A NEW ORBIT FOR COMET C/1819 N1 (GREAT COMET OF 1819)

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RESUMEN

Se calcula una nueva órbita para el Cometa C/1819 N1 (el Gran Cometa de 1819) que reemplaza la órbita parabólica de 1906. La nueva órbita se basa en 402 observaciones en ascensión recta y 294 en declinación, realizadas entre julio y octubre de 1819. La órbita es una elipse con gran excentricidad.

ABSTRACT

A new orbit is calculated for Comet C/1819 N1 (Great Comet of 1819) to replace Peck's parabolic orbit of 1906. The orbit is based upon 402 observations in right ascension and 294 in declination, made between July and October of 1819. The orbit is a high eccentricity ellipse.

Key Words: celestial mechanics — comets: individual (C/1819 N1) — methods: data analysis

1. INTRODUCTION

The Great Comet of 1819 (C/1819 N1), also known as Comet Tralles, discovered on 2 July 1819 and followed until 15 October of that year, was the first comet to be observed with polarimetry (Kolokolova, Hough & Levasseur-Regourd 1999, p. 380). It also has the distinction of being a visual comet that transited the Sun, on 26 June, shortly before discovery (Hind 1876). Hind also discusses whether the transit was actually observed rather than thought to be observed; on the day of the transit no one knew that an actual comet was passing over the solar surface.

Because the orbit contained in the Marsden and Williams catalog (2003) and the JPL Small-Body Database Browser (`http://ssd.jpl.nasa.gov/sbdb.cqi`) was calculated in 1906 (Peck 1906), to recompute the orbit by use of modern computing techniques and statistical analysis seems a worthwhile endeavor. Peck concluded that the orbit was indistinguishable from a parabola (Peck 1907), but seeing as he based his analysis on normal places, a computational expediency almost necessary a century ago but deleterious nevertheless, this conclusion must be checked against what modern computing has to say.

2. THE OBSERVATIONS AND THEIR TREATMENT

Because it was discovered before standard journals such as *Monthly Notices* and *Astronomische Nachrichten* were founded, observations of the Great Comet are difficult to obtain. Many are contained in sources such as the *Berliner Jahrbuch* and in the annals of various observatories not available in the ADS database (`http://adswww.harvard.edu/`). Fortunately, Peck (1906) published a list of all of the observations, 402 in right ascension (α) and 294 in declination (δ). Because the comet was bright, many observations, 135 in α and 106 in δ, were made by meridian instruments. Peck also managed to identify individual reference stars for some of the non-meridian observations. He lists 29 reference stars referred to the equinox of 1819. Of these 29, I was able to find all but 3 in the Tycho-2 catalog (Høg et al. 2000). Therefore, 100 of the observations could be corrected for the difference between the Tycho-2 catalog, presumably more precise, and Peck's reference star list. All observations must be corrected for the astronomical-civil day difference and also for the difference between Greenwich mean time and terrestrial time. Nor will the observations be formed into normal places, but rather used directly.
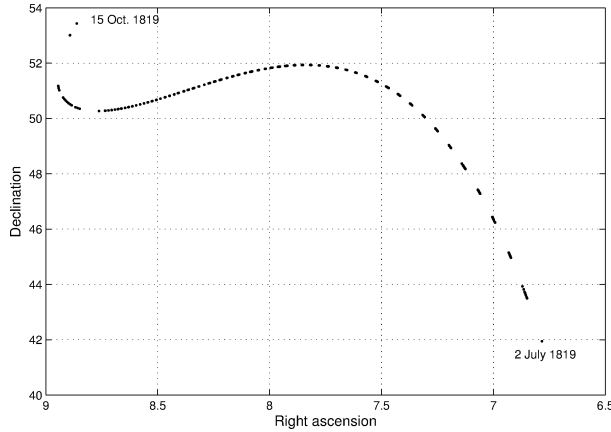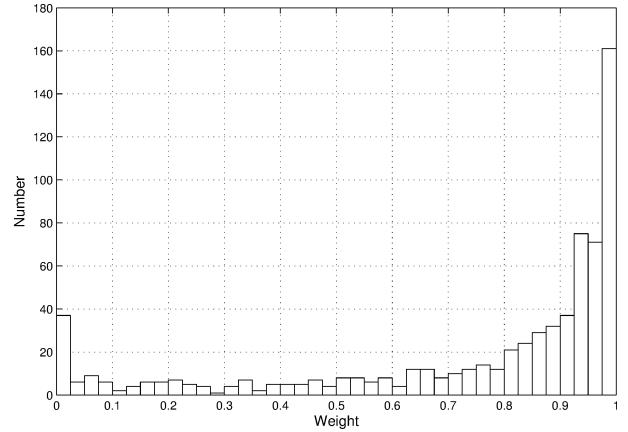
Fig. 1. The observations.

