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ELEMENTS AND EPHEMERIS OF COMET *a* 1904 (BROOKS)

A comparison of several observations made at the Lick Observatory and at Berkeley with the ephemeris published in Bulletin No. 54, gives the following residuals:

	$\Delta\alpha \cos\delta$	$\Delta\delta$
April 22.77	+ 3.8	+ 7"
28.74	+15.7	+35.
29.71	+18.9	+55.
May 3.5	+28.	+2.9

The residuals for May 3.5 represent a comparison of the old with the new ephemeris printed below. In order to determine how much the orbit would change with a longer arc it has been recomputed, chiefly by Messrs. Ralph H. Curtiss and Sebastian Albrecht, from observations taken April 17th, April 22d, and April 29th. The observations used were selected on

the basis of a comparison, made by them, with the original ephemeris. For the first date Aitken's observation was used, being entirely consistent with one by Seares, Columbia, Mo., of the same date. For April 22d an observation by Crawford, Berkeley, was used, the residuals being found to conform to the general run. For the last date, April 29th, observations by Maddrill, Mount Hamilton, and Crawford, Berkeley, were available. The residuals of these two observations in right ascension were entirely consistent, while the declinations showed a discrepancy of 7". Maddrill's observation was corrected by one-third of the discrepancy, the weights assigned being in the ratio of 2 to 1.

The adopted positions are:

1904 Greenwich M. T.	α	Comet's Apparent	δ	$\log \Delta \rho \alpha$	$\log \Delta \rho \delta$
April 17.7132	16 ^h 55 ^m 40 ^s .8	+44° 53' 37"	9.821 _n	0.602	
22.78465	16 49 32.71	+47 58 21.4	9.662 _n	0.103	
29.70462	16 15 53.91	+51 41 00.3	9.860 _n	0.255	

The star places were not investigated.

The method used in computing the new orbit consists in determining such corrections to the geocentric distance and to the heliocentric velocities at the middle date as will remove the residuals at the first and third dates (cf. Publ. of the L. O., Vol. VII, Part 1, formulae VI, etc., pp. 16-18). All results given below have been computed in duplicate. A first approximation of the geocentric distance and the heliocentric velocities was determined for the middle date from the preliminary ephemeris, the velocities being derived by numerical differentiation, as follows:

$\log \rho_0$	0.280290
$\log x'_0$	9.261620 _n
$\log y'_0$	9.579000
$\log z'_0$	9.605470

By formulae VI the residuals for April 17th and 29th were found to be as follows:

Residuals	Obs.—Comp.
I	III
$\Delta\alpha \cos\delta$ -53".4	+231".5
$\Delta\delta$ -17.9	+ 27.5

The corrections resulting from formulae VII were

$\log \delta \rho_0$	9.31266
$\log \delta x'_0$	8.90399 _n
$\log \delta y'_0$	8.90831
$\log \delta z'_0$	9.10855

These gave for new residuals, by VI,

	I	III
$\Delta\alpha \cos \delta$	-5".6	+22".6
$\Delta\delta$	-2.8	+ 2.3

From these residuals, by repeating part of VII, followed:

$\log \partial \rho_0$	8.3265
$\log \partial x'_0$	7.9257 _n
$\log \partial y'_0$	7.8693
$\log \partial z'_0$	8.1595

And again by VI,

	I	III
$\Delta \alpha \cos \delta$	$-0''.2$	$+0''.6$
$\Delta \delta$	± 0.0	-0.7

These final residuals are entirely within the accuracy of the adopted positions. The final values of the geocentric distance and the heliocentric velocities at the middle date are:

$\log \rho_0$	0.329070
$\log x'_0$	9.433366 _n
$\log y'_0$	9.669952
$\log z'_0$	9.737183

Although these data, together with the middle observation are entirely sufficient for the computation of a new ephemeris for a few weeks to come, elements were recomputed from them, with Mr. Curtiss, as follows:

Epoch 1904 April 22.77234				
$M_0 =$	4°	16'	58"	} 1904
$\omega =$	47	39	53	
$\Omega =$	274	10	26	
$i =$	125	22	32	
$e =$	0.57512			
$\log u =$	0.78661			
$\mu =$	234'47			

The residuals are given above.

