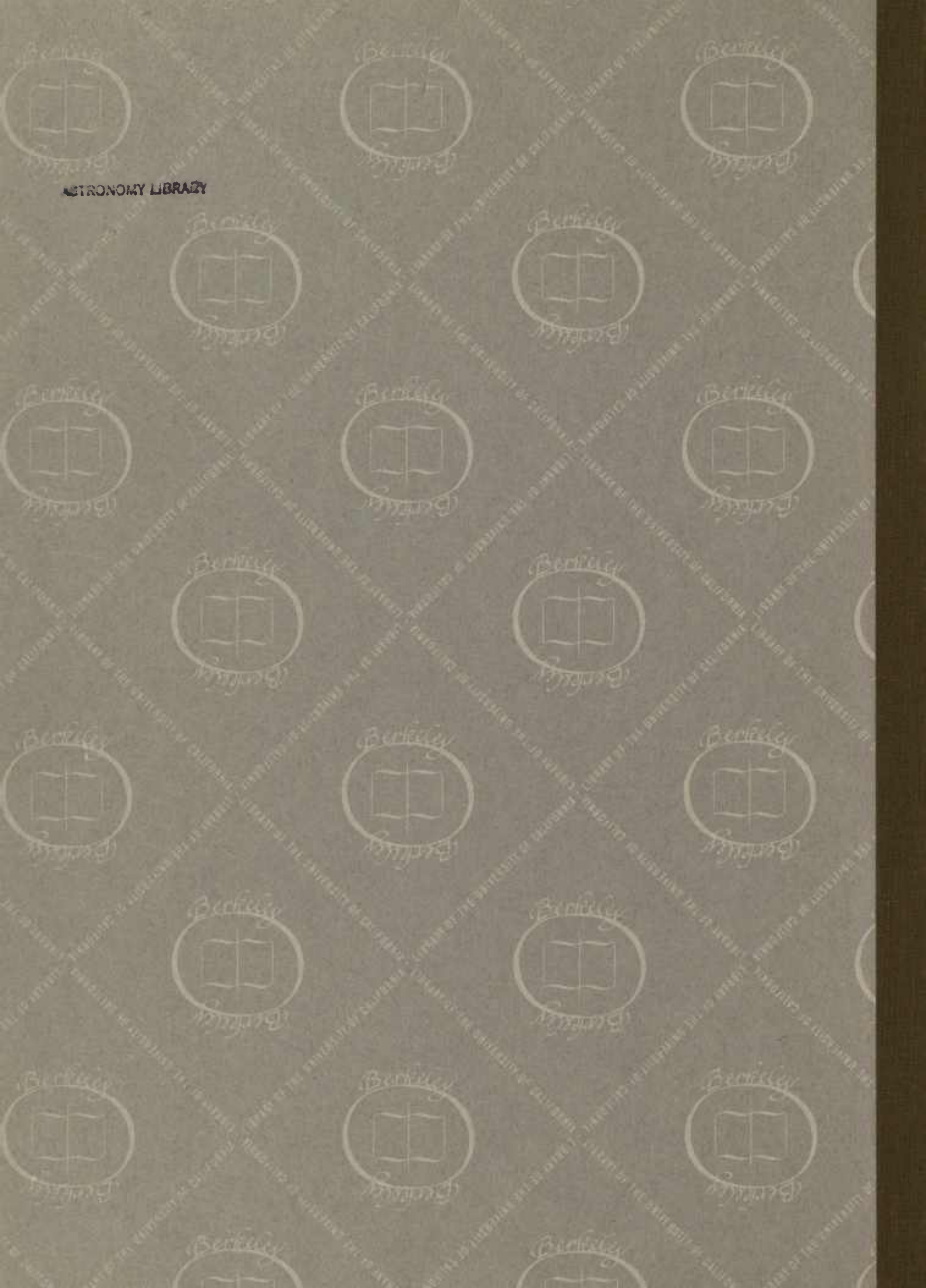


QB
M1838

UC-NRLF

#C 24 250

ASTRONOMY LIBRARY



"On the Orbit of the Seventh Satellite of Jupiter."
Daniel Walter Morehouse.

Dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in the University of California, April 6th, 1914.

COPY FOR
ASTRONOMY

1/4 Bind

Approved by Sub-Committee in Charge.

A. O. Leuschner
W. W. Campbell
Frederick Skiff
E. Lewis
H. W. Haskell

Accepted for Publication in Lick Observatory Bulletin, after revision

W. W. Campbell
Editor.

to the Berkeley Astronomical Dept.

CAT. FOR
ASTRONOMY

"On the Orbit of the Satellite of Jupiter."
L. A. J. W. M. K. M.

Dissertation submitted in partial fulfillment for the
requirement for the Degree of Doctor of Philosophy in the
University of California, April 22, 1914.

Approved by the Committee in Charge.

[Handwritten signatures]
W. W. ...
J. W. ...
G. W. ...
W. W. ...

Accepted for Publication in this Observatory Bulletin, under the name of ...

[Handwritten signature]
Editor.

[Handwritten notes in a box]
...
...
...

UNIVERSITY OF CALIFORNIA
DEAN OF THE GRADUATE SCHOOL
BERKELEY

QB3
.6
M838
ASTRONOMY
LIBRARY

April 7, 1914.

To the Sub-Committee in Charge of the
Candidacy of Daniel Walter Morehouse for
the Degree of Doctor of Philosophy:

Gentlemen:

Herewith, please find the dissertation
of Mr. Morehouse "On the Orbit of the Seventh
Satellite of Jupiter". While the work has not
been carried through the point originally con-
templated, Mr. Morehouse has done a very large
amount of ingenious work. He has met with un-
foreseen difficulties in the way of short period
perturbations, but is now entirely on the right
track for the ultimate solution of this difficult
problem. The thesis forms a very acceptable
record of the investigation necessary to over-
come the initial difficulties. For publication,
it should be condensed to about one-half its
size.

The dissertation in itself does not
reveal the enormous amount of work done by Mr.
Morehouse, who has had two computers at his own
expense for the past two years. I have no
hesitation in approving the thesis on my part.

Very truly yours,

A. O. Leuschner

ASTRONOMY
LIBRARY

UNIVERSITY OF CALIFORNIA
DEAN OF THE GRADUATE SCHOOL
BERKELEY

April 7, 1914.

To the Sub-Committee in Charge of the
 Candidacy of Daniel Walter Morehouse for
 the Degree of Doctor of Philosophy.

Gentlemen:

Respectfully please find the dissertation
 of Mr. Morehouse "On the Orbit of the Seventh
 Satellite of Jupiter." While the work has not
 been carried through the point originally con-
 templated, Mr. Morehouse has done a very large
 amount of ingenious work. He has met with un-
 foreseen difficulties in the way of short period
 perturbations, but is now entirely on the right
 track for the ultimate solution of this difficult
 problem. The thesis forms a very acceptable
 record of the investigation necessary to over-
 come the initial difficulties. For publication,
 it should be condensed to about one-half its
 size.

The dissertation in itself does not
 reveal the enormous amount of work done by Mr.
 Morehouse, who has had two computers at his own
 expense for the past two years. I have no
 hesitation in approving the thesis on my part.

Very truly yours,

A. O. Leitch

ON THE ORBIT OF THE SEVENTH SATELLITE OF JUPITER.

* * *

At the time this discussion was started there had been computed three orbits known to the writer. The first was computed by Dr. C. D. Perrine at the Lick Observatory and published in the *Lick Observatory Bulletin*, No. 78. The second was by Dr. F. E. Ross and published in the *Lick Observatory Bulletin*, No. 82. This orbit was afterward recomputed on the basis of twelve observations, distributed uniformly over the observed arc from January 3rd, 1905, to September 25th, 1906, and was published in *Astronomische Nachrichten Band 174 Nr. 4175*. The third was computed by Dr. R. T. Crawford at the Student's Observatory of the University of California, according to "Leuschner's General Theory of Satellite Orbits," which is published in volume ^{VII} of the Lick Observatory Publications, and in *Theoretische Astronomie von Dr. W. Klinkerfuss, Neubearbeitung, von Prof. Dr. H. Buchholz. Anhang zu den Leuschner'schen Methoden der Bahnbestimmung*.

The fundamental positions upon which this orbit is based are as follows:

Mean Place 1905.0

Date 1905	P.	S.	T.	R. A.			Dec.		
Jan. 3	7h.	12m.	0s.	1h.	16m.	23.68s.	+7°	13'	57".2
Feb. 8	7	10	0	1	34	40.59	+8	55	18.0
Mar. 6	7	40	0	1	54	24.15	+10	35	49.9

With the velocities and accelerations in right ascension and declination computed for the middle date from these positions, the right ascensions and declinations for January 28.623611 and February 21.642361 G. M. T. 1905 were computed to see if the higher derivatives

ON THE ORBIT OF THE SEVENTH SATELLITE OF JUPITER.

* * *

At the time this discussion was started there had been computed three orbits known to the writer. The first was computed by Dr. G. D. Perrine at the Lick Observatory and published in the Lick Observatory Bulletin, No. 78. The second was by Dr. F. B. Ross and published in the Lick Observatory Bulletin, No. 82. This orbit was afterward recomputed on the basis of twelve observations, distributed uniformly over the observed arc from January 3rd, 1905, to September 25th, 1906, and was published in Astronomische Nachrichten Band 174 Nr. 4175. The third was computed by Dr. R. T. Crawford at the Student's Observatory of the University of California, according to "Lescanor's General Theory of Satellite Orbits," which is published in volume V of the Lick Observatory Publications; and in Theoretische Astronomie von Dr. M. Littrow, 2te Ausgabe, von Prof. Dr. H. Bachholz. Abhandl. an der Leichter'schen Methoden der Bahnbestimmung.

The fundamental positions upon which this orbit is based are as follows:

Date 1905	P. S. T.	R. A.	Dec.	Mean Place 1905.0
Jan. 3	7h. 12m. 0s.	16m. 25.68s.	+7° 15' 27.2"	
Feb. 8	7 10 0	34 40.59	+8 55 18.0	
Mar. 6	7 40 0	54 24.15	+10 35 19.9	

With the velocities and accelerations in right ascension and declination computed for the middle date from these positions, the right ascensions and declinations for January 28.625611 and February 21.642301 G. M. T. 1905 were computed to see if the higher derivatives

were negligible. The residuals showed that they were not negligible and that more observations must be taken into account, so that the third and fourth derivatives in the two coordinates with respect to the time could be utilized. Two more observations were therefore chosen:

Mean Place 1905.0

Date 1905	P. S. T.	R. A.	Dec.
Jan. 28	6h. 58m. 0s.	1h. 27m. 44.32s.	+8° 18' 10".7
Feb. 21	7 25 0	1 44 2.98	9 43 51.6

With these five observations new velocities and accelerations for the middle date were determined and a double solution for the orbit accomplished. A representation of an observation taken August 9, 1905, showed clearly that the retrograde orbit was not the true one and the direct orbit was therefore retained as the physical solution.

After the Special Perturbations(I) had been computed by Encke's Method, with eight day intervals over this period and the corresponding corrections to the satellites' coordinates made, the representations of the fundamental positions gave residuals corresponding to orbit I_a (Crawford):

	Jan. 3	Jan. 28	Feb. 21	March 6
(O-C) $\Delta\alpha$	-9".6	-2".3	+2".6	+1".0
(3-0) $\Delta\delta$	+23.9	-0.4	-0.6	-11.3

A differential correction was then made using the series formulae for f , g , δf , and δg , which gave for the first differentially corrected orbit the following elements:

correcting the orbit. I now had reliable observations of the satellite in right ascension and declination for 1905 published in the *Lick Observatory Bulletin*, No. 130. In order to be sure that the

were negligible. The residuals showed that they were not negligible and that more observations must be taken into account, so that the third and fourth derivatives in the two coordinates with respect to the time could be utilized. Two more observations were therefore chosen:

Mean Place 1905.0

Date 1905	P. S. T.	R. A.	Dec.
Jan. 28	0h. 35m. 0s.	1h. 27m. 44.52s.	+8° 18' 10" V
Feb. 21	7 25 0	1 44 2.98	9 43 21.6

With these five observations new velocities and accelerations for the middle date were determined and a double solution for the orbit accomplished. A representation of an observation taken August 9, 1905, showed clearly that the retrograde orbit was not the true one and the direct orbit was therefore retained as the physical solution.

After the Special Perturbations (I) had been computed by Encke's Method, with eight day intervals over this period and the corresponding corrections to the satellite's coordinates made, the representations of the fundamental positions gave residuals corresponding to orbit I.

(Crawford):

(C-C)	$\Delta\alpha$	$\Delta\delta$	Jan. 2	Jan. 28	Feb. 21	March 6
	- 2"6	+ 25.9	- 2"7	+ 2"6	+ 1"0	
	+ 25.9	- 0.4	- 0.6	- 0.6	- 11.3	

A differential correction was then made using the series formulas for α , δ , $\dot{\alpha}$, $\dot{\delta}$, and $\ddot{\alpha}$, which gave for the first differentially corrected orbit the following elements:

residuals obtained ORBIT I_B BASED ON PERTURBATIONS I. On Feb. 8. 600930 G. M. T. I obtained the following residuals:

Ω	288 190 195	59"4	Mean Equinox
ω	6.954824	187.04	29.96250 41.4
$\Delta\alpha$	$\pi - 7' 58''$	115	49' 59" 40.8 Equator
$\Delta\delta$	$i - 0' 19''$	25	39' 18" 23.5 -1905.0
log e	9.084645	2.989583	
log a	8.893716	3.3273	
μ	1.390269	per day.	

