LICK OBSERVATORY BULLETIN

NUMBER 428

ELEMENTS AND EPHEMERIS OF COMET *d* 1930
(SCHWASSMANN-WACHMANN)

BY

PHYLLIS HAYFORD and CLAUDE M. ANDERSON, JR.

Comet *d* 1930 was discovered by Schwassmann and Wachmann at Bergedorf, Germany, on May 2, 1930. The brightness was estimated by various observers from 9 to 10.5 magnitude. Van Biesbroeck reported a

tail two degrees in length. Meyer observed a star-like nucleus until May 23, after which he described it as elongated and fuzzy.

The following observations have been received:

1930 U. T.	$\alpha(1930.0)$	$\delta(1930.0)$	Observer	Place	Authority
(1) Apr. 27.9257	15 ^h 51 ^m 54.3	+35° 02' 13"	Schneller	Neubabelsberg	B.C.A.C. 277
(2) Apr. 29.9792	15 56 30.7	+35 29 47	Schneller	Neubabelsberg	B.C.A.C. 277
(3) May 2.0265	16 01 34.87	+35 55 50.7	Schwassmann-Wachmann	Bergedorf	B.C.A.C. 277
(4) May 2.8933	16 03 55.48	+36 06 09.4	Mündler	Heidelberg	B.Z. 21, 1930
(5) May 2.9046	16 03 57.18	+36 06 15.5	Schwassmann-Wachmann	Bergedorf	B.Z. 21, 1930
(6) May 2.9170	16 03 59.13	+36 06 29	Struve	Neubabelsberg	H.A.C. 125
(7) May 2.9383	16 04 02.27	+36 06 44	Krumpholz	Wien	B.Z. 21, 1930
(8) May 3.9023	16 06 46.00	+36 17 35	Vinter Hansen-Möller	Copenhagen	Telegram, H.A.C. 125
(9) May 3.9529	16 06 54.33	+36 18 14	Struve	Neubabelsberg	B.Z. 22, 1930
(10) May 3.97275	16 06 58.20	+36 18 35.4	Gonnessiat	Alger	B.C.A.C. 280
(11) May 4.1474	16 07 29.7	+36 20 22	Van Biesbroeck	Williams Bay	Telegram
(12) May 4.8446	16 09 35.73	+36 27 48.8	Bianchi	Milano	B.C.A.C. 279
(13) May 4.8997	16 09 44.93	+36 28 23	Struve	Neubabelsberg	B.C.A.C. 277
(14) May 5.3703	16 11 11.4	+36 33 22	Van Biesbroeck	Williams Bay	H.A.C. 127
(15) May 6.80521	16 16 00.60	+36 47 10.9	Beljowsky	Simeis	B.Z. 22, 1930
(16) May 7.1776	16 17 20	+36 50 30	Thorndike	Berkeley	
(17) May 7.7825	16 19 31.94	+36 55 29.0	Beljowsky	Simeis	R.I.C. 314
(18) May 9.00451	16 24 16.09	+37 05 06.2	Reiss	Alger	B.C.A.C. 280
(19) May 9.2053	16 25 06.30	+37 06 22.7	Van Biesbroeck	Williams Bay	Air Mail Card
(20) May 9.97304	16 28 21.09	+37 11 11.3	Struve	Neubabelsberg	B.C.A.C. 280
(21) May 9.98987	16 28 25.25	+37 11 18.4	Schneider	Neubabelsberg	B.C.A.C. 280
(22) May 12.93396	16 42 59.27	+37 22 49.6	Renaux-Filippoff	Alger	B.C.A.C. 281
(23) May 15.92814	17 02 03.78	+37 16 36.9	Mündler	Heidelberg	B.Z. 24, 1930
(24) May 16.97573	17 10 04.67	+37 08 08.2	Struve	Neubabelsberg	B.C.A.C. 282
(25) May 17.23504	17 12 12.82	+37 05 27.8	Van Biesbroeck	Williams Bay	Air Mail Letter
(26) May 21.20796	17 52 45.97	+35 33 00.1	Van Biesbroeck	Williams Bay	Letter
(27) May 22.00715	18 03 07.60	+34 57 26.4	Struve	Neubabelsberg	B.C.A.C. 283
(28) May 22.34289	18 07 47.6	+34 40 36.7	Meyer	Mt. Hamilton	Letter
(29) May 22.94922	18 16 36.35	+34 05 04.5	Mündler	Heidelberg	B.Z. 24, 1930
(30) May 23.2302	18 20 52	+33 47 03	Manson	Columbus	H.A.C. 129
(31) May 23.29572	18 21 54.7	+33 42 42.5	Meyer	Mt. Hamilton	Letter
(32) June 2.44443	22 05 05.57	+ 0 02 36.5	Meyer	Mt. Hamilton	Telephone, Letter

A preliminary orbit by Leuschner's method was undertaken by Fred L. Whipple and Miss Hayford under the general direction of Professor Crawford, using the available observations (6) May 2, (8) May 3, and (11) May 4. In the course of the computation (14) May 5 became available and was substituted for (11) in a differential correction for a parabola which yielded the following elements:

$$\begin{aligned} 1930.0 \\ T=1930 \text{ June } 12.96 \text{ U.T.} \\ \omega=190^\circ 51' \\ \Omega=78^\circ 48' \\ i=21^\circ 02' \\ q=1.016 \end{aligned}$$

The residuals other than for the middle date (8) May 3 were:

	1930	$\Delta\alpha$	$\Delta\delta$
(6) May	2.92	-3".0	+2".3
(11) May	4.15	+2.9	+1.7
(14) May	5.37	-0.2	+0.7

This orbit and an ephemeris were telegraphed to Harvard College Observatory and distributed on *H.A.C.* 126. *H.A.C.* 127 extends this ephemeris and gives it in more detail.

