THE RADIAL VELOCITY VARIATION OF THETA OPHIUCHI

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ABSTRACT

A rediscussion of Henroteau's 1920 and 1922 radial-velocity measurements and new observations with the 82-inch McDonald telescope in February, 1955, show that Θ Ophiuchi very probably is a β Canis Majoris star with a period of 0.153846 day The γ-velocity, as well as the amplitude of the radial-velocity variation, is variable. A beat period of about 68 days is suspected

The variability of the radial velocity of Θ Ophiuchi [R.A. = $17^h18.9^m$, Decl. = $-24°57'$ (1950)] was discovered by F. Henroteau (1922), who observed the star on one night in June, 1920, and on several nights in June and July, 1922. From his observations of 1922, Henroteau concluded that the star is of the β Canis Majoris type with a period of 0.28620 day. The observations of 1920 seemed to indicate that a large variation in the mean velocity was present, and, probably on account of the very large scatter of the individual points around his mean curve, Henroteau concluded that "perhaps other complications have to be expected."

Recent lists of β CMa stars do not include this object, the reasons for its exclusion being that (1) Henroteau's period is definitely too large for the spectral type (B2) and luminosity class (IV) to make the star fit into the period-luminosity and period-spectrum relations found to hold for β CMa stars (Blaauw and Savedoff 1953; McNamara 1953*a*, *b*) and (2) the form of Henroteau's radial-velocity curve resembles, with its sharp maximum and broad minimum, that of a spectroscopic binary with fairly large eccentricity rather than that of a β CMa star.

However, after an inspection of Henroteau's results for the different nights separately, there is reason to think that the period proposed by him is not correct. In fact, Henroteau's measurements, which are here reproduced graphically in Figure 1, reveal among other things that (1) on all the "even" Julian days the radial velocity goes through a maximum at about 0.7 day, while it goes through a minimum at this same time of the day on all the "odd" Julian days, and (2) the rise from minimum to maximum, as well as the fall from maximum to minimum, radial velocity lasts in most instances less than 0.1 day.

The first circumstance proves that the period must be very close to

$$P=\frac{1^d}{n+0.5}, \qquad (1)$$

when n is an integer; the second circumstance reveals 5 to be the minimum value that should be tried for this integer and rules out the value 3, which actually is the one that corresponds to Henroteau's period of 0.28620 day.

In our opinion, which is strengthened by the results of our own measurements, Henroteau's investigation reveals further that the amplitude of the radial-velocity variation is variable; while it is large on JD 2422489, it is definitely smaller on JD 2423210 and 2423218 and increases again until the last night of the observations. This suggests that beats may be present, a phenomenon quite common among β CMa stars. This consideration, together with the expectation of a changing γ-velocity, has withheld us from constructing a mean curve with one of the periods derived from formula (1); instead, we drew curves with period $P = 0\overset{d}{.}153846$ (corresponding to $n = 6$ in formula [1]) through the points of the individual nights and adjusted their amplitudes and their mean velocities so as to get a reasonable scatter of the observations around them. We shall come back to these curves at the end of the present note.

In February, 1955, one of us (Bertiau) had the opportunity to take 29 spectrograms of Θ Ophiuchi at the McDonald Observatory, as part of Dr. Blaauw's spectroscopic program of stars in the nearest associations. All plates were taken with the D camera at the coudé spectrograph and have a dispersion of about 35 A/mm.

Their measurement by the senior author gives the results collected in Table 1 and shown graphically in Figure 2. The lines measured were the hydrogen lines Hβ–H15 and the He I lines between 4922 and 3819. In order to save labor, the computation of the mean errors has been limited to about half the total number of plates. The general average mean error per plate is seen to be of the order of 2 km/sec.

The only two nights on which several plates have been taken show the peculiarity to which we drew attention in considering Henroteau's results: at fraction 0.96 of the *even* Julian day, the radial velocity goes through a maximum, while it goes through a minimum at this same fraction of the *odd* Julian day.