The P residuals 258.9424 days. consistent. I therefore made a recompute. The residuals for January 3rd and March 6th, 1905, were then reduced to: geocentric coordinates of Jupiter, the first method (a) having been used in the above recompute. These are: March 6.

(O-C)	$\Delta\alpha$	190 -3"5	-1"4
$\Delta\delta$	+3.8	-1.2	

The Special Perturbations on the basis of these osculating elements were then continued at eight day intervals up to August 9th, 1905. The representation of the satellite's position for August 9.96 G. M. T. 1905 gave the following residuals:

(O-C)	$\Delta p = +1.4;$	$\Delta s = +7.7$
-------	--------------------	-------------------

the original observations having been taken in position angle and distance. It was at this point that the writer took up the problem of correcting the orbit. I now had reliable observations of the satellite in right ascension and declination for 1905 published in the *Lick Observatory Bulletin, No. 156.* In order to be sure that the

ORBIT IS BASED ON PERTURBATIONS I.

Epoch	1907, Feb. 8.00000 G. M. T.				
M	282°	4'	14"		
Q	288	13	39.4	Mean Epoch	
a	187	23	41.4	and	
π	115	49	40.8	Epocor	
i	22	22	22.0	1905.0	
log e	2.08402				
log a	8.83316				
u	1.290402 per day.				
P	258.9424 days.				

The residuals for January 5th and March 5th, 1905, were then

reduced to:

	Jan 5.	March 5.
(C-C)	Δx - 2.7	-1.4
Δz	+2.8	-1.2

The special perturbations on the basis of these occulting elements were then continued at eight day intervals up to August 25th, 1905. The representation of the satellite's position for August 2.96 G. M. T. 1905 gave the following residuals:

$$(C-C) \quad \Delta p = +1.4; \quad \Delta z = +1.7$$

the original observations having been taken in position angle and distance.

It was at this point that the writer took up the problem of correcting the orbit. I now had reliable observations of the satellite in right ascension and declination for 1905 published in the *Annals of the Astrophysical Observatory, Bulletin, No. 150*. In order to be sure that the

residuals obtained by Dr. Crawford were not spurious, I represented some August positions using his orbit I_b , the perturbations I , which he had computed, being included, and obtained the following residuals:

one included between 1905 G. M. T. 25th, 1905, before attempting a different method.

	Aug. 6.954824	Aug. 7.962500	Aug. 9.962500	Aug. 11.978125
(0-C) $\Delta\alpha$	-7' 5"8	-6' 59"1	-6' 51"4	-6' 37"0
Dr. Crawford	-0' 19"6	-0' 18"5	-0' 14"9	-0' 8"6
December, published in	Aug. 12.989583			
(0-C) $\Delta\delta$		-6' 32"0		
		-0' 7"2		

These residuals do not seem consistent. I therefore made a recomputation using my second method (b) page 14 for the determination of the geocentric coordinates of Jupiter, the first method (a) having been used in the above residuals. These are:

(0-C) $\Delta\alpha$ 1905 G. M. T. 25th, 1905, before attempting a different method.

	Aug. 6.954824	Aug. 7.962500	Aug. 9.962500	Aug. 11.978125
(0-C) $\Delta\alpha$	-7' 6"0	-6' 59"5	-6' 52"3	-6' 36"6
	-0' 19"6	-0' 18"3	-0' 14"9	-0' 8"8
G. M. T. 1905, and	Aug. 12.989583			
(0-C) $\Delta\delta$		-6' 31"5		
parallax were not applied		-0' 7"2		

In this work the dates were not corrected for aberration or the positions for parallax, it being intended only as a rough check and the residuals were not used in subsequent computation on the orbit. My plan was to correct Dr. Crawford's orbit by the application of differential corrections as developed in the "Leuschner's Short Method," using the Closed Expressions for f , g , δf , and δg . This method is published in

residuals obtained by Dr. Crawford were not spurious, I represented some August positions using his orbit 16, the perturbations I, which he had computed, being included, and obtained the following residuals:

1905 A. M. T.

Aug. 6. 224824	Aug. 7. 962500	Aug. 9. 962500	Aug. 11. 978125
(0-0) Δ ₁ -7' 52"	-6' 52"	-6' 52"	-6' 52"
Δ ₂ -0' 12"	-0' 12"	-0' 14"	-0' 8"
Aug. 12. 982500			
(0-0)	-6' 52"		
	-0' 7"		

These residuals do not seem consistent. I therefore made a recomputation using my second method (b) gave 14 for the determination of the eccentric coordinates of Jupiter, the first method (a) having been used in the above residuals. These are:

1905 A. M. T.

Aug. 6. 224824	Aug. 7. 962500	Aug. 9. 962500	Aug. 11. 978125
(0-0) Δ ₁ -7' 50"	-6' 52"	-6' 52"	-6' 52"
-0' 12"	-0' 12"	-0' 14"	-0' 8"
Aug. 12. 982500			
(0-0) Δ ₂	-6' 52"		
	-0' 7"		

In this work the dates were not corrected for aberration or the positions for parallax, it being intended only as a rough check and the residuals were not used in subsequent computation on the orbit. My plan was to correct Dr. Crawford's orbit by the application of differential corrections as developed in the "Lieschner's Short Method," using the Closed Expressions for δ , δ' , and δ'' . This method is published in

Theoretische Astronomie von Dr. W. Klinkerfues, neubearbeitung, von Prof. Dr. H. Buchholz; Zweiundachtzigste Vorlesung ab Seite 477 bis 490.

Under the false impression that I should have a longer arc than the one included between Jan. 3rd and Aug. 9th, 1905, before attempting a differential correction I continued the computation of perturbations I from Aug. 16 to Dec. 30th, 1905, at eight day intervals, on the basis of Dr. Crawford's orbit I_b . I then represented a series of positions for December, published in the *Lick Observatory Bulletin, No. 156*, as follows:

1905 G. M. T.

	Dec. 2.931763	Dec. 3.922627	Dec. 4.909664	
(O-C) $\Delta\alpha$	-0' 4"8	-0' 2"9	-0' 0"5	
$\Delta\delta$	+1' 17"5	+1' 15"6	+1' 15"9	
	Dec. 22.825776	Dec. 23.831921	Dec. 25.361805*	Dec. 29.836111
(O-C) $\Delta\alpha$	-1' 48"0	-2' 1"3	-2' 21"5	-3' 31"6
$\Delta\delta$	+1' 26"1	+1' 26"3	+1' 26"7	+1' 33"4

It was finally decided to retain Dr. Crawford's first and middle places and introduce as third place a position for August 9.962500 G. M. T. 1905, and make a differential correction to remove the residuals of Jan. 3rd and August 9th. The corrections for aberration and parallax were now applied to the residuals to be removed, on the basis of the satellite's distance obtained with the orbit to be corrected, i.e., the distance of the satellite from the earth as found by means of Dr.

Crawford's orbit was used to correct the dates of Jan. 3rd and Aug. 9th for aberration, and the satellite's mean places for geocentric parallax.

*Greenwich observation.

Under the false impression that I should have a longer arc than the
 one included between Jan. 3rd and Aug. 25th, 1905, before attempting a
 differential correction I continued the computation of perturbations
 from Apr. 10 to Dec. 30th, 1905, at eight day intervals, on the basis of
 Dr. Crawford's orbit. I then represented a series of positions for
 December, published in the *Annals of the Astrophysical Observatory*, Vol. 15, as
 follows:

1905 G. M. T.

Dec. 29.521763	Dec. 29.521763	Dec. 29.521763	Dec. 29.521763	Dec. 29.521763	Dec. 29.521763
Δx	-0' 4"8	-0' 2"9	-0' 0"9	Δx	(0-0)
Δδ	+1' 17"5	+1' 15"6	+1' 13"7	Δδ	0.4
Dec. 25.521976	Dec. 25.521976	Dec. 25.521976	Dec. 25.521976	Dec. 25.521976	Dec. 25.521976
Δx	-1' 48"0	-2' 1"2	-2' 21"5	Δx	(0-0)
Δδ	+1' 26"1	+1' 28"2	+1' 30"7	Δδ	0.4

It was finally decided to retain Dr. Crawford's first and middle
 places and introduce as third place a position for August 5.522000
 G. M. T. 1905, and make a differential correction to remove the residuals
 of Jan. 3rd and August 5th. The corrections for aberration and
 parallax were now applied to the residuals to be removed, on the basis
 of the satellite's distance obtained with the orbit to be corrected, i.e.,
 the distance of the satellite from the earth as found by means of Dr.
 Crawford's orbit was used to correct the dates of Jan. 3rd and Aug. 5th
 for aberration, and the satellite's mean places for geocentric parallax.
 *Greenwich observation.

The f's and g's for these corrected intervals were obtained by means of Closed Expressions, using both of the following sets of formulae:

(a) $f_t = \frac{x_t y'_0 - x'_0 y_t}{x_0 y'_0 - x'_0 y_0}$; $g_t = \frac{x_0 y_t - y_0 x_t}{x_0 y'_0 - x'_0 y_0}$

(b) $f_t = 1 - \frac{\gamma^2}{r_0}$; $g_t = (2r_t r_0 - p \gamma_t^2) \gamma_t^2$ where $\gamma = \sqrt{2a \sin \bar{g}}$, and $2\bar{g} = E_t - E_0$; and $\gamma_t, \sin \bar{g}$?

and g must have the same sign and are negative for dates previous to the epoch. In the first set of formulae (a) the x, y, and z's are the satellite's rectangular equatorial coordinates referred to Jupiter, and uncorrected for perturbations. The f's and g's from these two formulae were found to check.

In the solution for the sixteen differential coefficients I, based on orbit I₀, the geocentric equatorial coordinates ξ_0, η_0, ζ_0 and the geocentric distance ρ_0 of the satellite for the middle date are needed, in addition to the jovocentric velocities x', y', and z'. Consider the equations:

$\xi_0 = \rho_0 \cos \alpha_0 \cos \delta_0$; $\eta_0 = \rho_0 \cos \delta_0 \sin \alpha_0$ and $\zeta_0 = \rho_0 \sin \delta_0$

Since we have an approximate value of ρ_0 from our osculating orbit and since our osculating orbit must pass through the middle observed position we can obtain $\xi_0, \eta_0,$ and ζ_0 from our observed right ascension and declination and our best value of ρ_0 .

This was the method used in computing the first differential correction where Dr. Crawford's best value of $\log \rho_0 = 0.730278$ was employed, together with the satellite's observed mean place corrected for parallax on the basis of the same ρ_0 . With these sixteen differential coefficients (See page 17) and the four residuals expressed in radians

The δ_1 's and δ_2 's for these corrected intervals were obtained by means of closed expressions, using each of the following sets of formulae:

$$\delta_1 = \frac{x_0 \delta_1 - y_0 \delta_2}{x_0' \delta_1 - y_0' \delta_2} \quad ; \quad \delta_2 = \frac{x_0' \delta_1 - x_0 \delta_2}{x_0' \delta_1 - y_0' \delta_2} \quad (a)$$

$$\delta_1 = 1 - \frac{y_0}{y_0'} \quad (b) \quad \text{where } \delta_2 = (2x_0' y_0' - y_0^2) \delta_1$$

$$y_0 = x_0 \sin \bar{\delta}_1 \quad \text{and } x_0' = D_0 - E_0 \quad ; \quad \text{and } y_0' = D_0 \sin \bar{\delta}_1$$

and δ_2 must have the same sign and are negative for dates previous to the epoch. In the first set of formulae (a) the x , y , and x' are the satellite's rectangular equatorial coordinates referred to Jupiter, and uncorrected for perturbations. The δ_1 's and δ_2 's from these two formulae were found to check.

In the solution for the sixteenth differential coefficient, based on orbit I_0 , the eccentric equatorial coordinates \bar{x}_0 , \bar{y}_0 and the geocentric distance ρ_0 of the satellite for the middle date are needed, in addition to the geocentric velocities x' , y' , and ρ' . Consider the equations:

$$\bar{x}_0 = \rho_0 \cos \delta_0 \cos \alpha_0 \quad ; \quad \bar{y}_0 = \rho_0 \cos \delta_0 \sin \alpha_0 \quad \text{and } \rho_0' = \rho_0 \sin \delta_0$$

Since we have an approximate value of ρ_0 from our osculating orbit and since our osculating orbit must pass through the middle observed position we can obtain \bar{x}_0 , \bar{y}_0 , and ρ_0 from our observed right ascension and declination and our best value of ρ_0 .

This was the method used in computing the first differential

correction where Dr. Crawford's best value of $\log \rho_0 = 0.750275$ was

employed, together with the satellite's observed mean place corrected

for parallax on the basis of the same ρ_0 . With these sixteen differential

coefficients (see page 17) and the four residuals expressed in radians

for Jan. 3rd and Aug. 9th, the following equations were solved by Gauss's method of elimination:

$$a_i \delta \rho_o + b_i \delta x'_o + c_i \delta y'_o + d_i \delta z'_o = n_i \quad (i=1, 2, 3, 4)$$

giving as a correction to the geocentric distance and velocities

$$\log \delta \rho_o = 7.468111n; \log \delta x'_o = 9.476219n; \log \delta y'_o = 8.328423n;$$

$$\log \delta z'_o = 8.682262n.$$

To obtain the corrections to the jovocentric coordinates of the satellite for the middle date the relations

$$\delta x_o = \frac{\xi_o}{\rho_o} \delta \rho_o \quad \delta y_o = \frac{\eta_o}{\rho_o} \delta \rho_o \quad \delta z_o = \frac{\zeta_o}{\rho_o} \delta \rho_o$$

were used.

