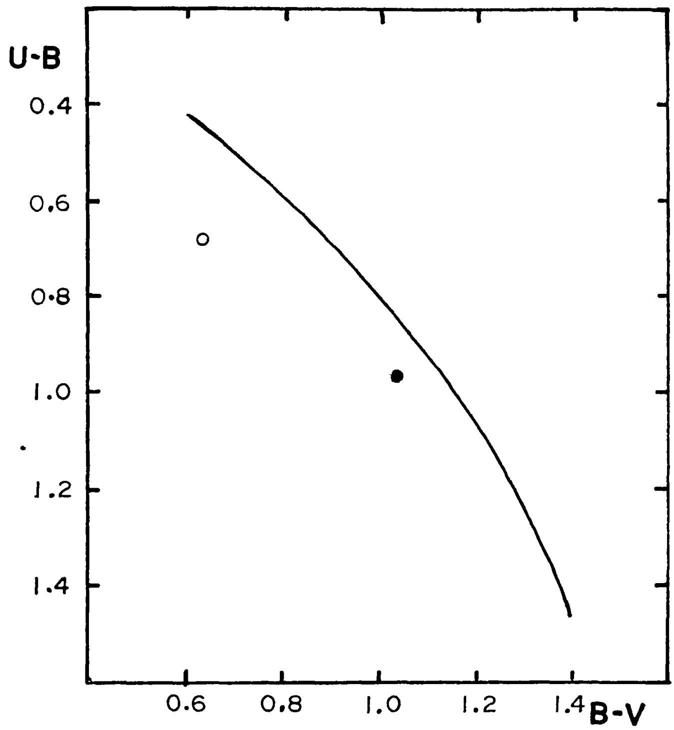

FIG. 4—Position of V725 Sgr on the colour-colour diagram: ● Solution 1, ○ Solution 2.

V725 Sgr must certainly be a Population II object, since its colours are similar to RV Tauri variables which are also Population II stars. No Population II Cepheids or RV Tauri stars have mean colours similar to the values given by solution 2. The possibility of a double star cannot be excluded at this time, but we shall see in the *Discussion* that it is improbable that V725 Sgr is a member of a binary system.

Search for Periodicity in 1968 and 1969. During the first few months of observations in 1968 it was believed that a period of 15.4 days could fit the observations (Demers 1968). With more observations it became apparent that this period could not be valid and that other periods must be tried. There are several published techniques for finding periodic variations in a variable star (Whittaker and Robinson 1944, Wehlau and Leung 1964, Lafler and Kinman 1965, Broglia and Guerrero 1972). But in our case we are somewhat limited in the choice of methods, this for two reasons, the small number of observations and the uneven distribution of the observations in time. We used first the method of Lafler and Kinman (1965) which requires the sum of the squares of the magnitude differences between observations of adjacent phases to be a minimum. In principle the period with the minimum sum is nearest to the true period. We tried one thousand periods between 10 and 100 days; for the 1969 observations we also tried periods between 1 and 10 days. We found periods which could fit the ΔV's but no conclusive results can be drawn. All the 1968 measures fit a period of 69.5 days; if we exclude the first five measures (see figure 2) periods of 36.5 and 48.7 days fit the 1968 data best. A period of 45.3 days give the best fit for the 1969 observations. For both years the light curves produced by the above periods are unusual and do not match known variables, except irregular or semi-regular variables. We feel that these periods may not represent the true behaviour of V725 Sgr for if we had, say, twice as many measures these periods might not hold. We tried also to explain the light variation by a superposition of two periods, i.e. by fitting Fourier series to the ΔV's. The best fit obtained for 1968 with 1969 data was with two periods of 44 and 20 days. The scatter around the computed light curve, however, was rather large, so we feel that two periods cannot satisfy the observations better than one period. We have not investigated the possible modulation of light curves of periods in the 45–50 day range, because the total amplitude is only 0.4 magnitude and another low variation superimposed on the light curve would have a much smaller amplitude and would be difficult to investigate. To summarize, we may say that V725 Sgr varies in a semi-periodic fashion with a dominant period between 45 and 50 days.

