

THE ASTRONOMICAL JOURNAL.

FOUNDED BY B. A. GOULD.

No. 548.

VOL. XXIII.

BOSTON, 1903 OCTOBER 31.

NO. 20

ORBIT OF COMET 1900 II,

By J. M. POOR.

1. INTRODUCTION.

The definitive orbit of this comet has already been published as it was determined by MANOEL SOARES DE MELLO E SIMAS from a very thorough discussion of nearly all the published observations.* The following elements of the same comet had been deduced, and were nearly ready for the printer when DE MELLO's paper was received. Publication has been delayed that the discussion of the perturbations might be carried considerably farther than was at first intended, though most of the computations were completed by the writer while Fellow at Princeton University. The writer congratulates himself as well as the astronomical public in general on the close agreement of the results as assuring confidence in the numerical accuracy of the computations, though this work would not have been undertaken had occupation of the same field by another been known. The following paper is abridged in order to avoid repetition so far as is consistent with the satisfactory statement of results.

This comet, independently discovered on July 23, 1900, by BORRELLY, at Marseilles, and BROOKS of Geneva, U.S.A., was observed for a little more than three months, while an attempted observation by AITKEN at Mt. Hamilton, five months after discovery, though interrupted by rising fog, showed the comet to be nearly in its predicted position, and indicated that the orbit was nearly parabolic.

2. ELEMENTS, EPHEMERIS, AND STARS.

The elements here employed for comparison and correction are based on those computed by SCHELLER and WEDEMAYER (*A.N.* 3660). They are

$$T = 1900 \text{ August } 3.19930 \text{ Gr. M.T.}$$

$$\left. \begin{array}{l} \omega = 12^{\circ} 25' 34.80'' \\ \Omega = 328^{\circ} 0' 26.20'' \\ i = 62^{\circ} 30' 44.00'' \end{array} \right\} \text{Ecliptic } 1900.0$$

$$\log q = 0.0063830$$

* *Astronomische Abhandlungen als Ergänzungshefte zu den Astronomischen Nachrichten herausgegebenen von Prof. Dr. H. KREUTZ, Nr. 4, 1 Teil.*

$$\begin{aligned} \text{which give } x &= r(9.9457964) \sin(86^{\circ} 20' 32.37'' + v) \\ y &= r(9.6867100) \sin(283^{\circ} 8' 27.03'' + v) \\ z &= r(9.9966354) \sin(0^{\circ} 9' 27.35'' + v) \end{aligned}$$

Throughout the computation Greenwich mean time has been employed, and solar coordinates have been taken from the *American Ephemeris and Nautical Almanac*.

Comparisons with the ephemeris from these elements were made by interpolation for the date of observation corrected for aberration-time from positions computed at intervals of twelve or twenty-four hours, as the case might require, except for observations in right-ascension between August 20.5 and August 29.5, and in declination between August 23.5 and August 27.5, when the motion of the comet near the pole made it seem best to compute the place for the time of each observation directly from the elements.

As far as possible A.G. star places have been employed, but for polar stars *Carrington* has been used. Several star places are the result of comparison with A.G. stars or Berlin J.B. stars, and others are the result of meridian observations published with the comet observations. D.M., Cincinnati, Nos. 12 and 13, Berlin J.B. 1900, Gr. Obs. 1896, Romberg, and Hamburg zones have been used, and some positions have been modified by Pulkowa Obs., Yarnall, Greenwich Ten-Year Catal., Radcliffe (1860.0), and Gr. Obs. 1898. Sixteen A.G. Dorpat places were kindly furnished in manuscript by Profs. LEVITZKY and SCHARBE of Dorpat Observatory. Romberg was consulted for me by Mr. D. T. WILSON at Cincinnati, and *Fedorenko* by Prof. SEARLE at Harvard, though the latter positions were not employed. Proper motions have been applied whenever found. The position of the star 100 of DE MELLO's list, to which he calls attention, was found to be R.A. = $3^{\text{h}} 34^{\text{m}} 33^{\text{s}}.54$; Decl. = $71^{\circ} 58' 42''.1$ as deduced from positions furnished from Dorpat. The reduction of observations depending on the star *Carrington* 685 (DE MELLO's star 120) indicated a proper motion in declination, and its comparison with Nos. 708 and 720 of the same Catalogue, made at Princeton