Miss Hayford and Anderson undertook an improvement of the orbit under the general direction of Professors Leuschner and Crawford using a longer arc made possible by later observations. On account of unavoidable choice of erroneous observations several differential corrections were required before presumably reliable observations could finally be selected. (19) May 9 was made the middle date and a differential correction made to satisfy (1) April 27 and (25) May 17. Two more differential corrections of this orbit, with the arc extended by substituting (31) May 23 for (25), removed all the residuals except the one in the first declination, indicating ellipticity. A study of the residuals of the parabolic orbit apparently also indicated an error in one of the basic observations, which after further experiments proved to be (31). (25) May 17 was chosen as the new middle date. (4), (5), and (6) were combined into a normal place (5):

$$(5) \text{ 1930, May 2.9046, } \alpha=240^\circ 59' 17".0, \delta=+36^\circ 06' 17".3.$$

A differential correction on the parabolic hypothesis satisfying (5) May 2, (25) May 17, and (31) May 23 gave the following residuals, proving ellipticity:

	1930	$\Delta\alpha$	$\Delta\delta$
(5)* May	2.90	-0".6	-152".0
(8) May	3.90	+6.0	-131.4
(14) May	5.37	+10.4	-97.2
(25)* May	17.23	0.0	0.0
(26) May	21.21	-16.6	+15.7
(28) May	22.34	-11.0	+4.0
(31)* May	23.30	+3.5	-1.2

*The basic observations.

A differential correction for a general solution with the same basic positions left the following residuals:

	1930	$\Delta\alpha$	$\Delta\delta$
(5) May	2.90	-18".2	-62".5
(31) May	23.30	+31.8	-7.7

Because of the uncertainty in some of the basic observations, and the question of the magnitude of the Earth's perturbations, a much needed ephemeris was computed on this elliptic orbit before removing the residuals. The ephemeris was telegraphed to Harvard College Observatory and was published on *H.A.C.* 129.

A second differential correction of the elliptic orbit without perturbations gave the residuals:

	1930	$\Delta\alpha$	$\Delta\delta$
(5)* May	2.90	-18".7	-48".2
(10) May	3.97	-17.0	-42.1
(18) May	9.00	-5.4	-15.2
(19) May	9.21	-6.4	-14.8
(20) May	9.97	-6.3	-14.7
(21) May	9.99	-6.8	-14.8
(22) May	12.93	-6.8	-4.4
(25)* May	17.24	0.0	0.0
(26) May	21.21	-6.8	+18.7
(28) May	22.34	-8.5	+10.7
(30) May	23.23	-12.3	+4.0
(31)* May	23.30	+4.0	+14.2
(32) June	2.44	+182.1	-402.6

A study of these residuals indicated an error in the middle date (25). A normal place was formed from (18), (19), (20), and (21):

$$(20) \text{ May } 9.97304, \alpha=247^\circ 05' 16".48, \delta=+37^\circ 11' 11".1.$$

The middle date was changed to (26) May 21 because it was apparently consistent with the few observations then available near that date. Before differentially correcting, special perturbations due to the Earth were computed by Encke's method. Because of the slow convergence of the series the differential correction was made with closed expressions to satisfy (5) normal, May 2, (26) May 21, and (32) June 2. The following residuals were obtained:

	1930	$\Delta\alpha$	$\Delta\delta$
(5)* May	2.90	+1".4	-6".4
(20) May	9.97	-2.9	-13.3
(22) May	12.93	-3.4	-12.4
(24) May	16.98	-0.9	-11.2
(25) May	17.24	+2.4	-13.3
(26)* May	21.21	0.0	0.0
(28) May	22.34	+0.6	-11.1
(31) May	23.29	+1.8	-8.0
(32)* June	2.44	+0.6	-2.8

*The basic observations.

