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THE ORBITS OF THE SPECTROSCOPIC BINARIES  
H.D. 99967, H.D. 181144, H.D. 209813 and H.D. 213389

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THE ORBITS OF THE SPECTROSCOPIC BINARIES  
H.D. 99967, H.D. 181144, H.D. 209813 and H.D. 213389.

BY RUTH J. NORTHCOTT

THESE four stars were found to have variable velocities in the course of radial-velocity programmes at this Observatory. The positions, visual magnitudes, spectral classes, together with the reference announcing the variable character of the stars are given in Table I.

TABLE I

| Star        | 1900                               |          | Vis.<br>Mag. | D.D.O.<br>Type | Reference in<br>Pub. D.D.O. |
|-------------|------------------------------------|----------|--------------|----------------|-----------------------------|
|             | $\alpha$                           | $\delta$ |              |                |                             |
| H.D. 99967  | 11 <sup>h</sup> 25 <sup>m</sup> .0 | 47° 12'  | 6.49         | K0             | v.l. no. 16, 1945           |
| H.D. 181144 | 19 14.2                            | 16 19    | 6.92         | F7             | v.l. no. 3, 1939            |
| H.D. 209813 | 22 01.0                            | 46 45    | 6.52         | K0             | v.l. no. 3, 1939            |
| H.D. 213389 | 22 25.9                            | 48 51    | 6.52         | K1             | v.l. no. 16, 1945           |

The spectra of each of the stars were examined in order to determine the absolute magnitudes and spectroscopic parallaxes. The lines used were those used by R. K. Young and W. E. Harper.<sup>1</sup> The values are given in the tables of binary elements.

H.D. 99967

The first four plates taken of this star in 1942 and 1943 showed the velocity to vary over 50 km./sec., and it was put on the spectroscopic binary programme. Due to the poor observing weather during the winter and the binary's long and somewhat uncertain period of 75 days, observation of this star was not completed until 1946, with a total of 55 plates. All the plates but the first were taken with the 25-inch camera and one-prism spectrograph, giving a dispersion of about 33 Å./mm. at H $\gamma$ . The information obtained from these plates is given in Table II. The observations were grouped according to phase into 33 observational equations; in no case did the observations to be grouped differ in time by more than one revolution. Weights (1, 2, 3) were assigned according to the number of plates.

<sup>1</sup>Pub. D. A. O., v. 3, p. 1, 1924.

The preliminary elements were derived using R. K. Young's<sup>2</sup> graphical method. It was found that a circular orbit fitted the observations fairly well. Final elements were derived using T. E.