These equations are derived by differentiating the relations $(\xi)+x=\rho \cos \delta \cos \alpha$; $(\eta)+y=\rho \cos \delta \sin \alpha$; and $(\zeta)+z=\rho \sin \delta$ with respect to ρ considering $x, y,$ and z as the variables. This is rigorous if the geocentric coordinates of Jupiter remain constant. But these remain constant only if the true middle date corresponding to the new geocentric distance of the satellite remain unchanged, or in other words, if the aberration time remain practically constant. An appreciable change in aberration time would require a small correction $\delta(\xi), \delta(\eta),$ and $\delta(\zeta)$. We would then have $\delta x_o = \frac{\xi_o}{\rho_o} \delta \rho_o + \delta(\xi)$; $\delta y_o = \frac{\eta_o}{\rho_o} \delta \rho_o + \delta(\eta)$; and $\delta z_o = \frac{\zeta_o}{\rho_o} \delta \rho_o + \delta(\zeta)$. These corrections are negligible as will be shown on page 19.

The accuracy of the solution of the four equations $a_i \delta \rho_o + b_i \delta x'_o + c_i \delta y'_o + d_i \delta z'_o = n_i \quad (i=1, 2, 3, 4)$ was tested by substituting the computed values of the unknowns in the equations and proving them identities. These six corrected constants and the corrected geocentric distance gave

above equations with the values of n_i from the above residuals. The

For Jan. 27 and Aug. 27, the following equations were solved by

Gauss's method of elimination:

$$a_1 \delta x_0 + a_2 \delta y_0 + a_3 \delta z_0 + a_4 \delta t_0 = n_i \quad (i=1, 2, 3, 4)$$

giving as a correction to the geocentric distance and velocities

$$\log \delta x_0 = 7.46111; \log \delta y_0 = 2.47021; \log \delta z_0 = 6.22842; \log \delta t_0 = 8.62262.$$

To obtain the corrections to the geocentric

coordinates of the satellite for the middle date the relations

$$\delta x_0 = \frac{dx}{c} \quad \delta y_0 = \frac{dy}{c} \quad \delta z_0 = \frac{dz}{c}$$

were used.

These equations are derived by differentiating the relations

$$(\xi+x)^2 + \eta^2 + \zeta^2 = \rho^2 \quad \text{and} \quad (\xi+x)^2 + \eta^2 + \zeta^2 = \rho^2 \quad \text{with respect}$$

to x, y, z and t as the variables. This is rigorous if the

geocentric coordinates of Jupiter remain constant. But these remain

constant only if the true middle date corresponding to the new

geocentric distance of the satellite remain unchanged, or in other words,

if the aberration time remain practically constant. An approximate

change in aberration time would require a small correction $\delta(\xi), \delta(\eta),$

$$\text{and } \delta(\zeta). \text{ We would then have } \delta x_0 = \frac{dx}{c} + \delta(\xi); \delta y_0 = \frac{dy}{c} + \delta(\eta); \text{ and } \delta z_0 = \frac{dz}{c} + \delta(\zeta).$$

These corrections are negligible as will be shown on

page 19.

The accuracy of the solution of the four equations

$$a_1 \delta x_0 + a_2 \delta y_0 + a_3 \delta z_0 + a_4 \delta t_0 = n_i \quad (i=1, 2, 3, 4)$$

was tested by substituting the computed values of the unknowns in the

equations and proving them identities. These six corrected constants

and the corrected geocentric distance gave

ORBIT II BASED ON PERTURBATIONS I.

Epoch	1905	Feb. 8.600947	G. M. T.
M_0	297°	$51'$	$11''1$
Ω	291	39	42.1 Mean Equinox
ω	177	41	31.5 and
π	109	21	13.6 Equator
i	26	10	25.3 1905.0.
e	0.195772		
$\log a$	8.897738		
$\log \mu$	0.137067		per day
P	262.56437		days.

Constants for the Equator 1905.0

$$x=r(9.960048) \sin (201^\circ 33' 50''5 + v).$$

$$y=r(9.994166) \sin (107 18 38.2 + v).$$

$$z=r(9.644531) \sin (177 41 31.5 + v).$$

The residuals obtained from this orbit are:

$$(O-C) \quad \Delta\alpha \quad \text{Dec. 1} \quad 2''1 \quad -1' 31''8$$

$$(O-C) \quad \Delta\delta \quad -35+0' 14''4 \quad -1'+0' 31''3$$

Three of these residuals are larger than those to be removed, viz., the $\Delta\alpha$ and $\Delta\delta$ for January 3rd, and the $\Delta\delta$ for August 9th. When the residuals to be removed are as large as the $\Delta\alpha$ for August 9th, the linear relations are not satisfied and a second solution of the four equations, the right ascensions a_i , δ_i , ρ_i , σ_i $+ b_i \delta x'_0 + c_i \delta y'_0 + d_i \delta z'_0 = n_i$ ($i=1, 2, 3, 4$) using the same differential coefficients and the remaining residuals, is generally advantageous. I therefore made a second solution of the above equations with new values of n_i from the above residuals. The

ORBIT II BASED ON PERTURBATIONS I.

Epoch	1902	Feb. 6.300947	G. M. T.
ω	297°	51'	17.1
Ω	291	59	45.1 Mean Epoch
μ	177	41	51.5 and
π	109	51	15.6 Equator
i	26	10	25.5 1905.0
e	0.152772		
$\log a$	8.897728		
$\log n$	0.152007 per day		
P	262.26437 days		

Constants for the Equator 1905.0

$$x = r(0.960048) \sin(201^\circ 55' 50'' + v)$$

$$y = r(0.924166) \sin(107^\circ 18' 38.2'' + v)$$

$$z = r(0.644531) \sin(177^\circ 41' 51.5'' + v)$$

The residuals obtained from this orbit are:

	Jan. 2.	Aug. 2.
Δx	+1' 21"	-1' 21"
Δz	+0' 14"	+0' 21"

Three of these residuals are larger than those to be removed, viz., the Δx and Δz for January 2d, and the Δz for August 2d. When the residuals to be removed are as large as the Δx for August 2d, the linear relations are not satisfied and a second solution of the four equations,

$$a_1 \delta x + a_2 \delta y + a_3 \delta z + a_4 \delta t = n, \quad (2=1, 2, 3, 4)$$

using the same differential coefficients and the remaining residuals, is generally advantageous. I therefore made a second solution of the above equations with new values of n from the above residuals. The

result is interesting. The elements were changed to:

Epoch	1905	Feb. 8.600930	G. M. T.
(0-C) $\Delta\alpha$ -0' M_0	277°	20'	44"3
$\Delta\delta$ +0' Ω	291	19	18.6
ω	197	2	14.7
Jan 3 i	25	7	47.0
(0-C) $\Delta\alpha$ +1' e	0.178696		
$\log a$	8.894601		
$\log \mu$	0.141774	per day	
P	259.7341	days.	

The residuals for the same days were:

	Jan. 3	Aug. 9.
(0-C) $\Delta\alpha$	-1' 22"4	+0' 51"5
$\Delta\delta$	-0' 15"6	-0' 11"1

These residuals have exactly opposite signs to those above and are less satisfactory for Jan. 3rd. To test orbit II a little further, I represented Dec. 4 and 29, 1905, with the following residuals:

	Dec. 4	Dec. 29
(0-C) $\Delta\alpha$	-38"3	+1' 25"2
$\Delta\delta$	-19"1	+0' 27"1

If we compare these residuals for the four dates Jan. 3rd, Aug. 9th, Dec. 4th, and Dec. 29th, 1905, with the corresponding residuals computed with Dr. Crawford's orbit, we find that, excepting Jan. 3rd and Dec. 4th, the right ascensions represent much closer and the declinations are all improved with the exception of Jan. 3rd and Aug. 9th. The tabulation would be as follows:

4	17.0	Equator
25	0	120310

The elements were changed to: result is interesting.

Epoch	1907	Feb. 8. 1907	G. M. T.
M.	277°	20'	44.5
Q	291	19	18.6
w	197	2	14.7
i	25	7	47.0
e	0.178996		
log n	5.591601		
log u	0.141774 per day		
P	228.7341 days.		

The residuals for the same days were:

	Jan. 2	Aug. 9.
(O-C)	-1' 22.4	+0' 21.5
Δ	-0' 15.6	-0' 11.1

These residuals have exactly opposite signs to those above and are less satisfactory for Jan. 2nd. To test orbit II a little farther, I represented Dec. 4 and 29, 1907, with the following residuals:

	Dec. 4	Dec. 29
(O-C)	-35.2	+1' 25.2
Δ	-19.1	+0' 27.1

If we compare these residuals for the four dates Jan. 2nd, Aug. 9th, Dec. 4th, and Dec. 29th, 1907, with the corresponding residuals computed with Dr. Crawford's orbit, we find that, excepting Jan. 2nd and Dec. 4th, the right ascensions represent much closer and the declinations are all improved with the exception of Jan. 2nd and Aug. 9th. The tabulation would be as follows:

ORBIT I_b AND PERTURBATIONS I.

	Jan. 3	Aug. 9	Dec. 4	Dec. 29
(O-C) $\Delta\alpha$	-0' 3"5	-6' 31"4	-0' 0"5	-3' 31"6
$\Delta\delta$	+0' 3"8	-0' 14"9	+1' 15"9	+1' 33"4

ORBIT II AND PERTURBATIONS I.

	Jan. 3	Aug. 9	Dec. 4	Dec. 29
(O-C) $\Delta\alpha$	+1' 2"1	-1' 31"8	-0' 38"3	+1' 25"2
$\Delta\delta$	+0' 14"4	+0' 31"3	-0' 19"1	+0' 27"1

It seems that the orbit I_b has been improved for the longer arc. New differential coefficients II based on Orbit II were now computed. The dates Jan. 3rd and August 9th were again corrected for aberration and the residuals for parallax. The f's and g's were obtained for the Closed Expressions. The corrections to the geocentric distance $\delta\rho_0$ and the velocities $\delta x'_0$, $\delta y'_0$, $\delta z'_0$, were $\log \delta\rho_0 = 7.737805$; $\log \delta x'_0 = 9.251133$; $\log \delta y'_0 = 9.266393n$; $\log \delta z'_0 = 8.807418$. Using the relations $\delta x_0 = \frac{r_0}{\rho_0} \delta\rho_0$, etc., the corrections to the jovocentric equatorial coordinates were: $\log \delta x_0 = 7.694355$; $\log \delta y_0 = 7.336159$; $\log \delta z_0 = 6.928382$. The elements and residuals resulting from the correspondingly corrected constants are:

ORBIT III_a BASED ON PERTURBATIONS I AND DIFFERENTIAL COEFFICIENTS II.

Epoch	1905	Feb. 8.600915	G. M. T.
M ₀	274°	8' 44"2	
Ω	291	34 17"9	Mean Equinox
ω	199	30 00.1	and
π	131	4 17.0	Equator
i	25	0 32.4	1905.0

ORBIT I⁰ AND PERTURBATIONS I.

Jan. 3	Aug. 3	Dec. 4	Dec. 23
$\Delta x + 0' 14''$	$-1' 31''$	$-0' 0''$	$-3' 31''$
$\Delta y + 0' 58''$	$-0' 14''$	$+1' 12''$	$+1' 32''$

ORBIT II AND PERTURBATIONS I.

Jan. 3	Aug. 3	Dec. 4	Dec. 23
$\Delta x + 1' 21''$	$-1' 31''$	$-0' 38''$	$+1' 22''$
$\Delta y + 0' 14''$	$+0' 31''$	$-0' 12''$	$+0' 27''$

It seems that the orbit I⁰ has been improved for the longer arc. New differential coefficients II based on Orbit II were now computed. The dates Jan. 3rd and August 3rd were again corrected for aberration and the residuals for parallax. The δ_1 's and δ_2 's were obtained for the closed expressions. The corrections to the geocentric distance δ_0 and the velocities $\delta x', \delta y', \delta z'$, were $\log \delta_0 = 7.737805$; $\log \delta x' = 2.251155$; $\log \delta y' = 2.262555$; $\log \delta z' = 6.907416$. Using the relations $\delta x = \frac{r}{\rho} \delta_0$, etc., the corrections to the Jovocentric geocentric coordinates were: $\log \delta x = 7.694555$; $\log \delta y = 7.556155$; $\log \delta z = 6.928352$. The elements and residuals resulting from the correspondingly corrected constants are:

ORBIT III, BASED ON PERTURBATIONS I AND DIFFERENTIAL

COEFFICIENTS II.

Epoch	1907	Feb. 5.600915	G. M. T.
M.	274°	0'	44.2
R	291	34	17.3
W	193	30	00.1
Equator	131	4	17.0
i	23	0	32.8

e 0.175418
 log a 8.893754
 log μ 0.143043 per day
 P 258.9765 days.

Constants to the Equator 1905.

$$x=r(9.963541) \sin (223^{\circ} 4' 10''8 + v)$$

$$y=r(9.994689) \sin (129 12 43.2 + v)$$

$$z=r(9.626095) \sin (199 30 00.1 + v.)$$

Residuals 1905 G.M.T.

	Jan 3.605636	Aug. 9.932841	Dec. 4.881934	Dec. 29.806383
(O-C) $\Delta\alpha$	-1' 38"9	+0' 36"5	+1' 19"3	+0' 47"3
$\Delta\delta$	-0' 10.3	-0' 8"7	-0' 8"0	-0' 25"1

These residuals are of the same order as those to be removed except that they are opposite in sign, showing a lack of convergency. It was thought worth while, however, to substitute these last found residuals in the equations $a_i \delta p_o + b_i \delta x_o + c_i \delta y_o + d_i \delta z_o = n_i (i=1, 2, 3, 4)$ and solve by means of the differential coefficients II computed in the second differential correction. This proved quite successful, giving the following elements and residuals:

ORBIT III, BASED ON PERTURBATIONS I AND DIFFERENTIAL COEFFICIENTS II.

