# SPECTROSCOPIC OBSERVATIONS OF V CANUM VENATICORUM*

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ABSTRACT

Thirty spectrograms of the irregular variable V Canum Venaticorum have been obtained, mostly in 1935 and 1936, at various phases of the light-change.

*Radial velocities.*—The velocity ranges for emission and absorption are 5.5 and 8.1 km/sec, respectively. The displacement of the emission lines toward the violet with respect to the absorption lines averages 6.3 km/sec.

*Spectral changes.*—The spectrum changes very little during the period. Hydrogen emission lines persist throughout, but are somewhat weaker at minimum. $H\gamma$ and $H\delta$ are nearly equal in intensity and stronger than $H\beta$. The spectral type varies from M4 to M6.

The variability of V Canum Venaticorum ($\alpha = 13^h15^m.1$, $\delta = +46° 3'$, 1900) was discovered in 1910 by Miss Cannon, but irregularities in the light-curve have made classification difficult. In general, the light-changes resemble those of the Mira type, but the range of variation is small. The visual magnitude varies from about 6.8

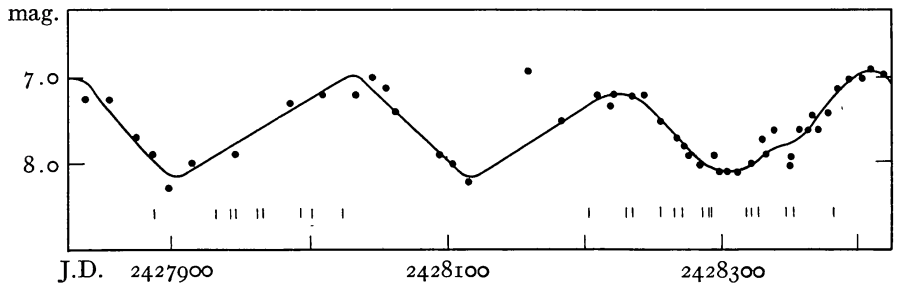


FIG. 1.—Light-curve of V Canum Venaticorum from observations by the American Association of Variable Star Observers. Dates of spectrographic observations are indicated by marks below the light-curve.

to about 8.4, although the limits are quite uncertain. The period apparently fluctuates between 190 and 198 days. In recent years the minima have been sharper than the maxima, but this has not always been the case. The rise in brightness from minimum to maximum is usually about 85 days, but in the last three periods it has been considerably longer; e.g., 129 days in 1935.

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Excellent series of light-curves have been published by Jacchia[1] and Lause.[2] We are greatly indebted to Mr. Leon Campbell, who has kindly furnished us with recent light-curves from observations made by members (chiefly Mr. Loreta) of the American Association of Variable Star Observers.

TABLE I

SPECTROGRAMS OF V CANUM VENATICORUM

| Plate | Date | J.D.− 2420000 | Phase from Max. (Days) | Velocities (Km/Sec) | |
|---|---|---|---|---|---|
| | | | | Emission | Absorption |
| C 5138 | 1929 Feb. 27 | 5670 | 173 | − 1.5 | + 1.1 |
| 5142 | Feb. 28 | 5671 | 174 | 2.6 | + 4.0 |
| 5147 | Mar. 1 | 5672 | 175 | 9.3 | − 4.0 |
| 6640 | 1935 Mar. 25 | 7887 | 50 | 18.4 | −13.8 |
| 6660 | May 9 | 7932 | 95 | 9.8 | + 2.2 |
| 6675 | May 19 | 7942 | 105 | 13.8 | − 4.2 |
| 6682 | May 23 | 7946 | 109 | 13.0 | − 7.0 |
| 6686 | June 8 | 7962 | 125 | 9.2 | − 5.0 |
| 6700 | June 12 | 7966 | 129 | 1.2 | + 7.0 |
| 6746 | July 7 | 7991 | 154 | 3.0 | − 0.4 |
| 6780 | July 17 | 8001 | 164 | 6.0 | + 0.2 |
| 6787 | Aug. 8 | 8023 | 186 | 13.9 | − 0.2 |
| γ 20924 | 1936 Feb. 4 | 8203 | 171 | 9.6 | − 1.6 |
| 20936 | Mar. 2 | 8230 | 3 | 10.9 | − 3.3 |
| C 6874 | Mar. 6 | 8234 | 7 | 5.9 | − 4.2 |
| γ 20968 | Mar. 27 | 8255 | 28 | 10.1 | − 1.6 |
| C 6885 | Apr. 6 | 8265 | 38 | 2.3 | ..... |
| 6887 | Apr. 7 | 8266 | 39 | 10.8 | − 6.2 |
| 6898 | Apr. 12 | 8271 | 44 | 5.2 | − 1.2 |
| 6900 | Apr. 27 | 8286 | 59 | 14.4 | − 5.8 |
| γ 21003 | May 1 | 8290 | 63 | 12.6 | − 4.8 |
| C 6915 | May 3 | 8292 | 65 | 13.0 | − 0.8 |
| 6924 | May 29 | 8318 | 91 | 15.2 | ..... |
| γ 21013 | June 1 | 8321 | 94 | 22.5 | ..... |
| V 1373 | June 7 | 8327 | 100 | 14.8 | − 8.2 |
| 1403 | June 27 | 8347 | 120 | 16.7 | −17.4 |
| C 6926 | July 2 | 8352 | 125 | 10.8 | − 9.7 |
| γ 21043 | Aug. 1 | 8382 | 155 | − 3.4 | + 0.2 |