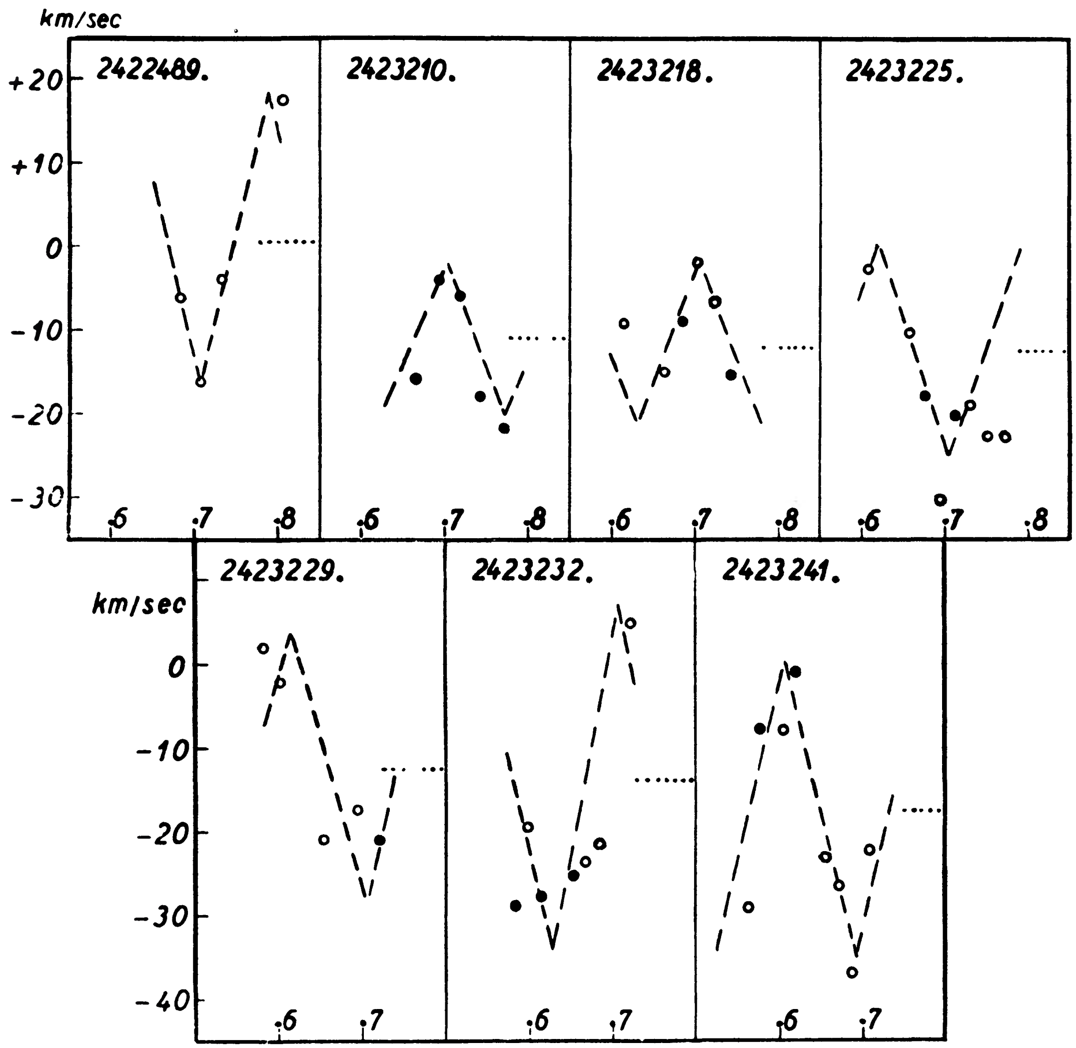

FIG. 1.—Henroteau's radial velocities for the Julian day marked on each plot Abscissae are fractions of the Julian day. Dots represent observations qualified as "the best" by Henroteau.

From this we felt entitled to represent all the observations in one plot having the fraction of the Julian day corresponding to the time of the observation as abscissa. A mean curve was then drawn through the points of the *even* nights and another one through the points on the *odd* nights. As the nights of both sets are in regular alternation and are about equal in number, a variation in the amplitude or in the γ-velocity in the course of the 3 weeks covered by the observations must have affected the tracing of our two curves by practically the same amount, so that the period is very nearly equal to twice the distance between their points of intersection.

