ELEMENTS AND EPHEMERIS OF MINOR PLANET 1929 PA

BY

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This planet, originally mistaken for Comet b 1929 (Neujmin),¹ was discovered and announced by Max

Wolf² in August 1929. The magnitude was given as 15.0. The observations are as follows:

1929 U. T.	$\alpha(1929.0)$	$\delta(1929.0)$	Observer, Place	Authority
(1) Aug. 4.9478	21 ^h 14 ^m 27 ^s .14	-12° 28' 24".3	Wolf, Heidelberg	B. Z. 29, 1929
(2) Aug. 6.9319	21 12 52.84	-12 32 31.7	Wolf, Heidelberg	Letter
(3) Aug. 9.3560	21 10 56.66	-12 37 45.7	Krieger, Mt. Hamilton	Letter
(4) Aug. 9.39138	21 10 55.11	-12 37 48.2	Krieger, Mt. Hamilton	†
(5) Aug. 12.9925	21 08 03.42	-12 45 43.8	Wolf, Heidelberg	Letter
(6) Aug. 13.9804	21 07 16.56	-12 47 56.2	Wolf, Heidelberg	Letter
(7) Aug. 14.9992	21 06 29.00	-12 50 13.0	Wolf, Heidelberg	Letter
(8) Aug. 15.42193	21 06 09.19	-12 51 11.9	Krieger, Mt. Hamilton	Letter
(9) Aug. 30.9089	II 20 55 31.33	-13 24 09.2	Wolf, Heidelberg	Letter
	III 20 55 27.93	-13 23 45.8	Wolf, Heidelberg	Letter
	IV*20 55 02.30	-13 20 56.2	Wolf, Heidelberg	Letter
(10) Aug. 30.9430*	20 57 10.17	-13 21 02.2	Wolf, Heidelberg	Letter

* Observation later rejected.

† Measured by F. L. Whipple on plate taken by C. J. Krieger.

A preliminary orbit and ephemeris³ for 1929.0 were derived from the first three available observations (1) Aug. 4, (3) Aug. 9, and (8) Aug. 15, by direct solution.

ELEMENTS 1929.0

Epoch 1929 Aug. 26.60870 U.T.	$e=0.05074$
$M=-3^{\circ} 01' 13''$	$a=3.1663$
$\omega=30 31 46$	$\mu=0^{\circ}17494$
$\Omega=289 13 17$	$P=5.6340$ years
$i=5 02 42$	

EPHEMERIS

1929 U. T.	$\alpha(1929.0)$	$\delta(1929.0)$	$\log p$
Sept. 22.0	20 ^h 46 ^m 48 ^s	-13° 51' 42"	0.351
30.0	20 46 24	-13 53 47	0.368
Oct. 8.0	20 47 27	-13 50 59	0.385
16.0	20 49 55	-13 43 07	0.404

The residuals, including those for the next observation received, (10), are as follows:

Date	$\Delta\alpha$	$\Delta\delta$
(1) Aug. 4.94	-0".6	-0".1
(3) Aug. 9.35	-0.6	+0.2
(8) Aug. 15.42	-0.4	+0.3
(10) Aug. 30.94	+1741.0	+169.8

An attempt was then made to satisfy the observation (10) Aug. 30, without change of middle date, by variation of M and μ . Since this variation introduced large residuals in the observations (1) Aug. 4 and (8) Aug. 15, the middle date was changed to (8) Aug. 15, using the original orbit. After two differential corrections the resulting residuals indicated that the four

observations (1), (3), (8), (10) did not belong together. Observation (10) was rejected.

In this situation, Dr. Wolf was requested to verify observation (10) and furnish accurate measurements of observations (2) Aug. 6, (5) Aug. 12, (6) Aug. 13, and (7) Aug. 14 for which approximate positions had been published,⁴ and to search for the planet with the aid of the foregoing ephemeris. In addition to the requested accurate measurements, Dr. Wolf reported positions (9) of three objects discovered in close proximity on Aug. 30. Of these, objects II and IV were found on both plates of Aug. 30, while object III was found on only one plate. A plate, also, was secured from Mt. Hamilton⁵ from which Mr. Whipple obtained observation (4) Aug. 9 as a check on the middle date. The residuals of these observations with the original orbit based on (1) Aug. 4, (3) Aug. 9, and (8) Aug. 15 are as follows:

Date	$\Delta\alpha$	$\Delta\delta$
(2) Aug. 6.93	+2".4	+1".7
(4) Aug. 9.39	+1.0	+2.3
(5) Aug. 12.99	-2.8	+3.9
(6) Aug. 13.98	-5.2	+3.6
(7) Aug. 14.99	-1.5	+3.0
(9) Aug. 30.90	II+238.8	-21.1
	III+187.8	+ 2.3
	IV-196.7	+171.9

A differential correction was made to satisfy (2) Aug. 6, (3) Aug. 9, and (7) Aug. 14, as the above residuals indicated that (1) Aug. 4 and (8) Aug. 15, the two outer dates on which the original orbit was

¹ B. Z. 27, 1929.