Fig. 2. Histogram of Welsch weights.

TABLE 1

OBSERVATIONS OF COMET C/1819 N1
(GREAT COMET)

Observatory	Obs. in α	Obs. in δ
Kremsmünster, Austria	14	0
Vienna, Austria	41	0
Prague, Czechoslovakia	25	0
Greenwich, England	14	14
Paris, France	50	47
Berlin, Germany	9	9
Bremen, Germany	26	25
Göttingen, Germany	9	8
Gotha, Germany	32	19
Leipzig, Germany	1	1
Mannheim, Germany	9	9
Munich, Germany	14	14
Florence, Italy	2	2
Milan, Italy	35	34
Padua, Italy	31	31
Palermo, Italy	29	29
Wilno (Vilnius), Lithuania	27	27
Dorpat, Russia	34	25
Total	402	294

Figure 1 graphs the observations, and Table 1 shows their distribution among observatories. Table 1 gives no references because Peck (1906) identifies the sources for all of the observations.

3. EPHEMERIDES AND DIFFERENTIAL CORRECTIONS

The procedure for calculating coordinates, velocities, and partial derivatives for differential corrections has been given in previous publications of mine. See Branham (2005), for example. The first differential correction was based on the robust L_1 criterion, minimizing the sum of the absolute values of the residuals, being insensitive to discordant data, and leaving 696 equations of condition.

Various weighting schemes are possible once one has post-fit residuals from a differential correction. Modern schemes assign higher weight to smaller residuals and zero weight to large residuals, recognizing them as errors rather than genuine but improbable residuals. Among these robust weightings I chose the Welsch (Branham 1990, § 5.5), largely because it yields good results with Galactic kinematics; see Branham (2014). Welsch weighting accepts all residuals, but assigns low weight to large residuals, so low as to become less than the machine ϵ for extremely large residuals,

$$ wt = \exp(-r_i/2.985)^2; |r_i| < \infty. \qquad (1) $$

Weights calculated from equation (1) were applied to the equations of condition.

Figure 2 shows a histogram of the weights. The mean error of unit weight, $\sigma(1)$, becomes $11.''23$, somewhat high but still in a normal range for 19th century comets; see Table A1 in Branham (2012).

TABLE 2

SOLUTION FOR RECTANGULAR
COORDINATES AND VELOCITIES FOR THE
GREAT COMET OF 1819: EPOCH JD 2385640.5
(25 JULY 1819), EQUINOX J2000

Unknown	Value	Mean Error
x_0 (AU)	8.7118333e-002	3.1247522e-005
y_0 (AU)	-2.1854439e-002	5.6286005e-005
z_0 (AU)	7.7948830e-001	2.3118544e-005
$\dot{x}_0$ $(AU\ day^{-1})$	-5.7387965e-004	1.3568693e-006
$\dot{y}_0$ $(AU\ day^{-1})$	1.7300751e-002	1.6746598e-006
$\dot{z}_0$ $(AU\ day^{-1})$	2.1296637e-002	1.5521707e-006
$\sigma(1)$	11.″23	

TABLE 3

COVARIANCE (DIAGONAL AND LOWER
TRIANGLE) AND CORRELATION (UPPER
TRIANGLE) MATRICES FOR THE GREAT
COMET OF 1819

0.32960	-0.97708	0.93688	0.88656	-0.70238	0.89723
-0.58009	1.0694	-0.89414	-0.81347	0.60575	-0.84983
0.22846	-0.39275	0.18041	0.87669	-0.73247	0.93107
0.01269	-0.02097	0.00928	0.00062	-0.91950	0.92556
-0.01241	0.01927	-0.00957	-0.00070	0.00094	0.80136
0.01469	-0.02506	0.01128	0.00066	-0.00070	0.00081

4. THE SOLUTION

Table 2 shows the final solution for the rectangular coordinates, x_0, y_0, z_0, and velocities, $\dot{x}_0$, $\dot{y}_0$, $\dot{z}_0$, along with their mean errors and also $\sigma(1)$ for the comet. Table 3 gives the corresponding covariance and correlation matrices. All correlation are high, the highest being -97.7% between x_0 and y_0. Although statistically significant, these correlations nevertheless do not imply an unstable solution because the condition number of 3.2×10^2 for the data matrix shows that it is far from poorly conditioned. The rectangular coordinates indicate that the orbit is elliptical. Table 4 converts the rectangular coordinates to elliptical orbital elements using the well known expressions linking orbital elements with their rectangular counterparts. The orbit represents a high eccentricity ellipse rather than a parabola. The calculation of the mean errors of the orbital elements proceeds via a modernized version of Rice's procedure (1902). See Branham (2005).

