1941ApJ....94...99S

A CONTRIBUTION TO THE STUDY OF β CANIS MAJORIS*

O. STRUVE AND P. SWINGS

ABSTRACT

Coudé spectrograms obtained at the McDonald Observatory on January 22 and 24, 1941, show a velocity range of about 9 km/sec, in a period of 6 hours. The lines are diffuse and shallow near minimum velocity and sharper and deeper near maximum velocity. The *Ca* II line K shares in the oscillations. It is probably a blend of a stellar and an interstellar line. The lines suggest turbulence of an appreciable amount. A line at λ 4469.71 is probably a blend of *O* II and forbidden *He* I. A comparison with β Cephei shows that β Canis Majoris is more luminous. It is, however, not a supergiant. The similarity in the periods suggests similarity of internal structure.

I. OBSERVATIONS OF β CANIS MAJORIS

Many years ago Henroteau[1] found that the appearance of the spectrum of β Canis Majoris undergoes periodic changes: "Sometimes the lines are narrower, sometimes wider and more diffuse than the general average condition." The period of these changes in line width is 0.25130 day. This is close to the period derived from the velocities, namely, 0.25714 day, which Henroteau[2] obtained from the material of the Lick Observatory but which he was not able to substantiate from a discussion of several hundred spectrograms secured by him at Ottawa.[3] More recently Meyer has investigated the radial velocity of β Canis Majoris at the Lick Observatory,[4] and Fath [5] has used a formula from Meyer's work which gives the radial velocity as the sum of two simple harmonics with periods of 0.2513015 day and 0.2500222 day. The longer period is identical with Henroteau's period for the line widths. It is perhaps surprising that of the six curves for the line widths shown in Henroteau's paper[1] five give a maximum line width at about the same phase at which his velocity-curves show minima, but Meyer's observations confirm the difference in the two periods. Since the observations of line widths are difficult and are subject to systematic errors due to differences in the densities of the plates and the photographic treatment, it was desirable to secure additional material in order to clarify the relation between the velocity-curve and the curve of line widths.

During January, 1941, we secured 10 spectrograms of β Canis Majoris with the Coudé spectrograph[6] of the McDonald Observatory. The dispersion is 1.88 A/mm at λ 3933 and 4.05 A/mm at λ 4490. The fast and very contrasty new Eastman emulsion (experimental astronomical blue plate Type Ia-o) coated on glass, gave good exposures in about 30 minutes. A list of 77 suitable star lines was compiled mainly from the work of Struve[7] and of Kühlborn.[8] The adopted laboratory wave lengths are the best available at the present time. Many are known only to about 0.01 A. Table 1 contains these lines. The first column gives the element; the second the adopted laboratory wave length; the third a rough estimate of the intensity in β Canis Majoris; the fourth the number of plates on which each line was measured; the fifth the mean residual, line *minus* average velocity;

---

* *Contributions from the McDonald Observatory, University of Texas*, No. 36.

[1] *Lick Obs. Bull.*, **9**, 157, 1918.

[2] *Ibid.*, p. 160.

[3] *Pub. Dom. Obs.*, **8**, 31, 1922.

[4] *Pub. A.S.P.*, **46**, 202, 1934.

[5] *Lick Obs. Bull.*, **17**, 116, 1935.

[6] For a description of this instrument see *Contr. McDonald Obs.*, No. 1, p. 103, 1940.

[7] *Ap. J.*, **74**, 225, 1931.

[8] *Veröff. Univ. Stern. Berlin-Babelsberg*, **12**, No. 1, 1938.