TABLE II  
RADIAL-VELOCITY OBSERVATIONS OF H.D. 99967

| J.D. 243 | V <sub>o</sub><br>km./sec. | Phase from<br>final T | V <sub>o</sub><br>km./sec. | V <sub>o</sub> -V <sub>c</sub><br>km./sec. |
|----------|----------------------------|-----------------------|----------------------------|--|
| 0442.687 | +43.6                      | 39.837                | +45.8                      | -2.2                                       |
| 0797.752 | +51.1                      | 20.599                | +48.9                      | +2.2                                       |
| 0832.691 | +13.8                      | 55.538                | +11.8                      | +2.0                                       |
| 0849.611 | +00.6                      | 72.458                | +01.4                      | -0.8                                       |
| 0859.583 | +24.2                      | 7.569                 | +20.8                      | +3.4                                       |
| 0867.594 | +40.5                      | 15.580                | +40.2                      | +0.3                                       |
| 0873.594 | +50.8                      | 21.580                | +51.0                      | -0.2                                       |
| 0878.601 | +53.2                      | 26.587                | +55.5                      | -2.3                                       |
| 0885.609 | +57.0                      | 33.595                | +54.0                      | +3.0                                       |
| 0894.578 | +44.0                      | 42.573                | +40.7                      | +3.3                                       |
| 1187.665 | +52.7                      | 36.208                | +51.3                      | +1.4                                       |
| 1191.660 | +43.4                      | 40.203                | +45.2                      | -1.8                                       |
| 1194.662 | +38.9                      | 43.205                | +39.4                      | -0.5                                       |
| 1197.635 | +33.0                      | 46.178                | +32.7                      | +0.3                                       |
| 1199.639 | +26.9                      | 48.182                | +28.8                      | -1.9                                       |
| 1200.650 | +23.6                      | 49.193                | +25.9                      | -2.3                                       |
| 1202.633 | +21.6                      | 51.176                | +21.3                      | +0.3                                       |
| 1207.618 | +09.5                      | 56.161                | +10.4                      | -0.9                                       |
| 1208.624 | +07.1                      | 57.167                | +08.6                      | -1.5                                       |
| 1209.611 | +07.5                      | 58.154                | +06.8                      | +0.7                                       |
| 1210.621 | +03.4                      | 59.164                | +05.2                      | -1.8                                       |
| 1213.619 | +03.2                      | 62.162                | +01.2                      | +2.0                                       |
| 1218.612 | -07.4                      | 67.155                | -01.1                      | -6.0                                       |
| 1221.609 | -01.0                      | 70.152                | -00.6                      | -0.4                                       |
| 1224.604 | +03.2                      | 73.147                | +02.3                      | +0.9                                       |
| 1226.567 | +06.6                      | 0.249                 | +05.2                      | +1.4                                       |
| 1227.574 | +05.3                      | 1.256                 | +06.9                      | -1.6                                       |
| 1231.578 | +15.7                      | 5.260                 | +15.3                      | +0.4                                       |
| 1235.617 | +24.4                      | 9.299                 | +25.1                      | -0.7                                       |
| 1528.702 | +12.0                      | 2.942                 | +10.2                      | +1.8                                       |
| 1537.646 | +33.6                      | 11.886                | +31.6                      | +2.0                                       |
| 1538.689 | +34.0                      | 12.929                | +34.1                      | -0.1                                       |
| 1539.653 | +33.8                      | 13.893                | +36.4                      | -2.6                                       |
| 1542.637 | +41.6                      | 16.877                | +43.0                      | -1.4                                       |

<sup>2</sup>J. R. A. S. C., v. 11, p. 130, 1917.

TABLE II—Continued  
 RADIAL-VELOCITY OBSERVATIONS OF H.D. 99967

| J.D. 243 | V <sub>o</sub><br>km./sec. | Phase from<br>final T | V <sub>c</sub><br>km./sec. | V <sub>o</sub> - V <sub>c</sub><br>km./sec. |
|----------|----------------------------|-----------------------|----------------------------|---|
| 1543.643 | +45.4                      | 17.883                | +44.9                      | +0.5  |
| 1551.586 | +53.1                      | 25.826                | +55.1                      | -2.0  |
| 1552.592 | +56.4                      | 26.832                | +55.6                      | +0.8  |
| 1553.570 | +56.6                      | 27.810                | +55.9                      | +0.7  |
| 1554.578 | +56.0                      | 28.818                | +56.0                      | 0.0   |
| 1555.599 | +54.2                      | 29.839                | +55.9                      | -1.7  |
| 1578.587 | +19.0                      | 52.827                | +17.6                      | +1.4  |
| 1589.585 | -01.4                      | 63.825                | -00.3                      | -1.1  |
| 1882.726 | +06.3                      | 57.523                | +08.0                      | -1.7  |
| 1883.703 | +08.2                      | 58.499                | +06.3                      | +1.9  |
| 1905.681 | +14.0                      | 5.617                 | +16.1                      | -2.1  |
| 1907.737 | +22.5                      | 7.673                 | +21.1                      | +1.4  |
| 1908.681 | +23.0                      | 8.617                 | +22.9                      | +0.1  |
| 1921.660 | +51.1                      | 21.596                | +51.0                      | +0.1  |
| 1922.684 | +51.3                      | 22.620                | +52.3                      | -1.0  |
| 1923.626 | +53.7                      | 23.562                | +53.4                      | +0.3  |
| 1929.597 | +59.2                      | 29.533                | +56.0                      | +3.2  |
| 1942.615 | +40.0                      | 42.551                | +40.7                      | -0.7  |
| 1943.606 | +36.7                      | 43.542                | +38.7                      | -2.0  |
| 1962.705 | +00.8                      | 62.641                | +00.7                      | +0.1  |
| 1985.621 | +30.0                      | 10.696                | +28.6                      | +1.4  |

Sterne's<sup>3</sup> form of least-squares solution for very small eccentricity. Corrections were computed for all six elements. Reduction of

