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THE ORBIT OF α ANDROMEDÆ.

BY ROBERT H. BAKER.

The spectroscopic binary α *Andromedæ* ($\alpha = 0^h 03^m$, $\delta = +28° 33'$) was discovered by Mr. V. M. Slipher,† whose observations indicated a period of about 100 days, and a highly eccentric orbit. Its variable radial velocity was announced also by Dr. Heber D. Curtis.‡ Provisional elements of the orbit are published by Dr. H. Ludendorff.§ The spectrum of this star is of Type Ia2 according to Vogel. In the later Harvard classification it is given as VIII P. In the portion of the spectrum shown on our plates, the lines K, λ4128, λ4131, H_γ and λ4481 are best defined; H_δ, λ4267, and four lines, presumably blends, are in general fairly sharp. The iron lines λ4233 and λ4549 were measured on a few plates, but rejected, because of the discordant results obtained from them. The helium lines λ4026 and λ4471 are present, but do not admit of accurate measurement. Numerous faint, diffuse lines appear throughout the spectrum. Discussion of the orbit is based on measures of the following eleven lines:

λ	R	Element.	λ	R	Element.
3933.789	82.7256	Calcium	4137.061	96.9641	
3943.919	83.5190		4206.211	101.1137	
3984.109	86.5722		4267.307	104.5367	Carbon
4101.927	94.7334	Hydrogen	4340.629	108.3742	Hydrogen
4128.195	96.4093	Silicon	4481.437	115.0194	Magnesium
4131.050	96.5885	Silicon			

Column λ contains adopted wave-lengths, and column R denotes the screw-readings on our measuring engine for zero displacement of the lines.

Ninety-four plates of α *Andromedæ*, obtained with the Mellon (single-prism) spectrograph attached to the 30-inch Keeler Memorial reflector, were measured by the writer, and reduced by the method described by Director Schlesinger in No. 2 of this volume of publications. They are Seed plates and, with the seven exceptions noted below, are of the 23 emulsion. The superiority of this emulsion over that of the coarser grained 27 plates is evident from comparison of the number of lines

* Published from the Magee Fund.
† *Lowell Observatory Bulletin*, No. 11, 1904.
‡ *Lick Observatory Bulletin*, No. 70, 1905.
§ *Astronomische Nachrichten*, 176, 327, 1907.

Table of Observations.