1941ApJ....94...99S

TABLE 1

WAVE LENGTHS OF STAR LINES USED FOR RADIAL VELOCITY

LABORATORY VALUE		Int.	NO. OF PLATES	RESIDUAL V (LINE) IN KM/SEC	RESIDUAL V (MEAN) IN A	ADJUSTED WAVE LENGTH	PROBABLE ERROR	
Elem.	λ						In km/sec	In A
Ca II........	3933.684	2	9	....	....	....	....	....
O II.........	4069.766	4	10	+ 3.84	+0.052	4069.818	0.30	0.004
O II.........	71.220	1	1	+ 3.05	+0.041	71.261	....	....
O II.........	72.164	3	10	+ 2.65	+0.036	72.200	0.33	0.004
O II.........	75.868	4	10	+ 2.83	+0.038	75.906	0.39	0.005
O II.........	78.862	1	9	+ 2.45	+0.033	78.895	0.99	0.013
O II.........	83.907	1	10	− 1.05	−0.014	83.893	0.54	0.007
O II.........	85.124	2	10	+ 1.22	+0.017	85.141	0.35	0.005
Si IV........	88.862	3	7	+ 1.55	+0.021	88.883	1.87	0.026
O II.........	89.295	2	6	− 0.85	−0.012	89.283	0.97	0.013
O II.........	92.940	1	8	− 0.14	−0.002	92.938	1.15	0.016
O II.........	97.250	1	2	+ 3.86	+0.053	97.303	....	....
O II.........	4104.892	1	6	+ 0.02	0.000	4104.892	1.08	0.015
O II.........	10.800	1	2	+ 0.98	+0.013	10.813	....	....
O II.........	12.040	1	2	− 0.16	−0.002	12.038	....	....
Si IV........	16.103	2	10	+ 1.27	+0.017	16.120	0.81	0.011
O II.........	19.221	3	10	+ 1.30	+0.018	19.239	0.51	0.007
He I.........	20.860	2	6	− 6.75	−0.093	20.767	0.81	0.011
O II.........	32.806	2	9	+ 0.16	+0.002	32.808	0.78	0.011
Fe III........	37.720	1	1	+ 7.00	+0.097	37.817	....	....
He I.........	43.759	5	10	+ 5.68	+0.078	43.837	0.57	0.008
O II.........	53.302	3	10	+ 0.58	+0.008	53.310	0.36	0.005
O II.........	56.540	1	6	− 1.03	−0.014	56.526	1.14	0.016
S II.........	64.980	2	9	−12.76	−0.177	64.803	0.70	0.010
He, *O* II.....	69.100	3	10	+ 2.47	+0.034	69.134	0.53	0.007
O II.........	85.456	3	9	+ 1.90	+0.027	85.483	0.28	0.004
O II.........	89.788	3	10	+ 0.03	0.000	89.788	0.30	0.004
N II.........	4236.983	1	8	+ 2.18	+0.031	4237.014	0.73	0.010
N II.........	41.787	2	8	+ 2.44	+0.035	41.822	0.94	0.013
Ne II........	50.680	3	2	−10.36	−0.147	50.533	....	....
O II.........	53.980	3	7	−16.30	−0.231	53.749	0.41	0.006
C II.........	67.150	5	9	+ 1.47	+0.021	67.171	0.20	0.003
O II.........	75.520	1	8	+ 3.05	+0.043	75.563	1.31	0.019
O II.........	82.960	1	1	+ 4.18	+0.060	83.020	....	....
S III.........	85.000	2	9	− 1.53	−0.022	84.978	0.64	0.009
O II.........	85.700	1	5	+ 0.67	+0.010	85.710	0.99	0.014
O II.........	88.830	1	2	− 2.44	−0.035	88.795	....	....
O II.........	91.250	1	1	+ 0.58	+0.008	91.258	....	....
O II.........	94.820	1	9	− 0.35	−0.005	94.815	0.87	0.012
O II.........	4303.800	2	9	+ 0.16	+0.002	4303.802	0.73	0.010
O II.........	07.310	1	7	− 6.42	−0.092	07.218	1.86	0.027
O II.........	08.960	1	1	− 1.76	−0.025	08.935	....	....
O II.........	17.139	5	10	+ 1.59	+0.023	17.162	0.35	0.005
O II.........	19.664	5	10	− 0.50	−0.007	19.657	0.43	0.006
O II.........	25.770	1	9	− 1.12	−0.016	25.754	0.85	0.012
O II.........	27.480	1	5	− 2.96	−0.043	27.437	3.39	0.049
O II.........	28.620	1	3	− 4.41	−0.064	28.556	....	....
S III.........	32.690	1	8	+ 3.31	+0.048	32.738	0.92	0.013
O II.........	36.860	1	10	− 2.65	−0.038	36.822	1.27	0.018
O II.........	45.562	5	10	+ 0.27	+0.004	45.566	0.31	0.004
O II.........	47.425	5	10	− 0.15	−0.002	47.423	0.37	0.005
O II.........	49.426	5	10	+ 0.85	+0.012	49.438	0.32	0.005
O II.........	51.269	5	9	+ 1.25	+0.018	51.287	0.48	0.007

