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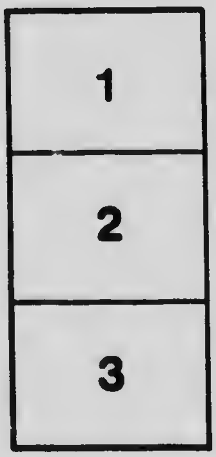
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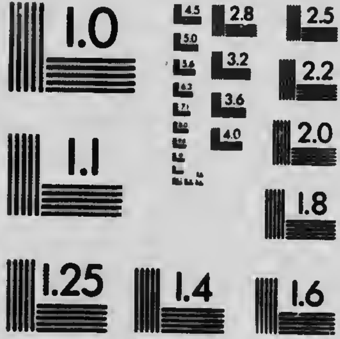

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THE ORBIT OF ν ORIONIS

BY

W. E. HARPER

1911

THE ORBIT OF ν ORIONIS

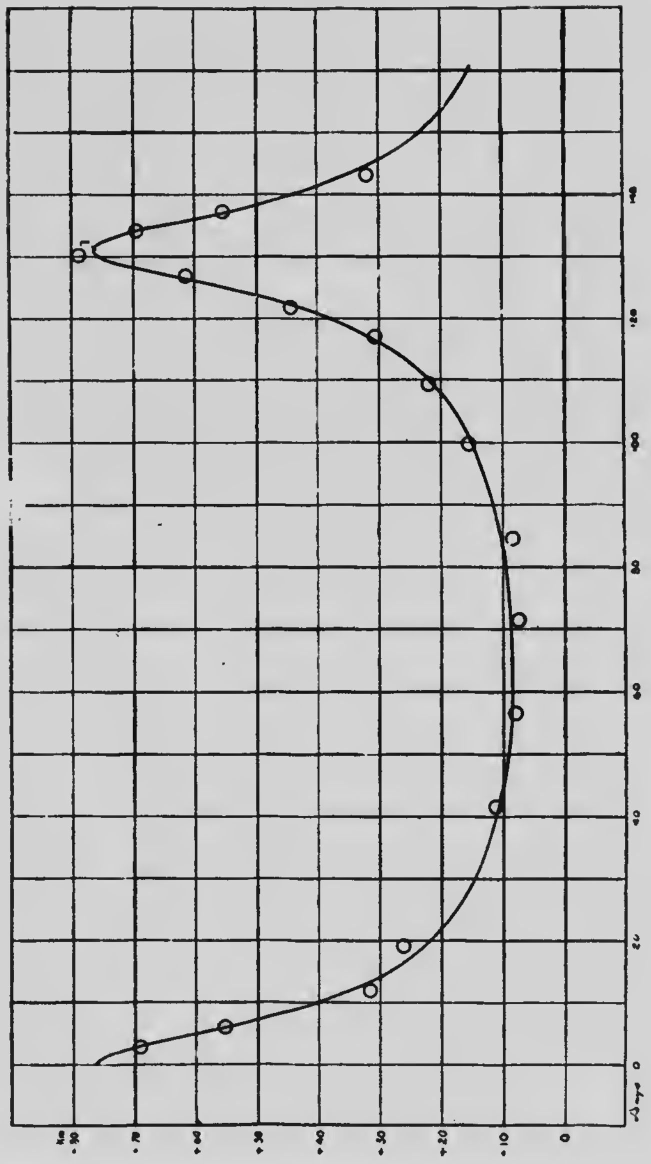
By W. E. Harper

THE spectroscopic binary ν Orionis ($\alpha = 6^h\ 02^m$, $\delta = +14°\ 47'$, photographic magnitude about 4·2) was discovered* by Frost and Adams in 1903. The range in velocity of their three plates is approximately 70 km., which is in fact about the total range for the star. Their first observation was made at a fortunate time, it falling on the crest of the velocity curve which rises rapidly to a high positive value and falls again as rapidly. On this account this observation has been of material assistance in getting a more accurate value of the period than could be obtained from our own observations.

Work was commenced on the star here November 11, 1907, and from that time to December 30, 1910, one hundred and nineteen plates were secured. The first season's work gave the general form of the curve, and during the three succeeding seasons efforts were made to obtain a full series of observations around periastron where the curve, as previously mentioned, changes so rapidly. In this we have been only partially successful, as cloudy weather at each return to periastron prevented our obtaining all the observations desired. Nevertheless quite a number of reliable plates have been secured for this part of the curve and the determination of the orbit has accordingly been proceeded with.

