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70 OPHIUCHI AS A TRIPLE SYSTEM

BY
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It has long been known that the orbital motion of 70 *Ophiuchi* (magn. 4.28, 5.98; sp. dK0, dK6) is not strictly Keplerian[1] during the course of its 88-year period so that at the present time the ellipse has failed to close on itself by 0″.3. The explanation accounting for the irregularities in the motion of this double star solely on the basis of systematic errors in position angle as advocated within recent times, principally by Lohse[2] and Lau[3], does not entirely remove the observed discrepancies.[4] A more plausible view, held by the majority of investigators, is that there exists a third member in the system giving rise to perturbations apparently of varying amplitude and of indefinite period.

The chief difficulty in undertaking a rational analysis of the remarkable behavior of this system has hitherto been the lack of precise observational data, despite the fact that 70 *Ophiuchi* has been perhaps more frequently observed than any other known double star. The spectrographic observations have therefore opened up a new line of attack which in collaboration with accurate photographic measures should eventually yield a solution to this baffling problem. At the present time the photographic results are too limited in number to be combined with the spectrographic data, now covering a 34-year span, for the purpose of completely investigating the anomolies presented by this system. As they stand now, the radial velocities obtained with the Mills three-prism spectrograph attached to the 36-inch refractor, while supporting the existence of a third dark body revolving about the brighter visual component in a period of eighteen years, cannot readily be reconciled with the deviations resulting from motion of this kind as revealed by the visual measures.

In 1908, Campbell[5] called attention to the radial velocities of the brighter component of 70 *Ophiuchi* derived from spectrograms taken during the years 1897–1908 and showed that they clearly exhibited the gradual change in the orbital velocity of the companion around the center of gravity of the visual system. On further examining the spectroscopic material available at the present time, the writer was struck with the abnormal departure of the observed velocities in the years 1911–1922 from the computed radial velocity curve of 70A *Ophiuchi*. In order to check the reality of its existence, the older spectrograms (at least those since 1905 when the system based upon the new Mills spectrograph was inaugurated) were carefully remeasured on the Hartmann spectro-comparator relative to a spectrogram of *Arcturus* (spectral class K0) adopted as the standard. Inasmuch as my measures confirm this deviation from true elliptic motion, already suspected from the previous measures, I have considered it advisable in forming the annual means to incorporate all the various individual plate determinations, reduced, of course, to the common system which the Lick observers[6] have used in the past.

The record of observations is presented in Table I below:

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[1] Mädler was, I believe, the first to suspect it. *A. N.*, **19**, 210, 1841.

[2] *Publ. Pots. Astr. Obs.*, **58**, 141, 1908.

[3] *Bull. Astr.*, **26**, 433, 1908.

[4] Tschilschke, *A. N.*, **236**, 410, 1929.

[5] *Lick Obs. Bull.*, **5**, 63, 1908.

[6] *Publ. Lick Obs.*, **16**, xxi, 1928.