(183)

by the computer, yielded as a result an annual proper motion in R.A. of $-0^s.0057$, and in Decl. of $-0''.1338$ (equator 1903.0). Its position for 1900.0, as deduced from these observations, was found to be R.A. = $4^h 46^m 37^s.92$; Decl. = $81^\circ 49' 57''.5$.

In reducing stars to the epoch 1900.0 the constants of STRUVE and PETERS have been uniformly employed, and above 75° declination rigorous formulas were used.

3. OBSERVATIONS AND WEIGHTS.

It was intended to collect all observations, and a request for such as had not been published was inserted in *A.N.*

1900 Gr. M.T.		Comet—Star		Parallax				Comp. Star
		R.A.	Decl.	R.A.	Decl.	R.A.	Decl.	
September	6.29000	$+2^m 27^s.65$	$-5' 27''.3$	$+1.67$	$+2.5$	$13^h 24^m 3.06$	$78^\circ 58' 32.7$	A.G. Kasan 2333
	11.33524	$+0 35.58$	$-2 7.2$	$+1.11$	$+3.8$	$13 46 53.67$	$76 2 46.7$	" " 2428

In reducing observations parallax factors have all been recomputed by means of BAUSCHINGER'S Tables and reductions from mean to apparent place have been made by the use of constants of the *American Ephemeris and Nautical Almanac*.

For convenience in weighting, observations have been divided into three groups. Group 1 consists of those cases where more than five observations were made with a filar micrometer by one observer. Group 2 is made up of those series more than five in number made by a single observer with a ring or bar micrometer; and Group 3 includes all series less than six in number by a single observer. The only apparent exceptions to these rules are two cases in Group 3 in which the series numbered six, but these were subsequently reduced to five or less by rejected observations. Such rejections were determined as follows:

First. Because recent or accurate catalogue-places of companion stars were not found, or because no catalogue place was found: Arcetri, Aug. 19 (comp.-star *Fedorenko*); Hamburg (Sch.), Sept. 19; Hamburg (M), Sept. 19; Kiel; July 28; Königsberg (S), Aug. 23; Paris, July 24; Pola (H), July 25; Pola (M), July 25. Letters in parenthesis indicate the observer as explained in the list below.

Second. Because of serious discrepancy with other observations made at nearly the same time: Denver (L), July 28, Decl.; Denver (H), July 30 and all other observations in declination; Heidelberg (C), July 25, Decl.; Heidelberg (V), Aug. 18, Decl.; Kiel, July 25, Decl.; Kremsmünster, Aug. 19, Decl.; Lemberg, Aug. 10 and all other observations in declination; Leipzig, July 25, Decl.; Göttingen, July 25; Utrecht (V), Aug. 16, Decl. and Sept. 5, R.A.; Geneva, July 26, Decl.; Padua, Aug. 1, second obs. Decl.

3753. The usual journals were examined, but by an oversight all observations published in *Comptes Rendus* only remained unknown to the computer until the appearance of DE MELLO'S work. These included three observations made at Algiers, the valuable series of Bordeaux and Lyons, with the less numerous series made at Marseilles, Paris and Toulouse. To those omitted must also be added the series made at Washington, and published in *A.J.* 535, too late for consideration in this discussion, and likewise omitted by DE MELLO, as were also two unpublished observations made at Pulkowa, which were kindly furnished by the observer, A. SOKOLOV. For completeness the latter are here inserted.

In no case was the attempt made to harmonize by changing the date of an observation.