TABLE 1—*Continued*

Laboratory Value		Int.	No. of Plates	Mean V (Line) In km/sec	Residual V (Mean) In A	Adjusted Wave Length	Probable Error	
Elem.	λ						In km/sec	In A
S III.........	4354.580	1	3	+ 1.29	+0.019	4354.599	....	....
S III.........	61.570	2	9	− 3.49	−0.051	61.519	0.74	0.011
O II.........	66.896	4	10	− 1.10	−0.016	66.880	0.31	0.005
O II.........	69.280	1	2	+ 0.32	+0.005	69.285	....	....
C II.........	72.490	1	8	− 0.83	−0.012	72.478	1.51	0.022
C II.........	74.280	1	1	− 6.11	−0.089	74.191	....	....
O II.........	78.400	1	1	−11.42	−0.167	78.233	....	....
Ne II........	79.480.	1	1	+ 4.94	+0.072	79.552	....	....
He I.........	87.931	10	10	+ 3.58	+0.052	87.983	0.39	0.006
O II.........	95.950	2	10	− 2.58	−0.038	95.912	0.67	0.010
C II.........	4411.200	1	1	+12.39	+0.182	4411.382	....	....
O II.........	14.909	10	10	+ 0.93	+0.014	14.923	0.40	0.006
O II.........	16.975	10	10	+ 0.19	+0.003	16.978	0.56	0.008
He I.........	37.552	2	10	+ 3.78	+0.056	37.608	0.70	0.010
O II.........	47.080	2	10	− 7.00	−0.104	46.976	1.15	0.017
O II.........	48.210	1	1	+ 2.15	+0.032	48.242	....	....
O II.........	52.377	2	10	− 0.08	−0.001	52.376	0.54	0.008
O II.........	65.400	1	1	− 5.49	−0.082	65.318	....	....
O II.........	66.320	1	1	+ 2.62	+0.039	66.359	....	....
O II.........	67.880	1	1	−12.44	−0.185	67.695	....	....
He I.........	71.508	20	10	+ 2.37	+0.035	71.543	0.39	0.006
Al III........	79.970	1	10	− 2.78	−0.042	79.928	1.19	0.018
Mg II........	81.228	3	10	+ 0.19	+0.003	81.231	0.37	0.006
O II.........	4491.250	1	9	− 1.13	−0.017	91.233	0.75	0.011

NOTES TO TABLE 1

4069 Blend of *O* II 9.636(5) and *O* II 9.897(7).
4078 Blend of *O* II 8.862(6); *O* II 9.00(0).
4097 Blend of *O* II 7.260(6); *N* III 7.331(10); *O* II 7.32(1).
4104 Blend of *O* II 5.000(6); *O* II 4.743(3).
4120 Blend *He* I 0.817(3); *He* I 0.989(1); *O* II 0.30; *O* II 0.55(2); *Fe* III 0.97(8).
4137 Swings and Edlén give λ 4137.93(8); the adjusted λ is identical with that measured by Kühlborn.
4156 Blend of *O* II 6.53(3); *C* III 6.50(4).
4164 This must be *Fe* III 4.79(20).
4169 Blend of *He* I 8.965; *O* II 9.230(4).
4236 Blend of *N* II 6.930(5); *N* II 7.049(4).
4250 Identification must be wrong.
4253 Blend of *O* II 3.74(4); *O* II 3.98(4).
4267 Blend of *C* II 7.27(20); *C* II 7.02(19).
4282 Blend of *O* II 2.82(2); *O* II 3.13(0).
4332 Blended with *S* III 2.71(4).
4372 Blended with *Fe* III 2.40(20).
4378 Blend of *O* II 8.40(0); *O* II 8.01(0).
4379 Blended with *O* II(?) 9.56(1) (see Kühlborn).
4411 Blend of *C* II 1.20(5); *C* II 1.52(5).
4447 Blended with *N* II 7.033(10).
4467 Blend of *O* II 7.86(4); *O* II 7.53(1).
4471 Blend of *He* I 1.479(1); *He* I 1.681(1).
4479 Blend of *Al* III 9.968(4); *Al* III 9.891(3).
4481 Blend of *Mg* II 1.129; *Mg* II 1.327.