TABLE I

Year	J. D.	Phase years	Observed Velocity km/sec	γAa km/sec	Corrected Velocity km/sec	Reduced by	O-C km/sec
1897.36	2414056.948	14.82	−10.78	−4.40	−6.38	Burns	−0.45
1898.34	4421.975	15.80	−10.28	−3.91	−6.37	Burns	−0.35
1898.51	4475.834	15.97	− 9.92	−3.83	−6.09	Burns	0.00
1901.30	5496.987	0.66	− 9.26	−2.27	−6.99	Burns	+1.03
1902.40	5896.903	1.76	−10.05	−1.73	−8.32	Burns	+0.24
1905.49	7024.887	4.85	− 8.40	−0.53	−7.87	Newkirk, Allen, Berman	+0.43
1908.32	8058.991	7.68	− 7.53	+0.20	−7.73	Plummer, Allen, Berman	−0.22
1908.58	8153.801	7.94	− 7.73	+0.25	−7.98	Allen, Berman	−0.55
1909.36	8441.003	8.72	− 5.30	+0.41	−5.71	Hobe, Berman	+1.51
1909.44	8468.842	8.80	− 6.21	+0.42	−6.63	Berman	+0.56
1909.48	8482.853	8.84	− 7.42	+0.43	−7.85	Hobe, Allen, Berman	−0.75
1910.42	8825.837	9.78	− 6.20	+0.59	−6.79	Hobe, Berman	+0.13
1910.47	8842.895	9.83	− 5.96	+0.59	−6.55	Hobe, Berman	+0.36
1911.40	9183.972	10.76	− 6.65	+0.73	−7.38	H. Wilson, Berman	−0.72
1911.43	9195.898	10.79	− 5.88	+0.74	−6.62	R. E. Wilson, Berman	+0.03
1912.22	9485.047	11.58	− 5.10	+0.84	−5.94	R. E. Wilson, Hobe, Berman	+0.51
1912.31	9516.010	11.67	− 5.49	+0.86	−6.35	R. E. Wilson, Hobe, Berman	+0.08
1917.35	2421359.002	16.71	− 5.00	+1.32	−6.32	Hobe, Young, Paddock, Berman	+0.08
1917.39	1371.980	16.75	− 4.56	+1.32	−5.88	Hobe, Young, Paddock, Berman	+0.54
1918.52	1785.784	17.88	− 5.78	+1.39	−7.17	Hobe, Berman	+0.12
1919.59	2174.768	0.85	− 7.36	+1.45	−8.81	Hobe, Berman	−0.66
1922.39	3196.988	3.65	− 7.44	+1.56	−9.00	Fairfield, Berman	−0.43
1926.41	4663.959	7.67	− 5.77	+1.66	−7.43	Brigham, Berman	+0.08
1929.39	5753.964	10.65	− 4.61	+1.70	−6.31	Stillman, Berman	+0.38
1929.57	5818.830	10.83	− 5.26	+1.70	−6.96	Stillman, Berman	−0.31
1930.67	6220.679	11.93	− 5.23	+1.70	−6.93	Jones, Berman	−0.56
1931.61	6563.758	12.87	− 4.77	+1.70	−6.47	Berman	−0.29
1931.61	6564.792	12.87	− 4.05	+1.70	−5.75	Berman	+0.43
1931.65	6580.852	12.91	− 4.13	+1.70	−5.83	Berman	+0.34
1931.72	6606.719	12.98	− 4.16	+1.70	−5.86	Berman	+0.29
1931.73	6610.700	12.99	− 4.05	+1.70	−5.75	Berman	+0.40

The first three columns of the above table are self-explanatory; the fourth column contains the simple means of the measurers' results; the fifth, the long period orbital velocity of the center of mass of the brighter visual component and its dark companion calculated on the basis of Pavel's[7] visual elements of the system according to the equation

$$(1)\qquad \gamma_{Aa} = -\frac{m_B}{M}\cdot\frac{2\pi}{P}\cdot\frac{a}{p}\cdot\frac{4.738\text{ km/sec}}{\sqrt{1-e^2}}\,[e\cos\omega+\cos(v+\omega)]\sin i$$

where $m_B=0.72\ \odot$, the mass of the fainter visual component, $M=1.72\ \odot$, the total mass of the system, and $p=0\overset{''}{.}190$, the parallax, represent the best values obtainable. The sixth column lists the observed velocities corrected for the effect of the 88-year motion, the seventh the name of the plate measurer, and the last one, the final observed minus computed values of the 18-year orbit.

In Figure 1 is shown the radial velocity curve of the brighter visual companion* computed from equation (1) to which the velocity of the center of mass of the entire system, $\gamma_{Aa+B}=-7.25$ km/sec, has been added.

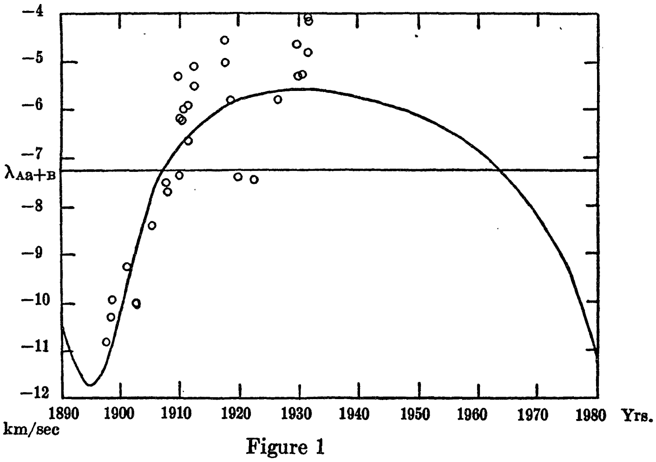

Figure 1

Radial Velocity Curve of the Brighter Visual Component in the Long Period System, Aa+B.