In determining weights each remaining residual was first given unit weight, and curves, one for each coordinate, were constructed by means of normals at convenient intervals. These curves were assumed to represent the true path of the comet with which the residuals of each observer were compared, thus giving "secondary" residuals from the first powers of which the computed weight of an observation was found by the formulas

$$r = 0.8453 \frac{[v]}{m} \text{ and } p = \frac{c^2}{r^2}$$

in which c , the mean value of r for all observers whose observations numbered more than 5, was found to be $0''.16$ in R.A., and $1''.9$ in Decl.

Observations of Group 1 were then given the integral weights 2, 3, or 4, according to the numerical value of the weight as computed. In the same way, those of Group 2 received weights $\frac{1}{2}$ or 1, while the weights of Group 3 were assigned arbitrarily because of the small number in each series.

From the results of comparisons with the curves it was thought best to apply corrections to observations as follows:

CORRECTION.		
Observatory	R.A.	Decl.
Arcetri,	-0.25	" "
Geneva,	$+0.20$	$+2.3$
Kiel,	" "	$+2.9$
Kremsmünster,	-0.34	" "

The following table contains details outlined above with references to journals where observations were found.

Observatory	Observer	Group	R.A.		Decl.		Journal
			Obs.	p	Obs.	p	
Algiers	Sy	1	8	4	8	3	<i>B.A.</i> , Vol. 18
Arcetri	Abetti	1	42	2	42	2	<i>A.N.</i> 3674, 3687. <i>Arcetri Pub.</i> , No. 15
Besançon	{ Chofardet = C	1	12	4	12	4	<i>A.N.</i> 3656, 3691. <i>B.A.</i> , Vol. 18
	{ Sallet = S	3	2	1	2	1	<i>A.N.</i> 3656
Copenhagen	Pechule	3	3	1	3	1	<i>A.N.</i> 3654, 3655
Denver	{ Heller = H	3	6	1	6	0	<i>A.J.</i> 508
	{ Ling = L	1	22	3	22	3	<i>A.J.</i> 492, 503
Geneva	Pidoux	1	8	2	8	2	<i>A.N.</i> 3660
Göttingen	Schur	3	1	0	1	0	<i>A.N.</i> 3655
Hamburg	{ Scheller = Sl	1	13	3	13	4	<i>A.N.</i> 3655, 3724
	{ Schorr = Sch.	3	3	1	3	1	<i>A.N.</i> 3724
	{ Messow = M	3	6	1	6	1	<i>A.N.</i> 3724
Heidelberg	{ Courvoisier = C	3	4	1	4	1	<i>A.N.</i> 3654, 3720
	{ Valentiner = V	3	4	1	4	1	<i>A.N.</i> 3720
Jena	Knopf	2	6	1	6	1	<i>A.N.</i> 3692
Kiel	Ristenpart	2	8	1	8	1	<i>A.N.</i> 3654, 3655
Königsberg	{ Cohn = C	3	1	1	1	1	<i>A.N.</i> 3655
	{ Struve = S	1	12	4	12	4	<i>A.N.</i> 3760
Kremsmünster, Leipzig	Schwab	2	8	1	8	1	<i>A.N.</i> 3760
	Hayes	3	1	1	1	0	<i>A.N.</i> 3654
Lick	{ Crawford = C	3	4	1	4	1	<i>A.J.</i> 484
	{ Aitken = A	1	10	3	10	2	<i>A.J.</i> 490
	{ Perrine = P	3	3	2	3	2	<i>A.J.</i> 494
Lemberg	Ernst	2	15	$\frac{1}{2}$	15	0	<i>A.N.</i> 3655, 3740
Nicolaëff	Kortazzi	1	11	2	11	3	<i>A.N.</i> 3677
Northampton	Byrd	3	2	1	2	1	<i>A.J.</i> 495
Paris	Bigourdan	3	1	0	1	0	<i>A.N.</i> 3654
Padua	Autoniazzi	1	13	3	13	3	<i>A.N.</i> 3678
Pola	{ Höhl = H	3	3	$\frac{1}{2}$	3	$\frac{1}{2}$	<i>A.N.</i> 3661
	{ Marchetti = M	3	1	0	1	0	<i>A.N.</i> 3661
Poughkeepsie	Whitney	3	2	1	2	1	<i>A.J.</i> 495
Pulkowa	Sokolow	3	2	2	2	2	Correspondence.
Rome	Millosevich	3	4	2	4	2	<i>A.N.</i> 3655, 3745
Strassburg	Kobold	1	10	4	10	4	<i>A.N.</i> 3654, 3726
Utrecht	{ Nijland = N	1	12	3	13	3	<i>A.N.</i> 3654, 3719
	{ Veenstra = V	1	11	2	11	2	<i>A.N.</i> 3719
Vienna	{ Palisa = P	3	2	$\frac{1}{2}$	2	$\frac{1}{2}$	<i>A.N.</i> 3655, 3718
	{ Holetschek = H	3	3	$\frac{1}{2}$	3	$\frac{1}{2}$	<i>A.N.</i> 3713