TABLE III  
 ORBITAL ELEMENTS OF H.D. 99967

|  | Preliminary       | Final                       |          |
|--|-------------------|-----------------------------|----------|
| Period                                 | P 74.87 days      | 74.861 days                 | ± 0.0148 |
| Eccentricity                           | e 0               | 0.0290                      | ± 0.0066 |
| Angle of periastron                    | ω                 | 218°.70                     | ± 12°.9  |
| Periastron passage                     | T                 | J.D.2430852.014             | ± 0.137  |
| Velocity of system                     | γ +27.85 km./sec. | +27.863                     | ± 0.107  |
| Semi-amplitude                         | K 29.0 km./sec.   | 28.771                      | ± 0.192  |
| a sin i                                |                   | 2.961 × 10 <sup>7</sup> km. |          |
| $\frac{m_1^3 \sin^3 i}{(m_1 + m_2)^2}$ |                   | 0.185☉                      |          |
| Absolute magnitude                     | M (spectroscopic) | +0.3                        |          |
| Spectroscopic parallax                 |                   | 0".006                      |          |

<sup>3</sup>Proc. Nat. Acad. of Sc., v. 27, p. 179, 1941.

$\Sigma pv^2$  was from 136 to 108. Table III gives the preliminary and final elements obtained.

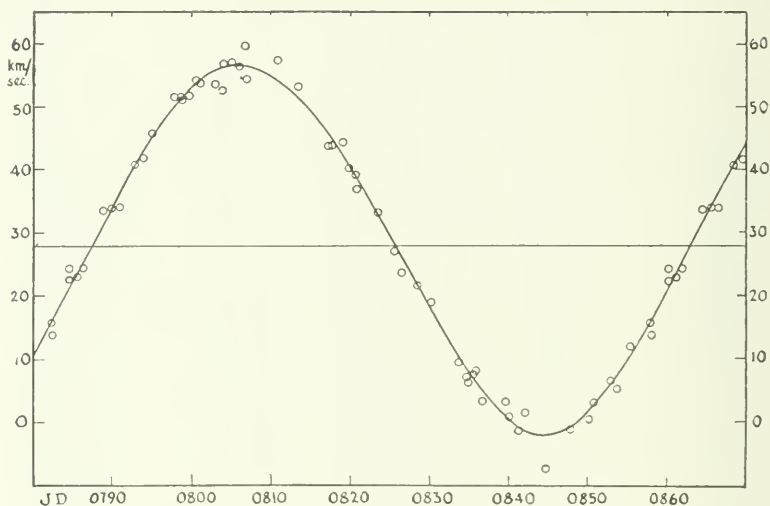


FIGURE 1—Velocity Curve of the Spectroscopic Binary H.D. 99967

The individual observations are plotted on the graph in figure 1. The probable error of a single plate is 1.9 km./sec.

#### H.D. 181144

Four plates of this star, taken in 1938, showed variation in radial velocity of over 50 km./sec. It was put on the spectroscopic binary programme in 1945 and 25 plates were obtained; a few plates were taken in 1946 to complete the observation. The early plates were taken with the one-prism spectrograph and the 12½-inch camera giving a dispersion of 66 Å./mm. at H $\gamma$ ; the rest of the plates were taken with the 25-inch camera and 33 Å./mm. at H $\gamma$ . The data from the individual plates are given in Table IV. The early observations enabled the period to be well determined and the others were grouped according to phase into 20 observational equations, weighted (1, 2, 3) according to number of plates.

The preliminary orbit, derived graphically, was essentially circular. T. E. Sterne's method of least-squares solution for very

small eccentricities was used to determine the corrections for the five elements. Reduction of  $\Sigma pv^2$  was from 117 to 101. Table V gives the preliminary and final elements obtained.