Epoch	1905, Feb. 8.6009739			
M_o	Aug. 7.293° 56'	Aug. 1"2.36250	Aug. 3.76250	
(O-C) $\Delta\alpha$	Ω	-0' 291	4 59.7	58 Mean Equinox
$\Delta\delta$	ω	+0' 182	11 4.5	257 and Equator
π		113	16 4.2	1905.0
i		26	1 5.2	

*Greenwich Observations.

$e = 0.175418$
 $\log a = 8.832734$
 $\log u = 0.143045$ per day
 $p = 258.2767$ days

Constants to the Epoch 1905.

$$x = r(0.965541) \sin (225^\circ 4' 10.8 + v)$$

$$y = r(0.94489) \sin (129 12 45.2 + v)$$

$$z = r(0.62633) \sin (199 30 00.1 + v)$$

Residuals 1905 G.M.T.

Jan 3.60550	Aug. 2.93284	Dec. 4.98194	Dec. 29.80383
(0-0) Δx	-1' 28.9	+0' 36.5	+1' 19.5
Δz	-0' 10.3	-0' 5.7	-0' 25.1

These residuals are of the same order as those to be removed except that they are opposite in sign, showing a lack of convergence. It was thought worth while, however, to substitute these last found residuals in the equations $a_0 + 0.6x + 0.8y + 1.4z = n_1$ ($n_1 = 1, 2, 3, 4$) and solve by means of the differential coefficients II computed in the second differential correction. This proved quite successful, giving the following elements and residuals:

ORBIT III, BASED ON PERTURBATIONS I AND DIFFERENTIAL

CORRECTIONS II.

Epoch	M_0	$\log a$	$\log u$	p
1905, Feb. 8.603733	225° 06'	8.832734	0.143045	258.2767
Mean Epoch	231	8.832734	0.143045	258.2767
and Epoch	182	8.832734	0.143045	258.2767
1905.0	113	8.832734	0.143045	258.2767
	26	8.832734	0.143045	258.2767

These residuals have been carefully checked and the geocentric coordinates of Jupiter are 8.895706 both methods (a) and (b) given on page 14 log μ . The $\log \mu$ is 0.140115 per day. Aug. 8 residual will be noted later on. According to 260.72830 days. at least his elements represent his fundamental Constants for the Equator 1905.0 of O.T. An observation taken Nov. 23 $x=r(9.960187) \sin(205^\circ 24' 15".7 + v)$. (Mercury) gives a residual in $y=r(9.994525) \sin(111 - 17.37.4 + v)$. On 22nd, 1906, an observation $z=r(9.642123) \sin(182 - 11.4.5 + v)$. right ascension by (O-C) +10.0 (See J. Residuals 1905 G. M. T. *ibid.* 374, 375).

An observation Jan. 3. 605602 Aug. 5. 930170 Aug. 6. 925025 Aug. 7. 932678
(O-C) $\Delta\alpha$ orb +0' 134"0 orb res -0' 48"6 right -0' 45"6 (O-C) -0' 45"6
declin $\Delta\delta$ orb +0' 3"2 orb res +0' 6"2 right +0' 7"5 (O-C) +0' 7"6

Dr. Ross Aug. 8. 934825 Aug. 9. 932772 Aug. 11. 948613 Aug. 12. 960060
(O-C) $\Delta\alpha$ orb -0' 56"3 orb res -0' 52"0 right -0' 46"4 (O-C) -0' 51"1
declin $\Delta\delta$ orb +0' 5"1 orb res +0' 9"4 right +0' 12"5 (O-C) +0' 12"2

From Jan. 30 Oct. 29. 570933* Dec. 25. 374269* Dec. 29. 836567 Dec. 30. 337915*
(O-C) $\Delta\alpha$ orb -0' 19"9 orb res -1' 08"9 right -1' 12"5 (O-C) -1' 12"7
declin $\Delta\delta$ orb +0' 4"4 orb res +0' 42"0 right +0' 39"4 (O-C) +0' 41"4

This orbit is strikingly like the one computed by Dr. Ross referred to on page 1, and the residuals are of the same order. Those obtained by Ross' orbit for dates around Aug. 9th are:

Again it is seen that in 1905 G. M. T. right ascension for Jan. 3rd and Aug. 9th are Aug. 7. 96250 Aug. 8. 96250 Aug. 9. 96250
(O-C) $\Delta\alpha$ orb -0' 48"0 orb res -0' 58"1 right -0' 43"9
declin $\Delta\delta$ orb +0' 22"0 orb res +0' 25"2 right +0' 19"9

(1) Error of observation; (2) Some error of computation or of handling the method;
*Greenwich Observations.
(3) Unavoidable inaccuracies in the perturbations, as these are all

0.199460
 log a
 8.892706
 log n
 0.14015 per day
 260.7850 days

Constants for the Biquat 1907.0

$$\begin{aligned}
 x &= r(2.960187) \sin (205^\circ 24' 15.7'' + v) \\
 y &= r(2.944225) \sin (111^\circ 17' 57.4'' + v) \\
 z &= r(2.642133) \sin (182^\circ 11' 4.7'' + v)
 \end{aligned}$$

Residuals 1907 G. W. T.

Date	Δx	Δy	Δz
Jan. 3.60502	+0' 34.0	-0' 48.0	+0' 43.6
Jan. 6.920170	+0' 32.2	+0' 6.2	+0' 7.6
Jan. 7.522678	-0' 25.2	-0' 43.6	-0' 43.6
Aug. 9.92272	+0' 31.1	+0' 12.7	+0' 12.7
Aug. 11.948613	-0' 28.2	-0' 43.6	-0' 51.1
Aug. 12.960060	+0' 41.4	+0' 3.4	+0' 12.7
Oct. 29.970933* Dec. 27.974269*	-0' 19.7	-1' 8.9	-1' 12.7
Dec. 30.97915*	+0' 41.4	+0' 42.0	+0' 41.4

This orbit is strikingly like the one computed by Dr. Ross referred to on page 1, and the residuals are of the same order. Those obtained by Ross' orbit for dates around Aug. 11 are:

1907 G. W. T.

Date	Δx	Δy	Δz
Aug. 7.96250	-0' 48.0	-0' 38.1	-0' 43.9
Aug. 8.96250	+0' 22.0	+0' 25.2	+0' 19.9
Aug. 9.96250			

*Greenwich Observations.

These residuals have been carefully checked and the geocentric coordinates of Jupiter computed by both methods (a) and (b) given on pages 14 and 15. The inconsistency in the Aug. 8 residual will be noted later on. According to Dr. Ross' own statement his elements represent his fundamental position with the average error of 0.4. An observation taken Nov. 23rd, 1906, by Dr. Perrine at the Lick Observatory gives a residual in right ascension (O-C) -3.3, and on Dec. 22nd, 1906, an observation by Dr. Wolf at Heidelberg represents in right ascension by (O-C) +10.0 (See *Astronomische Nachrichten Band 174, Nr. 4175.*). An observation on Dec. 14, 1907, made at Greenwich is represented by the above orbit III_b with residuals in right ascension (O-C) -25.7 and declination +3.2.

Dr. Ross calls attention to the fact that on account of the large perturbations to which the satellite is subjected, the process of determining elements is necessarily a slowly converging one, and that from Jan. 3rd to March 6th, 1905, the perturbations were so unusually large as to render it almost impossible. In view of these statements it is interesting to note that the above elements were derived by differentially correcting an orbit originally obtained over this identical arc, when the solar perturbations were included in the direct solution.

Again it is seen that the residuals in right ascension for Jan. 3rd and Aug. 9th are opposite in sign to those removed and also a little smaller. This lack of convergency could be explained on the basis of three assumptions, as was pointed out by Prof. ~~A. D.~~ Leuschner: (1) Errors of observations; (2) Some error of computation or of handling the method; (3) Unavoidable inaccuracies in the perturbations, as these are still

These residuals have been carefully checked and the eccentric coordinates of Jupiter computed by both methods (a) and (b) given on pages 14 and 15. The inconsistency in the Aug. 8 residual will be noted later on. According to Dr. Ross' own statement his elements represent his fundamental position with the average error of 0.4. An observation taken Nov. 2nd, 1906, by Dr. Perrine at the Lick Observatory gives a residual in right ascension (0-0) - 2.5, and on Dec. 22nd, 1906, an observation by Dr. Wolf at Heidelberg represents in right ascension (0-0) + 10.0 (See Astronomische Nachrichten Band 174, Nr. 4175.). An observation on Dec. 14, 1907, made at Greenwich is represented by the above orbit III, with residuals in right ascension (0-0) - 2.7 and - declination + 2.2.

Dr. Ross calls attention to the fact that on account of the large perturbations to which the satellite is subjected, the process of determining elements is necessarily a slowly converging one, and that from Jan. 3rd to March 6th, 1907, the perturbations were so unusually large as to render it almost impossible. In view of these statements it is interesting to note that the above elements were derived by differentially correcting an orbit originally obtained over this identical arc, when the solar perturbations were included in the direct solution.

Again it is seen that the residuals in right ascension for Jan. 3rd and Aug. 8th are opposite in sign to those removed and also a little smaller. This lack of convergency could be explained on the basis of three assumptions, as was pointed out by Prof. A. D. Leuschner: (1) Errors of observations; (2) Some error of computation or of handling the method; (3) Unavoidable inaccuracies in the perturbations, as these are still

coordinates X , Y , and Z from the *American Ephemeris* for the observed time based on Dr. Crawford's initial elements.

In representing the positions the geocentric equatorial coordinates of Jupiter must be known for the same instant of time as the computed coordinates of the satellite. This involves a question in aberration, since Jupiter's distance is not equal to the satellite's.

In the foregoing work the method of obtaining Jupiter's coordinates was as follows:

(a) First interpolate from the *American Ephemeris*, Jupiter's geocentric distance (ρ) geocentric apparent right ascension (α) and declination (δ) for the observed or uncorrected time ($t + \delta t$). Reduce the right ascension and declination to the mean equinox for the beginning of the year including the aberration terms (i , H , h), then

$$(\xi) = (\rho) \cos(\delta) \cos(\alpha); (\eta) = (\rho) \cos(\delta) \sin(\alpha); (\zeta) = (\rho) \sin(\delta).$$

There is a slight inaccuracy in this method owing to the fact that Jupiter's distance is not equal to the satellite's distance and the aberration time would differ for the two. This would introduce an error into ρ .

(b) A more accurate method would be to correct the observed time ($t + \delta t$) by δt obtained with the satellite's best ρ . With this true or reduced time interpolate from the *American Ephemeris* Jupiter's heliocentric longitude (λ) latitude (β) and distance (r), referred to the mean equinox of date. Then bring the longitude to the beginning of the year by applying the precession with opposite sign as interpolated from the *American Ephemeris* page 286. These heliocentric ecliptic coordinates (λ) and (β) are next converted into heliocentric equatorial coordinates (a) and (d) after which $(x) = (r) \cos(a) \cos(d)$; $(y) = (r) \cos(d) \sin(a)$; $(z) = (r) \sin(d)$. Now interpolate the solar

based on Dr. Crawford's initial elements.

In representing the positions the geocentric ephemeris

coordinates of Jupiter must be known for the same instant of time

as the computed coordinates of the satellite. This involves a question

in aberration, since Jupiter's distance is not equal to the satellite's.

In the foregoing work the method of obtaining Jupiter's coordinates

was as follows:

(a) First interpolate from the American Ephemeris, Jupiter's

geocentric distance (p), geocentric apparent right ascension (α) and

declination (δ) for the observed or uncorrected time (t+δt). Reduce

the right ascension and declination to the mean epoch for the

beginning of the year including the aberration terms (i, H, h), then

$$(z) = (c) \cos (\delta) \cos (\alpha); (r) = (p) \cos (\delta) \sin (\alpha); (l) = (c) \sin (\delta).$$

There is a slight inaccuracy in this method owing to the fact that

Jupiter's distance is not equal to the satellite's distance and the

aberration time would differ for the two. This would introduce an error

into c.

(b) A more accurate method would be to correct the observed time

(t+δt) by δt obtained with the satellite's orbit. With this true or

reduced time interpolate from the American Ephemeris Jupiter's

heliocentric longitude (λ) latitude (β) and distance (r), referred to

the mean epoch of date. Then bring the longitude to the beginning

of the year by applying the precession with opposite sign as interpolated

from the American Ephemeris page 28c. These heliocentric elliptic

coordinates (λ) and (β) are next converted into heliocentric equatorial

coordinates (α) and (δ) after which (x) = (r) cos (α) cos (δ);

(y) = (r) cos (α) sin (δ); (z) = (r) sin (α). Now interpolate the solar

coordinates X, Y, and Z from the *American Ephemeris* for the observed or uncorrected date, then $(\xi)=(x)+X$; $(\eta)=(y)+Y$; $(\zeta)=(z)+Z$, whence we obtain the geocentric equatorial coordinates ξ , η , and ζ of the satellite for the reduced date from the relation $(\xi)=(\xi)+x_0+\bar{\xi}$ etc., where x_0 is the jovocentric equatorial coordinate of the satellite for the reduced date obtained from the given osculating elements uncorrected for perturbations. We now have the three equations:

$$\rho \cos \delta \cos \alpha = \xi; \rho \cos \delta \sin \alpha = \eta; \rho \sin \delta = \zeta$$

where α and δ are the satellite's mean place and must be compared with the observed mean place, i.e., the photographic mean place as published.