Past Behaviour of V725 Sgr. It would now be of interest to reanalyse the published observations of V725 Sgr. Seven of Miss Swope's standards were observed among the stars surrounding V725 Sgr. A transformation equation between Swope's m_{pg} and the B magnitude, for the seven standards yields:

$$B = 2.18 + 0.85\, m_{pg} \qquad (1)$$
$$\pm.20 \quad \pm.01$$

The range in colour of the seven stars is much too small to determine if a colour term is present or not. The plate scales of the Harvard series are usually very small, often not only was the companion measured with V725 Sgr but also certain stars in its immediate neighbourhood. For this reason, we shall use only magnitudes from series A, B, and MF (Swope 1936) where only the companion was measured with the variable. Since we know its magnitude (see Table II) we can correct the measured magnitudes to get B of V725 Sgr. In Table V we tabulate a summary of Miss Swope's measures. For each year of observation we give the mean B (half way between B_{max} and B_{min}) and note that in many years B_{mean} is the only observed magnitude. From 1926 to 1935 there are a sufficient number of observations to draw a light curve, hence for these years we tabulate B, the magnitude corresponding

TABLE V

PAST BEHAVIOUR OF 725 SGR

Year	B_{mean}	$B_{max.}$	$B_{min.}$	n	Period (days)
1889	13.61			3	
1890	13.60			1	
1891	13.79			1	
1893	13.54			3	
1894	13.55			2	
1895	13.43	13.21	13.66	5	
1896	13.48	13.20	13.76	9	
1897	13.45	13.10	13.80	13	
1898	13.44	13.20	13.60	4	
1899	13.33	13.18	13.48	10	
1900	13.41	13.30	13.52	8	
1901	13.27			4	
1902	13.32	13.13	13.50	8	
1903	13.19	13.08	13.50	5	
1904	13.04			1	
1905	13.47			1	
1907	13.09			3	
1908	13.10			3	
1909	12.99			2	
1911	13.09			1	
1912	13.09			1	
1914	12.91	12.85	13.09	6	
1916	12.95			3	
1917	12.99			3	
1919	13.02			4	
1920	13.05	12.89	13.21	5	
1921	13.09			3	
1924	13.15	13.12	13.20	5	
1925	13.28			3	
1926	13.30*	13.15	13.48	17	12
1928	13.32*	12.72	15.00	11	14
1929	13.56*	13.00	14.64	10	15
1930	13.63*	12.96	15.00	91	16
1931	13.7*	13.10	15.5	42	17.2
1932	13.82	13.42	14.23	6	18.4
1933	13.72*	13.00	15.05	22	19
1934	13.92*	13.30	15.24	30	20
1935	13.92*	13.30	14.60	35	21
1936–49	14.2				
1956	14.02	13.95	14.10	27	
1959	14.02	13.93	14.10	15	

*B magnitude corresponding to mean intensity of light curve

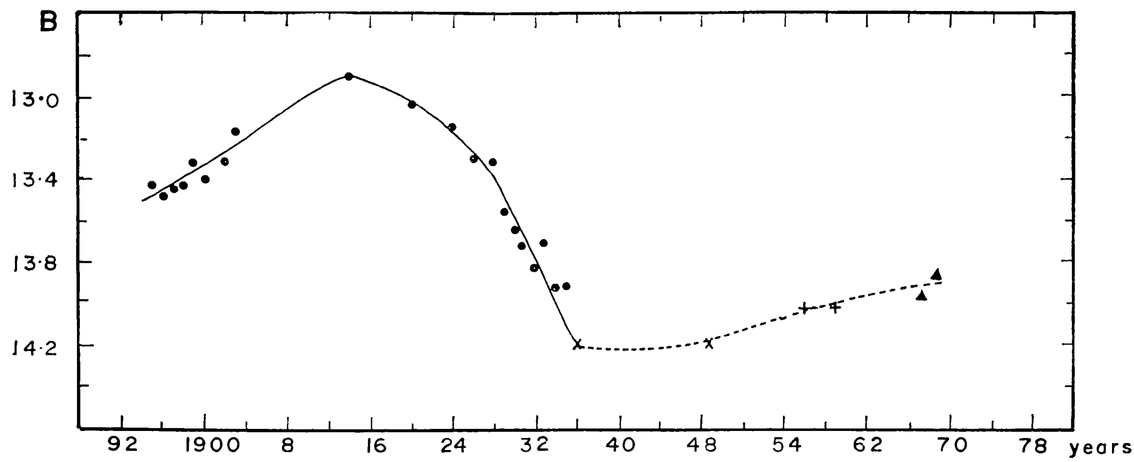

FIG. 5—V725 Sgr, variation of yearly mean B: dots, Swope's measures, x's Tzesevich's estimates, crosses, Plaut's estimates, triangles average of photoelectric measures.

to mean intensity. Miss Swope's periods were checked and found satisfactory. No periods quite different from hers can represent the observations and we must then conclude that these periods are real.