At first sight one might be inclined to consider the agreement between observation and theory satisfactory. However, it should be noted that while the greatest differences between the observed and computed radial velocities of the brighter component in the 88-year period are only in the neighborhood of 1.5 km/sec experience has shown that this amount is too far in excess of the error of measurement to be

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[7] *A. N.*, **212**, 347, 1920.

* To be accurate, the center of mass of System Aa.

consistently tolerated on three-prism spectrograms of a star of such late spectral type as that of 70 A *Ophiuchi*. On the assumption that the above discordances are purely accidental, the probable error of a single plate is found to be ±0.62 km/sec, an undeniably small value. Nevertheless, the agreement between the observed and computed velocities during the earlier period of observation is only apparent, for the discrepancies become evident only along the flatter portion of the curve, that is, where the orbital velocity is nearly constant, before and after passage through the descending node (1931.5).

The velocities tabulated in the sixth column of Table I have been plotted in the curve shown below.

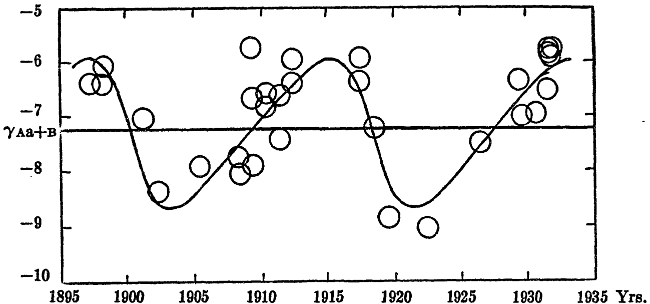

Figure 2

Radial Velocity Curve of the Brighter Visual Component in the System Aa

It is evident that an 18-year period is indicated and that it well represents the observations. The only outstanding residual comes from an apparently satisfactory plate taken on May 14, 1909. Careful remeasurement has failed to reduce this difference, which is but 1.5 km/sec, and, as there is no valid reason to reject the plate, I have included it in the discussion. It is, however, by no means certain that a shorter period, represented, for example, by some integral factor of 18 (one measured in years), might not fit the data as well. While this is not an easy matter to establish because of the limited amount of material available I am convinced, after trying various periods from three years up, that the 18-year period best fits the observations. Furthermore, if the systematic departures from relative motion of the visual pair represent disturbed binary motion resulting from the presence of a third member, as seems to be the case, the period of the sub-system ought to be long, as the following consideration shows. An examination of the residuals of the visual orbit during the period commensurate with spectroscopic observation suggests that the brighter component was perturbed to the extent of about one astronomical unit, which on the supposition of circular motion and a reasonable mass ratio $\left(\frac{m_A}{m_A}=\frac{1}{5};\ m_A+m_a=1.0\odot;\ m_A>0.7\odot\right)$, leads to a period of not less than 11 years. In 1920, Pavel,[8] on the basis of his calculations of the visual elements, advocated a period of 6.5 years while Jacob[9] and See,[10] many years before, were led to periods of 26 and 36 years respectively.

From a plot of the individual measures a preliminary set of elements was calculated by the well-known Lehmann-Filhes method:

Preliminary Elements I

T	1899.90
μ	$18\overset{\circ}{.}9075$
e	0.25
ω	$90\overset{\circ}{.}60$
K	1.425 km/sec
γ_{Aa+B}	−7.18 km/sec

The 31 observations were then grouped into 18 annual means which served as the normal places, an ephemeris was computed, and, following Schlesinger's procedure, differential coefficients were derived preparatory to a least squares reduction. Table II exhibits the normal places together with the assigned weights and residuals.