TABLE IV

RADIAL-VELOCITY OBSERVATIONS OF H.D. 181144

| J.D. 242-243 | $V_o$<br>km./sec. | Phase from<br>final T | $V_c$<br>km./sec. | $V_o - V_c$<br>km./sec. |
|--------------|-------------------|-----------------------|-------------------|-------------------------|
| 9082.758     | +23.8             | 5.262                 | +33.2             | -9.4                    |
| 9170.583     | -15.2             | 1.622                 | -09.9             | -5.3                    |
| 9172.540     | -33.8             | 3.579                 | -30.0             | -3.8                    |
| 9184.543     | +18.2             | 4.821                 | +21.3             | -3.1                    |
| 1630.812     | -39.3             | 3.055                 | -41.0             | +1.7                    |
| 1631.779     | -09.1             | 4.022                 | -13.1             | +4.0                    |
| 1647.751     | -21.3             | 3.853                 | -20.2             | -1.1                    |
| 1653.731     | +07.5             | 4.452                 | +06.0             | +1.5                    |
| 1656.663     | -24.4             | 2.004                 | -25.3             | +0.9                    |
| 1661.713     | -10.0             | 1.673                 | -12.1             | +2.1                    |
| 1666.713     | +06.7             | 1.293                 | +04.6             | +2.1                    |
| 1669.695     | -00.5             | 4.275                 | -01.9             | +1.4                    |
| 1670.707     | +34.4             | 5.287                 | +32.6             | +1.8                    |
| 1672.686     | -23.0             | 1.886                 | -20.8             | -2.2                    |
| 1678.701     | -39.7             | 2.521                 | -39.3             | -0.4                    |
| 1684.680     | -37.3             | 3.120                 | -40.3             | +3.0                    |
| 1686.626     | +26.0             | 5.066                 | +28.2             | -2.2                    |
| 1691.601     | +15.7             | 4.660                 | +14.7             | +1.0                    |
| 1694.674     | -36.4             | 2.353                 | -35.8             | -0.6                    |
| 1695.579     | -38.1             | 3.258                 | -38.2             | +0.1                    |
| 1704.533     | -04.1             | 1.451                 | -02.4             | -1.7                    |
| 1706.672     | -32.7             | 3.590                 | -29.7             | -3.0                    |
| 1708.656     | +33.9             | 0.194                 | +34.4             | -0.5                    |
| 1710.584     | -29.9             | 2.122                 | -29.3             | -0.6                    |
| 1711.649     | -37.2             | 3.187                 | -39.3             | +2.1                    |
| 1714.583     | +20.0             | 0.741                 | +25.5             | -5.5                    |
| 1746.488     | +32.1             | 0.364                 | +33.3             | -1.2                    |
| 1757.496     | +33.9             | 0.611                 | +29.0             | +4.9                    |
| 1763.467     | +09.6             | 1.202                 | +08.5             | +1.1                    |
| 1975.850     | -26.8             | 3.759                 | -23.8             | -3.0                    |
| 1981.831     | -01.8             | 4.354                 | +01.6             | -3.4                    |
| 1985.856     | -43.2             | 2.999                 | -41.5             | -1.7                    |
| 1990.761     | -39.9             | 2.523                 | -39.4             | -0.5                    |
| 2010.760     | +17.1             | 1.001                 | +16.7             | +0.4                    |

TABLE V  
ORBITAL ELEMENTS OF H.D. 181144

|  | Preliminary             | Final                   |                        |
|--|-------------------------|-------------------------|------------------------|
| Period                                 | P 5.3803 days           | 5.3803                  | $\pm 0.0004$ estimated |
| Eccentricity                           | e 0                     | 0.0183                  | $\pm 0.0091$           |
| Angle of periastron                    | $\omega$                | 348°.74                 | $\pm 29^\circ.2$       |
| Periastron passage                     | T                       | J.D.2431638.518         | $\pm 0.008$            |
| Velocity of system                     | $\gamma$ -04.6 km./sec. | -04.440                 | $\pm 0.253$            |
| Semi-amplitude                         | K 38.5 km./sec.         | 38.176                  | $\pm 0.364$            |
| $a \sin i$                             |                         | $2.824 \times 10^6$ km. |                        |
| $\frac{m_1^3 \sin^3 i}{(m_1 + m_2)^2}$ |                         | 0.0311 $\odot$          |                        |
| Absolute magnitude                     | M (spectroscopic)       | +4.2                    |                        |
| Spectroscopic parallax                 |                         | 0''.029                 |                        |

The individual observations are plotted on the graph in figure 2. The probable error of a single plate is 1.5 km./sec.