No. of Plate.	Plate Secured by	Date, G. M. T.	Phase.	No. of Lines.	Wt.	Velocity.	Resid. O-C.	Remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		1907 d h m	days			km.	km.	
740	Baker	Aug. 10 20 12	13.11	5	8	— 39.2	— 1.0	Seed 27
741	Baker	10 20 42	13.13	4	6	— 41.3	— 3.1	Seed 27
742	Baker	10 20 54	13.14	4	6	— 34.7	+ 3.5	Seed 27
762	Baker	14 20 21	17.11	6	8	— 39.7	— 3.4	Seed 27
763	Baker	14 20 48	17.13	5	5	— 34.7	+ 1.6	Seed 27
764	Baker	14 20 58	17.14	4	4	— 30.7	+ 5.6	27. Overexposed
794	Baker	28 21 20	31.15	10	16	— 24.6	+ 2.4	Comparison weak
806	Curtiss	31 19 29	34.08	7	11	— 24.3	+ 0.7	
807	Curtiss	31 20 06	34.10	7	10	— 32.7	— 7.7	
815	Schlesinger	Sept. 5 19 52	39.10	9	16	— 18.1	+ 3.4	Comparison weak
816	Schlesinger	5 20 14	39.11	8	11	— 12.6	+ 8.9	Remeasured
823	Baker	6 19 30	40.08	8	13	— 20.5	+ 0.3	
824	Baker	6 20 04	40.10	6	9	— 22.0	— 1.2	
832	Schlesinger	11 18 15	45.03	9	13	— 18.5	— 1.2	
833	Schlesinger	11 18 46	45.05	8	12	— 12.9	+ 4.4	
872	Schlesinger	19 17 48	53.01	6	12	— 17.6	— 6.0	Overexposed
873	Schlesinger	19 18 30	53.04	8	13	— 10.0	+ 1.6	
897	Baker	Oct. 2 18 43	66.05	11	16	— 5.1	— 4.0	Comparison weak
898	Baker	2 19 14	66.07	6	10	+ 0.4	+ 1.5	
903	Schlesinger	5 16 16	68.95	9	15	+ 4.5	+ 3.4	
904	Schlesinger	5 16 51	68.97	10	15	— 2.0	— 3.1	
905	Schlesinger	5 17 07	68.98	8	14	— 2.0	— 3.1	
911	Baker	6 17 29	70.00	8	12	+ 3.1	+ 1.1	
912	Baker	6 17 55	70.02	10	15	+ 5.6	+ 3.4	
926	Schlesinger	16 14 38	79.88	10	19	+ 11.8	— 1.2	
927	Schlesinger	16 15 26	79.91	9	19	+ 16.9	+ 3.9	
928	Schlesinger	16 15 53	79.94	9	14	+ 17.3	+ 4.3	
934	Baker	17 14 57	80.89	10	15	+ 10.1	— 4.1	
935	Baker	17 15 10	80.90	8	14	+ 16.0	+ 1.8	
941	Schlesinger	18 14 53	81.89	10	16	+ 9.2	— 6.2	
942	Schlesinger	18 15 34	81.91	8	12	+ 22.2	+ 6.8	Remeasured
948	Schlesinger	20 15 29	83.91	8	11	+ 17.7	— 0.2	
949	Schlesinger	20 15 58	83.94	5	7	+ 22.8	+ 4.9	Underexposed
951	Baker	Nov. 5 14 45	3.21	9	12	— 25.0	— 2.2	
952	Schlesinger	8 13 55	6.18	8	9	— 35.4	— 1.7	
953	Schlesinger	8 15 18	6.19	5	7	— 32.6	+ 1.1	
954	Schlesinger	8 15 29	6.20	8	11	— 38.3	— 4.6	
960	Schlesinger	10 14 14	8.19	9	12	— 28.4	+ 8.6	
961	Schlesinger	10 14 36	8.20	7	12	— 35.3	+ 1.7	
962	Schlesinger	10 14 46	8.21	9	13	— 41.7	— 4.7	
974	Baker	13 14 26	11.20	9	14	— 40.5	— 2.0	
975	Baker	13 14 36	11.20	8	13	— 38.9	— 0.4	
976	Baker	13 15 06	11.22	9	14	— 40.5	— 2.0	Lantern-slide
988	Baker	15 15 34	13.24	8	12	— 31.8	+ 6.4	Remeasured
989	Baker	15 16 00	13.27	6	8	— 40.5	— 2.3	
990	Baker	15 16 15	13.28	8	13	— 33.8	+ 4.4	
1007	Schlesinger	24 14 04	22.18	7	13	— 35.1	— 1.9	
1008	Schlesinger	24 14 22	22.20	7	11	— 36.2	— 3.0	
1009	Schlesinger	24 14 46	22.21	9	17	— 37.8	— 4.6	
1016	Schlesinger	26 13 45	26.17	10	16	— 29.4	+ 1.0	
1017	Schlesinger	28 14 07	26.18	11	18	— 30.2	+ 0.2	
1018	Schlesinger	28 14 20	26.19	9	15	— 33.7	— 3.3	
1021	Schlesinger	29 13 16	27.15	8	11	— 29.4	+ 0.5	
1025	Schlesinger	Dec. 4 13 06	32.14	7	10	— 26.9	— 0.6	Comparison weak
1026	Schlesinger	4 13 42	32.17	7	13	— 28.4	— 2.1	