4. PERTURBATIONS.

Perturbations taking into account the action of *Mercury*, *Venus*, *Earth*, *Mars*, *Jupiter* and *Saturn* were computed in rectangular coordinates referred to the ecliptic, with July 29.0 as the date of osculation. A uniform interval of 40 days was adopted for *Mars*, *Jupiter* and *Saturn*, while for *Mercury*, *Venus* and *Earth*, the interval was 10 days until September 17, after which it was 20 days. Referred to the equator as fundamental plane the perturbations in rectangular coordinates deduced were as follows:

PERTURBATIONS (Seventh decimal place).

Date	δx	δy	δz
July 19	— 1	0	0
29	0	0	0
Aug. 8	— 11	+ 0	— 3
18	— 30	+ 4	— 12
28	— 55	+ 10	— 25
Sept. 7	— 86	+ 20	— 43
17	— 121	+ 33	— 67

Date	δx	δy	δz
Sept. 27	— 160	+ 49	— 96
Oct. 7	— 201	+ 67	— 131
17	— 244	+ 88	— 172
27	— 288	+ 110	— 219

5. NORMAL PLACES AND LEAST-SQUARE SOLUTION.

For the construction of normal places the list of observations was divided into eight sections at the following dates: July 29.0, Aug. 3.0, Aug. 11.0, Aug. 20.0, Sept. 1.0, Sept. 14.0, and Oct. 10.0. To find a normal place with its corresponding time and weight, the following equations were applied to the observations of each section:

$$t_0 = \frac{[pt]}{[p]}, \quad (\cos \delta \cdot \Delta \alpha)_0 = \frac{[p \cdot \cos \delta \cdot \Delta \alpha]}{[p]},$$

$$\Delta \delta_0 = \frac{[p \cdot \Delta \delta]}{[p]} \quad \text{and} \quad p_0 = [p]$$

The normal places thus found, including corrections for perturbations, are as follows:

No.	Date	R.A.	(cos δ . $\Delta\alpha$) ₀	p_0	Decl.	($\Delta\delta$) ₀	p_0
1	July 26.7	41° 37' 49.84	-3.98	115	20° 51' 8.27	-0.04	114
2	31.7	43° 9' 30.24	-2.24	116	36° 9' 55.38	-2.88	113.5
3	Aug. 8.1	46° 51' 52.18	-2.90	76.5	57° 41' 49.99	-2.26	79
4	16.1	56° 36' 8.51	-3.28	72	75° 14' 47.31	+3.50	65
5	24.84	116° 19' 3.02	+5.46	61	85° 42' 33.68	+3.52	65
6	Sept. 8.62	204° 2' 46.37	+8.68	50	77° 33' 48.50	-9.82	54
7	22.0	213° 22' 48.83	+8.37	64	71° 23' 36.87	-13.42	60
8	Oct. 19.4	224° 5' 18.06	+4.11	44	65° 58' 25.52	-16.37	41

For the least-square solution the elements were referred to the mean equator of 1900.0 and differential coefficients computed by means of the formulas given in KLINKERFUES, *Theoretische Astronomie, Zweite Auflage*.