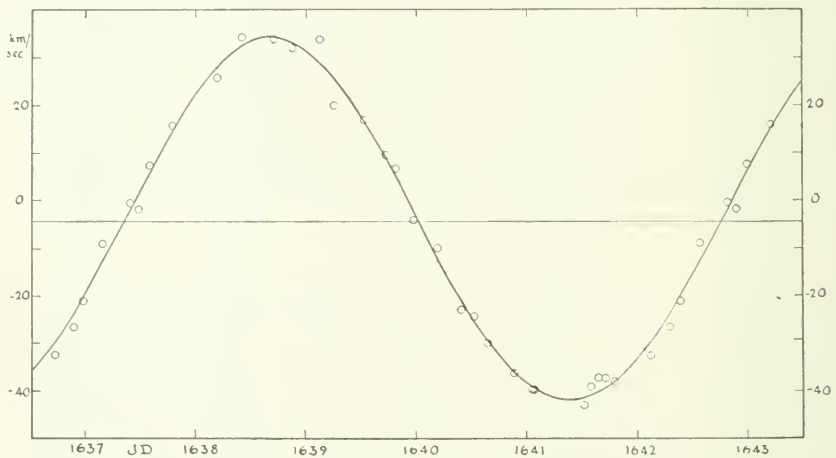


FIGURE 2—Velocity Curve of the Spectroscopic Binary H. D. 181144

### H.D. 209813

Four early plates, taken 1935-1937 showed this star to vary in radial velocity by about 55 km./sec. In 1945 observations to



TABLE VI  
 RADIAL-VELOCITY OBSERVATIONS OF H.D. 209813

| J.D. 242-243 | V <sub>o</sub><br>km./sec. | Phase from<br>final T | V <sub>c</sub><br>km./sec. | V <sub>o</sub> -V <sub>c</sub><br>km./sec. |
|--------------|----------------------------|-----------------------|----------------------------|--|
| 8131.491     | -32.6                      | 13.167                | -31.1                      | -1.5                                       |
| 8432.631     | +16.0                      | 21.135                | +11.0                      | +5.0                                       |
| 8769.750     | -08.0                      | 16.220                | -06.8                      | -1.2                                       |
| 8798.644     | +04.2                      | 20.683                | +11.4                      | -7.2                                       |
| 1647.847     | -46.1                      | 11.459                | -43.1                      | -3.0                                       |
| 1653.825     | +02.2                      | 17.437                | +01.4                      | +0.8                                       |
| 1666.803     | -51.2                      | 5.984                 | -51.0                      | -0.2                                       |
| 1669.794     | -49.7                      | 8.975                 | -53.8                      | +4.1                                       |
| 1672.779     | -38.6                      | 11.960                | -39.9                      | +1.3                                       |
| 1678.772     | +01.1                      | 18.043                | +04.8                      | -3.7                                       |
| 1683.772     | +03.1                      | 22.953                | +04.6                      | -1.5                                       |
| 1685.772     | -07.3                      | 0.522                 | -09.6                      | +2.3                                       |
| 1686.762     | -16.4                      | 1.512                 | -17.3                      | +0.9                                       |
| 1691.674     | -52.5                      | 6.424                 | -52.5                      | 0.0  |
| 1694.728     | -51.8                      | 9.478                 | -52.4                      | +0.6                                       |
| 1701.719     | -02.7                      | 16.469                | -05.0                      | +2.3                                       |
| 1702.712     | +02.5                      | 17.462                | +01.5                      | +1.0                                       |
| 1703.714     | +08.5                      | 18.464                | +06.8                      | +1.7                                       |
| 1704.706     | +13.6                      | 19.456                | +10.1                      | +3.5                                       |
| 1705.722     | +09.9                      | 20.472                | +11.4                      | -1.5                                       |
| 1706.697     | +09.2                      | 21.447                | +10.4                      | -1.2                                       |
| 1708.698     | -01.0                      | 23.448                | +01.6                      | -2.6                                       |
| 1710.644     | -15.5                      | 0.963                 | -13.4                      | -2.1                                       |
| 1714.718     | -48.9                      | 5.037                 | -46.3                      | -2.6                                       |
| 1715.782     | -52.9                      | 6.101                 | -51.4                      | -0.5                                       |
| 1728.686     | +08.9                      | 19.005                | +08.8                      | +0.1                                       |
| 1746.545     | -36.8                      | 12.433                | -36.6                      | -0.2                                       |
| 1747.633     | -28.2                      | 13.521                | -28.3                      | +0.1                                       |
| 1748.694     | -25.5                      | 14.582                | -19.7                      | -5.8                                       |
| 1757.590     | +02.6                      | 23.478                | +01.4                      | +1.2                                       |
| 1765.549     | -54.3                      | 7.006                 | -54.0                      | -0.3                                       |
| 1770.644     | -35.6                      | 12.101                | -38.9                      | +3.3                                       |
| 1790.476     | -57.3                      | 7.502                 | -54.7                      | -2.6                                       |
| 1791.489     | -54.8                      | 8.515                 | -54.5                      | -0.3                                       |
| 1813.454     | -51.5                      | 6.049                 | -51.2                      | -0.3                                       |
| 2017.831     | -16.1                      | 14.978                | -16.5                      | +0.4                                       |
| 2025.815     | +02.1                      | 22.962                | +04.5                      | -2.4                                       |
| 2028.865     | -18.6                      | 1.581                 | -18.9                      | +0.3                                       |
| 2037.783     | -49.3                      | 10.499                | -48.4                      | -0.9                                       |
| 2056.744     | -44.4                      | 5.029                 | -46.2                      | +1.8                                       |
| 2078.652     | -25.0                      | 2.506                 | -27.1                      | +2.1                                       |
| 2079.807     | -37.3                      | 3.661                 | -36.8                      | -0.5                                       |
| 2098.630     | +10.4                      | 22.484                | +06.9                      | +3.5                                       |