(c) As a check on this process, a third method is to obtain (x) , (y) , and (z) the same as in (b), viz., $(x)=(r) \cos (a) \cos (d)$, etc., But the Solar coordinates $X_1, Y_1,$ and Z_1 are interpolated from the

American Ephemeris for the reduced time (t), on the basis of the satellite's distance. Then $(\xi)=(x)+X_1$; $(\eta)=(y)+Y_1$; $(\zeta)=(z)+Z_1$; and $\xi=(\xi)+x$; $\eta=(\eta)+y$; $\zeta=(\zeta)+z$ where x , y , and z are the jovocentric equatorial coordinates for the reduced date (t) obtained from the osculating orbit and corrected for the perturbations. We can now write $\rho \cos \delta \cos \alpha = \xi$; $\rho \cos \delta \sin \alpha = \eta$; $\rho \sin \delta = \zeta$ where α , and δ , are the geocentric right ascension and declination of the satellite and are to be compared in obtaining the residuals with the observed apparent right ascension and declination of the satellite reduced to the beginning of the year exclusive of the aberration terms (i, H, h) the geocentric parallax having been applied.

When the residuals for Aug. 9th were recomputed by the two last methods they were found to check with each other, but to change the residuals obtained by the first method by less than 0".2 in right ascension and 0".1 in declination.

coordinates X, Y, Z from the known elements for the observed or uncorrected date, then $(\bar{x})=(x)+k; (\bar{y})=(y)+k; (\bar{z})=(z)+k$, whence we obtain the geocentric equatorial coordinates $\bar{x}, \bar{y}, \bar{z}$ of the satellite for the reduced date from the relation $(\bar{x})=(x)+k; (\bar{y})=(y)+k; (\bar{z})=(z)+k$, where k is the geocentric equatorial coordinate of the satellite for the reduced date obtained from the given osculating elements uncorrected for

perturbations. We now have the three equations:

$$\bar{x} \cos \delta \cos \alpha = x; \bar{y} \cos \delta \sin \alpha = y; \bar{z} \sin \delta = z$$

where x and δ are the satellite's mean place and must be compared with the observed mean place, i.e., the photographic mean place as published.

(c) As a check on this process, a third method is to obtain

$(x), (y),$ and (z) the same as in (c), viz., $(x)=(r) \cos (a) \cos (h),$ etc.,

But the polar coordinates $k, Y,$ and Z are interrelated from the

known elements for the reduced time (t) , on the basis of the satellite's distance. Then $(\bar{x})=(x)+k; (\bar{y})=(y)+k; (\bar{z})=(z)+k$, and $(\bar{x})+k;$

$\bar{y}=(y)+k; \bar{z}=(z)+k$ where $x, y,$ and z are the geocentric equatorial coordinates

for the reduced date (t) obtained from the osculating orbit and corrected for the perturbations. We can now write $\bar{x} \cos \delta \cos \alpha = x; \bar{y} \cos \delta \sin \alpha = y;$

$\bar{z} \sin \delta = z$ where $\alpha,$ and $\delta,$ are the geocentric right ascension and

declination of the satellite and are to be compared in obtaining the

residuals with the observed apparent right ascension and declination

of the satellite reduced to the beginning of the year exclusive of the aberration terms (i, h) the geocentric parallax having been applied.

When the residuals for Aug. 27th were recomputed by the two

last methods they were found to check with each other, but to change the

residuals obtained by the first method by less than 0.2 in right

ascension and 0.1 in declination.

In all of the foregoing residuals by the different orbits both methods (a) and (b) of computing Jupiter's geocentric coordinates were used, and with the Greenwich observations usually all three methods (a) (b) and (c) were made to check. As a rule the residuals from the Greenwich observations are consistent with those derived from the Lick observations. This would seem to check the observations insofar as those made at Greenwich are for the same period as those taken at the Lick Observatory. However, as has been noted, the residuals in right ascension for Aug. 8, 9, and 12 are inconsistent with those for Aug. 5, 6, 7, and 11. Unfortunately there are no Greenwich observations for this period, and as the errors might be explained by errors of computation or of handling the method, it was decided to investigate this point.

A third differential correction (III) was then started. The intervals were corrected for aberration with the last found value of ρ_1 and ρ_3 viz., $\log \rho_1 = 0.681225$ and $\log \rho_3 = 0.711153$, the epoch being Feb. 8.6009739, thus giving for the first corrected date for aberration Jan. 3.605631 and for the third corrected date Aug. 9.932822 G. M. T. 1905. The f's and g's were obtained by means of formula (a) page 6, with the values of x_1, y_1, z_1, x_3, y_3 and z_3 obtained from the previous orbit for the newly corrected dates, but not corrected for perturbations and $x_0, y_0, z_0, x'_0, y'_0$ and z'_0 corrected by $\delta x_0, \delta y_0$ and $\delta z_0, \delta x'_0, \delta y'_0$ and $\delta z'_0$ resulting from the last differential correction (III). The value of ρ_0 was now $\log \rho_0 = 0.729660$, which gave for ξ_0, η_0 and ζ_0 $\log \xi_0 = 0.686210$; $\log \eta_0 = 0.328014$; and $\log \zeta_0 = 9.920238$. $\log (\rho) \cos \psi = 0.724249$. The jovocentric distance r_0 of the satellite for the middle date from the previous orbit gave $\log r_0 = 8.876174$. The value of β

In all of the foregoing residuals by the different orbits both
 methods (a) and (c) of computing Jupiter's geocentric coordinates
 were used, and with the Greenwich observations usually all three
 methods (a) and (c) were made to check. As a rule the residuals from
 the Greenwich observations are consistent with those derived from the
 Lick observations. This would seem to check the observations insofar
 as those made at Greenwich are for the same period as those taken at
 the Lick Observatory. However, as has been noted, the residuals in
 right ascension for Aug. 8, 9, and 12 are inconsistent with those for
 Aug. 6, 7, and 11. Unfortunately there are no Greenwich observations
 for this period, and as the errors might be explained by errors of
 computation or of handling the method, it was decided to investigate
 this point.

A third differential correction (III) was then started. The
 intervals were corrected for aberration with the last found value of
 ρ_1 and ρ_2 , viz., $\log \rho_1 = 0.68122$ and $\log \rho_2 = 0.71122$, the epoch being
 Feb. 5.603757, thus giving for the first corrected date for aberration
 Jan. 3.60551 and for the third corrected date Aug. 2.52822 G. M. T.
 1907. The τ 's and λ 's were obtained by means of formula (a) page 6,
 with the values of $x_1, y_1, z_1, x_2, y_2, z_2$ obtained from the previous
 orbit for the newly corrected dates, but not corrected for perturbations
 and x_0, y_0, z_0 and λ_0 corrected by $\delta x_0, \delta y_0, \delta z_0$ and $\delta \lambda_0$. The
 and $\delta \lambda_0$ resulting from the last differential correction (III). The
 value of ρ_0 was now $\log \rho_0 = 0.72960$, which gave for ξ_0, η_0 and ζ_0
 $\log \xi_0 = 0.68310$; $\log \eta_0 = 0.52804$; and $\log \zeta_0 = 0.52028$. $\log (p)$ was $\frac{1}{2}$
 0.72429 . The geocentric distance r_0 of the satellite for the
 middle date from the previous orbit gave $\log r_0 = 8.87017$. The value of δ

therefore was $\log \cos \beta = 9.946241$. The sixteen differential coefficients as computed by the formulae on pages 1006 and 1007 in W. Klinkerfues' *Theoretische Astronomie* are tabulated in the third column of the following schedule; the first two columns contain the coefficients for first and second differential corrections respectively.

For the three differential corrections

From elements	1st I _b	2nd II	3rd III
$\log a_1 =$	0.209302	0.228051	0.209361
" $a_2 =$	9.630998	9.645120	9.603564
" $a_3 =$	8.837917	8.401832n	8.701107n
" $a_4 =$	7.392481n	7.917837	8.251896
" $b_1 =$	8.237495n	8.295849n	8.314689n
" $b_2 =$	7.605651n	7.655845n	7.648449n
" $b_3 =$	7.637328	7.689386	7.702844
" $b_4 =$	6.805157	6.944326	6.887308
" $c_1 =$	8.453489	8.446592	8.457053
" $c_2 =$	7.847013	7.828469	7.822172
" $c_3 =$	7.953902	7.840132	7.792554
" $c_4 =$	7.258555n	7.184887n	7.088483n
" $d_1 =$	7.557297n	7.603697n	7.634492n
" $d_2 =$	7.654382n	7.660809n	7.663015n
" $d_3 =$	7.257385	7.293142	7.266201
" $d_4 =$	7.701089n	7.715046n	7.715180n
resulting in elements	II	III _a and III _b	IV

therefore was not used. The sixteen differential coefficients
 as computed by the formulae on pages 1006 and 1007 in "Wissenschaften"
 Theoretische Astronomie are tabulated in the third column of the
 following schedule; the first two columns contain the coefficients
 for first and second differential corrections respectively.
 For the three differential corrections

From elements	1st	2nd	3rd
	I ₁	I ₂	I ₃
log a ₁	= 0.204502	0.228091	0.209561
" a ₂	= 2.630956	2.641120	2.609364
" a ₃	= 8.827217	8.401828	8.701107
" a ₄	= 7.921816	7.917857	8.221896
" b ₁	= 8.227452	8.225649	8.214622
" c ₁	= 7.605651	7.605842	7.648442
" d ₁	= 7.627228	7.682886	7.702844
" e ₁	= 6.302127	6.244226	6.887208
" f ₁	= 8.422469	8.446292	8.427022
" g ₁	= 7.847012	7.828463	7.812172
" h ₁	= 7.222202	7.240122	7.222204
" i ₁	= 7.228552	7.184872	7.088422
" j ₁	= 7.227227	7.602672	7.624422
" k ₁	= 7.622222	7.660822	7.663012
" l ₁	= 7.222222	7.222222	7.222222
" m ₁	= 7.222222	7.222222	7.222222

resulting in
 elements

With the third set of coefficients and the residuals for Jan. 3rd and Aug. 9th scheduled on page 12 reduced to radians, I solved the equations

$$a_i \delta p_o + b_i \delta x'_o + c_i \delta y'_o + d_i \delta z'_o = n_i \quad (i=1, 2, 3, 4)$$

and obtained $\log \delta p_o = 6.941987$, $\log \delta x'_o = 7.309435$, $\log \delta y'_o = 8.591934n$ and $\log \delta z'_o = 8.328896$.

From the relations $\delta x_o = \frac{r}{p_o} \delta p_o$ etc., the corrections to the jovicentric coordinates for the middle date were: $\log \delta x_o = 6.898537$, $\log \delta y_o = 6.540341$, and $\log \delta z_o = 6.132565$.

ORBIT IV BASED ON DIFFERENTIAL COEFFICIENTS III AND PERTURBATIONS I.

Epoch	Feb. 8.6009687			
M _o	291°	30'	46"7	
Ω	291	51	6.6	Mean Equinox
ω	184	14	23.0	and
π	116	5	29.6	Equator
i	25	48	5.1	1905.0
e	0.1950242			
log a	8.896734			
log μ	0.138573 per day			
P	261.655625 days.			

Constants for the Equator.

$$x = r(9.961311) \sin(208^\circ 14' 57".0 + v)$$

$$y = r(9.994225) \sin(114 \quad 5 \quad 29.2 + v)$$

$$z = r(9.638742) \sin(184 \quad 14 \quad 23.0 + v)$$

Representation by means of these constants to the equator and the three above described methods of obtaining Jupiter's geocentric

With the first set of coefficients and the residuals for Jan. 27 and Aug. 31th scheduled on page 12 reduced to rationals, I solved

the equations

$$a_1 \delta x_1 + a_2 \delta x_2 + a_3 \delta x_3 + a_4 \delta x_4 + a_5 \delta x_5 + a_6 \delta x_6 + a_7 \delta x_7 + a_8 \delta x_8 + a_9 \delta x_9 + a_{10} \delta x_{10} + a_{11} \delta x_{11} + a_{12} \delta x_{12} + a_{13} \delta x_{13} + a_{14} \delta x_{14} + a_{15} \delta x_{15} = 0 \quad (1)$$

and obtained $\log \delta x_1 = 0.341987$, $\log \delta x_2 = 0.303135$, $\log \delta x_3 = 0.351334$

and $\log \delta x_4 = 0.328536$.

From the relations $\delta x_5 = \frac{2}{3} \delta x_6$, etc., the corrections to the

heliocentric coordinates for the middle date were: $\log \delta x_5 = 0.328537$,

$\log \delta x_6 = 0.340341$, and $\log \delta x_7 = 0.345255$.

ORBIT IV BASED ON DIFFERENTIAL COEFFICIENTS III AND

PERTURBATIONS I.

Epoch	Feb. 6.6003687
M	291° 30' 46.17
D	291 31 6.6 Mean Longitude
w	184 14 25.0 and
r	116 3 25.6 Equation
i	25 48 5.1 1905.0
e	0.130242
log a	0.896754
log n	0.136273 per day
p	261.653625 days.