The result, 0.15 day, is closest to 1/6.5 day and, owing to the necessity to satisfy formula (1), the latter value or

$$P = 0^{\mathrm{d}}.153846 = 3^{\mathrm{h}}42^{\mathrm{m}}$$

TABLE 1

RADIAL VELOCITIES OF Θ OPHIUCHI OBSERVED IN FEBRUARY, 1955

Plate Cg	Night Feb., 1955	U T	JD 2430000	Radial Velocity (km/sec)	No. of Lines Used	Mean Error (km/sec)
1109	7–8	12:20	5146 014	− 5 3	24	±1 5
1110	7–8	12:43	030	− 5 2	26	1 4
1132	8–9	11:36	984	− 8 0	24	1 3
1162	9–10	11:50	7 993	−11 2	25	1 2
1163	9–10	12:01	8 001	−10 1	25	1 3
1204	11–12	11:42	9 988	− 6 1	20	1 4
1205	11–12	11:47	991	− 7 3	24	
1282	14–15	12:03	53 002	−10 6	24	1 5
1283	14–15	12:09	006	−10 5	25	
1364	16–17	11:54	4 996	− 8 0	24	1 2
1365	16–17	12:00	5 000	− 9 0	26	
1434	19–20	10:07	7 922	− 5 6	17	2 2
1436	19–20	10:58	957	−11 8	24	
1439	19–20	11:44	989	− 9 5	25	2 2
1443	19–20	12:50	8 035	− 6 7	20	
1444	19–20	13:00	042	− 5 2	23	2 2
1546	24–25	9:30	62 896	−12 2	19	3 0
1547	24–25	9:47	908	− 8 7	25	
1548	24–25	10:01	918	− 7 4	23	
1549	24–25	10:16	928	− 7 3	23	
1550	24–25	10:34	941	− 7 2	18	2 3
1551	24–25	10:52	953	− 4 2	20	
1552	24–25	11:08	964	− 4 6	23	
1553	24–25	11:23	975	− 2 9	20	
1554	24–25	11:38	985	− 7 4	17	
1556	24–25	12:27	3 019	−10 1	24	2 4
1563	25–26	12:38	4 026	− 3 8	24	2 0
1580	27–28	12:37	6 026	− 5 3	19	±0 9

is a better approximation to the real period. We say "approximation," because there is not between the exact period and the duration of the solar day the nice commensurability illustrated by formula (1).

At the time of Henroteau's observations the radial velocities went through a maximum at fraction 0.70 of the even Julian day; in our observations there is a maximum observed at fraction 0.96 of the even Julian day, so that the preceding one must have occurred at 0.81. Hence the 1922 maximum is seen to be shifted $0^d.11 + N$ periods forward in 1955, N being zero or a positive or negative integer. Because of the length of the interval between the two sets of observations, it is impossible to determine N and to improve P. The consideration, however, that the time of maximum radial velocity was practically the same in 1920 and in 1922 suggests that N is very small, 0 or +1 or −1 being the most probable values.