The elements so referred are

$T = 1900 \text{ Aug. } 3.19930 \text{ Gr. M.T.}$

$\omega' = 0^\circ 9' 27.35''$
 $\Omega' = 331^\circ 43' 41.17''$
 $i' = 82^\circ 52' 37.55''$ } Equator 1900.0

$\log q = 0.0063830$

Equations of the form

$$\cos \delta \cdot \frac{\partial \alpha}{\partial \Omega'} d\Omega' + \cos \delta \cdot \frac{\partial \alpha}{\partial i'} di' + \cos \delta \cdot \frac{\partial \alpha}{\partial \omega'} d\omega' + \cos \delta \cdot \frac{\partial \alpha}{\partial T} dT + \cos \delta \cdot \frac{\partial \alpha}{\partial q} dq + \cos \delta \cdot \frac{\partial \alpha}{\partial e} de = \Delta \alpha \cdot \cos \delta$$

$$\text{and } \frac{\partial \delta}{\partial \Omega'} d\Omega' + \frac{\partial \delta}{\partial i'} di' + \frac{\partial \delta}{\partial \omega'} d\omega' + \frac{\partial \delta}{\partial T} dT + \frac{\partial \delta}{\partial q} dq + \frac{\partial \delta}{\partial e} de = \Delta \delta$$

each made homogeneous and multiplied by the square root of its weight, after putting $x = d\Omega'$, $y = di'$, $z = d\omega'$, $t = 10^4 dT$, $u = 10^6 dq$ and $w = 10^4 de$, become the following:

EQUATIONS OF CONDITION.

Right-Ascension.

1	+7.7683	x	+1.4477	y	-2.9631	z	+0.4528	t	-4.6772	u	-1.0195	w	=	-42.6807
2	+7.7522		+0.4459		-0.3558		-0.1698		-4.7957		-0.3213		=	-24.1255
3	+5.0272		-0.5654		+2.7374		-0.8271		-3.6921		+0.3836		=	-25.3646
4	+1.8913		-0.4116		+4.7915		-1.2005		-3.2057		+0.2469		=	-27.8317
5	-8.1736		+4.6175		+2.2463		-0.2434		-1.4365		-3.1798		=	+42.6440
6	-4.4486		+3.7784		-5.4038		+1.2800		+1.6025		-1.1228		=	+61.3769
7	-3.1791		+3.5780		-6.9729		+1.4305		+1.8474		+1.3630		=	+66.9600
8	-1.3642		+2.0688		-6.6233		+1.0666		+1.5173		+6.6962		=	+26.2627

Declination.

1	-8.0679	x	-1.8922	y	+20.6923	z	-10.2847	t	-0.2164	u	-19.6231	w	=	-0.4271
2	-13.7908		-0.9145		+17.7338		-8.7714		-0.8230		-5.5256		=	-30.6825
3	-14.4487		+1.8634		+8.0771		-3.8545		-0.8764		+4.5982		=	-18.9085
4	-13.4567		+4.3590		+2.2498		-1.0104		-0.3191		+3.0084		=	+28.2179
5	-6.8807		+3.4364		-4.7621		+1.0979		+2.1503		+0.3760		=	+28.3792
6	+4.5611		-4.7897		-1.8458		-0.2072		+1.0876		+11.6799		=	-72.1620
7	+3.5866		-5.7932		-1.2974		-0.4515		+0.7335		+19.0539		=	-103.9509
8	+1.3023		-5.4001		-0.9393		-0.3970		+0.3366		+24.4664		=	-104.8192

in which coefficients are given in natural numbers.