TABLE OF OBSERVATIONS.—*Continued.*

No. of Plate.	Plate Secured by	Date, G. M. T.	Phase.	No. of Lines.	Wt.	Velocity.	Resid. O–C.	Remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		1907 d h m	days			km.	km.	
1027	Schlesinger	Dec. 4 14 20	32.19	8	12	—31.9	—5.6	
1029	Schlesinger	6 13 02	34.14	5	7	—27.6	—2.7	Uneven exposure
1030	Schlesinger	6 13 24	34.16	6	13	—18.5	+6.4	
1031	Schlesinger	6 13 52	34.17	10	18	—24.1	+0.8	Remeasured
1035	Schlesinger	7 13 56	35.18	7	13	—24.6	—0.4	Comparison weak
1039	Schlesinger	8 12 54	36.14	9	14	—22.5	+1.0	
1041	Baker	26 13 12	54.15	8	15	— 7.9	+2.8	
1045	Baker	31 12 40	59.13	9	11	— 5.1	+1.8	
1046	Baker	31 13 14	59.15	8	15	—10.8	—3.9	
1047	Baker	31 13 30	59.16	8	12	— 9.5	—2.6	
		1908						
1051	Schlesinger	Jan. 3 12 06	62.10	8	11	— 3.7	+0.9	
1052	Schlesinger	3 12 40	62.13	10	14	— 2.5	+2.1	
1054	Schlesinger	5 11 37	64.08	10	16	— 0.5	+2.3	
1055	Schlesinger	5 11 58	64.10	10	19	— 3.2	—0.4	
1056	Schlesinger	5 12 10	64.11	9	16	— 1.4	+1.4	
1085	Baker	16 12 50	75.13	9	13	+ 5.2	—2.5	
1086	Baker	16 13 21	75.15	8	12	+ 6.6	—1.1	
1087	Baker	16 13 34	75.16	7	12	+10.4	+2.7	
1098	Baker	18 12 34	77.12	9	14	+15.5	+5.5	
1099	Baker	18 12 57	77.14	7	10	+14.5	+4.5	
1100	Baker	18 13 10	77.15	8	14	+ 4.2	—5.8	
1121	Baker	22 12 59	81.14	10	15	+ 7.3	—7.5	
1122	Baker	22 13 18	81.15	8	12	+ 9.5	—5.4	
1123	Baker	24 12 36	83.12	9	12	+18.6	+1.5	
1124	Baker	24 12 57	83.14	9	15	+21.8	+4.7	
1130	Schlesinger	25 12 36	84.12	9	19	+14.3	—4.5	
1145	Schlesinger	30 11 26	89.08	7	9	+27.3	+4.4	
1146	Schlesinger	30 11 51	89.09	11	15	+25.3	+2.4	
1147	Schlesinger	30 12 24	89.12	8	11	+25.4	+2.5	
1152	Schlesinger	Feb. 2 11 34	92.08	10	18	+26.5	+5.2	
1153	Schlesinger	2 12 01	92.10	9	16	+19.6	—1.7	
1154	Schlesinger	2 12 15	92.11	9	15	+17.8	—3.5	
1160	Schlesinger	4 11 35	94.08	8	9	+12.3	—3.1	Underexposed
1164	Schlesinger	8 11 50	1.42	10	21	—15.2	—4.2	
1165	Schlesinger	8 12 27	1.45	8	13	—11.5	—0.5	Comparison weak
1167	Schlesinger	8 12 50	1.46	10	18	— 5.7	+5.3	
1171	Schlesinger	9 11 50	2.42	8	17	—14.6	+3.9	
1172	Schlesinger	9 12 25	2.45	6	9	—17.5	+1.0	
1179	Schlesinger	10 12 03	3.43	7	9	—26.7	—2.7	

measured and the weights in columns (5) and (6) of the table. The duration of exposure is about 2½ times that required for Seed 27 plates. For this star, whose photographic magnitude is 2.8, 10 minutes is sufficient for a full exposure under average conditions.

Column (4) contains the phase from periastron, computed with the final period of 96.67 days. Column (7) contains the observed velocities, and column (8) the residuals scaled from the final curve.

A comparison of the Allegheny velocities with those of the Lowell Observatory, obtained in 1903 and 1904, gave a provisional period of 96.63 days. With this period the above determinations were plotted, and an orbit was derived graphically by the method of Lehmann-Filhés.* The following preliminary elements resulted:

$$\left.\begin{array}{ll} P = 96.63 \text{ days} & \varpi = 72.^\circ 0 \\ e = 0.51 & K = 31.5 \text{ km.} \\ T = 1907 \text{ Nov. } 2.^d 0 & \gamma = -12.0 \text{ km.} \end{array}\right\} \text{Preliminary elements.}$$

The observations were now formed into seventeen normal places, the sole basis of grouping being the phase. Relative weights were assigned to these places, depending not only on the sum of the separate plate weights, but also upon the number of plates and nights involved.