TABLE II

Normal Places

Number	Year	Phase years	Velocity km/sec	Weight	Elements I o-c km/sec	Final o-c
1	1897.36	14.82	−6.38	0.25	−0.56	−0.45
2	1898.42	15.88	−6.23	0.50	−0.06	−0.17
3	1901.30	0.66	−6.99	0.25	+1.19	+1.03
4	1902.40	1.76	−8.32	0.25	+0.23	+0.24
5	1905.49	4.85	−7.87	0.25	+0.39	+0.43
6	1908.45	7.81	−7.85	0.75	−0.40	−0.38
7	1909.43	8.79	−6.73	0.75	+0.43	+0.46
8	1910.45	9.81	−6.67	0.75	+0.19	+0.24
9	1911.42	10.78	−7.00	0.75	−0.41	−0.34
10	1912.26	11.62	−6.15	0.75	+0.21	+0.30
11	1917.37	16.73	−6.10	0.75	+0.03	+0.31
12	1918.52	17.88	−7.17	0.50	−0.30	+0.12
13	1919.59	0.85	−8.81	0.50	−1.10	−0.66
14	1922.39	3.65	−9.00	0.50	−0.40	−0.43
15	1926.41	7.67	−7.43	0.50	+0.33	+0.08
16	1929.48	10.74	−6.64	0.75	+0.23	+0.03
17	1930.67	11.93	−6.93	0.50	−0.40	−0.56
18	1931.66	12.92	−5.93	1.00	+0.34	+0.23

The solution of the resulting normal equations, in which the period was included as an additional unknown, yielded the following final elements:

Spectroscopic Elements of A

P	$18.101^y \pm 1.053^y$
μ	$19\overset{\circ}{.}889 \pm 1\overset{\circ}{.}157$
T	1900.643 ± 1.108
e	0.279 ± 0.260
ω	$97\overset{\circ}{.}51 \pm 34\overset{\circ}{.}81$

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[8] *A. N.*, **212**, 347, 1920.

[9] *M. N.*, **15**, 228, 1855.

[10] *A. J.*, **16**, 17, 1895.

$$
\begin{array}{ll}
K & 1.37\ \mathrm{km/sec} \pm 0.15\ \mathrm{km/sec} \\
\gamma_{Aa+B} & -7.25\ \mathrm{km/sec} \\
a \sin i & 119{,}600{,}000\ \mathrm{km} \\
\dfrac{m_a^3 \sin^3 i_{Aa}}{(m_A+m_a)^2} & 0.001563\ \odot
\end{array}
$$

The probable error of a normal place of weight unity is ±0.24 km/sec. The probable error of a single plate is ±0.35 km/sec as against ±0.62 km/sec on the assumption that the distribution of observations is purely accidental. The sum of the squares of the weighted residuals was reduced from 1.951 to 1.477, or nearly 25 per cent. Owing to the fact that the radial velocities exhibit a total variation under 3 km/sec during an interval of observation that extends over but one and one-half periods of revolution it is not surprising to find that the least squares adjustment of the elements results in rather large probable errors. In view of the existing uncertainty the elements should therefore be regarded only as provisional.

Application of Kepler's harmonic law leads to the conclusion that the bright star and its invisible companion are widely separated. The semi-major axis of the relative orbit has the value

$$A_{A+a} = \sqrt[3]{P^2_{Aa}(m_A+m_a)} = \sqrt[3]{18^2 \times 1\odot} = 6.894 \text{ astronomical units.}$$

It appears likely that the orbit of the system is highly inclined to the sky plane. Since $m_A + m_a = 1\odot$, $m_B = 0.7\odot$, and the observed difference in brightness between the visual pair (1.7^{m}) easily corresponds to a mass difference of $0.2\odot$ it follows that

$$m_a \approx 0.1\odot$$

which on substitution in the mass function yields a vulue of i close to 90°. This would make the mass of the dark companion one of the smallest in existence and the mean radius of the apparent orbit of the bright star about the center of gravity of the system Aa equal to $0\overset{''}{.}13$. The mass of the secondary obviously cannot exceed $0.3\odot$.

