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THE SPECTROSCOPIC BINARY γ_1 VELORUM

CARLOS A. HERNÁNDEZ*
Observatorio Astronómico de La Plata, La Plata, Argentina
AND
JORGE SAHADE†
Instituto de Astronomía y Física del Espacio, Buenos Aires, Argentina

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The radial velocities of γ_1 Vel suggest that we are dealing with a spectroscopic binary of a period of $1^d.482575$. The scatter of the velocities is large and there seem to be variations in the velocity distribution at different cycles particularly at the quadrature of maximum positive velocity. A new spectrographic investigation with a very good coverage of a number of different cycles is desirable.

Key words: binary, spectroscopic—γ_1 Velorum

I. Introduction

At about 41″ preceding the brightest Wolf-Rayet star in the sky (γ_2 Velorum) there is a fourth-magnitude object which is designated as γ_1 Velorum (BS 3206 ($4^m.79$) = GC 11103 = HD 68243 (B3); $\alpha = 8^h07^m57^s$; $\delta = -47°11'.8$ (1950.0)). As early as 1911, Moore (1911) announced, from the measurements of four spectrograms secured a year earlier by the Mills Expedition to Chile, with a dispersion of 20.3 Å mm^{-1} at Hγ, that γ_1 Vel is variable in radial velocity with a range of some 75 km s^{-1}. In his announcement, Moore added that "five or six broad lines of helium, hydrogen, and magnesium are available for measurement, the range of over 75 km s^{-1} is sufficient to have no doubt of the reality of the variation. The period is probably short." The plates were apparently remeasured later on by Miss Hobe and her results together with Moore's are quoted in the *Lick Catalogue of Observed Radial Velocities* (Campbell and Moore 1928). Abt et al. (1976) in their study of the γ Velorum group confirmed the variability in radial velocity of γ_1 Vel.

The star is included in Innes' Southern Double Star Catalogue as one of the members of Δ65; eleven micrometric measures of position angle and angular separation, made in the interval 1835.1–1913.1, relative to γ_2 Vel, yield average values of 219°.4 ± 0.33 and 41″.3 ± 0.15, respectively. Four unpublished additional micrometric measurements are given in the accompanying tabulation; they were very kindly made, at our request, by Mr. Carlos Rogati (C.R.) and Mr. Claudio Brunini (C.B.) with the 43-cm refractor of the La Plata Observatory.

Date	P.A. (°)	Angular Separation (arc sec)	Observer
1963 Apr 25	219.6	41.60	C.R.
1963 May 1	219.7	41.69	C.R.
1979 Dec 29	220.0	41.41	C.B.
1980 Jan 3	219.8	41.39	C.B.

No changes seem to be apparent in the relative position of the two stars, but this does not rule out the possibility of their forming a physical system because, at the distance of 480 pc (Abt et al. 1976), a semiaxis major of 41″ for the relative orbit would imply an orbital period at least of the order of 10^6 years. Moreover, the values of the space motion of the two stars appear to suggest that they are physically connected. Thus, the proper motions, as quoted in the SAO Catalog, are

	μ_α	μ_δ
γ_1 Vel:	$-0^s.0009$	$-0''.006$
γ_2 Vel:	−0.0006	+0.004

while the radial velocities (systemic velocities in both cases) amount to

$$\gamma_1 \text{ Vel: } +9.7 \pm 1.0 \text{ km s}^{-1}$$

(as we shall see later in this paper)

$$\gamma_2 \text{ Vel: } +12 \pm 1 \text{ km s}^{-1}$$

(Niemelä and Sahade 1980).

II. The Observational Material

In order to confirm the reported variation in velocity and eventually to determine the orbital elements, we placed the star on the observing program of the Bosque Alegre Astrophysical Station of the Córdoba Observatory and 51 measurable spectrograms were taken in 1950, 1951, 1958–63 with the grating spectrograph at-

*Visiting Astronomer, Cerro Tololo Inter-American Observatory, which is supported by the National Science Foundation under contract No. AST 78-27879.

†Member of the Carrera del Investigador Cientifico, CONICET, Argentina.