TABLE OF NORMAL PLACES.

No.	Phase.	Limits of Phase.		Velocity.	Resid. O-C	Wt.	No.	Phase.	Limits of Phase.		Velocity.	Resid. O-C	Wt.
	days	days	days	km.	km.			days	days	days	km.	km.	
1	1.82	1.5 to	2.5	−12.53	+1.18	1	10	64.10	62.1 to	66.0	−2.40	+0.52	2
2	3.32	3.2	3.5	−25.73	−2.74	½	11	69.32	68.9	70.0	+1.84	+0.06	1
3	7.35	6.2	8.2	−35.54	+0.42	1	12	76.15	75.1	77.2	+9.01	+0.26	1
4	12.33	11.2	13.3	−37.81	+0.56	2	13	80.74	79.8	81.9	+13.16	−0.96	3
5	20.70	17.1	22.2	−36.40	−2.24	1	14	83.64	83.1	84.1	+18.38	+0.72	1
6	28.87	26.2	32.2	−29.35	−0.80	3	15	89.10	89.1	89.1	+25.85	+2.95	½
7	34.73	34.0	36.1	−24.38	+0.11	3	16	92.10	92.1	92.1	+21.58	+0.31	½
8	41.36	39.1	45.0	−17.41	+2.48	2	17	94.08	94.1		+12.30	−2.89	⅓
9	56.21	53.0	59.2	−10.15	−0.90	2							

From the assumed elements an ephemeris was computed and differential coefficients derived for the normal places. Putting for simplification:

$$\delta e' = K \cdot \delta e, \quad \delta\varpi' = K \cdot \delta\varpi, \quad \delta T' = K \cdot \mu \cdot \delta T / (1 - e^2)^{\frac{3}{2}},$$

the resulting normal equations are:

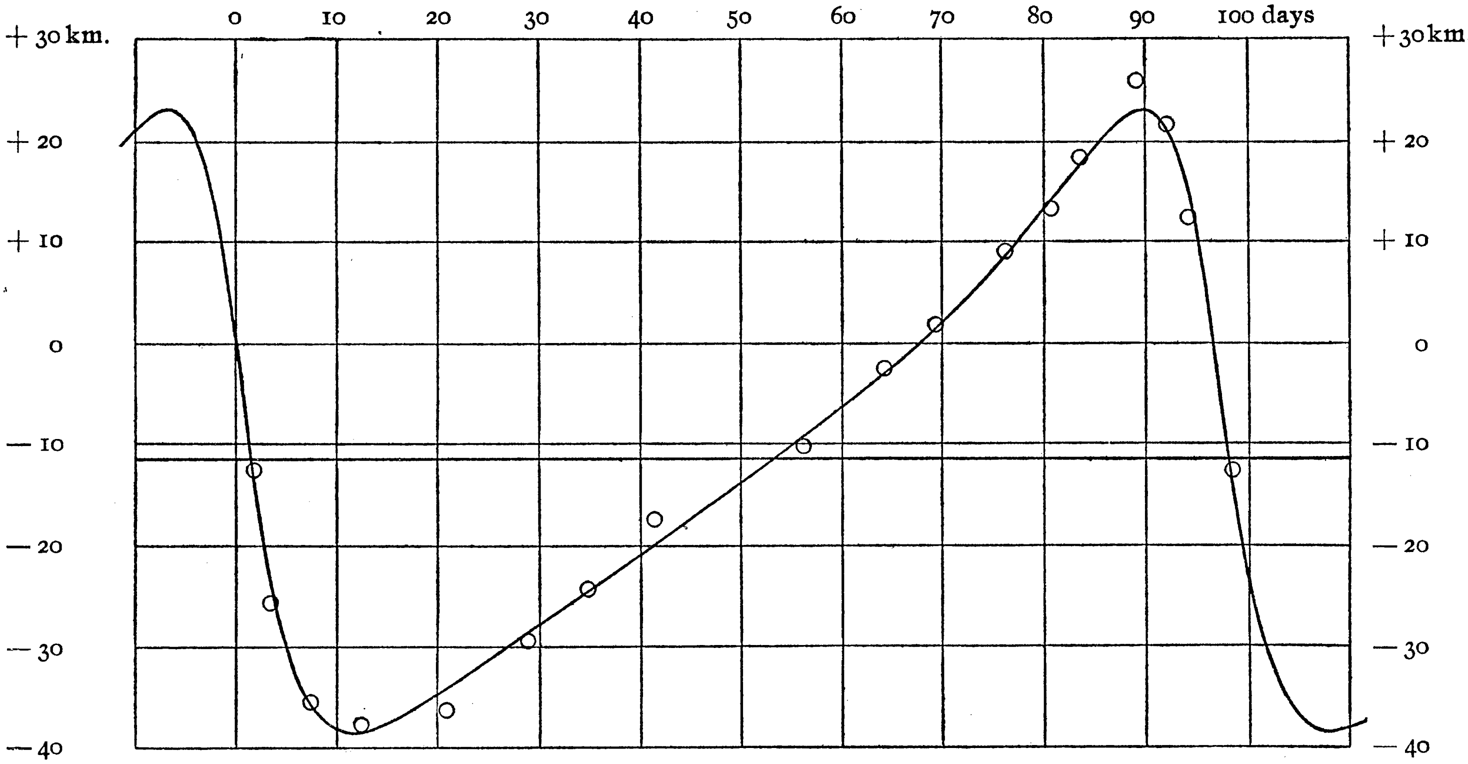
$$\begin{array}{rrrrrl} +24.833\delta\gamma & -1.148\,\delta T' & -0.347\delta K & +0.860\delta\varpi' & -1.524\delta e' & = +11.44 \\ & +8.357 & -1.105 & -7.112 & -2.041 & = -6.34 \\ & & +9.750 & +1.224 & -7.864 & = -9.88 \\ & & & +7.683 & +1.960 & = +9.02 \\ & & & & +20.429 & = +16.96 \end{array}$$