The spectrum is of type B_2 and has numerous lines suitable for measurement. The hydrogen lines $H\beta$, $H\gamma$, $H\delta$ and $H\epsilon$ appear in the range of spectrum measured, but the latter was scarcely

* *A. J.*, vol. xviii., p. 386, 1903.



VELOCITY CURVE OF ν ORIONIS

ever measured owing to the close proximity of the *H* line of calcium and consequent overlapping. The helium series λλ 4713, 4471, 4388, 4143, 4121, 4026 and 4009 are all measurable and these, excepting the first and last, were among the most frequently used. The magnesium λ 4481 and the calcium *K* λ 3933 are not so intense as either the helium or hydrogen series and do not appear in many of the spectra.

In view of the fact that a number of binaries have recently been discovered in which the calcium lines *H* and *K* give different velocities to the other lines it may be noted here that this is not the case with ν Orionis; the velocites of the *K* line agree with those of the other lines. Another good line is the carbon λ 4267. These were the lines most frequently measured but additional lines in a number of cases have been seen, and where these have been measured the resulting velocities were always in agreement with the lines most commonly used. Among these additional lines may be mentioned: λλ 4572, 4563, 4549, 4528, 4452, 4383, 4325, 4308, 4233, 4131 and 4128. There are also indications of the second series of hydrogen.

On the first one hundred plates all the lines that were at all measurable were used. When the results were plotted with the the provisional period of 131·4 days there were many little irregularities in the curve; its appearance was that of a wavy line. As no indications of a second spectrum had been detected, even though a fine-grained plate had been used at the time of maximum positive velocity, it was difficult to account for this. It was thought that a possible cause might exist in the selection of lines varying from one plate to another. To decide this point and incidentally see if the wave-lengths used needed any arbitrary correction a table was constructed of the residuals for each line from the mean of the plate. The result is contained in the accompanying table. Besides the twelve lines here listed there were various others which did not occur frequently enough to make mention of. The lines are arranged in order of frequency of measurement, the total number of plates being 100.

Lines Measured in ν Orionis

λ	Number of Times Measured	Average Residual	Corresponding Correction to Wave-length
4340·634	97	− 1·39 km.	+ ·020 t. m.
4388·100	94	0·43 "	+ ·007 "
4471·676	94	+ 1·51 "	·022 "
4143·928	86	− 0·03 "	·000 "
4026·352	75	+ 1·67 "	·022 "
4267·301	68	− 2·45 "	+ ·035 "
4121·016	63	− 0·11 "	+ ·002 "
4481·400	62	+ 1·95 "	·029 "
4101·890	56	+ 0·99 "	− ·014 "
4713·308	20	− 1·48 "	
4861·527	19	+ 3·70 "	
3933·825	13	+ 1·40 "	

No corrections to wave-length are given for the last three as the observations were deemed too few in number, and, furthermore, the ends of the spectrum may not always have been in focus, thereby causing these residuals to be abnormal. The residuals in the above table are, in general, small relative to the probable error of a plate, and while somewhat better accordance among the different lines on a plate would be secured by adopting an arbitrary set of wave-lengths based on the corrections, yet none of the residuals are so abnormal as to warrant such a procedure and accordingly the normal values have been retained. In subsequent measuring the first nine lines of the table were the only ones used, and the other hundred plates were recomputed, using these lines alone so that the results ought, at least from a consideration of wave-length, to be consistent.

Plates from 1140 to 2257 were made with the single-prism spectrograph II, as first constructed, the dispersion at $H\gamma$ being 30·2 tenth-metres per millimetre. The balance were made with the new single-prism instrument, designated I, whose dispersion is 33·4 tenth-metres per millimetre at the same region. Plates 3369, 3847, 3865 and 3890 were made on Seed 23 plates, the remainder on Seed 27 emulsion. The four Seed 23 plates were made at times of high positive velocity to see if any trace of the second spectrum could be detected. No indications of such were seen.

Two plates have been omitted in the discussion, one, 2098, which gives a residual of 25 km. where the curve is well-defined in the flat part. This is probably owing to some instrumental error. The other case is that of plate 1315 which was taken immediately following plate 1314 under almost identical conditions and yet gives a decidedly greater positive velocity. The plate is somewhat underexposed, but there would seem to be some additional cause for the great difference in velocity, and as these observations occur around periastron, this was one reason why a continuous series of plates at this phase was much wished for. The intention is to make more plates next season at this critical place in the curve. The remaining 117 plates form the basis of this discussion and the data regarding them is contained in the table following. The phases are reckoned from the periastron finally accepted, Julian Date 2,417,975·16, and the residuals are scaled to about ± 0·2 km. from the curve representing the final elements.