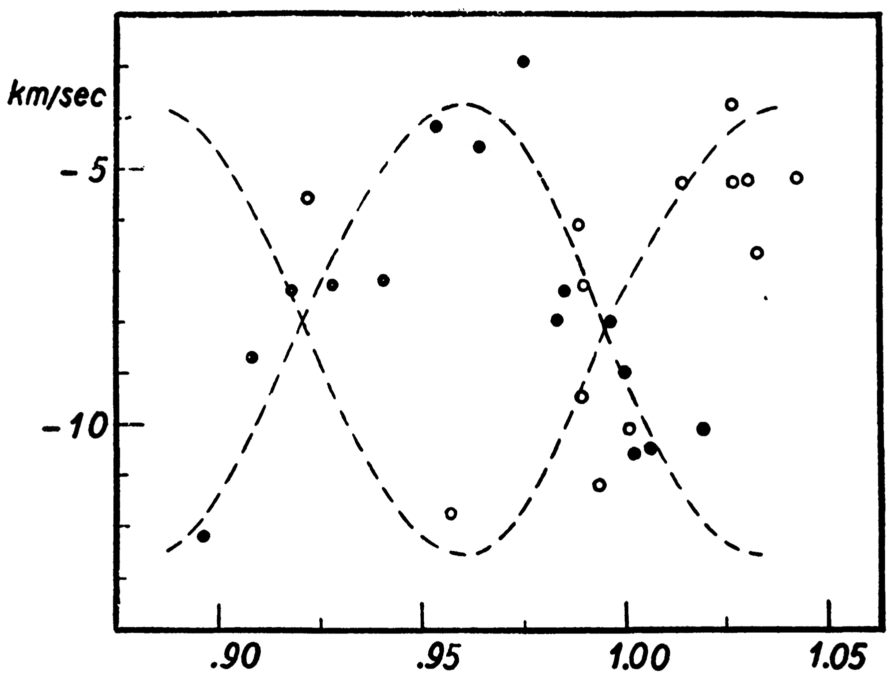

FIG. 2 —The new observations. Abscissae are fractions of the Julian day. Dots represent observations on the mornings of "odd" days in February, 1955 (= "even" Julian days); circles refer to observations on the mornings of "even" days in that same month (= "odd" Julian days).

The period proposed by us is therefore a very close approximation to the true period, and it places the star at the right spot in Struve's (1955) synoptic table of β CMa stars. With its spectral type B2 and luminosity class IV in Morgan's system, Θ Oph has indeed the expected absolute magnitude $M_v = -3.0$, as was determined recently by Bertiau from its membership of the Scorpio-Centaurus cluster.

The γ-velocity at the time of our observations was −8 km/sec, a value distinctly different from the 1920 and 1922 values, which were 0 and −15 km/sec, respectively. Henroteau's statement concerning the variability of the γ-velocity is therefore confirmed.

For the amplitude of the radial-velocity variation we find about 8 km/sec, which value is based mainly on the observations of February 19 and 24. This value is again definitely smaller than those that can be derived from Henroteau's observations. Beats may therefore well be present.

Taking into account the conclusions from the two foregoing paragraphs, we drew through Henroteau's points the curves shown as dashed lines in Figure 1. Some arbitrariness in their drawing was unavoidable, but, as they stand, they show a reasonable spread of the observations and seem to indicate (1) that the γ-velocity increased from about -12.5 km/sec at the beginning of the 1922 observations to about -17.5 km/sec near the end and (2) that the amplitude increased at the same time from about 20 km/sec to about 35 km/sec. The latter value has also been attained on the single night that the star has been under observation in 1920.

Assuming 35 km/sec to be the maximum amplitude (there is apparently no further increase between JD 2423232 and 2423241) and 8 km/sec to be the minimum amplitude (our observations, though inadequate for the purpose, seem to indicate a standstill in the amplitude variation), we have the following information for the determination of the hypothetical beat period:

1. $2423239^{d} - 2422489^{d} = 750 \text{ days} = N' \times P'$,

2. $2435162^{d} - 2423239^{d} = 11923 \text{ days} = (N'' + \frac{1}{2}) \times P'$

where N' and N'' are integers and P' is the beat period; and

3. $$\frac{P'}{2} > 30 \text{ days} .$$

All these requirements are fulfilled with $P' = 68.3$ days, which is believed to give at least the order of the minimum value that may be expected for the beat period. The result can, of course, not be said to rest on a very solid base, but it constitutes the only information that can be gained from the existing material, and it may therefore be useful to those who are planning further observations of this star. [The old Lick observations (Campbell and Moore 1928) are of little use as long as the variation of the γ-velocity remains unknown.]

Because of unsteady weather conditions, our material is rather heterogeneous and does not lend itself well to a study of possible changes in the line widths. Our impression is, however, that the lines are somewhat broader on the ascending branch of the radial-velocity-curve than they are on the descending branch. Should this really be the case, then it would indicate that $K_2 > K_1$ (in Struve's notations). The star would then in this respect be similar to β CMa.

REFERENCES

Blaauw, A , and Savedoff, M P. 1953, *B A.N.*, **13**, 69.
Campbell, W. W., and Moore, J. H. 1928, *Pub Lick Obs.*, **16**, 253
Henroteau, F. 1922, *Pub. Dominion Obs., Ottawa*, **8**, 1.
McNamara, D. H. 1953*a*, *Pub. A S.P.*, **65**, 165.
———. 1953*b*, *ibid.*, p 286.
Struve, O. 1955, *Pub. A.S.P.*, **67**, 150.