Whence the following corrections to the preliminary elements:

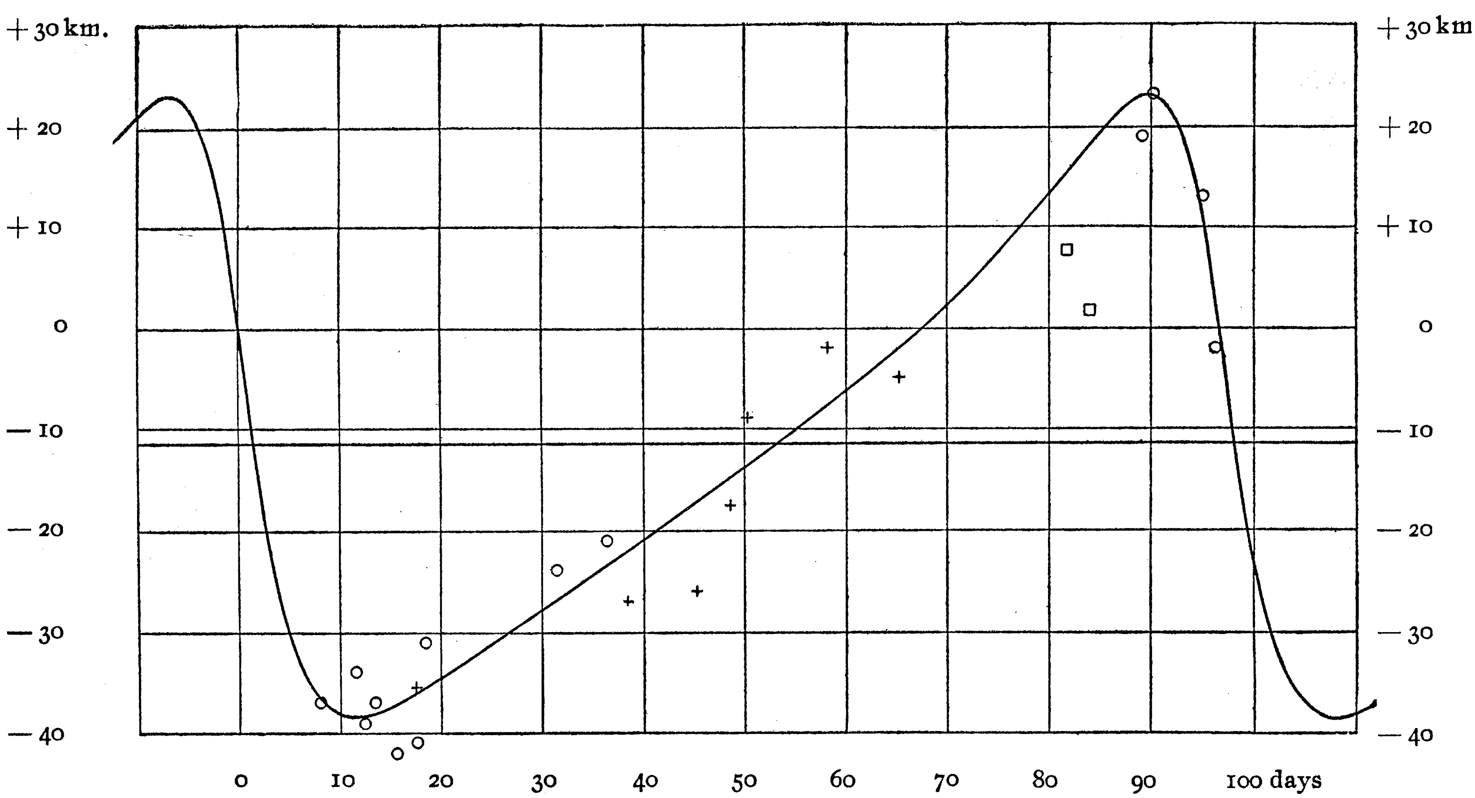
$$\begin{array}{ll} \delta\gamma = +0.45 \text{ km.} & \delta\varpi = +4.^\circ 21 \\ \delta T = +0.40 \text{ days} & \delta e = +0.015 \\ \delta K = -0.75 \text{ km.} & \end{array}$$