Spectroscopic observations of V Canum Venaticorum were undertaken for the purpose of studying the radial velocities and spectral changes in an Me variable whose period is intermediate between that of R Virginis and *o* Ceti. Especial attention has been given to the radial-velocity determinations. Standard wave-lengths[3] adjusted to

[1] *Pub. Osser. Astr. R. Univ. Bologna*, **2**, 175, 1933. [2] *A.N.*, **252**, 147, 1934.

[3] Merrill, *Mt. W. Contr.*, No. 265; *Ap. J.*, **58**, 199, 1923.

M type were employed. The average number of absorption lines measured was 35 per plate. The 18-inch camera, giving a dispersion of about 35 A per millimeter at $H\gamma$, was used for all the spectrograms except the first (C 5138), which was exposed with the 10-inch camera.

Thirty spectrograms were obtained with the aid of the 60- and 100-inch reflectors. The data concerning the plates are listed in Table I. The velocities are the means of the values obtained by the two measurers, Miss Burwell and Joy. The emission lines $H\gamma$ and $H\delta$ appear on all the plates and are best adapted to accurate meas-

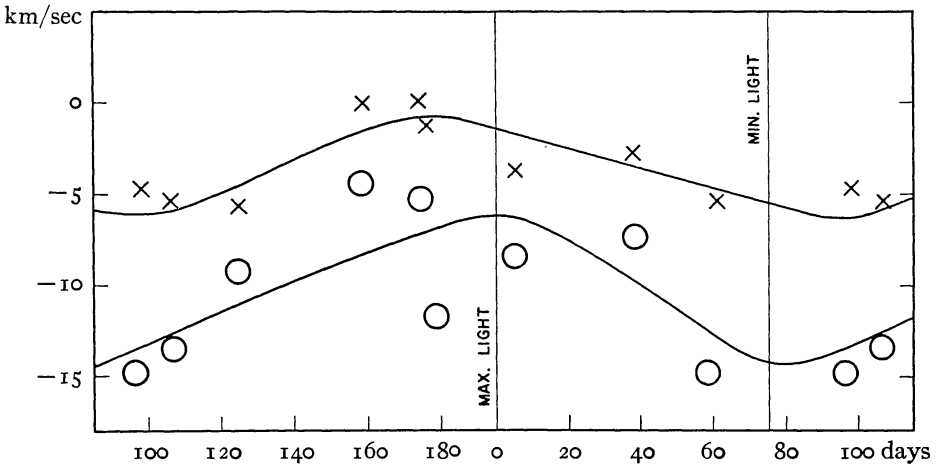


FIG. 2.—Radial velocity-curves of V Canum Venaticorum. Velocities from absorption lines (above) and from emission lines (below). Plotted points are normal places, including two to four observations.

urement. The velocities given by the other bright lines, $H\beta$, $H\zeta$, $H\eta$, and λ 3905 *Si*, have been adjusted so as to give values consistent in the mean with $H\gamma$ and $H\delta$.