TABLE I

Radial Velocities of γ_1 Velorum

Date (JD hel.) 2,400,000.0000+	Phase (P)	Radial Velocity (km s^{-1})	O - C (km s^{-1})	Observatory*
33,316.6902	.042	- 34	- 4	B.A.
33,317.5118	.596	+ 28	- 9	B.A.
33,317.5916	.650	+ 9	- 16	B.A.
33,317.7580	.762	- 3	+ 2	B.A.
33,318.5899	.323	+ 47	+ 5	B.A.
33,318.6580	.369	+ 50	+ 2	B.A.
33,322.5170	.972	- 17	+ 21	B.A.
33,338.7774	.940	- 26	+ 11	B.A.
33,340.5080	.107	- 33	- 18	B.A.
33,340.5968	.167	- 19	- 21	B.A.
33,340.6649	.213	- 5	- 21	B.A.
33,340.7719	.285	+ 13	- 21	B.A.
33,345.5648	.518	+ 53	+ 4	B.A.
33,346.5585	.188	+ 16	+ 8	B.A.
33,347.5884	.883	- 37	- 5	B.A.
33,348.5342	.521	+ 37	- 11	B.A.
33,351.5633	.564	+ 8	- 35	B.A.
33,410.5551	.354	+ 41	- 5	B.A.
33,413.5307	.361	+ 40	- 7	B.A.
33,580.8061	.188	+ 20	+ 11	B.A.
33,581.7214	.806	- 2	+ 14	B.A.
33,581.8429	.888	- 41	- 8	B.A.
33,666.7928	.187	+ 32	+ 24	B.A.
33,667.5314	.685	0	- 16	B.A.
33,704.5218	.635	+ 48	+ 19	B.A.
33,704.5330	.642	+ 38	+ 11	B.A.
36,558.8223	.867	- 18	+ 11	B.A.
36,652.5125	.061	- 28	- 2	B.A.
36,654.5296	.421	+ 56	+ 4	B.A.
36,654.5529	.437	+ 49	- 3	B.A.
36,654.5774	.454	+ 52	0	B.A.
36,988.5470	.717	+ 4	- 4	B.A.
36,991.5364	.733	+ 15	+ 12	B.A.
36,991.6910	.838	+ 22	+ 46	B.A.
36,992.5938	.446	+ 37	- 15	B.A.
36,992.6528	.486	+ 39	- 12	B.A.
36,992.6620	.492	+ 47	- 4	B.A.
37,303.7157	.299	+ 36	- 1	B.A.
37,660.6572	.057	- 8	+ 19	B.A.
37,660.7037	.088	- 12	+ 8	B.A.
37,660.7342	.109	- 11	+ 4	B.A.

TABLE I (Continued)

Date (JD hel.) 2,400,000.0000+	Phase (P)	Radial Velocity (km s^{-1})	O - C (km s^{-1})	Observatory*
37,660.7759	.137	0	+ 7	B.A.
37,660.8078	.158	+ 10	+ 10	B.A.
37,662.6210	.381	+ 59	+ 10	B.A.
37,662.6551	.404	+ 57	+ 6	B.A.
37,662.6947	.431	+ 54	+ 2	B.A.
37,662.7551	.472	+ 52	0	B.A.
37,664.7166	.795	- 34	- 21	B.A.
37,667.6032	.742	- 18	- 19	B.A.
37,667.7317	.828	- 18	+ 4	B.A.
37,667.7657	.851	- 23	+ 4	B.A.
37,667.7990	.874	- 37	- 6	B.A.
37,667.8393	.901	- 40	- 6	B.A.
37,668.8525	.584	+ 27	- 12	B.A.
38,128.5431	.647	+ 60	+ 34	B.A.
38,129.4841	.281	+ 26	- 7	B.A.
38,131.4615	.615	+ 59	+ 26	B.A.
38,131.4854	.631	+ 50	+ 20	B.A.
38,131.5070	.646	+ 68	+ 42	B.A.
38,132.4761	.300	+ 46	+ 9	B.A.
39,965.5069	.683	+ 20	+ 3	C.T.
39,965.5104	.685	+ 20	+ 4	C.T.
39,965.5135	.687	+ 18	+ 2	C.T.
39,965.5503	.712	+ 24	+ 15	C.T.
39,965.5538	.714	+ 6	- 2	C.T.
39,965.5569	.716	+ 16	+ 8	C.T.
39,965.6718	.794	- 11	+ 2	C.T.
39,965.6743	.796	+ 1	+ 15	C.T.
39,966.5024	.354	+ 58	+ 12	C.T.
39,966.5052	.356	+ 56	+ 9	C.T.
39,966.5086	.358	+ 70	+ 23	C.T.
39,966.5822	.408	+ 45	- 6	C.T.
39,966.5864	.411	+ 38	- 13	C.T.
39,966.6246	.437	+ 56	+ 4	C.T.
39,966.6277	.439	+ 63	+ 11	C.T.
39,966.6312	.441	+ 44	- 8	C.T.
39,967.4769	.011	- 43	- 9	C.T.
39,967.4803	.014	- 45	- 11	C.T.
39,967.5156	.038	- 30	+ 1	C.T.
39,967.5198	.040	- 25	+ 5	C.T.
39,967.5524	.062	- 28	- 2	C.T.
39,967.5557	.065	- 25	0	C.T.