These differential coefficients were checked according to the method given in the above reference with very slight modification. To check

$$\frac{\partial \alpha}{\partial T}, \frac{\partial \alpha}{\partial q}, \frac{\partial \alpha}{\partial e}, \frac{\partial \delta}{\partial T}, \frac{\partial \delta}{\partial q}, \text{ and } \frac{\partial \delta}{\partial e}$$

as well as the computation of the positions to which residuals had been applied in finding the normal places, increments appropriate for each date were successively applied to T , q , and e , and new positions computed from the

slightly changed elements. The remaining coefficients were checked by finding $d \log \xi$, $d \log \eta$ and $d \log \zeta$ where the notation is that of the reference.

To illustrate (KLINKERFUES, page 710),

$$dx = -y d\Omega' \text{ or } d \log \xi = -\frac{m}{206265} \frac{y}{\xi} (d\Omega')'' \text{ where}$$

$(d\Omega')''$ is given in seconds of arc. This in units of the seventh place becomes

$$d \log \xi = [1.82336_u] \frac{y}{\xi} (d\Omega')''$$

where numbers are expressed in logarithms. Similar expressions for

$$d \log \xi, d \log \eta \text{ and } d \log \zeta$$

were found in terms of $(d\Omega')''$, $(di')''$, and $(d\omega')''$.

Whether the numerical values of $\log \xi$, $\log \eta$ and $\log \zeta$

were to be increased or decreased in a particular case was easily determined by inspection of the equations.

From the equations of condition normal and elimination equations given below were obtained. As a Brunsviga computing machine was employed, coefficients are given in natural numbers.

NORMAL EQUATIONS.

$$\begin{array}{rcccccccc} +1603.4289w & - & 580.7418z & + & 287.9879x & + & 216.6062t & - & 235.4222y & + & 59.0753u & = & -5097.5544 \\ - & 580.7418 & + & 1007.7049 & - & 506.0848 & - & 439.4582 & - & 82.1140 & - & 85.1039 & = & -1361.9109 \\ + & 287.9879 & - & 506.0848 & + & 975.6906 & + & 248.6591 & - & 188.6705 & - & 78.1787 & = & -2284.0715 \\ + & 216.6062 & - & 439.4582 & + & 248.6591 & + & 207.4411 & + & 37.9990 & + & 27.0762 & = & +684.7583 \\ - & 235.4222 & - & 82.1140 & - & 188.6705 & + & 37.9990 & + & 179.8256 & - & 2.0807 & = & +2406.0835 \\ + & 59.0753 & - & 85.1039 & - & 78.1787 & + & 27.0762 & - & 2.0807 & + & 87.1817 & = & +604.2810 \end{array}$$

ELIMINATION EQUATIONS.

$$\begin{array}{rcccccccc} w & - & 0.362187z & + & 0.179608x & + & 0.135089t & - & 0.146824y & + & 0.036843u & = & -3.179158 \\ & & z & - & 0.503882x & - & 0.452748t & - & 0.209917y & - & 0.079897u & = & -4.023466 \\ & & & & x & + & 0.038600t & - & 0.319781y & - & 0.167550u & = & -4.137199 \\ & & & & & & t & + & 0.214254y & - & 0.371981u & = & +2.643481 \\ & & & & & & & & y & - & 1.241788u & = & +0.612815 \\ & & & & & & & & & & u & = & +28.268782 \end{array}$$

Whence

$$\begin{array}{ll} u = +28.269 & x = +11.81 \\ y = +35.72 & z = +14.18 \\ t = +5.5065 & w = +3.2929 \text{ and } [nn.6] = 807.6 \end{array}$$

Reversed elimination gave identical results and also quantities by means of which were obtained

$$\begin{array}{ll} r_w = \pm 1.0484 & r_t = \pm 1.6997 \\ r_z = \pm 2.60 & r_y = \pm 4.70 \\ r_x = \pm 2.21 & r_u = \pm 3.691 \end{array}$$

Substitution in the equations of condition gave as check $[pvv] = 807.6$. We have, therefore, the following corrections to the equatorial elements

$$\begin{array}{ll} d\Omega' = +11.81 \pm 2.21 & dT = +0.000551 \pm 0.000170 \\ di' = +35.72 \pm 4.70 & dq = +0.0000283 \pm 0.0000037 \\ d\omega' = +14.18 \pm 2.60 & de = +0.0003293 \pm 0.0001048 \end{array}$$