A fair determination of the absolute parallax of 70 *Ophiuchi* may be obtained from a knowledge of the radial velocities of both visual components combined with the elements of the system in accordance with the well-established relation

$$(2) \qquad p = \frac{2\pi\, a \sin i\,[e \cos\omega + \cos(v+\omega)]\ 4.738\ \mathrm{km/sec}}{P\sqrt{1-e^2}\,(V_A - V_B)}$$

From three spectrograms of the fainter, and nine of the brighter companion taken during the years 1929, 1930, 1931 we have the following information for the mean epoch of observation, 1931.10:

$$V_A = -4.51\ \mathrm{km/sec} \pm 0.11\ \mathrm{km/sec}^*$$
$$V_B = -8.83\ \mathrm{km/sec} \pm 0.16\ \mathrm{km/sec}$$

whence

$$p = 0\overset{''}{.}179 \pm 0\overset{''}{.}008$$

which compares favorably with the value adopted in our discussion ($p = 0\overset{''}{.}190$).

If the above spectrographic results may properly be ascribed to binary motion, then, since Pavel's elements refer the motion of companion B to that of the center of gravity of system *Aa*, it would be natural to look for evidence of a periodic perturbation of 18 years in the motion of the bright component *A* in the sky plane. Such an examination has proved disappointing† presumably because the relatively large errors affecting the measures of position angle and distance tend to obscure any real existing variation of small magnitude.

In Figures 3 and 4 below I have plotted, for the interval covered by spectrographic observation, the annual residuals of the visual and photographic measures separately in rectangular coordinates ($\Delta x = \Delta\alpha \cos\delta$, $\Delta y = \Delta\delta$). The photographic material has been compiled from the following sources: Hertzsprung, *Publ. Astr. Obs. Potsdam*, No. 75, 50, 1920, Olivier, *Publ.*

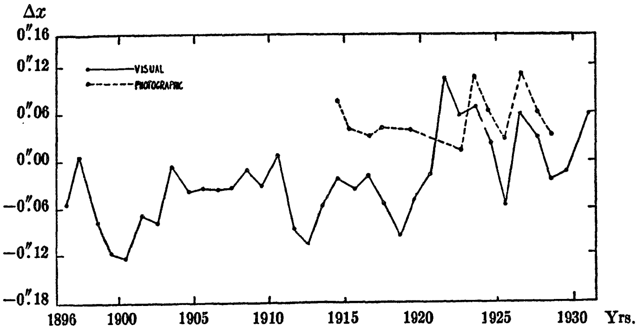

Figure 3

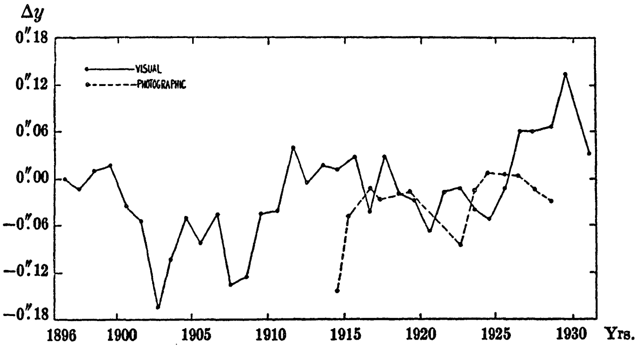

Figure 4

Annual Residuals of the Visual Orbit in Rectangular Coordinates

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* To be strictly accurate we should take the velocity of the center of gravity of system Aa (γ_{Aa}) relative to the center of mass of the visual system.

† Also to previous investigators, notably Prey and Tschilschke.

McCormick Obs., **3**, part 2, Van Biesbroeck, *A. J.*, **29**, 175, 1916, Przybyllok, *Astr. Beob. Univ.-Sternwarte zu Königsberg*, **45**, part 4, 65, 1929. The visual residuals from 1896 to 1921 have been taken from Prey's[11] table; the remainder I have computed on the basis of Pavel's Elements II, which Prey used in his calculations, from measures kindly supplied me by Dr. Aitken. Attention should be directed to the fact that the annual means which represent the grouping of many nights of observation throughout each year have been derived from a mass of non-homogeneous material. While no account has been taken of the systematic errors that would be introduced by various observers' methods and instruments, their effect is too slight to alter the character of the above graphs.[12]