TABLE I (Continued)

Date (JD hel.) 2,400,000.0000+	Phase (P)	Radial Velocity (km s^{-1})	O - C (km s^{-1})	Observatory*
39,967.5869	.086	- 30	- 10	C.T.
39,967.5906	.088	- 40	- 20	C.T.
39,968.4947	.698	- 4	- 17	C.T.
39,968.4995	.701	- 2	- 14	C.T.
39,968.5335	.724	- 13	- 19	C.T.
43,202.6613	.150	+ 1	+ 4	C.T.
43,202.6635	.152	- 1	+ 1	C.T.
43,202.6647	.153	+ 1	+ 3	C.T.
43,202.7729	.226	+ 16	- 3	C.T.
43,202.7750	.227	+ 17	- 2	C.T.
43,203.5371	.741	- 26	- 27	C.T.
43,203.5398	.743	- 24	- 25	C.T.
43,203.6603	.824	- 31	- 10	C.T.
43,203.6624	.826	- 31	- 10	C.T.
43,203.7521	.886	- 42	- 9	C.T.
43,203.7547	.888	- 38	- 5	C.T.

*B.A. = Bosque Alegre; C.T. = Cerro Tololo.

Table II

ORBITAL ELEMENTS OF γ_1 VELORUM (AND PROBABLE ERRORS)

	Bosque Alegre Feb./May 1950	Bosque Alegre Dec. 1961/Jan. 1962	Cerro Tololo April 1968	Cerro Tololo April 1968/March 1977	Bosque Alegre + Cerro Tololo (all our observations)
γ (km s^{-1})	+ 4.2 ± 2.0	+ 9.0 ± 1.3	+ 12.5 ± 3.0	+ 7.7 ± 1.3	+ 9.7 ± 1.0
K (km s^{-1})	40.4 ± 3.0	44.9 ± 1.7	46.9 ± 2.9	49.4 ± 2.1	45.0 ± 1.5
e	0.197 ± 0.060	0.077 ± 0.043	0.307 ± 0.094	0.075 ± 0.041	0.057 ± 0.033
ω (degrees)	323.2 ± 25.0	9.9 ± 37.8	264.5 ± 14.6	237.9 ± 47.1	197.6 ± 31.2
T (JD Hel.) (2400000.000+)	37662.572 ± 0.094	37662.693 ± 0.160	37663.783 ± 0.084	37663.687 ± 0.191	37663.538 ± 0.127
$f(\mathfrak{M})$ ($\mathfrak{M}_\odot$)	0.010	0.014	0.014	0.018	0.014
$a_1 \sin i$ (10^6 km)	0.808	0.912	0.916	1.004	0.916
Number of plates	19	16	27	38	98
Time interval of observations considered (days)	97	8	3	3238	9887

tached to the 1.52-m reflector which gives a dispersion of about 42 Å mm^{-1}. Most of the material was exposed on Eastman 103 a-O or II a-O emulsion while a few observations were secured on red-sensitive plates.