Collecting results the definitive equatorial elements are

$$\begin{array}{l} \text{Epoch of osculation, July 29.0, 1900} \\ T = 1900 \text{ August } 3.199851 \text{ Gr.M.T.} \end{array}$$

$$\begin{array}{l} \omega' = 0^\circ 9' 41.53'' \\ \Omega' = 331^\circ 43' 52.98'' \\ i' = 82^\circ 53' 13.27'' \end{array} \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{Equator 1900.0}$$

$$\begin{array}{l} \log q = 0.0063951 \\ e = 1.0003293 \\ \log e = 0.0001430 \end{array}$$

from which are found

$$\begin{array}{l} x = r(9.9458067) \sin(86^\circ 21' 7.40'' + v) \\ y = r(9.6866365) \sin(283^\circ 7' 44.84'' + v) \\ z = r(9.9966447) \sin(0^\circ 9' 41.53'' + v) \end{array}$$

and also

$$\begin{array}{l} \omega = 12^\circ 25' 40.55'' \\ \Omega = 328^\circ 0' 47.62'' \\ i = 62^\circ 31' 16.38'' \end{array} \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{Ecliptic of 1900.0}$$

As a final check on the accuracy of the computation the residuals due to elements and those due to equations were determined for each normal place. They are as follows:

		ELEMENTS		EQUATIONS	
		$\Delta a \cos \delta$	$\Delta \delta$	$\Delta a \cos \delta$	$\Delta \delta$
July	26.7	+1.1	+0.3	+1.0	+0.3
"	31.7	-1.1	-0.3	-1.0	-0.3
Aug.	8.1	-0.4	-0.1	-0.5	-0.2
"	16.1	+1.1	-0.7	+0.8	-0.5
"	24.84	+0.8	+1.7	+0.7	+1.7
Sept.	8.62	-1.0	-0.4	-1.0	-0.4
"	22.0	-1.4	+0.2	-1.4	+0.3
Oct.	19.4	+1.1	+0.3	+1.1	+0.3

From the equations $[vv] = 11.2$

Collecting, the definitive elements referred to the ecliptic are

$$\begin{array}{l} \text{Epoch of osculation, July 29.0, 1900} \\ T = 1900 \text{ Aug. } 3.199851 \text{ Gr.M.T.} \\ \omega = 12^\circ 25' 40.55'' \\ \Omega = 328^\circ 0' 47.62'' \\ i = 62^\circ 31' 16.38'' \end{array} \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{Ecliptic 1900.0}$$
$$\begin{array}{l} \log q = 0.0063951 \\ \log e = 0.0001430 \end{array}$$

6. PERTURBATIONS BEFORE DISCOVERY.

A comparison of these elements with those found by DE MELLO shows slight differences, but both computations show the important result that at the time of discovery the comet was describing a hyperbolic orbit, and this agreement is quite close notwithstanding the considerable omission of observations from this discussion. This fact tempted the writer to make a preliminary investigation of the perturbations during the year previous to the comet's discovery.

Accordingly $\omega^2 X$, $\omega^2 Y$, and $\omega^2 Z$ (WATSON, page 453) were computed for *Venus*, *Earth*, *Mars*, *Jupiter*, and *Saturn* at intervals of 40/3 days. These quantities were directly computed for *Mars* and *Saturn* at intervals of 40 days from June 4.0, 1899, to Aug. 18.0, 1900. Likewise they were computed for *Jupiter* until May 30, 1900, after which date they were directly computed at intervals of 40/3 days. All remaining intermediate values were found by interpolation. For *Venus* and the *Earth* the quantities were directly computed at intervals of 40/3 days throughout the whole period. The quantities

$$\Sigma(\omega^2 X), \Sigma(\omega^2 Y) \text{ and } \Sigma(\omega^2 Z)$$

were obtained from which mechanical quadrature gave the perturbations referred to the ecliptic in the table below. The computing machine was used whenever possible. In this table perturbations at intervals of 40 days only are included.