² B. Z. 29, 1929.

³ H. A. C. 98.

⁴ B. Z. 29, 31, and 33, 1929.

⁵ The three Mt. Hamilton observations are given on pp. 20 and 21 of this Bulletin.

based, might be slightly in error. This orbit, by which all the observations were represented, did not improve the residuals.

Three simultaneous differential corrections were then made to satisfy (1) Aug. 4, (3) Aug. 9, and the three objects (9) Aug. 30. These gave the residuals:

Date	Object II		Object III		Object IV	
	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
(1) Aug. 4.94	-0 ^s .4	-0 ^s .5	-0 ^s .6	-0 ^s .4	-0 ^s .2	-0 ^s .8
(7) Aug. 14.99	-11.7	+11.1	-14.3	+5.2	-24.3	-18.2
(8) Aug. 15.42	-11.9	+8.8	-15.2	+2.3	-25.2	-23.3
(9) Aug. 30.90	-41.0	+4.3	-14.2	-0.2	-52.6	+62.3

As a result of this representation object IV was discarded, since a removal of its residuals would increase the error of the other observations. For orbits II and III the middle date was changed to (8) which throws the residuals of this observation into those of (1) and (9). Two differential corrections of each orbit left the following residuals:

	Object II		Object III	
	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
(1)	+0 ^s .3	-0 ^s .6	+0 ^s .3	-0 ^s .4
(2)	+0.9	-2.3	+5.0	+0.2
(3)	-0.5	-5.2	+5.3	-1.6
(4)	+2.1	-3.1	+6.9	+0.5
(5)	-0.6	+0.6	+2.7	+2.7
(6)	-4.0	+1.6	-1.6	+2.9
(7)	-1.3	+2.3	+0.3	+2.7
(8)	-0.9	+0.1	0.0	-0.2
(9)	+0.4	+0.3	+0.6	+0.1

From these residuals (9) II has been selected as the correct object. This seems especially justifiable since Wolf stated that object III was present on only one plate. Because of the uncertainty which still remains orbits have been computed for objects (9), II and III.

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ELEMENTS 1929.0		EPOCH=	
II, Object II	III, Object III	II, Object II	III, Object III
Epoch=	Epoch=	1929 Aug. 15.41287 U. T.	1929 Aug. 15.41177 U. T.
$M = -6^{\circ}47'22''$	$M = +10^{\circ}13'08''$		
$\omega = 45^{\circ}50'17''$	$\omega = 18^{\circ}89'11''$		
$\Omega = 281^{\circ}85'17''$	$\Omega = 285^{\circ}62'20''$		
$i = 3^{\circ}7'25''$	$i = 4^{\circ}30'62''$		
$e = 0.17910$	$e = 0.12985$		
$a = 3.13216$	$a = 3.16937$		
$\mu = 0^{\circ}17'78''$	$\mu = 0^{\circ}17'46''$		
$P = 5.54326$ years	$P = 5.64235$ years		

II

$$\begin{aligned}x &= +2.63312 (\cos E - e) + 1.65718 \sin E \\y &= -1.60813 (\cos E - e) + 2.32407 \sin E \\z &= -0.53929 (\cos E - e) + 1.16099 \sin E\end{aligned}$$

III

$$\begin{aligned}x &= +1.79297 (\cos E - e) + 2.58136 \sin E \\y &= -2.42726 (\cos E - e) + 1.54261 \sin E \\z &= -0.96883 (\cos E - e) + 0.91244 \sin E\end{aligned}$$

EPHEMERIS FOR THE OPPOSITION OF 1930—OBJECT AND ORBIT II

1930 U. T.	$\alpha(1930.0)$	$\delta(1930.0)$	ρ	Mag.
Oct. 7	4 ^h 40 ^m .3	+25° 38'	2.376	15.0
15	4 39.4	+25 39	2.300	
23	4 36.8	+25 35	2.234	
31	4 32.7	+25 27	2.180	
Nov. 8	4 27.2	+25 15	2.140	
16	4 20.7	+24 57	2.118	
24	4 13.6	+24 35	2.114	

A change in α of +1^m corresponds to +2^s.7 in δ on 1930, Nov. 24.

CORRECTION TO THE ABOVE EPHEMERIS TO REPRESENT OBJECT AND ORBIT III

1930 U. T.	$\Delta\alpha$	$\Delta\delta$	$\Delta\rho$
Oct. 7	-1 ^h 16 ^m .6	-1° 41'	-0.017
Nov. 24	-1 24.7	-3 05	+0.157

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