Unfortunately, the photographic observations, although reputedly of superior accuracy, do not extend over a whole period. While some slight indication of an 18-year period may exist in the coordinate, Δy, such purported evidence is apparently offset by the lack of corresponding agreement in Δx. There is, as a matter of fact, no convincing agreement between the photographic and visual measures. Unless there is some additional complication of which we are unaware it would seem best, under the circumstances, to place little if any reliance upon the micrometer measures in investigating this problem. As an argument against the supposed unreliability of the visual material it may be pointed out that in such multiple systems as ζ *Cancri* and ξ *Ursae Majoris* the visual measures alone have sufficed at least to establish periodicity in the disturbed motion of the bright component due to the presence of a circulating dark body. However, in neither of these instances has it been necessary to contend with the perturbing influence of the other members of the system upon the dark-bright star combination over any length of time—a different situation from that which undoubtedly exists in the case of 70 *Ophiuchi*. In this system the mean separation of the visual pair is 23, that of the spectroscopic pair, 6.9 A. U., so that, taking the highly eccentric orbit of the visual system into account ($e=0.5$), there exists ample opportunity for the development of serious perturbations of a non-periodic nature. Prey[13] has demonstrated from a study of the residuals that perturbations of extraordinarily large amplitude occurred in the relative motion of 70 *Ophiuchi* during the period 1820–1830. These were interpreted by him as denoting a near catastrophic approach of the three members comprising the multiple system. Under a suitable orientation of the orbit planes of the two systems it becomes possible for the dark companion of A to approach so perilously close to the visual companion B that the stability of the spectroscopic combination would be endangered. Future spectroscopic observations may indeed succeed in showing that a marked variation in the elements of the system Aa exists such as would be demanded by the close proximity of the disturbing companion B.

By making various assumptions regarding the inclination and the position angle of the node in system Aa it might be possible with the aid of the spectroscopic elements to duplicate in a rough measure the trend of the residuals shown in Figures 3 and 4, but the writer has not deemed this advisable in view of the character of the material at hand. Given that the elements of the smaller system are known as accurately as those of the visual system it should, moreover, become possible to compute the perturbing influences upon system Aa by the method of quadratures from a knowledge of the relative positions and velocities of all three bodies at any specified instant. The labor involved in trying to represent the perturbations after adopting the correct initial data would probably be too burdensome and would again hardly justify the comparison with the observed residuals. Recently, Slavenas[14] has applied the general perturbation theory to the case of the stellar problem of three bodies but the analytical formulae which he has developed are not easily applicable to calculation. Aside from perturbations of the magnitude we have been discussing, the stability of the 18-year system where the period is a considerable fraction of the period of the visual system is, in any event, a matter of disquieting concern.

In 1899, Moulton[15] on the basis of See's announcement of a periodic perturbation of 36 years showed from a theoretical standpoint that ". . . . there is no dark star in the binary system 70 *Ophiuchi* permanently revolving around the companion with a period of 36 years." In the light of our present knowledge it becomes of interest to consider the question of stability anew. While it will be seen that the approach is made from the viewpoint of the simplified problem the modifications introduced tend to favor the existence of stability.[16]

In the treatment of the restricted problem of three bodies moving in the same plane it can be shown[17] that the motion of an infinitesimal body expressed in canonical units and referred to axes rotating with uniform angular velocity unity, possessed by two finite bodies revolving in circles around their common center of gravity, leads to the well-known Jacobi integral

$$V^2=x^2+y^2+\frac{2(1-\mu)}{r_1}+\frac{2\mu}{r_2}-C. \tag{3}$$

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[11] *A. N.*, **220**, 282, 1923.

[12] *Ibid.*, p. 283.

[13] *Ibid.*, p. 294.

[14] *Trans. Yale Astr. Obs.* **6**, part 3, 1927.

[15] *A. J.*, **20**, 33, 1899.

[16] *Ibid.*, p. 33.

[17] Moulton, *Celestial Mechanics*, p. 281.

Here V is the velocity, (x, y) are the coordinates of the infinitesimal body referred to the rotating axes so chosen that the $x-$ axis continually passes through the centers of the finite bodies, (r_1, r_2) the distances of the infinitesimal body from the two bodies of mass $1-\mu$ and $\mu(\mu \leqq \frac{1}{2})$, respectively, and C is the constant of integration.