1941ApJ....94...99S

the sixth gives the same quantity in A; and the seventh column gives the adjusted wave lengths. In all cases where a line had been measured on at least 4 plates the probable error of the adjusted wave length has been computed. These values are given in km/sec in column 8, and in A in column 9. The notes at the end of the table explain some of the departures. The wave lengths of the comparison lines of the iron arc were taken from the work of Burns and Walters[9] and are those listed by them for air.

Nearly all large residuals in the star lines are accounted for by blends. The large discrepancy for λ 4250.680 remains unexplained. The *He* I lines seem to show a positive displacement with respect to the other lines, most of which are due to *O* II. Two lines, λ 4122 and λ 4169, are seriously blended. The others give the following:

λ 4144.........	Δλ=+0.078	±0.008 A
4387.........	+ .052	.006
4437.........	+ .056	.010
4472.........	+0.035	±0.006

This is probably not caused by Stark effect, because λ 4437 is not much affected by an electrical field. The laboratory wave lengths which we have used are from Kühlborn's compilation[10] and, in the case of *He* I, are due to Paschen. The best stellar wave lengths are those by Albrecht,[11] which are given in Table 2.

TABLE 2

WAVE LENGTHS OF HELIUM LINES

Lab. λ (Paschen)	Lab. λ (Fowler)	λ (Mean Stellar, Albrecht)	λ (β CMa)
4143.759(2).....	0.77(2)	....	0.837±0.008
4387.931(3).....	.928(3)	0.946±0.003	.983± .006
4437.552(1).....	.549(1)	.554± .005	.608± .010
4471.479(6).....	.477(6)	0.524±0.002	0.543±0.006
4471.681(1).....	0.689(1)		

Albrecht's wave lengths refer to the mean of many measurements of radial velocities in B-type stars by Frost and Adams. The mean difference, β CMa *minus* Albrecht, is +0.037 A; and the mean difference, β CMa *minus* mean laboratory value, is +0.052 A. These values represent the systematic difference of the *He* I lines with respect to the mean of all lines—most of these being due to *O* II.

The velocities from individual lines were given different weights: 1 for a faint line and 2 for lines of intensity 2 or more. The adjusted velocities in Table 3 were obtained by means of the adjusted wave lengths of Table 1. Whenever the adjusted wave length depended upon 4 or more plates it was used in forming these means. All lines measured on fewer than 4 plates were used with their original, unadjusted wave lengths. The probable errors are satisfactorily small. The influence of the unadjusted wave lengths in column 7 of Table 3 probably more than balances the errors introduced by taking mean wave lengths from relatively few plates—4 to 10—for those lines for which adjusted wave lengths were used.

The calcium line K was treated separately. It was measured and reduced independently of the other lines; because of the probable existence of an interstellar component no attempt was made to adjust its wave length.

---

[9] *Pub. Allegheny Obs.*, **6**, No. 11, 1929.

[10] *Op. cit.*, p. 42.

[11] *Ap. J.*, **67**, 305, 1928.

The radial velocities show that on January 24 there was a marked variation with a total range of about 9 km/sec. It is surprising that the calcium line shows a similar variation, which suggests that the interstellar line is blended with a stellar component of appreciable intensity. The appearance of the calcium line supports this conclusion: with the high dispersion it is broad and diffuse, resembling in appearance the star lines of *O* II, etc. Near minimum velocity the two plates Cd 68 and Cd 69 give a suspicion of doubling, but the evidence is not conclusive. The calcium line is not strong[12], even aside from the effect of blending, and does not suggest a great distance. Allowing for the stellar component, the distance cannot be much greater than about 100 parsecs.