MEASURES OF ν ORIONIS

Plate	Julian Date	Phase	Velocity	Weight	Observer	O - C
1140	2,417,891·93	48·03	+ 5·0	4	H	− 4·4
1160	903·78	59·88	+ 12·0	3	P	+ 3·4
1184	914·92	71·02	+ 4·5	5	P	− 4·3
1185	914·95	71·05	+ 3·9	5	P	− 4·9
1197	938·73	94·83	+ 12·6	6	P	− 0·3
1198	938·75	94·85	+ 15·2	4	P	+ 2·3
1217	944·73	100·83	+ 18·1	6	P	+ 2·7
1223	954·81	110·91	+ 23·8	5	P	+ 1·1
1224	954·84	110·94	+ 30·6	5	P	+ 7·9
1229	955·84	111·94	+ 28·1	3	H	+ 3·3
1235	957·54	113·64	+ 22·5	4	H	− 1·5
1250	961·71	117·81	+ 37·6	6	P	+ 4·8
1251	961·73	117·83	+ 36·5	3	H	+ 3·7
1261	963·78	119·88	+ 37·4	5	P	0·0
1273	965·59	121·69	+ 41·4	6	P	− 1·3
1282	968·58	124·68	+ 52·6	4	P	− 1·6
1302	970·65	126·75	+ 51·0	7	H	− 11·5
1303	970·67	126·77	+ 60·4	6	H	− 2·1
1314	975·62	0·46	+ 73·5	4	H	− 2·7
1320	980·70	5·54	+ 56·1	7	P	+ 0·5
1325	989·65	14·49	+ 29·5	6	H	+ 0·7
1326	989·66	14·50	+ 14·7	3	H	− 15·5
1335	992·57	17·41	+ 22·5	5	P	− 2·1
1337	993·69	18·53	+ 30·8	7	P	+ 7·6

Plate	Julian Date	Phase	Velocity	Weight	Observer	O - C
1348	2,417,994.72	[illegible]	+28.5	6	P	+ 6.2
1352	996.62	[illegible].46	+26.7	6	P	+ 6.4
1377	8,005.68	30.52	+21.4	4	H	+ 7.0
1385	010.68	35.52	+12.2	6	P	− 0.1
1396	017.53	42.37	+14.3	6	P	+ 3.8
1485	047.50	72.40	+16.9	2	H	+ 8.1
1497	049.53	74.37	+10.3	6	P	+ 1.4
1503	054.55	79.39	0.3	2	H	9.6
1916	217.94	111.52	+20.[illegible]	3.5	C	− 3.4
1943	234.96	128.54	+63.[illegible]	1.5	H	− 7.5
2009	283.85	46.17	+ 7.1	5	H	− 2.6
2010	283.87	46.19	+ 2.[illegible]	1.5	H	− 7.7
2019	285.87	48.19	+ 3.6	3.[illegible]	C	− 5.7
2020	285.90	48.22	+ 0.3	2.5	C	− 9.0
2025	286.67	48.99	− 3.0	3	P′	12.2
2034	291.82	55.14	+ [illegible]	5	C	0.0
2035	292.85	55.17	2.[illegible]	4	[illegible]	− 11.7
2061	297.85	60.17	+ 2.6	5	[illegible]	− 6.0
2133	320.79	83.11	+10.3	7.5	C	+ 0.4
2147	322.78	85.10	+ 6.2	2.[illegible]	P	− 4.1
2230	341.70	104.02	+11.8	6	H	− 0.2
2257	346.72	109.04	+20.7	[illegible]	P′	0.0
2339	374.70	5.76	+51.7	[illegible]	P′	− 3.0
2380	381.69	12.75	+[illegible]5.9	5	P′	+ 3.2
2410	388.67	19.73	[illegible]0.0	4	P′	+ 8.0
2428	389.66	20.72	+30.9	6	C	+ 9.9
2446	397.62	28.68	+24.2	7	H	+ 9.0
2524	425.55	56.61	+12.6	7	H	+ 3.8
2781	557.89	57.69	+14.0	7	P′	+ 5.3
2808	570.88	70.68	+ 9.0	4	C	+ 0.2
2809	570.91	70.71	+ 7.1	6	C	1.7
2831	578.89	78.69	+ 8.8	8	C	− 0.4
2832	578.92	78.72	+10.1	7	C	+ 0.8
2844	584.81	84.61	+ 5.6	6	H	4.6
2876	588.84	88.64	+ 3.9	5	P′	− 6.0
2877	588.87	88.67	+ 0.1	4	P′	− 10.8
2898	599.95	99.75	+19.6	5	C	+ 4.7
2907	600.84	100.64	+ 9.5	6	C	− 5.7
2908	600.90	100.70	+20.4	8	C	+ 5.0
2927	609.86	109.66	+16.0	8	P′	5.3
2928	609.90	109.70	+20.9	[illegible]	P′	− 0.3
2939	619.95	119.75	+38.4	8	H	+ 1.4
2942	620.88	120.68	+47.[illegible]	2	C	+ 7.1
2948	623.77	123.57	+54.5	7	P′	+ 5.0
2949	623.81	123.61	+49.0	8	P′	− 0.5
2957	626.82	126.62	+64.8	7	P′	+ 2.0
2958	626.85	126.65	+60.3	7	P′	− 2.5
2969	634.78	3.32	+73.1	8	H	+ 6.1
2970	634.82	3.36	+72.5	7	H	+ 5.5
2977	637.66	6.20	+60.2	6	H	+ 7.7
2978	637.69	6.23	+55.8	7	H	+ 3.3
2986	641.87	10.41	+48.8	2	C	+ 10.8
2998	642.68	11.22	+27.0	7	P	8.6
2999	642.70	11.24	+30.[illegible]	3	P	− 5.5
3094	682.64	51.18	+ 1.5	5	H	− 7.7