Constants for the Equation.

$$\begin{aligned}
 x &= r(0.961511) \sin(208^\circ 14' 57.0 + v) \\
 y &= r(0.994225) \sin(114 \quad 5 \quad 29.2 + v) \\
 z &= r(0.656712) \sin(184 \quad 14 \quad 25.0 + v)
 \end{aligned}$$

Representation by means of these constants to the equation and the

three above described methods of obtaining Jupiter's geocentric

The results (see page 14) resulted as follows:

	(a)		(b)		(c)	
	Jan. 3	Aug. 9	Jan. 3	Aug. 9	Jan. 3	Aug. 9
(O-C) $\Delta\alpha$	+9"9	-15"8	+10"4	-15"6	+10"4	-15"7
$\Delta\delta$	+1.4	+6.2	+1.4	+6.3	+1.5	+6.2

The above results check the accuracy of Jupiter's geocentric coordinates for the first and third dates. I have continued to use the relations $\delta x_0 = \frac{\xi}{\rho_0} \delta \rho_0$ etc., to correct the satellite's jovicentric coordinates for the middle date, while the rigorous equation would be $\delta x_0 = \frac{\xi}{\rho_0} \delta \rho_0 + \delta(\xi)$. I therefore recomputed the true geocentric coordinates of Jupiter by my method (b) page 14 for the observed middle date corrected for aberration on the basis of this last corrected ρ_0 , to see if they had changed or if $\delta(\xi)$, $\delta(\eta)$ and $\delta(\zeta)$ were negligible. These values together with those previously used from Dr. Crawford's work are:

New Values.

$$\log(\xi) = 0.681180; \log(\eta) = 0.322423; \log(\zeta) = 9.903184$$

Crawford's Values.

$$\log(\xi) = 0.681177; \log(\eta) = 0.322421; \log(\zeta) = 9.903183$$

The changes in these values are so slight that there can be no question about the accuracy of the simpler form of the formulae.

As a further check I used the x , y , and z of the jovicentric coordinates of the satellite for the middle date as obtained by Orbit IV and Perturbations I and these new values of Jupiter's geocentric coordinates for the same instant in the equations

$$(\xi) + x = \rho \cos \delta \cos \alpha; (\eta) + y = \rho \cos \delta \sin \alpha; \text{ and } (\zeta) + z = \rho \sin \delta$$

and solved for the right ascension and declination of the satellite.

coordinates (see page 14) resulted as follows:

(a)	(b)	(c)
Jan. 3 Aug. 3	Jan. 3 Aug. 3	Jan. 3 Aug. 3
Δx +1.4 -1.7	Δx +1.4 -1.7	Δx +1.4 -1.7
Δy +0.2 -0.2	Δy +0.2 -0.2	Δy +0.2 -0.2

The above results check the accuracy of Jupiter's geocentric coordinates for the first and third dates. I have continued to use the relations $\delta x_0 = \frac{1}{2} \delta \alpha_0$, etc., to correct the satellite's geocentric coordinates for the middle date, while the rigorous equation would be $\delta x_0 = \frac{1}{2} \delta \alpha_0 + \delta(\epsilon)$. I therefore recomputed the true geocentric coordinates of Jupiter by my method (B) page 14 for the observed middle date corrected for aberration on the basis of this last corrected δ , to see if they had changed on $\delta(\epsilon)$, $\delta(\eta)$ and $\delta(\zeta)$ were negligible. These values together with those previously used from Dr. Crawford's work are:

New Values.

$$\log(\epsilon) = 0.681180; \log(\eta) = 0.322425; \log(\zeta) = 9.93184$$

Crawford's Values.

$$\log(\epsilon) = 0.681177; \log(\eta) = 0.322421; \log(\zeta) = 9.93182$$

The changes in these values are so slight that there can be no

question about the accuracy of the simpler form of the formulae.

As a further check I used the x , y , and z of the geocentric

coordinates of the satellite for the middle date as obtained by Orbit IV

and perturbations I and these new values of Jupiter's geocentric

coordinates for the same instant in the equations

$$(\zeta) + x = c \cos \eta; (\eta) + y = c \cos \delta \sin \eta; \text{ and } (\zeta) + z = c \sin \delta$$

and solved for the right ascension and declination of the satellite.

The results are:

	R. A.	Dec.
C	23° 40' 9".6	+8° 55' 18".5
O	23° 40' 9".75	+8° 55' 18".8

This seems to be quite satisfactory.

With this orbit IV, I represented a series of observations using both the f's and g's and the constants for the equator in the computation of the jovocentric coordinates of the satellite and the second method (b) page 14 for the geocentric coordinates of Jupiter. The following residuals were obtained:

	Jan. 3.605622	Aug. 5.930170	Aug. 6.925025	Aug. 7.932678
(O-C) $\Delta\alpha$	+0' 10".4	-0' 12".7	-0' 10".2	-0' 9".9
$\Delta\delta$	+0' 1".4	+0' 7".3	+0' 6".5	+0' 6".6
	Aug. 8.935059	Aug. 9.932821	Aug. 11.948613	Aug. 12.96060
(O-C) $\Delta\alpha$	-0' 20".1	-0' 15".6	-0' 9".8	-0' 14".4
$\Delta\delta$	+0' 8".9	+0' 6".3	-0' 2".5	+0' 3".2
	Oct. 29.571277*	Dec. 25.374184*	Dec. 29.811540	Dec. 30.337969*
(O-C) $\Delta\alpha$	+0' 36".4	-0' 31".1	-0' 55".8	-0' 58".1
$\Delta\alpha$	+0' 15".7	+0' 5".8	+0' 3".0	+0' 5".7

These residuals are still on the basis of the perturbations I computed with Dr. Crawford's orbit Ib.

The inconsistency in the $\Delta\alpha$ for Dec. 25th, I have tried to remove. A new aberration time was determined and the jovocentric coordinates of the satellite were recomputed. These were used with the geocentric coordinates of Jupiter obtained by method (c) page 14, and the computed right ascension compared with the observed apparent place reduced to the beginning of the year exclusive of the h, H, i terms. This gave for $\Delta\alpha$ -31".3.

The results are:

Dec.	R. A.	0	1
1875	23° 40'	+8°	278
1878	23° 40'	+8°	277

This seems to be quite satisfactory.

With this orbit IV, I represented a series of observations using both the δ 's and α 's and the constants for the equator in the computation of the Jovian coordinates of the satellite and the second method (b) page 14 for the geocentric coordinates of Jupiter. The following

residuals were obtained:

Jan. 5.60522	Aug. 5.350170	Aug. 6.925025	Aug. 7.932675
(0-0) $\Delta\alpha$	+0' 10"4	-0' 12"7	-0' 10"2
$\Delta\delta$	+0' 14"	+0' 7"2	+0' 6"6
Aug. 8.935025	Aug. 9.942675	Aug. 11.948675	Aug. 12.950675
(0-0) $\Delta\alpha$	-0' 20"1	-0' 12"6	-0' 14"4
$\Delta\delta$	+0' 8"9	+0' 6"2	+0' 5"2
Oct. 22.971277*	Dec. 25.974184*	Dec. 29.981540	Dec. 30.987569*
(0-0) $\Delta\alpha$	+0' 36"4	-0' 31"1	-0' 35"1
$\Delta\alpha$	+0' 12"7	+0' 3"6	+0' 2"7

These residuals are still on the basis of the perturbations I

computed with Dr. Crawford's orbit I^b.

U. S.

The inconsistency in the $\Delta\alpha$ for Dec. 29th, I have tried to

remove. A new aberration time was determined and the Jovian

coordinates of the satellite were recomputed. These were used with

the geocentric coordinates of Jupiter obtained by method (c) page 14,

and the computed right ascension compared with the observed apparent

place reduced to the beginning of the year exclusive of the μ, δ, i terms.

This gave for $\Delta\alpha - 31"$.

It was now decided to recompute the Perturbations II on the basis of this last orbit (IV) at eight day intervals, retaining Feb. 8 as the date of osculation. The new constants of integration, determined by the method of Mechanical Quadrature, are practically the same as those obtained by Dr. Crawford. His values for the second determination are:

As computed by the last elements they are:

Using the same differential coefficient (page 17) an attempt to remove the perturbations themselves are uniformly smaller and as is shown by the table of integration, are irregular and slowly converging for March and April.

When these new perturbations were substituted for the old ones the residuals were changed to:

	Jan. 3.605622	Aug. 5.930170	Aug. 6.925025	Aug. 7.932678
(O-C) Δα	+0' 11"8	-0' 30"4	-0' 27"4	-0' 27"2
Δδ	+0' 2"1	+0' 8"7	+0' 7"7	+0' 7"9
	Aug. 8.935059	Aug. 9.932821	Aug. 11.948613	Aug. 12.96060
(O-C) Δα	-0' 37"9	-0' 31"1	-0' 27"1	-0' 31"5
Δδ	+0' 10"6	+0' 7"4	+0' 3"5	+0' 3"9
	Oct. 29.571277*	Dec. 25.374184*	Dec. 29.811540	Dec. 30.337969*
(O-C) Δα	+0' 33"5	-0' 11"9	-0' 47"0	-0' 50"4
Δδ	+0' 16"4	-0' 25"7	-0' 23"0	-0' 20"2

*Greenwich observations.

It was now decided to recalculate the Perturbations II on the basis of this last orbit (IV) at eight day intervals, retaining Feb. 8 as the date of osculation. The new constants of integration, determined by the method of Mechanical Quaternions, are practically the same as those obtained by Dr. Crawford. His values for the second determination are:

\bar{e}	\bar{h}	\bar{g}	
+ 86	+ 74	+ 86	"
+ 120	+ 35	+ 114	"
+ 8	+ 74	+ 3	"
+ 119	+ 94	+ 13	"

As computed by the last elements they are:

The Perturbations (II) themselves are uniformly smaller and as is shown by the table of integration, are irregular and slowly converging for March and April. When these new perturbations were substituted for the old ones the residuals were changed to:

Jan. 5.60522	Aug. 5.930170	Aug. 6.925025	Aug. 7.922678
(0-0) Δx +0' 11"8	-0' 20"4	-0' 27"4	-0' 27"2
Δδ +0' 28"1	+0' 6"7	+0' 7"7	+0' 7"9
Aug. 8.925009	Aug. 9.922821	Aug. 11.946613	Aug. 12.96060
(0-0) Δx -0' 27"9	-0' 21"1	-0' 23"1	-0' 21"5
Δδ +0' 10"6	+0' 7"4	+0' 5"9	+0' 5"9
Oct. 22.771277* Dec. 22.74184*	Dec. 22.611240	Dec. 20.327969*	
(0-0) Δx +0' 28"2	-0' 18"9	-0' 47"0	-0' 30"4
Δδ +0' 16"4	-0' 25"7	-0' 25"0	-0' 20"2

*Greenwich observations.

These residuals are increased in both coordinates for all but the October and December observations. It is to be noted that the Aug. 8th, 9th, and 12th residuals bear about the same ratio to each other, and to the other August residuals as they have in all the representations. The Aug. 9th and August 12th residuals have been consistent with each other all the time. It would hardly seem that the same error of observation would be made in both positions unless they were referred to the same fundamental stars whose positions were in error.

Using the same differential coefficient (III) page 17, an attempt to remove the Jan. 3 $\Delta\alpha$ (+11"8), $\Delta\delta$ (+2"1) and Aug. 9 $\Delta\alpha$ (-31"1) $\Delta\delta$ (+7"4) residuals resulted in the following elements:

ORBIT V BASED ON PERTURBATIONS II AND DIFFERENTIAL

(0-C) $\Delta\alpha$ +0' 4370 COEFFICIENTS III. -0' 3987 -0' 4370

Epoch -0' 486 1905, Feb. 8. 60096570' 1892 -0' 1374

M_0 It is difficult to un286° 37' 43"5 residual in $\Delta\alpha$ for Jan. 3rd.

The inconsistencies in the 291 days 52s 10.0 Aug. 8th and 12th as noted above are also apparent in this 0188. 49. 53.0 therefore seem quite evident that they are due to mistake 120 of 42 days 3.0m.

It may be of interest 25 no 30 th 16.5 these last elements are not greatly different from the 0.191387 elements by Dr. Crawford, except in $\log a$ magnitude of the nodes, 8.89680 eccentricity, and the period. This is just $\log \mu$ condition we might 0.138468 per day length of the arc used.

It is more than probable 261:71888 days period perturbations which have Representation by the f and g formulae gives the residuals: one are the cause. It Jan. 3. 605622: make Aug. 9. 932824: settle this

(0-C) $\Delta\alpha$ a zero -0' 27"9 differential 0 -0' 0"9 on based on normal
 $\Delta\delta$ -0, 6"1 +0' 1"7

These residuals are increased in both coordinates for all but the October and December observations. It is to be noted that the Aug. 8th, 9th, and 12th residuals bear about the same ratio to each other, and to the other August residuals as they have in all the representations. The Aug. 9th and August 12th residuals have been consistent with each other all the time. It would hardly seem that the same error of observation would be made in both positions unless they were referred to the same fundamental stars whose positions were in error.

Using the same differential coefficient (III) page 17 an attempt to remove the Jan. 3rd $\Delta x (+11.8)$, 4th $(+2.1)$ and Aug. 9th (-31.1) $\Delta z (+7.4)$ residuals resulted in the following elements:

ORBIT V BASED ON PERTURBATIONS II AND DIFFERENTIAL

Coefficients III.

Epoch	1905, Feb. 8.603627	1905, Feb. 8.603627
μ	256° 37' 43.5"	256° 37' 43.5"
Ω	271 52 10.0	271 52 10.0
ω	188 49 55.0	188 49 55.0
r	120 42 3.0	120 42 3.0
i	25 50 16.5	25 50 16.5
e	0.121287	0.121287
$\log a$	8.928304	8.928304
$\log u$	0.18408 per day	0.18408 per day
p	201.7188 days.	201.7188 days.