determine its orbit were started; 39 plates were obtained in 1945 and 1946. Three early plates were taken with the 12½-inch camera and one-prism spectrograph; the rest were with the 25-inch camera giving a dispersion of about 33 Å./mm. at H $\gamma$ . Table VI gives the information from these plates. Using the early plates, the period was well determined; the other plates were grouped according to phase into 25 observational equations. Weights (1, 2) were assigned according to the number of plates.

TABLE VII

| J. D.<br>242-243 | V <sub>H and K</sub><br>km./sec. | V <sub>c</sub><br>km./sec. | O-C<br>km./sec. |
|------------------|----------------------------------|----------------------------|-----------------|
| 8798.644         | +11.4                            | +11.4                      | 0.0             |
| 1672.779         | -48.8                            | -39.9                      | -8.9            |
| 1678.772         | +00.4                            | +04.8                      | -3.4            |
| 1790.476         | -54.3                            | -54.7                      | +0.4            |
| 2028.865         | -32.7*                           | -18.9                      | -13.8           |
| 2037.783         | -54.7*                           | -48.4                      | -6.3            |

The spectrum of the star is K0. Emission H and K lines of calcium were observed on six plates of strong exposure. The velocities given by the H and K lines are shown in Table VII. The asterisk means the velocity of the H line only is given.

TABLE VIII

ORBITAL ELEMENTS OF H.D. 209813

|  | Preliminary             | Final                       |
|--|-------------------------|-----------------------------|
| Period                                 | P 24.431 days           | 24.431 ± 0.002 (estim'd)    |
| Eccentricity                           | e 0                     | 0.0271 ± 0.0079             |
| Angle of periastron                    | $\omega$                | 60°.38 ± 17°.8              |
| Periastron passage                     | T                       | J.D.2431660.819 ± 0.026     |
| Velocity of system                     | $\gamma$ -22.0 km./sec. | -22.208 ± 0.147             |
| Semi-amplitude                         | K 34.5 km./sec.         | 33.135 ± 0.240              |
| $a \sin i$                             |                         | 1.113 × 10 <sup>7</sup> km. |
| $\frac{m_1^3 \sin^3 i}{(m_1 + m_2)^2}$ |                         | 0.0922☉                     |
| Absolute magnitude                     | M (spectroscopic)       | +3.3                        |
| Spectroscopic parallax                 |                         | 0''.023                     |

The preliminary orbit was circular and was found graphically. The five final elements were found using T. E. Sterne's method of least-squares solution for small eccentricities. Reduction of  $\Sigma pv^2$  was from 167 to 105. Table VIII gives the preliminary and final elements obtained.