TABLE 3

RADIAL VELOCITIES OF β CANIS MAJORIS

Plate	Date	U.T.	No. of Lines	Vel. in km/sec	P.E. in km/sec	Adjusted Vel. in km/sec.	P.E. in km/sec.	Vel. of *Ca* K
54	1941 January	22.217	36	+24.67	±0.59	+24.61	±0.44	+24.5
65	January	24.104	68	38.26	.38	38.17	.31	33.3
66	January	24.137	62	35.23	.45	35.39	.25	....
67	January	24.168	54	29.86	.38	29.85	.24	23.8
68	January	24.203	53	25.73	.52	25.74	.37	16.2
69	January	24.235	47	25.78	.45	25.55	.26	18.3
70	January	24.264	49	28.75	.42	28.64	.24	27.7
71	January	24.287	51	30.66	.45	30.83	.29	28.7
72	January	24.313	51	32.00	.42	31.99	.25	30.2
73	January	24.342	51	+34.77	±0.40	+34.83	±0.20	+30.6

There is a very remarkable change in the intensities of the star lines: they are rather sharp and deep near maximum radial velocity and appear diffuse and faint—even slightly broadened—near minimum radial velocity (see Fig. 1). As far as we are able to ascertain, all star lines show this effect. It does not seem to be associated with a change in ionization or excitation. For example, the lines of *Si* III and *Si* IV behave in the same manner. Nor is there an appreciable difference between lines arising from metastable levels and those arising from ordinary levels. For example, the line *Fe* III 4420, which arises from a metastable level, is not strengthened with respect to *Fe* III 4138 and 4165, which arise from ordinary excited levels. The broadening of the lines does not resemble that associated with an increase in turbulence. The turbulent broadening, which is quite appreciable in this star, does not vary within the short period. Even near the violet end of our spectrograms, where the dispersion is 2 A/mm, the broadened lines look symmetrical (with the exception of *Ca* K). There are no unsymmetrical wings, such as have been observed by Adams[13] in the normal Cepheid variable, η Aquilae. The change in the appearance of the lines is so conspicuous that many of the fainter lines which were easily measured on plates taken near maximum radial velocity could not be seen at all near minimum. The phenomenon suggests some mechanical cause; for example, a change in the velocity of rotation might produce the observed changes in the contours of the lines. But, of course, it is very improbable that such a change really does take place.

There can be no doubt that the variation in the line contours is identical with the

---

[12] Merrill, Sanford, Wilson, and Burwell (*Ap. J.*, **86**, 291, 1937) assign β CMa to their Group I, which means that the *Ca* II line K is "either not seen or a barely perceptible trace." However, a good contrasty plate taken at the Yerkes Observatory (see Pl. XIV, *Ap. J.*, **74**, 248, 1931) shows a moderately strong line.

[13] *Pub. A.S.P.*, **52**, 385, 1940.

effect of line broadening described by Henroteau. It is very suggestive that our observations give the same phase relationship between the velocity-curve and the curve of line widths as do the five epochs out of six in which Henroteau finds maximum line width to fall near minimum velocity. Our observations are, of course, not sufficiently numerous to prove that this relationship will always hold. But perhaps allowance should be made in Henroteau's observations for possible errors in the curves based upon such difficult measurements as those of line widths. Unless the range in the variation of line widths changes greatly, it is an indication of great skill that Henroteau was able to detect it at all.

II. COMPARISON WITH OTHER STARS

There are available at the present time three modern lists of stars usually designated as belonging to the type of β Canis Majoris. The one by Henroteau[14] lists 29 stars, known and suspected, of which 22 belong to class B. J. H. Moore's list in the fourth catalogue of spectroscopic binaries[15] lists 13 stars, of which 7 are of type B. The most recent list, that by C. P. and S. Gaposchkin[16] has a total of 30 stars, of which 13 are regarded as unreliable, leaving a total of 17, with 9 of type B.