PERTURBATIONS. (Seventh decimal place).

Date	δx	δy	δz
1899 June 4	-35	+291	+5413
July 14	-305	+244	+4259
Aug. 23	-483	+206	+3257
Oct. 2	-569	+173	+2401
Nov. 11	-575	+156	+1689
Dec. 21	-528	+154	+1116
1900 Jan. 30	-457	+151	+677
Mar. 11	-367	+126	+360
Apr. 20	-257	+75	+154
May 30	-129	+21	+41
July 9	-21	+0	+1

The disturbances in the components of the velocity on June 4.0 were found to be $\delta \frac{dx}{dt} = -7.9$, $\delta \frac{dy}{dt} = -1.4$, $\delta \frac{dz}{dt} = -30.8$, in the same units.

Following the method of WATSON, Sec. 168, the definitive elements gave for this date the undisturbed coordinates

$$x_0 = -3.1959772; y_0 = -0.6369125; z_0 = -4.2938069;$$

and the velocities

$$\frac{dx_0}{dt} = +0.00857336; \frac{dy_0}{dt} = -0.00182998;$$

$$\frac{dz_0}{dt} = +0.00574773;$$

Shattuck Observatory, Dartmouth College, Hanover, N.H.

from which, after corrections for perturbations had been applied, the following elements were deduced.

Epoch of osculation, June 4.0 1899

$T = 1900$ August 3.24627

$$\left. \begin{array}{l} \omega = 12^\circ 25' 42.5'' \\ \Omega = 328^\circ 1' 16.6'' \\ i = 62^\circ 31' 19.2'' \end{array} \right\} \text{Ecliptic of 1900.0}$$

$$\log q = 0.006438$$

$$\log e = 0.000058$$

$$e = 1.000133$$

According to this computation, therefore, the eccentricity had increased during the 400 days previous to the comet's discovery.

Among the disturbances caused by the planets during this period those of *Jupiter* were the most important during the greater part of the time, while those of *Saturn* and *Mars* were much less, as were also those of *Venus* and *Earth*, except near the time of discovery. Therefore the quantities, $\omega^2 X$, $\omega^2 Y$, $\omega^2 Z$ for *Jupiter* alone were computed for four dates at intervals of 100 days previous to June 4, 1899. When the position and motion of the comet during this time are considered, $\omega^2 X$, $\omega^2 Y$, $\omega^2 Z$, indicate that the effect of perturbations during this earlier period was acting in the same direction.

In the light of this preliminary study it seems not unreasonable therefore to account for this hyperbolic orbit at the time of discovery as the result of perturbations, and to conclude that a careful study sufficiently extended would show that this comet entered the solar system in a sensibly parabolic orbit.

7. CONCLUSION.

Defective though it is, this piece of work is now brought to a point where it is possible for the computer to lay it aside. The long computations involved would certainly never have reached even their present degree of perfection had it not been for the continued encouragement and many suggestions received from Prof. YOUNG of Princeton.

Besides being indebted to those already mentioned, I am also indebted to Prof. ANTONIO ABETTI of Arcetri for publications from that Observatory, to Prof. OTTO KNOPF of Jena for a correction to his observations as published, and to Prof. LOVETT and Mr. HILTEBEITEL of Princeton, for actually assisting in the computations.

OBSERVED MINIMA OF 4.1903 DRACONIS,

By W. M. REED.

[Communicated by Prof. C. A. YOUNG.]

Seven minima of this star have recently been observed by Mr. ZACHEUS DANIEL and the author with a photometer attached to the 23-inch equatorial of the Halsted Observatory. A part of the expense of these observa-

tions is borne by the Carnegie Institution. An artificial star, caused by an electric light, was compared alternately with a neighboring comparison-star and with the variable. The light of the artificial star was diminished by means of