The definitive elements with their probable errors are given at the end of the paper. These elements are represented by the accompanying velocity curves. With

* *Astronomische Nachrichten*, **136**, 17, 1894.



Velocity curve of α Andromedæ from the Allegheny Observations.



Previous observations at other observatories.

Lowell...... ○ Lick...... + Potsdam...... □

the upper curve are plotted the seventeen normal places employed in the discussion of the orbit. There seems to be some slight indication of a secondary curve having small amplitude and a period one-half that of the primary. A trial of several combinations of curves, however, resulted in no great improvement in the residuals. The phase in the diagram is referred to periastron, and the heavy horizontal line denotes the velocity of the center of mass of the system. The probable error of a normal place of weight 1 is 1.19 km., that of an average plate, derived from the plate residuals, is 2.55 km. The change in the normal residuals obtained from the final ephemeris as compared with those from a direct substitution in the equations of condition has a maximum value of 0.16 km.

The lower figure shows the velocity determinations previously made at the Lowell, the Lick and the Potsdam observatories. The measures of the two first named are preliminary. A correction of + 3.0 km. is added to the Lowell observations, this systematic difference being apparent between Mr. Slipher's points and mine. This correction, together with the change in the curve due to the least-square solution, made necessary the addition of + 0.04 day to the preliminary period. The two Potsdam observations,* made in 1888 and 1891, would be better suited by a period ot 96.86 or of 96.51 days. The later, and presumably more accurate, observations will admit of neither of these periods.

$P = 96.67$ days		Definitive elements.
$e = 0.525$	± 0.011	
$T = 1907$ Nov. $2^{d}.40$	± 0.28 days	
$\varpi = 76^{\circ}.21$	$\pm 1^{\circ}.71$	
$K = 30.75$ km.	± 0.48 km.	
$\gamma = -11.55$ km.	± 0.24 km.	
$A = 34.60$ km.		
$B = 26.90$ km.		
$a \sin i = 34{,}790{,}000$ km.		

I wish to acknowledge my indebtedness to Director Schlesinger for advice and assistance during the discussion of this orbit.

* *Potsdam Publications*, VII, Part 1.

16 March, 1908.