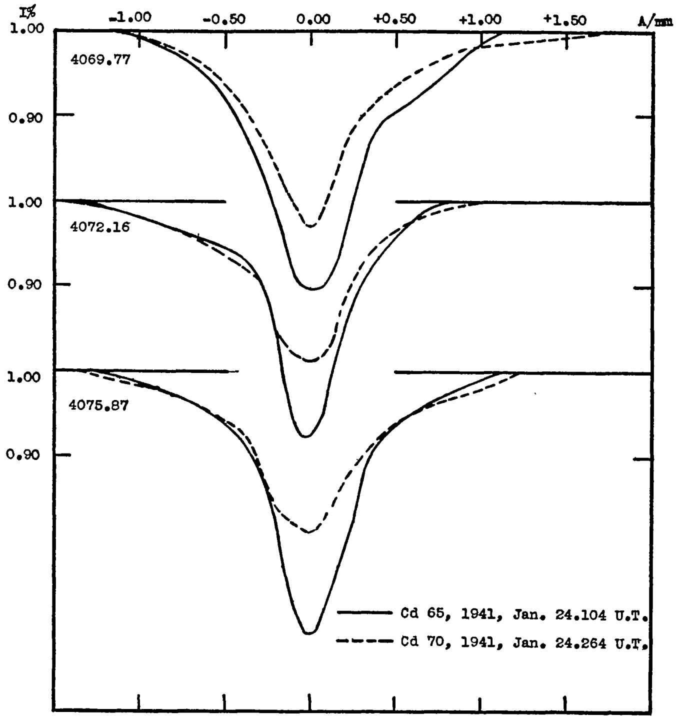

FIG. 1—Contours of three lines of O II in β Canis Majoris. On Plate Cd 65, taken near maximum radial velocity, the lines are deep, while on Plate Cd 70, taken near minimum velocity, they are shallow.

An inspection of the B-type stars in the Gaposchkin list shows that only 4 are definitely known to be stars of variable radial velocity whose periods are less than half a day, whose velocity ranges are so small that they can hardly all be explained in terms of binary motion, and whose velocity-curves undergo slow changes in γ, K, e, and ω, if we use the description of the curves in terms of the elements of a spectroscopic binary. A few other stars may belong to the same group, but the available information is either unreliable, being based upon inconclusive observations by only one observer, or the data

---

[14] *Handb. d. Ap.*, **6**, No. 2, 1928.

[15] *Lick Obs. Bull.*, No. 483, 1936.

[16] *Variable Stars*, p. 188, Cambridge, 1938.

are contradictory in themselves and fail to give a clear picture of the variations. For example, in the case of δ Ceti, for which J. H. Moore accepts the evidence as indicating a variable radial velocity,[17] Crump[18] finds a period of 0.1556 day, while Henroteau[19] had found 0.16122 day. Moreover, the light of δ Ceti is not known to vary. Henroteau thought the lines were diffuse, which contradicts the evidence of the Yerkes plates. In fact, δ Ceti is among the B stars whose lines appear very sharp with a dispersion of about 30 A/mm. The amplitude of the velocity variations is small—of the order of 10 km/sec. Clearly, no useful purpose can be accomplished by lumping this star with others for which a large amount of reliable information is available.

Another possible representative of this group of stars is ν Eridani, which occurs in all the lists but for which the available information is highly unsatisfactory. Henroteau[20] had originally determined a period of 0.23667 day, with the peculiar qualification that this period gives either a maximum or a minimum. But in a later paper[21] he was unable to verify this period or to give any other value which would combine what looks like rapid oscillations repeating themselves at intervals of between 0.15 day and 0.20 day. Instead of this he gave a period of 7 days for the variation in velocity range. The problem is even more complicated by the fact that Baker had announced a period of 0.15430 day for a variation in the light of ν Eridani.[22] It is, of course, possible that in this star the variations are essentially irregular. But this is not the case in β Cephei, and it seems best for our present purpose to use only those stars in which there is some degree of periodicity.

For η Aurigae the evidence is even less satisfactory. Moore[23] concludes that the Yerkes and Lick results fail to confirm a variation in the radial velocity, as is borne out by the small probable errors from 8 and 5 plates, respectively:

η AURIGAE

Yerkes	+6.2	±1.2 km/sec.
Lick	2.0	1.0
Ottawa	+8.8	±3.2

Among the rest of the B stars in the Gaposchkin list which have not already been questioned by the authors, 42 Camelopardi must be excluded for lack of sufficient radial-velocity data, the sole existing evidence being Edwards'[24] period of 0.1385 day for the line intensities. The star θ Ophiuchi, for which Henroteau had found a short period[25] has been questioned by Moore.[26] Eight Lick Observatory plates give a mean velocity of −1.2±0.6 km/sec, while 45 Ottawa plates give −15.0±1.2 km/sec. It seems best to exclude this star until more information is available. Altogether we are left with the 4 classical representatives of this group of stars,[27] for which we have summarized the pertinent information in Table 4.