On setting V equal to zero, equation (3) leads to the interesting discussion of the surfaces of zero relative velocity. Expressed in bipolar coordinates with the origin at the center of mass of the two finite bodies equation (3) then becomes

$$(4) \qquad (1-\mu)\left[r_1^2+\frac{2}{r_1}\right]+\mu\left[r_2^2+\frac{2}{r_2}\right]=C+\mu(1-\mu)=C'.$$

The locus defined by the above equation, which represents the possible positions of zero velocity the infinitesimal body may occupy in its plane of motion, is found to consist of closed ovals around each of the finite bodies for large values of C′; for smaller values of C′ the ovals coalesce forming a dumb-bell shaped figure of different sized heads; for very small values of C′ the neck of the dumb-bell swells until in the outer portions there is only one oval enclosing both finite bodies.

The method of computing the sphere of stability may be taken from Moulton's presentation and applied to the case of 70 *Ophiuchi*. The first step consists in locating that particular double point, of the three which lie on the x-axis, where the ovals around the finite bodies unite, the condition for which is $r_1=1-r_2$. On substituting the value of $r_1=1-r_2$ in (4) and solving the resulting quintic equation for its only real positive root, we obtain for a distribution of mass, $1-\mu=\frac{9}{16}$, $\mu=\frac{7}{16}(m_A=0.9\odot,\ m_B=0.7\odot)$,

$$(5) \qquad \begin{aligned} r_2&=0.35\\ r_1&=0.65\end{aligned}$$

for which the corresponding value of C′ is 7.23324.

If the path of the infinitesimal body is entirely confined within the critical oval surrounding the more massive companion then the motion will be considered stable although this does not necessarily follow since, as Moulton[18] has pointed out, the simplifications introduced in the theory result in perturbations which are far less than in the actual case where the disturbances arising from the action of the visual companion B may be considerable. It will be sufficient to calculate the minimum distance of the oval from the bright body A and to note whether the dimensions of the orbit of the spectroscopic system Aa are greater or less than this minimum distance. For brevity, the details of computation are omitted and the interested reader is referred to Moulton's text, pages 288–290. Calculation shows that for our assumed distribution of masses ($m_A=0.9\odot$, $m_B=0.7\odot$) the critical curve of zero relative velocity has a minimum value of r_1 equal to 0.359 from the primary. Expressed in the same units the relative major axes of the systems Aa and $Aa+B$ are found by hypothesis to bear the ratio 0.293 so that the orbit barely lies within the required minimum distance and stability is thus favored. By a slightly different distribution of masses and with due regard for the eccentricity of the smaller system the motion of the secondary can be made to coincide practically with the boundary separating the regions of stability from instability. In this event the permanent stability of the system would not be assured. However, it is well to point out that too much importance should not be attached to the theoretical implication involved in the stability consideration and that, in the final analysis, the problem remains one for future investigation to settle.

SUMMARY

1. The radial velocities of the brighter member of the visual binary, 70 *Ophiuchi*, have been found to exhibit considerable departure from elliptic motion, confirming what is already known from micrometer observations of the relative motion of the visual pair.

2. The spectrographic measures, after due allowance is made for the orbital velocity of the visual companion in the 88-year period, are interpreted as indicating the presence of a third dark body circulating about the brighter component in a period of 18 years. Provisional spectroscopic elements of the system have been obtained from 31 three-prism spectrograms, taken during the years 1897–1931, on the basis of a least squares solution.

3. The mean separation between the visual primary and its invisible companion in the spectroscopic system, calculated from Kepler's third law, is 6.89 A. U.; that between the components in the visual system is 23.56 A. U.

4. The mass of the dark body is probably one of the smallest known to exist ($m_a=0.1\odot$ to $0.2\odot$). On this supposition the orbital inclination of the spectroscopic system is fairly high.

5. The absolute parallax ($p=0''.179\pm0''.008$) has been derived by combining the relative radial velocities of the visual pair with Pavel's elements of the system. The velocity of the center of gravity of the entire system is -7.25 km/sec.

6. Although supporting the hypothesis of binary motion, the radial velocities are not in apparent harmony with the visual measures of the disturbed motion of the brighter component. It is inferred that the

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[18] *A. J.* **20**, 36, 1899.

micrometer observations are too crude to enable the 18-year periodic perturbation to be unambiguously detected.

7. The stability of the spectroscopic system has been considered. It is found that further investigation will be required to decide the question of permanent stability. The combination of accurate photographic and spectrographic data may be expected to yield in the future a rational explanation of the remarkable behavior of this system.

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