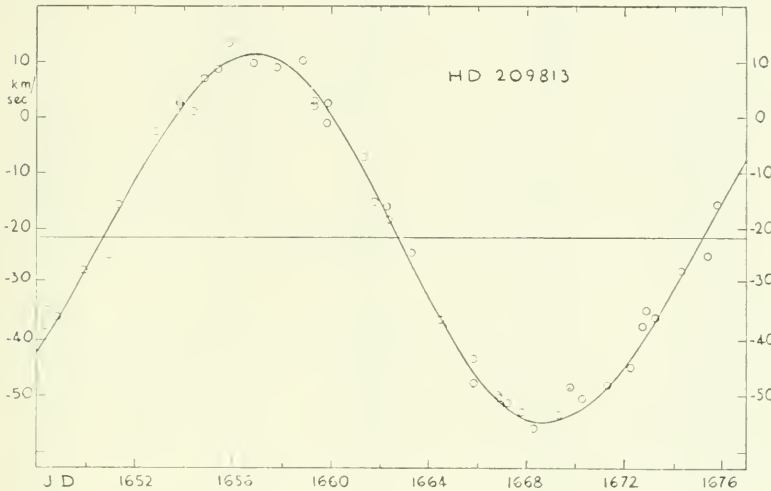


FIGURE 3—Velocity Curve of the Spectroscopic Binary H. D. 209813

The individual observations are plotted on the graph in figure 3. The probable error of a single plate is 1.4 km./sec.

#### H.D. 213389

During 1942 and 1943 five plates of this star were taken, showing it to vary by about 66 km./sec. In 1945 observations were commenced to determine its orbit; 36 plates were obtained during 1945 and 1946. All the plates were taken with the one-prism spectrograph and the 25-inch camera giving a dispersion of about 33 A./mm. at  $H\gamma$ . Table IX gives the information from these plates. The period was determined with considerable accuracy from the early plates. The other plates were grouped according to phase into 24 observational equations and weighted (1, 2) according to the number of plates.

TABLE IX  
 RADIAL-VELOCITY OBSERVATIONS OF H.D. 213389

| J.D. 243 | V <sub>o</sub><br>km./sec. | Phase from<br>final T | V <sub>c</sub><br>km./sec. | V <sub>o</sub> -V <sub>c</sub><br>km./sec. |
|----------|----------------------------|-----------------------|----------------------------|--|
| 0576.784 | -33.4                      | 2.886                 | -33.5                      | +0.1                                       |
| 0914.844 | -32.0                      | 3.601                 | -35.0                      | +3.0                                       |
| 0973.762 | +18.6                      | 9.251                 | +18.0                      | +0.6                                       |
| 0989.655 | -05.1                      | 7.392                 | -05.6                      | +0.5                                       |
| 1010.635 | +32.8                      | 10.617                | +34.6                      | -1.8                                       |
| 1656.726 | +03.1                      | 17.528                | -00.8                      | +3.9                                       |
| 1666.772 | +28.5                      | 9.819                 | +26.2                      | +2.3                                       |
| 1672.807 | +27.0                      | 15.854                | +23.3                      | +3.7                                       |
| 1678.799 | -33.9                      | 4.092                 | -34.5                      | +0.6                                       |
| 1684.738 | +33.2                      | 10.030                | +28.6                      | +5.6                                       |
| 1686.784 | +45.1                      | 12.076                | +44.1                      | +1.0                                       |
| 1694.756 | -30.1                      | 2.293                 | -30.2                      | +0.1                                       |
| 1701.745 | +15.4                      | 9.282                 | +19.7                      | -4.3                                       |
| 1702.747 | +31.2                      | 10.284                | +31.3                      | -0.1                                       |
| 1704.755 | +39.3                      | 12.292                | +44.7                      | -5.4                                       |
| 1705.756 | +43.4                      | 13.293                | +44.7                      | -1.3                                       |
| 1706.758 | +41.8                      | 14.295                | +39.7                      | +2.1                                       |
| 1708.725 | +17.6                      | 16.262                | +18.0                      | -0.4                                       |
| 1710.692 | -11.4                      | 0.474                 | -10.8                      | -0.6                                       |
| 1715.729 | -27.2                      | 5.511                 | -26.7                      | -0.5                                       |
| 1733.649 | -25.1                      | 5.676                 | -25.3                      | +0.2                                       |
| 1746.579 | -15.0                      | 0.851                 | -15.8                      | +0.8                                       |
| 1747.533 | -29.1                      | 1.805                 | -26.2                      | -2.9                                       |
| 1764.594 | -21.4                      | 1.111                 | -19.0                      | -2.4                                       |
| 1770.699 | -09.4                      | 7.216                 | -07.8                      | -1.6                                       |
| 1778.567 | +30.2                      | 15.084                | +32.5                      | -2.3                                       |
| 1780.534 | +06.0                      | 17.051                | +06.3                      | -0.3                                       |
| 1791.532 | +31.6                      | 10.294                | +31.4                      | +0.2                                       |
| 1794.490 | +46.6                      | 13.252                | +44.9                      | +1.7                                       |
| 1797.467 | +15.8                      | 16.229                | +18.2                      | -2.4                                       |
| 1813.497 | +37.1                      | 14.504                | +38.0                      | -0.9                                       |
| 2018.728 | -15.2                      | 6.675                 | -14.6                      | -0.6                                       |
| 2019.847 | +00.8                      | 7.794                 | -00.2                      | +1.0                                       |
| 2020.831 | +09.8                      | 8.778                 | +10.5                      | -0.7                                       |
| 2053.784 | -17.9                      | 6.221                 | -19.8                      | +1.9                                       |
| 2059.822 | +47.2                      | 12.259                | +43.5                      | +3.7                                       |
| 2066.716 | -19.6                      | 1.398                 | -22.2                      | +2.6                                       |
| 2076.603 | +40.8                      | 11.285                | +40.0                      | +0.8                                       |
| 2090.750 | -01.8                      | 7.677                 | -01.8                      | 0.0  |
| 2121.603 | -34.2                      | 3.020                 | -34.0                      | -0.2                                       |
| 2157.554 | -35.3                      | 3.461                 | -34.9                      | -0.4                                       |