---

[17] *Lick Obs. Pub.*, **18**, 19, 1932.

[18] *Ap. J.*, **79**, 351, 1934.

[19] *Pub. Dom. Obs.*, **9**, 26, 1925.

[20] *Ibid.*, **5**, 59, 1921.

[21] *Ibid.*, **9**, 119, 1927.

[22] *Pub. A.S.P.*, **38**, 93, 1926.

[23] *Lick Obs. Pub.*, **18**, 40, 1932.

[24] *M.N.*, **93**, 729, 1933.

[25] *Pub. Dom. Obs.*, **8**, 3, 1922.

[26] *Lick Obs. Pub.*, **18**, 208, 1932.

[27] It is difficult to see any justification, other than habit, for designating this group as the β Canis Majoris stars. Not only was β Cephei the first member of the group to be discovered with the spectrograph, but its well-established variability in light was known 22 years before there was any definite evidence of such a variability in β CMa. It is also hard to see why the Gaposchkins, in referring to Eddington's work on pulsating stars (*op. cit.*, p. 175), remark that β Cephei was "not, however, a happy example, for the data concerning this star are still inadequate and doubtful." As a matter of fact, β Cephei is the only star of the group for which our information is reasonably reliable. Since the designation "β Canis Majoris stars" is historically incorrect and scientifically misleading, we suggest that β Cephei be regarded as the type star and that its name be used to designate the group.

1941ApJ....94...99S

TABLE 4

B STARS OF β CEPHEI TYPE

No.	Star	Sp.	Discovery	Velocity-Curve	Period	K in km/sec	Light Variation	Δ*m*	Absolute Magnitudes
1.....	β Cep	B1s	1902, Frost	1906, Frost	0.1904=4.6 h	15, slightly variable	1913, Guthnick	0.05–0.08	−3.5 (Morgan) 3.6 (Williams, L) 3.0 (Williams, K)
2.....	12 Lac	B1sk	1912, Adams	1915, Young	.1931=4.6	60, variable	1917, Stebbins	0.04–0.13	
3.....	σ Sco	B1	1904, Slipher	1916, Selga	.2468=5.9	41, variable	1916, Stebbins	0.03, suspected	2.1 (Kapteyn)
4.....	β CMa	B1	1908, Albrecht	1910, Albrecht	0.2571=6.2	9, variable	1928, Stebbins 1935, Fath	0.00, no var. 0.03	5 (Morgan) 3.8 (Williams, L) 4.3 (Williams, K) −5.4 (Wilson, c stars)

An inspection of three prism spectrograms of β Cephei taken at the Yerkes Observatory shows no change in the contours of the absorption lines. In this respect the star differs greatly from β Canis Majoris. On the other hand, its period is nearly constant; but both Kohl[28] and Crump[29] find that $P=0.1904795$ day satisfies the observations from 1906 to 1918, but that later observations, up to 1932, are better represented with $P=0.1904851$. Nevertheless, it is clear that we have no such complication with the period as has been found in the case of β Canis Majoris.

It is of great interest that in all three stars for which definite variations in light have been announced maximum light falls between the point of maximum compression on the pulsating star model (or the most distant point of the orbit, on the binary model) and minimum velocity. This was first established by Miss Cummings in the case of β Cephei,[30] but it is also true for 12 Lacertae[31] and for β Canis Majoris.[32] The phase relation is definitely not the same as in the case of normal Cepheids, but it may perhaps be easier to explain on the pulsation theory than the latter.

Probably the most remarkable result of the spectroscopic investigations is contained in the estimates of absolute magnitudes and of spectral types. The types are nearly alike—perhaps even more so than the estimates show. There are no cases of rapid axial rotation, but this may be due to observational selection. But β Cephei is somewhat dwarfish in character. It has narrow, sharp lines of *O* II, *Mg* II, etc., while *H* and some *He* I lines are broadened by Stark effect. The forbidden line *He* 4470 is present but is not as strong as in δ Ceti, γ Pegasi, or τ Scorpii; β Cephei has no appreciable turbulence.