Representation by the 1 and 2 formulae gives the residuals:

	Jan. 3.603622	Aug. 3.922824
(O-C) Δx	-0' 27.9"	-0' 08.9"
Δz	-0' 6.1"	+0' 11.7"

A further test of this orbit made, using
 $x=r(9.962224) \sin (212^{\circ} 48' 24'' + v)$
 $y=r(9.994340) \sin (118 44 42.2 + v)$
 $z=r(9.634057) \sin (188 49 53.0 + v)$
 gave as residuals for

ORBIT V AND PERTURBATIONS III

	Jan. 3.605622	Jan. 28.593554	Feb. 21.610333	Mar. 6.619898
(O-C) $\Delta\alpha$	-0' 27"9	-0' 10"8	+0' 6"6	+0' 13"4
$\Delta\delta$	-0' 6"1	-0' 3"4	+0' 0"5	+0' 6"4
	Aug. 5.930099	Aug. 8.934825	Aug. 11.948366	Aug. 26.931126
(O-C) $\Delta\alpha$	+0' 0"2	+0' 10"0	+0' 7"7	+0' 9"4
$\Delta\delta$	+0' 1"6	+0' 3"2	-0' 4"6	+0' 1"5
	Oct. 3.904190	Oct. 29.570933*	Dec. 29.811468	Dec. 30.337933*
(O-C) $\Delta\alpha$	+0' 43"0	+0' 28"0	-0' 39"7	-0' 43"0
$\Delta\delta$	-0' 4"6	-0' 9"2	-0' 18"2	-0' 15"4

It is difficult to understand the residual in $\Delta\alpha$ for Jan. 3rd. The inconsistencies in the residuals for Aug. 8th and 11th as noted above are also apparent in this orbit. It would therefore seem quite evident that they are due to mistakes of observation.

It may be of interest to note that these last elements are not greatly different from the original elements by Dr. Crawford, except in the longitude of the node, the eccentricity, and the period. This is just the condition we might expect with the length of the arc used.

It is more than probable that short period perturbations which have not been considered in the successive differential corrections are the cause. It certainly would make a safe check to settle this point before a more complete differential correction based on normal

A further test of this orbit made, using

$$\begin{aligned}
 x &= r(2.962224) \sin(212^\circ 48' 24'' + v) \\
 y &= r(2.974310) \sin(115^\circ 42' 22'' + v) \\
 z &= r(2.634057) \sin(128^\circ 33' 00'' + v)
 \end{aligned}$$

have as residuals for

ORBIT V AND PERTURBATIONS III

Date	Δx	Δy	Δz
Jan. 2.602522	-0' 27" 5	-0' 10" 8	+0' 6" 6
Jan. 25.293374	-0' 6" 1	-0' 2" 4	+0' 0" 5
Mar. 6.619828	+0' 13" 4	+0' 5" 1	+0' 13" 4
Aug. 2.250022	+0' 0" 2	+0' 10" 7	+0' 7" 7
Aug. 6.934825	+0' 1" 6	+0' 2" 2	-0' 4" 6
Aug. 26.931126	+0' 1" 5	+0' 1" 5	+0' 1" 5
Oct. 2.904120	+0' 4" 0	+0' 2" 0	-0' 4" 0
Oct. 22.270222	-0' 1" 6	-0' 2" 2	-0' 1" 6
Dec. 22.811684	-0' 1" 6	-0' 1" 6	-0' 1" 6
Dec. 30.237222	-0' 1" 6	-0' 1" 6	-0' 1" 6

It is difficult to understand the residual in Δx for Jan. 2nd.

The inconsistencies in the residuals for Aug. 2nd and 11th as noted above are also apparent in this orbit. It would therefore seem quite evident that they are due to mistakes of observation.

It may be of interest to note that these last elements are not greatly different from the original elements by Dr. Crawford, except in the longitude of the node, the eccentricity, and the period. This is just the condition we might expect with the length of the arc used. It is more than probable that short period perturbations which have not been considered in the successive differential corrections are the cause. It certainly would make a safe check to settle this point before a more complete differential correction based on normal

PERTURBATIONS (III) IN X.

places should be made. It was therefore decided to take Dr. Crawford's initial orbit (I_a) and recompute the perturbations for a four day interval or even a two day interval if this should seem necessary.

The new constants of integration for a four day interval are:

Jan. 4	+16814	+297	-21		
	-3493	$\bar{\xi}$	+43	$\bar{\eta}$	$\bar{\zeta}$ +8
Jan. 8	+13361	+345	-13	-21	-5
	-5108	-179	+35	-137	+3
Jan. 12	+10253	"f	-27	-10	-5
	-2728	-350			-6

as compared with Dr. Crawford's values on the bases of the same orbit for an eight day interval, which are:

Jan. 20	+5202	+417	-4	+9	-9
	-1906	+86	+8	+74	0
Jan. 24	+5296	"f	-4	+14	+4
	-1491	+1205		+95	

For the sake of comparison both tables of perturbations are given herewith:

Jan. 1	+703	+433	+4	+3	-1
	-619		+7	0	-3
Feb. 5	+144	+440	+3	+2	+2
	-179		+10	+2	
Feb. 9	-35	+950	+5	-2	-4
	+271		+15		
Feb. 13	+236	+465	+3	-5	-3
	+736		+18		
Feb. 17	+972	+483	-2	-4	+1
	+1219		+16		
Feb. 21	+2191	+499	-6	-10	-6
	+1718		+10		
Feb. 25	+3909	+509	-16	-8	+2
	+2227		0		
Mar. 1	+6136	+503	-24	-9	-1
	+2730		-20		
Mar. 5	+8866	+473	-33		
	+3203		-63		
Mar. 9	+12069	+410			

In units of the eighth decimal place.

The new constants of integration for a four day interval are:
 interval or even a two day interval if this should seem necessary.
 initial orbit (I_0) and recompute the perturbations for a four day
 places should be made. It was therefore decided to take Dr. Crawford's

\bar{m}	\bar{n}	\bar{p}
1'	-179	-21
2'	-35	-5

as compared with Dr. Crawford's values on the bases of the same orbit
 for an eight day interval, which are:

1'	+86	+74	+9
2'	+120	+95	+14

For the sake of comparison both tables of perturbations are

given herewith:

PERTURBATIONS (III) IN X.

Date	"f	'f	f	f'	f''	f'''	f''''
Jan. 0	+17291		+193				
Jan. 0	+20564	-3121	+228	-32			
Jan. 4	+14170	-3750	+229	-69	+10		
Jan. 4	+16814	-2896	+297	+12	-21		
Jan. 8	+11274	-3453	+267	+48	-3	+8	
Jan. 8	+13361	-2825	+345	+39	-13		
Jan. 12	+8649	-3108	+306	+35	-7	+3	-5
Jan. 12	+10253	-2325	+380	+34	-10		-6
Jan. 16	+6322	-2728	+338	+25	-7	-3	
Jan. 16	+7525	-1985	+405	+29	-13		+12
Jan. 20	+4537	-2323	+263	+12	-11	+9	
Jan. 20	+5202	-1622	+417	+14	-4		-9
Jan. 24	+2715	-1906	+377	+8	-12	0	
Jan. 24	+3296	-1245	+425	+2	-4	+3	+4
Jan. 28	+1430	-1481	+379	+4	9	+4	
Jan. 28	+1815	-866	+429	-7	+0	+1	-1
Feb. 1	+624	-1052	+372	+4	-6	+3	
Feb. 1	+763	-454	+433	+15	+3		-3
Feb. 5	+140	-619	+357	+7		0	
Feb. 5	+144	-477	+440	+16	+3		+2
Feb. 9	+37	-179	+328	+10		+2	
Feb. 9	-35	+202	+450	-19	+5		-4
Feb. 13	+374	+271	+349	+15	+7	-2	
Feb. 13	+236	+520	+465	-12	+3		-3
Feb. 17	+694	+736	+307	+18	+10	-5	
Feb. 17	+972	+627	+483	-2	-2		+1
Feb. 21	+1521	+1219	+502	+16	+16	-4	
Feb. 21	+2191	+1135	+499	+14	-6		-6
Feb. 25	+2653	+1718	+319	+10	+13	-10	
Feb. 25	+3909	+1451	+509	+29	-16		+2
Mar. 1	+4104	+2227	+348	+6	+19	-8	
Mar. 1	+6136	+1739	+503	+14	-24		-1
Mar. 5	+5963	+2730	+392	-30	6	-9	
Mar. 5	+8866	+2191	+473	+50	-33		
Mar. 9	+3094	+3203	+442	-63			
Mar. 9	+12069		+410				

In units of the eighth decimal place.

PERIODIC TABLE (III) IN X.

Date	"1"	"2"	"3"	"4"	"5"	"6"	"7"
Jan. 0	+20504						+258
Jan. 4	+10814		-21				-69
Jan. 8	+13361		+8				+48
Jan. 12	+10253		+3				+25
Jan. 16	+7825		-3				+25
Jan. 20	+2202		+3				+12
Jan. 24	+3296		0				+8
Jan. 28	+1812		+4				+4
Feb. 1	+782		-4				+4
Feb. 5	+144		+3				+4
Feb. 9	-25		0				+7
Feb. 13	+256		+3				+4
Feb. 17	+272		+3				+4
Feb. 21	+2121		-3				+18
Feb. 25	+2802		-3				+18
Mar. 1	+6136		-3				+18
Mar. 5	+8866		-3				+18
Mar. 9	+12052		-3				+18
Mar. 13	+2750		-3				+18
Mar. 17	+2750		-3				+18
Mar. 21	+2121		-3				+18
Mar. 25	+2802		-3				+18
Mar. 29	+2121		-3				+18
Mar. 31	+2121		-3				+18

In units of the eighth decimal place.

PERTURBATIONS (III) IN Z.
PERTURBATIONS (III) IN Y.

Date	"f	'f	f	f'	f''	f'''	f''''
Jan. 0	+3058		+53				
Jan. 0	+17291	-622	+193	+13			
Jan. 4	+2436	-3121	+66	+32	-5		
Jan. 4	+14170	-556	+225	+8	+10	0	
Jan. 8	+1880	-2896	+74	+42	-5	-13	+1
Jan. 8	+11274	-482	+267	+3	-3	+1	+9
Jan. 12	+1398	-2629	+77	+39	-4	-4	+1
Jan. 12	+8645	-405	+306	-1	-7	+2	+4
Jan. 16	+993	-2323	+76	+32	+2	0	-3
Jan. 16	+6322	-329	+338	-3	-7	-1	-4
Jan. 20	+664	-1985	+73	+25	-3	-4	+3
Jan. 20	+4337	-256	+363	-6	-11	+2	+3
Jan. 24	+408	-1622	+67	+14	-1	-1	+1
Jan. 24	+2715	-189	+377	-7	-12	+3	+4
Jan. 28	+319	-1245	+60	+2	+2	+3	-2
Jan. 28	+1470	-129	+379	-3	-9	+1	-2
Feb. 1	+90	-866	+55	-7	+3	+1	0
Feb. 1	+604	-74	+372	-2	-8	+1	+3
Feb. 5	+16	-494	+53	-15	+4	+4	+1
Feb. 5	+7110	-21	+357	+2	-4	+2	0
Feb. 9	-5	-137	+55	-19	+6	+4	-1
Feb. 9	-27	+34	+338	+8	0	+1	+3
Feb. 13	+29	+201	+63	-19	+7	+7	-3
Feb. 13	+174	+97	+319	+15	+7	-2	-4
Feb. 17	+126	+520	+78	-12	+5	+3	0
Feb. 17	+694	+175	+307	+20	+10	-2	+3
Feb. 21	+301	+827	+98	-2	+3	+6	0
Feb. 21	+1521	+273	+305	+23	+16	-2	-7
Feb. 25	+574	+1132	+121	+14	+1	-1	-3
Feb. 25	+2653	+394	+319	+24	+15	-7	+1
Mar. 1	+968	+1451	+145	+29	-6	0	+4
Mar. 1	+4104	+539	+348	+18	+15	-3	-9
Mar. 5	+1507	+1799	+163	+44	-9	-9	
Mar. 5	+5903	+702	+392	+9	+6		
Mar. 9	+2209	+2191	+172	+50			
Mar. 9	+8094		+442				

In units of the eighth decimal place.

In units of the eighth decimal place.

PERTURBATIONS (LII) IN Y.

Date	"	'	"	'	"	'	"
Mar. 9	+ 6094	+ 2191	+ 442				
Mar. 5	+ 5903	+ 1799	+ 44	+ 6			
Mar. 1	+ 4104	+ 1451	+ 29	+ 15			
Feb. 25	+ 2653	+ 319	+ 29				
Feb. 21	+ 1521	+ 1132	+ 14	- 1			
Feb. 17	+ 694	+ 307	+ 10	+ 6			
Feb. 13	+ 174	+ 520	+ 12	+ 3			
Feb. 9	- 27	+ 201	- 19	+ 7			
Feb. 5	+ 110	+ 338	- 19	+ 4			
Feb. 1	+ 604	+ 494	- 15	+ 4			
Jan. 28	+ 1470	+ 372	- 7	+ 1			
Jan. 24	+ 2715	+ 379	- 9	+ 3			
Jan. 20	+ 4337	+ 377	+ 2	+ 4			
Jan. 16	+ 6322	+ 1245	+ 14	- 1			
Jan. 12	+ 8645	+ 1622	+ 14	- 1			
Jan. 8	+ 11274	+ 363	- 11	- 3			
Jan. 4	+ 14170	+ 388	- 7	- 4			
Jan. 0	+ 17291	+ 396	- 7	0			
		+ 2629	- 7	- 4			
		+ 267	- 3	- 4			
		+ 42	- 3	- 4			
		+ 225	+ 10	- 13			
		+ 32					
		+ 193					

PERTURBATIONS (III) IN Z.