Tzesevich (1964) examined plates of the MF series taken between 1936 and 1949 and concluded that V725 Sgr was always faint and showed little variation; the average magnitude was $M_{pg} = 14.1 \pm 0.15$. A correction for the companion measured with the variable and transformation into the B system yield B = 14.2. The author is aware of only one other series of magnitude estimates done during the 1949–1968 period. In 1956 and 1959 L. Plaut, (Swope, private communication) took a total of forty-one 48-inch Schmidt plates of V725 Sgr. During these two years the amplitude of V725 Sgr was not larger than 0.15 mag. The average B magnitude was 14.02, assuming that the companion was not measured with the variable. Figure 5 presents the variation of the mean B magnitude from year to year from 1896 until 1969. We note that the peculiar phase, when V725 Sgr started to vary periodically occurred a few years after the star reached maximum brightness. During this unusual period its amplitude reached a maximum of nearly two magnitudes while its mean brightness decreased rapidly by one magnitude. Figure 5 suggests that V725 Sgr is brightening at the present time. It is interesting to note that if we assume that the period of V725 Sgr has been increasing at the same rate since 1935 that it did just prior to 1935, i.e. about 1 day per year, then its period in 1968–1969 should be of the order of 55 days. Our data fit best a period of 48 days, not too far from the expected period. We tried to fit a period to Plaut's 1956 measures using the method of Lafler and Kinman (1965) as used for our photoelectric observations. A period near 40 days fits the observations, but since the observations of 1956 extend over only 60 days it is difficult to say if this period is real or not. It fits rather well in the range of expected periods if the period of V725 Sgr had been increasing since 1935.

Discussion. The most puzzling property of V725 Sgr is without doubt its period change from 12 to 21 days during an interval of nine years. We can possibly explain the appearance of the pulsation and the decrease in brightness by supposing that V725 Sgr is a member of an eclipsing binary. The pulsation and the decrease of brightness then occur when V725 Sgr occults the other star. The hypothesis is not satisfactory, however, because V725 Sgr is still faint and has only a very small pulsation. Furthermore, this hypothesis does not explain the change of period. We might hypothesize that V725 Sgr is a system of two variable stars with almost identical periods. During the 1926–1935 decade one of the periods changed slightly and one star became fainter. The net effect was the large apparent change of period and a decrease in brightness of the system. We have not investigated this possibility, mainly because it seems very remote. It requires again the simultaneous evolution of both stars. The behaviour of V725 Sgr since 1935 is similar to its behaviour before 1925, with only a small amplitude but a mean magnitude more than one magnitude fainter.

A more plausible explanation would be that V725 Sgr is a single star. RU Cam is the only other variable which is known to have stopped pulsating (Demers and Fernie 1966). Its period and mean magnitude changed very little during the decrease of amplitude, unlike V725 Sgr which is now much fainter. Four years after the decrease of amplitude RU Cam exhibited a somewhat erratic light curve with no constant period (Broglia and Guerrero 1972). But the dominant periodic term present was very close to the original period of 22 days. V725 Sgr is probably not a Population II Cepheid, its period increased while its mean magnitude decreased, which is contrary to any period-luminosity relation. It seems more probable that V725 Sgr is related to the RV Tauri or semi-regular variables. It became fainter in 1926 due to evolutionary effects, while at the same time the amplitude of its pulsation increased very much and became periodic. The variations are now semi-periodic with a period in the 45–50 day range and the amplitude is now only 0.4 magnitude. The 1968–1969 behaviour of V725 Sgr is rather similar to its behaviour around 1900 but unfortunately there are not enough observations covering this epoch to check if the semi-periodicity was the same. The thirteen measures of 1897 fit best a period of 54 days, but because there are so few observations this period may be spurious.

Conclusion. The behaviour of V725 Sgr has not been fully explained. It is most probably a population II star; its colours correspond to an RV Tauri variable. The eclipsing binary and double variable hypotheses do not explain the present faintness of V725 Sgr unless we assume that both stars have evolved. The most recent observations, in 1968 and 1969, suggest that the star is brightening. If its behaviour were recurrent it could reach a maximum again in the late 1980's and could show periodic variations in the mid 1990's.

It would be of interest to follow this star rather closely. Spectroscopic observations could be useful to establish the type of variability. The next observing season will be four years after the last observations reported here and the star may have brightened by over one tenth of a magnitude. This investigation was supported in part by the National Research Council of Canada.

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