On the other hand, the turbulence must be large in β Canis Majoris. Its lines are broad, with sharp edges, and the curve of growth is apparently steep. A comparison with τ Scorpii shows that the latter brings out many more faint lines than β Canis Majoris. This effect of turbulence suggests relatively high luminosity. Merrill[33] includes it among the c stars and so does R. E. Wilson.[34] Morgan[35] definitely makes its luminosity greater than that of β Cephei. On our spectrograms the *H* lines are appreciably broadened, as are also the members of the $2^1P^0-n^1D$ and the $2^3P^0-n^3D$ series of *He* I. Hence we doubt that β Canis Majoris is as luminous as β Orionis or α Cygni, but there can, in our opinion, be little question that it is roughly 2 mag. more luminous than β Cephei. This agrees essentially with an earlier estimate by Struve,[36] who placed β Canis Majoris among stars of intermediate luminosity and β Cephei among those of low luminosity.

All modern estimates of the absolute magnitudes, and especially those for β Canis Majoris, are in violent disagreement with the period-luminosity relation for normal Cepheids, which approaches absolute photographic magnitude 0.00 for periods of the order of a quarter of a day. This contradicts earlier conclusions that these stars may be regarded as "dwarf Cepheids,"[37] or that they fail to display spectroscopic characteristics of high luminosity.[38] The latter conclusion was based upon the identification of a faint line with forbidden *He* I 4470. A new measurement on Coudé plates gives a wave length of λ 4469.71, which is about halfway between *O* II 4469.32(3) and forbidden *He* I 4469.97. The measured line is quite broad and may be a blend of a weak forbidden line with the *O* II line.

[28] *A.N.*, **248**, No. 22, 1933.

[29] *Op. cit.*, p. 260.

[30] *Lick Obs. Bull.*, **11**, 118, 1923.

[31] Christie, *Pub. Dom. Ap. Obs.*, *Victoria*, **4**, 62, 1927.

[32] Fath, *loc. cit.*

[33] *Ap. J.*, **81**, 351, 1935.

[34] *Ap. J.*, **93**, 212, 1941.

[35] Unpublished.

[36] *Op. cit.*, p. 250.

[37] Gaposchkin, *op. cit.*, p. 177.

[38] Struve and Ogrodnikoff, *Pub. A.A.S.*, **7**, 106, 1931.

Summarizing the observational results we have:

1. The velocity changes are probably not purely atmospheric phenomena. Otherwise it would be incomprehensible that the periods should be so similar, while the spectra are so different in character.
2. The changes in the line intensities in β CMa suggest a phenomenon associated solely with its tenuous atmosphere. Certainly, β Cep shows nothing like it, although changes were observed by Young in 12 Lacertae.
3. The small variability in light suggests an intrinsic process rather than binary motion.
4. The existence of slow variation in γ may indicate binary motion, but there is no certainty on this point.
5. The relation between light- and velocity-curves is definite, and, while it differs from that of a true Cepheid, it does have some resemblance to it. In particular, maximum light always comes soon after the phase of greatest compression: the famous lag of $\frac{1}{4}P$ observed in normal Cepheids is greatly reduced.

If, in spite of the discordance in the period-luminosity relation, we apply the formula $P\sqrt{\rho}$ = const, the ratio of the mean densities of β Cephei and β Canis Majoris would be

$$\frac{\rho(\beta\ \mathrm{Cep})}{\rho(\beta\ \mathrm{CMa})} = 1.74 .$$

It would be difficult to reconcile this small ratio with the observed difference in the luminosities. We should have expected that the ratio would be more nearly 10 or 20. But perhaps the internal constitution of the two stars is much more nearly alike than the spectra would lead us to believe. The essential physical difference between the two stellar atmospheres is that the one star has turbulence while the other has not. A support by turbulent motions of an extended reversing layer in β Canis Majoris—somewhat along the lines of McCrea's theory of chromospheric support[39]—might serve to reconcile the relatively high luminosity of β Canis Majoris and the similarity in internal structure suggested by the periods.

YERKES OBSERVATORY
March 31, 1941

---

[39] *M.N.*, **89**, 718, 1929.