The preliminary orbit was found by graphical means to be circular and T. E. Sterne's method of least-squares solution for orbits of small eccentricity was used to determine the five final elements. Reduction of  $\Sigma pv^2$  was from 178 to 111. Table X gives the preliminary and final elements obtained.

TABLE X  
ORBITAL ELEMENTS OF H.D. 213389

|  | Preliminary             | Final                   |                       |
|--|-------------------------|-------------------------|-----------------------|
| Period                                 | P 17.755 days           | 17.755                  | $\pm 0.002$ (estim'd) |
| Eccentricity                           | e 0                     | 0.0226                  | $\pm 0.0073$          |
| Angle of periastron                    | $\omega$                | $103^\circ.34$          | $\pm 19^\circ.8$      |
| Periastron passage                     | T                       | J.D.2431656.953         | $\pm 0.021$           |
| Velocity of system                     | $\gamma$ +05.0 km./sec. | +05.356                 | $\pm 0.215$           |
| Semi-amplitude                         | K 40.0 km./sec.         | 40.172                  | $\pm 0.305$           |
| $a \sin i$                             |                         | $9.806 \times 10^6$ km. |                       |
| $\frac{m_1^3 \sin^3 i}{(m_1 + m_2)^2}$ |                         | 0.119 $\odot$           |                       |
| Absolute magnitude                     | M (spectroscopic)       | +2.2                    |                       |
| Spectroscopic parallax                 |                         | 0".014                  |                       |

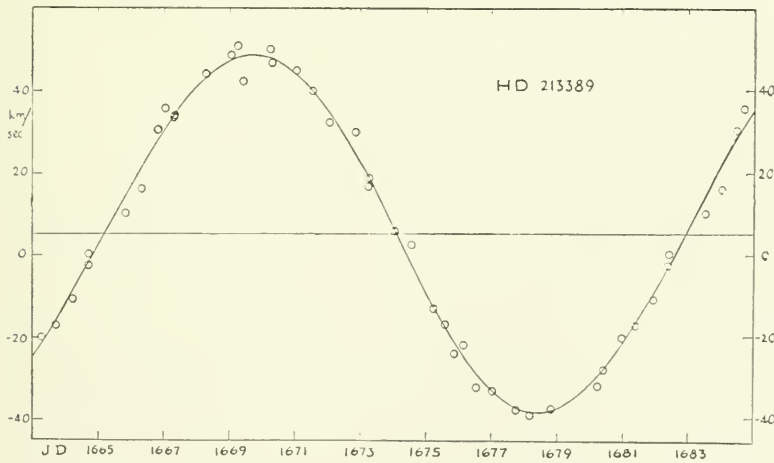


FIGURE 4—Velocity Curve of the Spectroscopic Binary H. D. 213389

The individual observations are plotted on the graph in figure 4. The probable error of a single plate is 1.5 km./sec.

Richmond Hill, Ontario  
March 1, 1947.