## RADIAL VELOCITIES

The radial velocities from emission and absorption lines have been weighted and combined into nine normal places, which are plotted in Figure 2. The phases were computed from the elements

$$\text{Max.} = \text{J.D. } 2428032 + 195^{d}\,\text{E}\,.$$

The range is small in both curves, 5.5 km/sec for the absorption lines and 8.1 km/sec for the bright lines, and details of the variation

shown should not be accorded too much weight since the spread in the individual observations is rather large. There is some indication that for both absorption and emission lines the algebraically larger values, in the mean, fall near maximum light and the smaller velocities just after minimum; but the effect is so small that its significance is open to question.

The indicated effect is, for the dark lines, similar to that found in o Ceti[4] and R Virginis,[5] but in these stars the range of velocity is greater. The bright lines in other Me variables exhibit different behavior. In V Canum Venaticorum, however, we are inclined to emphasize the small range in the displacements of both bright and dark lines, rather than the dependence of displacement on phase.

The mean displacement of the dark lines is $-3.1$ km/sec, which may be taken as the radial velocity of the star. The mean value derived from the bright lines is $-9.7$ km/sec, yielding for the difference absorption *minus* emission ($A - E$), $+6.6$ km/sec. The average difference $A - E$ on individual plates is $+6.3$ km/sec, which is perhaps the preferable value. This is smaller than the value read from the curve of Figure 2, *Mt. Wilson Contr.*, No. 264,[6] but falls nearly on a smooth curve which neglects the apparent maximum near 215 days.

## SPECTRAL CHANGES

The spectral class is M5e with only minor variations. The absorption lines, including *Ca* 4227, exhibit a tendency toward lower intensities near minimum light, but the effect is less pronounced than for most of the lines in typical Me variables of longer period. In o Ceti and other advanced Me variables, however, *Ca* 4227 grows wider toward minimum. This line appears subject to two opposing effects, one of which tends to increase the intensity toward minimum, the other to decrease it. In V Canum Venaticorum the second effect prevails. The titanium oxide bands show variations in intensity corresponding approximately to the spectral range M4 to M6. At the high maximum of 1929 the bands were noticeably less intense than

[4] *Mt. W. Contr.*, No. 311; *Ap. J.*, **63**, 298, 1926.

[5] *Mt. W. Contr.*, No. 382; *Ap. J.*, **69**, 380, 1929.

[6] *Ap. J.*, **58**, 215, 1923.

usual. Slight variations were probably present at other times also, but no systematic correlation with phase is obvious.

The bright hydrogen lines $H\gamma$ and $H\delta$ are conspicuous on all the spectrograms of V Canum Venaticorum, but are less intense than in a typical long-period variable at time of maximum light. $H\beta$ is clearly seen on a few plates, while on others it is barely visible. $H\zeta$, and occasionally $H\eta$, are seen on the stronger exposures. The apparent intensities of $H\beta$, $H\gamma$, and $H\delta$ are approximately 1, 5, 6, respectively. So far as we recall, V Canum Venaticorum is the only Me variable yet observed in whose spectrum well-marked bright hydrogen lines persist without radical change throughout the whole light-cycle. These lines are, in fact, about three-fifths as intense at minimum light as at maximum, but this change is far less than that in the typical long-period variable in whose spectrum $H\gamma$ and $H\delta$ are extremely intense at maximum and disappear altogether at minimum. Thus, in variables with larger light-ranges, the conditions which produce hydrogen emission exist during a portion of the cycle only; but in V Canum Venaticorum they apparently prevail, in a nearly steady state, throughout the whole cycle. This circumstance is especially interesting because these bright lines, requiring an excitation (from the ground level of the hydrogen atom) of 13 volts, are anomalous in a spectrum which appears to originate in gases above a photosphere whose temperature is about 2500° C.

The fact that Harvard observers[7] found no bright lines on plates taken April 27, 1891, and June 1, 1899, may indicate that a secular change in the occurrence of emission lines has taken place.

On the stronger exposures taken near maximum light λ 3905 *Si* is present. Neither λλ 4202, 4308, 4571 nor the extreme low-temperature lines of iron have been noted in emission.

Lause[8] has suggested that a double-star system composed of two variable stars might account for the light-changes of V Canum Venaticorum, but the spectroscopic observations lend little support to such a hypothesis.

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[7] *H.A.*, **79**, 199, 1928.

[8] *Op. cit.*, p. 150.