The radial-velocity distribution derived from the Bosque Alegre spectrograms was such that it was thought advisable to supplement the material with additional plates. As a consequence, further observations were carried out at the Cerro Tololo Inter-American Observatory (CTIO): 27 spectrograms were secured in April 1968, and 15 more in February/March 1977, the latter by Virpi Niemelä. The Cerro Tololo material was secured with the 90-cm reflector at a dispersion of 60 Å mm^{-1} (27 plates) and with the 1.50-m reflecting telescope at a dispersion of 38 Å mm^{-1} (10 plates). The emulsion used was Eastman III a-J throughout.

III. The Spectrum

The spectrum of γ_1 Vel is single-lined and corresponds to spectral class B2 III, the classification having been made by comparing our spectra with Morgan, Abt, and Tapscott's (1978) *Revised MK Spectral Atlas for Stars Earlier than the Sun*. In general, the stellar lines are relatively narrow and well-defined and the members of the Balmer series are seen up to H14–H15 which is somewhat below what one would expect for a B2 III star (Unsöld and Struve 1940). The object had been classified earlier as B2 IV by Ganesh and Bappu (1967), as B1 IV by Hiltner, Garrison, and Schild (1969), and as B1.5 V by Abt et al. (1976). The visual absolute magnitude of γ_1 Vel, as derived from Abt et al.'s (1976) distance, corresponds to the luminosity of a B2 III or to a B0.5 IV object (Arp 1958). As for the color indices, $(B-V) = -0^m.22$ and $(U-B) = -0^m.92$ (Abt et al. 1976), they suggest a star around B2 III (cf. Johnson 1963). Therefore, our spectral classification does not conflict with the luminosity and the color indices of the object. Hα displays no emission on our red-sensitive plates.

IV. Period

The determination of the radial velocities was made by measuring 14 lines on the Bosque Alegre plates and eight lines on the Cerro Tololo material; the derived individual values are given in Table I. The Bosque Alegre material confirmed the variability in radial velocity of γ_1 Vel and suggested that the object is a spectroscopic binary (Hernández and Sahade 1960) with an amplitude of the order of 90 km s^{-1} and a period of about 1.5 days. The whole of the Bosque Alegre and CTIO available material led to a value of the period of 1.48256 days and this figure was improved to 1.482575 days by considering the radial velocities that we measured on the plates taken in Chile by the Mills Expedition of the Lick Observatory.

V. The Orbital Elements

Orbital elements of γ_1 Vel (the fifth column of Table II) were derived by feeding the radial velocities from our material into the IBM 360/50 computer of the University of La Plata's CESPI. The corresponding velocity curve is drawn in Figure 1 where all our radial velocities are plotted together with those that were derived from the early Chile spectrograms and those determined by Abt et al. (1976) from their five Cerro Tololo 1969 plates.

The scatter of our radial velocities, in spite of the probable error of the individual plates—of the order of 3.3 km s^{-1}, on the average—is rather large. As a consequence, we derived orbital elements separately for each of the three groups of our radial velocities that were taken in rather short time intervals; they are given in the first three columns of Table II. These three groups correspond to the following time intervals, namely,

(a) JD2433316.69–2433413.53 (19 spectrograms) ;

(b) JD2437660.66–2437668.85 (16 spectrograms) ;

(c) JD2439965.51–2439968.53 (27 spectrograms) .

Although the ranges in the values of γ, e, and ω are not very much larger than one would expect from the probable errors, the material suggests that there are real changes in the velocity distribution at different cycles, particularly at the quadrature of maximum positive velocity. In order to understand the meaning of such variations and, therefore, to try to understand the system, it would be desirable to undertake a new spectrographic investigation of the star with a very good coverage of a number of different cycles.

Jerzykiewicz and Sterken (1977) placed γ_1 Vel in a program aimed at searching for β Canis Majoris stars south of declination $-20°$ and their conclusion was that there is no strong evidence in favor but "the possibility that the star is a small amplitude β Cephei variable cannot be excluded." Our observations do not seem to lend support to such a possibility.

We are greatly indebted to the Director of the Lick Observatory for the loan of the 1910 plates and Drs. J. Landi Dessy and V.S. Niemelä for securing a number of the spectrograms used in the present investigation. One of us (C.A.H.) would like to record his deep appreciation to the Director and staff of the Cerro Tololo Inter-American Observatory for their hospitality and help during his observing runs at the CTIO.