Plate	Julian Date	Phase	Velocity	Weight	Observer	O − C
3099	2,418,684·60	53·14	+10·0	2	P	+ 1·0
3100	685·67	54·21	+10·5	3	P	+ 1·6
3101	685·71	54·25	+ 2·6	6	P	− 6·2
3143	697·79	66·33	+ 4·4	5	P	− 4·3
3159	703·63	72·17	+12·0	4	C	+ 3·2
3160	703·67	72·21	+ 5·8	3	C	3·0
3203	724·62	93·16	+16·4	8	C	+ 4·0
3319	742·57	111·11	+25·4	9	H	+ 2·3
3320	742·60	111·14	+17·7	7	H	− 5·4
3351	747·60	116·14	+27·6	7	P′	2·2
3352	747·64	116·18	+24·5	8	H	5·3
3356	754·63	123·17	+37·7	3	P′	− 6·7
3361	759·59	128·13	+65·3	7	C	− 3·7
3362	759·62	128·16	+75·8	6	C	+ 6·8
3369	763·55	0·83	+81·6	5	H	+ 6·0
3370	764·52	1·80	+66·7	8	P	6·0
3373	765·52	2·80	+67·0	7	H	− 2·0
3374	765·55	2·83	+64·9	9	H	4·1
3390	775·57	12·85	+29·1	7	P′	3·0
3401	784·55	21·83	+15·3	5	H	4·7
3404	787·56	24·84	+21·8	1	C	+ 3·0
3653	929·92	35·94	+17·9	3	C	+ 5·6
3670	931·87	37·89	+17·2	2	P′	+ 5·4
3671	931·91	37·93	+ 7·6	4	P′	− 4·2
3688	936·91	42·93	+17·2	4	C	+ 6·9
3703	943·88	49·90	+16·7	2	C	+ 7·5
3704	943·91	49·93	+ 6·4	3	C	2·8
3822	9,011·87	117·89	+32·4	4	H	0·6
3823	011·90	117·92	+34·0	4	H	+ 1·0
3828	012·89	118·91	+35·4	5	P′	+ 0·4
3837	014·71	120·73	+43·3	6	H	+ 3·3
3847	015·82	121·84	+48·0	8	P′	+ 5·0
3865	018·89	124·91	+54·2	4	H	+ 0·2
3878	022·69	128·71	+77·5	7	H	+ 5·8
3879	022·73	128·75	+82·0	5	H	+10·3
3890	027·75	2·51	+72·7	6	P′	+ 1·4
3908	036·76	11·52	+33·6	5	H	1·4
3909	036·79	11·55	+31·6	6	H	− 3·4

For convenience of reference the early measures of Frost and Adams are appended :

Yerkes Measures of ν Orionis

Date	Julian Date	Phase	Velocity	Residual from Ottawa Curve
1903 Jan. 22	2,416,137·85	0·33	+ 81	+ 4·8
Oct. 31	419·94	19·90	+ 21	− 0·8
Nov. 14	433·90	33·86	+ 12	− 0·8

The first plate was stated to have such broad and fuzzy lines owing to the dispersion of three prisms used that the result was considered only a rough approximation. In a personal communication to the writer Professor Frost gives the velocities from the different lines used. These agree among themselves very closely and he suggests that the plate should be given considerable weight and no doubt its result is close to the actual velocity. The period that suits all observations best is that given, viz.: 131·26 days, though possibly the first decimal place is as close as this can be relied on.