Constants for the Equator of 1904.0:

$$\begin{aligned} x &= r [9.76490] \sin (220^\circ 28' 49'' + v) \\ y &= r [9.99317] \sin (296 \quad 0 \quad 59 + v) \\ z &= r [9.92014] \sin (19 \quad 10 \quad 19 + v) \end{aligned}$$

An accurate ephemeris has been computed from March 8th to June 12th at intervals of eight days, partly by Dr. Newkirk and Miss Hobe and partly by Mr. Curtiss. Intermediate positions were obtained by interpolation to the middle, with the exception of the positions for April 21.5, April 29.5, and May 7.5, which were computed directly by Mr. Curtiss, to serve in a determination of the residuals of the second and third positions used for the first orbit, the first positions being the same in both orbits. Only that part of the ephemeris which may assist in finding the comet, is given here.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1904	True α	True δ	$\log \Delta$	Br.
May 3.5	16 ^h 00 ^m 29 ^s	53° 24'.8	0.33644	0.91
7.5	15 43 07	54 57.1		
11.5	24 50	56 10.9	0.34822	0.85
15.5	06 06	57 05.7		
19.5	14 47 22	57 41.9	0.36419	0.78
23.5	29 09	58 00.6		
27.5	11 46	58 03.8	0.38306	0.71
31.5	55 33	57 55.6		
June 4.5	40 51	57 31.9	0.40359	0.63
8.5	27 35	57 01.1		
12.5	15 52	56 24.2	0.42474	0.56

The change of the elements in the plane of the orbit is due, aside from the numerical values of the corrections to the fundamental data $\partial \rho_0$, x'_0 , y'_0 , z'_0 , to the circumstance that in the first orbit p was less than r while in the second it is greater, $e \cos v$ being computed from $\frac{p}{r} - 1$. Since $e \sin v$ has the same sign in both orbits, v fell in the second quadrant in the first orbit, while in the present orbit it falls in the first quadrant.

As pointed out in the last Bulletin, it was expected that the elements would change considerably with a longer arc. The new elements, also, are subject to some variation in the same direction as the first ones. They are true probably only to two decimals, the accuracy of μ , e , and ω being considerably less.

In the "Short Method" velocities and accelerations in α and δ are determined from the observations by neglecting higher differences in the first approximation. The residuals of the first and third places are then computed, and corrections are determined so as to represent the three places as exactly as seems advisable within the accuracy of the observations. This amounts to introducing higher differences sufficient to represent the observations. It is evident that, as in the case of an ephemeris, the longer the arc the more accurately these higher differences will be determined; also that comparatively small relative errors in the observations will effect the accuracy of the differences of the resulting ephemeris in a given case. To test this point in the present case Mr. Curtiss has accurately determined the residuals of the three places used in the first orbit. The first place, April 17th, leaves no residual, having also been used in the second orbit. The residuals of the second and third places, April 18th and 19th respectively, were as follows:

$\Delta \alpha \cos \delta$	$-5''.12$	$-5''.6$
$\Delta \delta$	$-2''.2$	$-9''.7$

The observed arc between the second and third places was therefore too small as compared with the observed arc between the first and second places, which ought to cause the resulting ephemeris to lag behind, as was actually the case with the first orbit as seen from the residuals printed at the beginning of this paper. The relative discrepancies in these residuals are probably due to the star places. The last observation, however, was secured under unfavorable circumstances through fog to furnish the necessary material for a preliminary orbit.

The new ephemeris was compared with an observation secured by Dr. Crawford last night, May 5.71 Gr. M. T. resulting in the following corrections to the ephemeris on that date

$$\Delta \alpha \cos \delta + 2''.5 \quad + 3''$$

which indicates that with a still longer arc the eccentricity and period, which is now 15.14 years as compared to 3.02 years for the first orbit, will still further increase.

The ephemeris represents the approximate Harvard photographic positions satisfactorily as far back as April 1.89 Gr. M. T., the residuals on that date being

$$\Delta\alpha \cos \delta + 19^s \qquad \Delta\delta + 6'$$

The residuals for the first two Harvard photographic positions are

Gr. M. T.	$\Delta\alpha \cos \delta$	$\Delta\delta$
March 11.87	+16 ^m	—3 ^s .9
15.90	+13	—3.1

The advisability of determining an orbit from a short arc without hypothesis as to the eccentricity might be questioned, were it not for the fact that in applying the "Short Method," the aim is to determine as rapidly as possible a finding ephemeris which

accurately represents the given observations, the computation of the elements being incidental to conform to established custom. The fact that such an ephemeris, as far as comets are concerned, can thus be derived more conveniently than by means of a preliminary parabola is sufficient justification for departing from the old method. In many cases the periodic character of an orbit is readily revealed from a short arc. (cf. Publ. L. O., Vol. VII, part 3.)

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