Date	"f	'f	f	f'	f''	f'''	f''''
Jan. 0	+3058		+53				
		-622		+13			
Jan. 4	+2436		+66		-5		
		-556		+8		0	
Jan. 8	+1880		+74		-5		+1
		-482		+3		+1	
Jan. 12	+1398		+77		-4		+1
Jan. 12	+20152		+1519		-1	-182	+2
Jan. 16	+993		+76		+2		-3
		-329		-3		-1	
Jan. 20	+664		+73		-3		+3
		-256		-6		+2	
Jan. 24	+408		+67		-1		+1
Jan. 28	+1706		+1716		-7	+4	+3
Jan. 28	+219		+60		+2		-2
		-129		-5		+1	
Feb. 1	+90		+55		+3		0
		-74		+2		+1	
Feb. 5	+16		+53		+4		+1
Feb. 13	+120		+1859		+2		+2
Feb. 9	-5		+555		+6		-1
		+34		+8		+1	
Feb. 13	+29		+63		+7		-3
		+97		+15		-2	
Feb. 17	+126		+78		+5		0
Feb. 21	+301		+98		+3		0
		+273		+23		-2	
Feb. 25	+574		+121		+1		-5
		+394		+24		-7	
Mar. 1	+968		+145		-6		+4
		+539		+18		-3	
Mar. 5	+1507		+163		-9		
		+702		+9			
Mar. 9	+2209		+172				

In units of the eighth decimal place.

In units of the eighth decimal place.

PERTURBATIONS (III) IN Σ .

Date	"	'	"	'	"	'
Mar. 9	+2209	+702	+9	+172		
Mar. 5	+1507	+163	-9	+18		
Mar. 1	+968	+145	-6			
Feb. 25	+574	+121	+1			
Feb. 21	+301	+98	+3			
Feb. 17	+126	+78	+5			
Feb. 13	+29	+63	+7			
Feb. 9	-5	+55	+6			
Feb. 5	+16	+52	+4			
Feb. 1	+90	+55	+3			
Jan. 28	+219	+60	+2			
Jan. 24	+408	+67	-1			
Jan. 20	+664	+73	-2			
Jan. 16	+993	+76	+2			
Jan. 12	+1398	+77	-4			
Jan. 8	+1880	+74	-5			
Jan. 4	+2436	+66	+8			
Jan. 0	+3058	+53	+13			

PERTURBATIONS (I) IN X (Crawford).

Date	"f	'f	f	f'	f''	f'''	f''''
Jan. 4	+16729		+1186				
Jan. 4	+14120	-6577	+902	+333			
Jan. 12	+10152	+5590	+1519	+324	-182		
Jan. 12	+ 8370	-5058	+1226	+151	-97	+ 77	
Jan. 20	+ 5094	+4324	+1670	+237	-105	- 66	+24
Jan. 20	+ 4246	-3388	+1453	+ 46	-163	+101	+ 76
Jan. 28	+1706	-2871	+1716	+ 14	- 4	+ 10	-38
Jan. 28	+ 1375	-1672	+1517	+ 42	-153	+ 63	+ 81
Feb. 5	+ 34	-1354	+1758	- 89	+ 59	+ 91	-87
Feb. 5	+ 21	+ 86	+1428	+101	+ 62	- 24	+ 64
Feb. 13	+ 120	+ 74	+1859	-151	+ 35	+130	-132
Feb. 13	+ 93	+1945	+1777	+136	+ 93	-156	- 16
Feb. 21	+ 2065	+1551	+1995	- 36	-121	+127	-198
Feb. 21	+ 1446	+3940	+1213	+ 15	+232	-264	-131
Mar. 1	+ 6005	+2570	+2010	+174	-385	- 33	
Mar. 1	+ 4016	+5950	+1523	-370	+199		
Mar. 9	+11955	+3963	+1640	+375			
Mar. 9	+ 7972						

In units of the eighth decimal place.

In units of the eighth decimal place.

PERTURBATIONS (I) IN X (Crawford).

date	"1"	"2"	"3"	"4"	"5"	"6"	"7"
n. 4	+16729			+1186			
n. 12	+10152			+1519			+333
n. 20	+5094			+1670			+77
n. 28	+1706			+1716			+101
n. 36	+34			+1758			+63
n. 44	+120			+1829			+24
n. 52	+2069			+1995			+35
n. 60	+3350			+2010			+156
n. 68	+11955			+1640			+181
n. 76							+264
n. 84							+382
n. 92							-270
n. 100							-370
n. 108							-482
n. 116							-594
n. 124							-706
n. 132							-818
n. 140							-930
n. 148							-1042
n. 156							-1154
n. 164							-1266
n. 172							-1378
n. 180							-1490
n. 188							-1602
n. 196							-1714
n. 204							-1826
n. 212							-1938
n. 220							-2050
n. 228							-2162
n. 236							-2274
n. 244							-2386
n. 252							-2498
n. 260							-2610
n. 268							-2722
n. 276							-2834
n. 284							-2946
n. 292							-3058
n. 300							-3170
n. 308							-3282
n. 316							-3394
n. 324							-3506
n. 332							-3618
n. 340							-3730
n. 348							-3842
n. 356							-3954
n. 364							-4066
n. 372							-4178
n. 380							-4290
n. 388							-4402
n. 396							-4514
n. 404							-4626
n. 412							-4738
n. 420							-4850
n. 428							-4962
n. 436							-5074
n. 444							-5186
n. 452							-5298
n. 460							-5410
n. 468							-5522
n. 476							-5634
n. 484							-5746
n. 492							-5858
n. 500							-5970
n. 508							-6082
n. 516							-6194
n. 524							-6306
n. 532							-6418
n. 540							-6530
n. 548							-6642
n. 556							-6754
n. 564							-6866
n. 572							-6978
n. 580							-7090
n. 588							-7202
n. 596							-7314
n. 604							-7426
n. 612							-7538
n. 620							-7650
n. 628							-7762
n. 636							-7874
n. 644							-7986
n. 652							-8098
n. 660							-8210
n. 668							-8322
n. 676							-8434
n. 684							-8546
n. 692							-8658
n. 700							-8770
n. 708							-8882
n. 716							-8994
n. 724							-9106
n. 732							-9218
n. 740							-9330
n. 748							-9442
n. 756							-9554
n. 764							-9666
n. 772							-9778
n. 780							-9890
n. 788							-10002
n. 796							-10114
n. 804							-10226
n. 812							-10338
n. 820							-10450
n. 828							-10562
n. 836							-10674
n. 844							-10786
n. 852							-10898
n. 860							-11010
n. 868							-11122
n. 876							-11234
n. 884							-11346
n. 892							-11458
n. 900							-11570
n. 908							-11682
n. 916							-11794
n. 924							-11906
n. 932							-12018
n. 940							-12130
n. 948							-12242
n. 956							-12354
n. 964							-12466
n. 972							-12578
n. 980							-12690
n. 988							-12802
n. 996							-12914

In units of the eighth decimal place.

PERTURBATIONS (I) IN Y (Crawford).

Date	"f	'f	f	f'	f''	f'''	f''''
Jan. 4	+14120		+ 902				
		-5550		+324			
Jan. 12	+ 8570		+1226		--97		
		-4324		+227		- 66	
Jan. 20	+ 4246		+1453		-163		+ 76
		-2871		+ 64		+ 10	
Jan. 28	+ 1375		+1517		-153		+ 81
		-1354		- 89		+ 91	
Feb. 5	+ 21		+1428		- 62		+ 64
		+ 74		-151		+155	
Feb. 13	+ 95		+1277		+ 93		- 16
		+1351		- 58		+139	
Feb. 21	+ 1446		+1219		+232		-172
		+2570		+174		- 33	
Mar. 1	+ 4016		+1393		+199		
		+3963		+373			
Mar. 9	+ 7979						

In units of the eighth decimal place.

PERCENTAGE (1) IN Y (Crawford).

Date	"1"	"2"	"3"	"4"	"5"	"6"
Jan. 4	+14120			+902		
Jan. 12	+8270		-97	+1226	+224	
Jan. 20	+4246		-163	+1423	+227	-86
Jan. 28	+1272		-122	+1217	+64	+10
Feb. 5	+21		-82	+1428	-81	+91
Feb. 12	+22		+22	+1277	-121	+122
Feb. 21	+1446		+222	+1212	-22	+122
Mar. 1	+4016		+122	+1222	+174	-22
Mar. 2	+2222			+272		

In units of the eighth decimal place.

PERTURBATIONS (I) IN Z (Crawford).

Date	"f	'f	f	f'	f''	f'''	f ^{iv}
Jan. 4	+2420		+262				
		-1041		+ 47			
Jan. 12	+1379		+309		-65		
		- 732		- 18		+ 32	
Jan. 20	+ 647		+291		-33		+22
		- 441		- 51		+ 54	
Jan. 28	+ 206		+240		+21		- 1
		- 201		- 30		+ 53	
Feb. 5	+ 5		+210		+74		-34
		+ 9		+ 44		+ 19	
Feb. 13	+ 14		+254		+93		-61
		+ 263		+137		- 42	
Feb. 21	+ 277		+391		+51		-88
		+ 654		+188		-130	
Mar. 1	+ 931		+579		-79		
		+1233		+109			
Mar. 9	+2164		+688				

In units of the eighth decimal place.

Yours very truly,

W. M. R. R. R.

TEMPERATURES (1) IN 2 (Crawford).

Date	"1"	"2"	"3"	"4"	"5"	"6"	"7"
Jan. 4	+2420			+262			
Jan. 12	+1279		+47	+309			
Jan. 20	+677		-18	+291			
Jan. 28	+206		-21	+240			
Feb. 5	+2		-32	+201			
Feb. 13	+14		+21	+210			
Feb. 21	+277		+74	+11			
Mar. 1	+921		+19	+254			
Mar. 9	+2164		+92	+127			
Mar. 17	+1222		-42	+188			
Mar. 25	+277		+21	+79			
Mar. 31	+1222		-130	+109			
Apr. 7	+2164			+688			

In units of the eighth decimal place.

March twenty-nineth,
1914.

D. W. MOREHOUSE

DEPARTMENT OF PHYSICS AND ASTRONOMY

My dear Prof. Leuschner:-

Your telegram and letters of March 19th and 24th received, also the computations and my first report. Immediately upon receiving your telegram I set to work to revising my report in accordance with the notations you had made and which I had copied on my duplicate report. I have re-computed and checked every residual that goes into the report, the coordinates of Jupiter have been checked by both my methods (a) and (b) and for the Greenwich observations by all three methods (a), (b), and (c). This has required no little time I assure you but I feel the work is very much more satisfactory than when I first presented my report. The thesis goes into the hands of the typewriter to-morrow morning. I will undoubtedly be able to send you the finished report not later than Friday or Saturday of this week.

Now as to the continuation of the short period perturbations I beg to say that I have no other thought than to continue these throughout the remainder of the year and I would not think of resting for a moment until another differential correction has been made upon the basis of three good normal places. There is one question upon which I am not certain and would like your advice before proceeding with the short period perturbations, that is, would you continue them on the basis of Dr. Crawford's orbit Ia; Ib; or my orbit IV? After this has been decided we will need some further conference concerning the formation of normal places before proceeding to the differential correction. I can assure you that this work will be completed before you are ready to print the thesis. I have no thought of stopping the work for sometime to come.

With regard to my being present to receive my Doctor's degree, it was my understanding that it would not be necessary for me to return to Berkeley but that the degree could be granted in absentia. However, I beg to say, Dr. Leuschner, that if this is against all of your rules and practices I will not ask this still further favor, but if in your judgment, it will be better for me to come to Berkeley in May and thus not cause you any further trouble over special favors for me, I will be glad to do so. I begin to feel that I have been one constant exception which has burdened your department and I hasten to assure you that the degree is worth coming after. Of course, if it is not necessary, I can ill afford to spend the amount of money necessary to make the trip for the personal satisfaction I would receive from it, as great as that certainly would be. You understand there are no rates to the coast at this time of the year, but that will not stand in my way in the least. Of course I could talk over the matter of continuing the work and gain very much by a personal interview unless, perchance, you should be coming East sometime this summer.

Trusting you will receive my report in due time and that you will find the revisions I have made in accordance with your wishes, I await your further suggestions.

I may say that I have not received the blanks from the recorder's office that I received last year and I am wondering if it will be necessary to fill this out.

Yours very truly,

D. W. Morehouse

Dean A. O. Leuschner,
University of California,
Berkeley, California.

Dear Mr. [Name]

Your letter of March 17th and 28th was received and we are sorry that we have not been able to get you a copy of the report in time. The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready.

The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready. We are sorry that we have not been able to get you a copy of the report in time.

Very truly yours,
[Signature]

The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready. We are sorry that we have not been able to get you a copy of the report in time.

Very truly yours,
[Signature]

Your letter of March 17th and 28th was received and we are sorry that we have not been able to get you a copy of the report in time. The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready.

The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready. We are sorry that we have not been able to get you a copy of the report in time.

Very truly yours,
[Signature]

The report is being prepared and will be ready in a few days. It will be sent to you as soon as it is ready. We are sorry that we have not been able to get you a copy of the report in time.

Very truly yours,
[Signature]

[Handwritten signature]

Drake University
[Handwritten signature]

QB3
16
M838
Astron.
Lib.
881

14 DAY USE

RETURN TO DESK FROM WHICH BORROWED

ASTRONOMY LIBRARY

This book is due on the last date stamped below, or on the date to which renewed.

Renewed books are subject to immediate recall.

LD 21-100m-6,'56
(B9311s10)476

General Library
University of California
Berkeley