With this period the plates were grouped according to phase into fourteen normal places. The weights given to each group was approximately the sum of the individual plates comprising the group.

NORMAL PLACES

	Mean Phase	Mean Velocity	Weight	O – C	Equation-Ephemeris
1	2·77	+ 69·23	5·	– ·28	·05
2	5·93	55·25	3·	+ ·50	+ ·10
3	11·75	31·69	4·5	– 3·22	+ ·12
4	18·99	26·21	5·	+ 3·47	+ ·05
5	41·55	11·18	7·	+ ·56	– ·04
6	56·46	7·99	4·5	·05	– ·04
7	71·13	7·59	4·5	– 1·07	– ·06
8	84·52	8·38	5·	1·83	·05
9	99·65	15·46	4·5	+ ·68	·03
10	109·27	21·98	5·5	+ ·82	– ·03
11	116·05	30·66	4·5	– ·63	+ ·01
12	121·63	44·27	6·	+ 1·73	+ ·18
13	126·82	61·19	5·	2·06	+ ·40
14	130·10	+ 78·79	2·5	+ 3·19	+ ·17

Preliminary elements were obtained by the graphical method of Dr. King* as follows:

$$P = 131{\cdot}26 \text{ days}$$
$$e = {\cdot}575$$
$$\omega = 0{\cdot}^\circ$$
$$K = 33 \text{ km.}$$
$$\gamma = +\ 21{\cdot}53 \text{ km.}$$
$$T = \text{J. D. } 2{,}417{,}974{\cdot}69.$$

With these elements it was decided to make a least squares solution. Using the differential form† of Lehmann-Filhés,

* *A. J.*, Vol. XXVII, No. 2, 1908, p. 27.

† *A. N.*, 3242.

fourteen observation equations were formed connecting the residuals with the elements γ, K, e, ω and T. The period was considered determined as closely as could be.

The following corrections resulted:

$$\begin{aligned}\delta\gamma &= +\ \cdot 57 \text{ km.}\\ \delta K &= +\ 1\cdot 09\ ``\\ \delta e &= +\ \cdot 024\\ \delta\omega &= +\ 1^\circ\cdot 58\\ \delta T &= +\ \cdot 47 \text{ d.}\end{aligned}$$

giving as the corrected elements, with their probable errors,

$$\begin{aligned}P &= 131\cdot 26 \text{ days}\\ e &= \cdot 599 \pm \cdot 014\\ \omega &= 1^\circ\cdot 58 \pm 2^\circ\cdot 12\\ \gamma &= +\ 22\cdot 10 \text{ km.} \pm \cdot 47 \text{ km.}\\ K &= 34\cdot 09 \text{ km.} \pm \cdot 75 \text{ km.}\\ T &= \text{J. D. } 2{,}417{,}975\cdot 16 \pm \cdot 38 \text{ days}\\ A &= 54\cdot 50 \text{ km.}\\ B &= 13\cdot 68\ ``\\ a \sin i &= 49{,}270{,}000 \text{ km.}\end{aligned}$$

The sum of the squares for the normal places lowered from 298·5 to 205·9, about 31 per cent. The residuals given in the table of normal places are those from the final elements. The agreement between equation and ephemeris residuals was satisfactory, so that no further solution was necessary.

The probable error of a single observation obtained from columns 5 and 7 of the Measures is ± 3·47 km. per second. For this type of spectrum one would expect that this value should be somewhat lower, but remeasurement of many of the plates giving large residuals failed to make any sensible difference in the results. In a few cases, as may be noted in the measures, plates made consecutively on the same night differ from each other by 10 to 12 km. per sec. so that the above value was not unexpected.

Quite recently Mr. Jordan*, of the Allegheny Observatory, in discussing the orbit of π Andromedæ, calls attention to the

* *Publications of the Allegheny Observatory*, Vol. II., No. 8.

large gap between the short and long periods for the helium stars. The star under discussion here furnishes another illustration of the marked increase of eccentricity with period, the value of e being ·60 for an orbital period of 131· days.

The curve shown represents the corrected values of the elements.

The interest shown and the encouragement given by the Director in this work is hereby gratefully acknowledged.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
January, 1911.