From the run of these residuals, (26) was assumed to be in error by $-0''.4$ in α and $+11''.1$ in δ and was arbitrarily corrected, necessitating a further differential correction. The residuals resulting from this orbit were removed by using the coefficients from the previous differential correction based on the same dates. This resulted in the adopted orbit:

ELEMENTS, 1930.0

Epoch of Osculation May 21.21 U.T.

$$\begin{aligned}
 T &= 1930 \text{ June } 14.21981 \text{ U.T.} & e &= 0.665883 \\
 \omega &= 192^\circ 19' 23''.8 & a &= 3.027129 \\
 \Omega &= 76 \quad 45 \quad 13.3 & q &= 1.011415 \\
 i &= 17 \quad 17 \quad 56.2 & P &= 5.2668 \text{ years} \\
 x &= -0.0772134 (\cos E - e) + 2.1609683 \sin E \\
 y &= -2.6941953 (\cos E - e) + 0.2486716 \sin E \\
 z &= -1.3779924 (\cos E - e) - 0.6072796 \sin E
 \end{aligned}$$

PERTURBATIONS IN THE HELIOCENTRIC EQUATORIAL CO-ORDINATES
BY THE EARTH

(Units of the seventh decimal.)

1930	ξ'	η'	ζ'
April 25	+ 23	+ 83	- 61
April 29	+ 16	+ 65	- 47
May 3	+ 11	+ 47	- 35
May 7	+ 6	+ 32	- 23
May 11	+ 3	+ 18	- 13
May 15	+ 1	+ 8	- 6
May 19	0	+ 1	- 1
May 23	0	+ 1	- 1
May 27	- 1	+ 13	- 8
May 31	- 11	+ 44	- 26
June 4	- 42	+ 94	- 49
June 8	- 96	+154	- 69
June 12	-165	+217	- 82
June 16	-242	+279	- 91
June 20	-323	+342	- 94
June 24	-406	+404	- 93
June 28	-491	+469	- 87
July 2	-578	+535	- 76
July 6	-666	+604	- 60
July 10	-755	+676	- 38
July 14	-847	+751	- 11
July 18	-942	+830	+ 23
July 22	-1042	+911	+ 62
July 26	-1145	+996	+108
July 30	-1254	+1083	+160
Aug. 3	-1369	+1173	+218
Aug. 7	-1490	+1264	+282
Aug. 11	-1618	+1357	+350

BERKELEY ASTRONOMICAL DEPARTMENT,

June 16, 1930.

Issued August 8, 1930.

The observations are represented as follows:

	1930	$\Delta\alpha$	$\Delta\delta$
(1) Apr. 27.93		+2''.8	- 3''.6
(2) Apr. 29.98		-0.8	-14.9
* (5)† May 2.90		+1.3	+ 1.1
(7) May 2.94		+0.6	- 0.9
(8) May 3.90		+2.2	- 1.6
(9) May 3.95		+1.2	- 0.4
(10) May 3.97		+0.9	- 1.4
(11) May 4.15		+1.8	- 1.2
(12) May 4.84		+2.3	+ 1.3
(13) May 4.90		-1.9	- 0.8
(14) May 5.37		+5.3	- 1.6
(15) May 6.81		+2.3	+ 5.9
(16) May 7.17		-0.1	+ 9.7
(17) May 7.78		-1.3	- 1.8
(20)† May 9.97		-0.4	- 3.3
(22) May 12.93		-2.0	- 2.1
(23) May 15.93		+0.2	- 1.0
(24) May 16.98		+0.1	- 0.5
(25) May 17.24		+4.3	- 3.6
* (26) ¹ May 21.21		-0.4	+11.0
(27) May 22.01		-0.4	- 2.7
(28) May 22.34		-0.6	+ 1.1
(29) May 22.95		+2.2	- 0.6
(30) May 23.23		-6.7	- 5.4
(31) May 23.30		-1.2	+ 4.0
* (32) June 2.44		-0.2	- 1.1

* The basic observations.

¹ Residuals zero after arbitrary correction.

† Normal places, individual observations represented on another orbit.

EPHEMERIS

1930 U.T.	$\alpha(1930.0)$	$\delta(1930.0)$	ρ	Mag.
June 16.0	1 ^h 01 ^m 08 ^s .3	-29° 45' 35"	0.138352	9.5
June 20.0	1 22 20.3	-31 55 52	0.167099	
June 24.0	1 37 53.9	-33 19 37	0.195990	9.9
June 28.0	1 49 43.1	-34 17 52	0.224551	
July 2.0	1 58 53.2	-35 01 29	0.252503	10.5
July 6.0	2 06 04.4	-35 36 26	0.279658	
July 10.0	2 11 41.5	-36 06 33	0.305870	11.1
July 14.0	2 15 59.2	-36 34 14	0.331054	
July 18.0	2 19 5.5	-37 01 11	0.355166	11.6
July 22.0	2 21 4.7	-37 28 22	0.378217	
July 26.0	2 21 57.8	-37 56 15	0.400275	11.9
July 30.0	2 21 45.4	-38 24 42	0.421463	
Aug. 3.0	2 20 27.9	-38 53 19	0.441928	12.2
Aug. 7.0	2 18 6.4	-39 21 28	0.461846	
Aug. 11.0	2 14 41.5	-39 48 27	0.481412	12.5

The perturbations of the Earth have been included both in the representations and in the ephemeris, with the date of osculation 1930 May 21.21, U.T. The Earth's perturbations amounted to approximately $15''$ in α and $12''$ in δ by June 2. In representing the observations throughout the computation, closed expressions have been used when the interval was more than four days.