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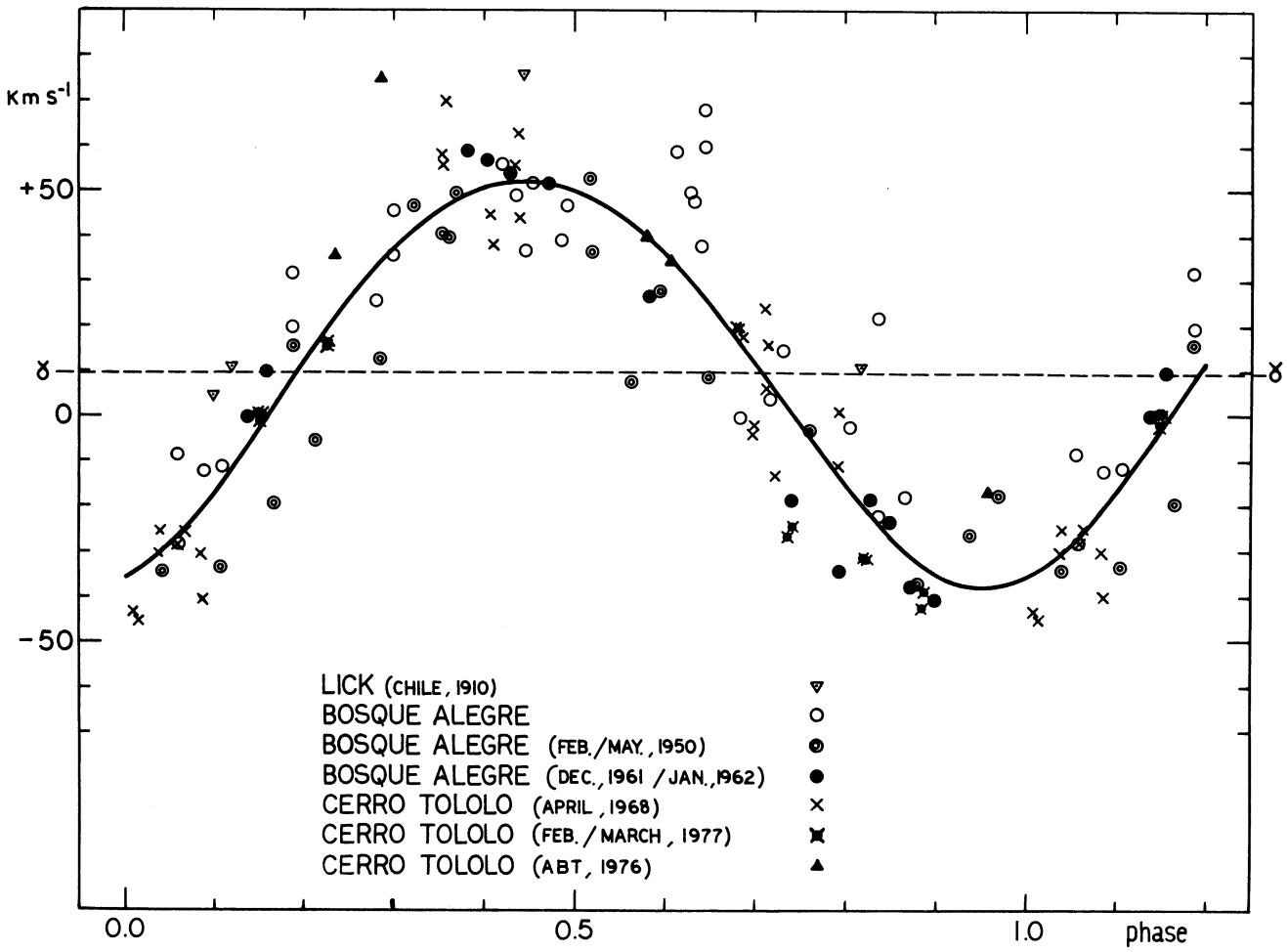

FIG. 1—Radial velocities and velocity curve of γ_1 Velorum.