The fact that the calculated orbit is a high eccentricity ellipse actually agrees with Peck's orbit, which finds an eccentricity of 0.999792±0.000079. In

TABLE 4

ELLIPTIC ORBITAL ELEMENTS AND MEAN
ERRORS FOR THE GREAT COMET OF 1819:
EPOCH JD 2385640.5 (25 JULY 1819), EQUINOX
J2000

Unknown	Value	Mean Error
T_0	JD 2385613.70350 28.20350 June 1819	14.^{d}72752
P (yr)	4634.22	14.47
a (AU)	277.95408	0.56372
e	0.998770	0.249081e-005
q (AU)	0.341817	0.000224
Ω	279.°37226	0.°62361e-002
i	83.°96591	0.°32762e-002
ω	87.°38860	0.°11782e-001

a later publication, however, Peck (1907) suggests that a parabola represents the observations just as well, and thus a parabola has entered the literature for the orbit of the Great Comet. A high eccentricity ellipse, however, is better, as the next section shows.

5. DISCUSSION

To check how good a solution is, one should study the residuals. The residuals from the first L1 solution are plotted in Figure 3; there are evidently some outliers. Because I have no access to the original observations, I cannot search for a cause for these anomalies. A runs test, a statistic of the randomness of the residuals, measures how often a variable, distributed about the mean, changes sign from plus to negative or negative to positive, the runs, which have a mean for n data points of $n/2 + 1$ and a variance of $n(n - 2)/4(n - 1)$ (Wonnacott and Wonnacott 1972, pp. 409-411). The L_1 residuals evince 362 runs out of an anticipated 348. The probability of randomness becomes 28.9%, sufficient to state that the residuals are indeed random and can be used with equation (1) to calculate weights. Random, but not arising from a normal distribution. Statistics on residuals trimmed to under $\left|0.5 \cdot 10^{-3}\right|$ radian, leaving 680 residuals, show that the residuals are skewed, coefficient of skewness 0.11 versus 0 for a normal distribution, platykurtic, kurtosis of 1.57 versus 3 for the normal, and with a Q factor 0.36 versus 2.11 for the normal and thus lighter-tailed. Figure 4 shows a histogram of the trimmed L_1 residuals.

After a new solution has been calculated with the Welsch weights, the solution given in Tables 2 and 4, the statistics change. Figure 5 plots the residu-
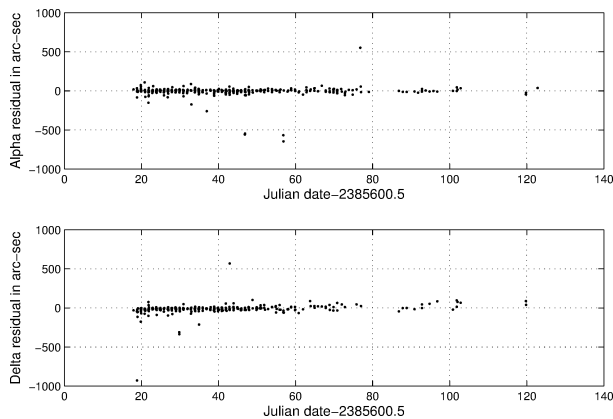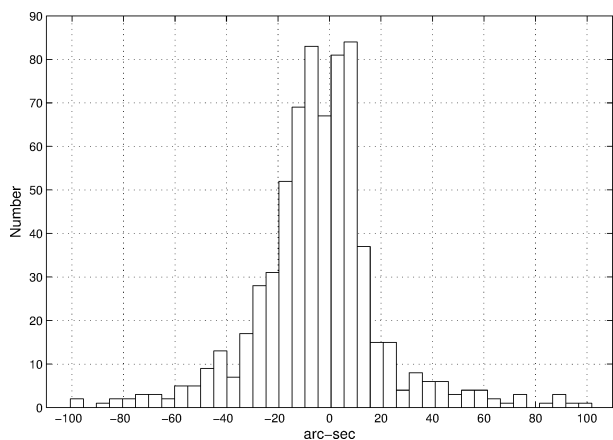
Fig. 3. The L1 residuals.

Fig. 4. Histogram of trimmed L1 residuals.

Fig. 5. Residuals from Welsch weighting.

als from the new solution. A runs test on the non-zero residuals shows 333 runs out of an expected 339, a 64.5% chance of being random. Random, but again non-normal. Statistics on the residuals themselves mean little because the Welsch weighting flattens the distribution and distorts a statistic such as the kurtosis. A mean squared successive difference test (Wonnacott and Wonnacott 1972, 411-413), also known as the Durbin-Watson statistic, measures the serial correlation of one residual with its successor and assumes a normal distribution. For the residuals of Figure 5 the Durbin-Watson statistic becomes 19.7%, sufficient to infer randomness but with low normality. These statistics show that a high eccentricity ellipse fits the data well.

Having the orbit, the question of whether the Great Comet could be a danger to the Earth in the future should be answered. The answer is "no." The Great Comet will return to its close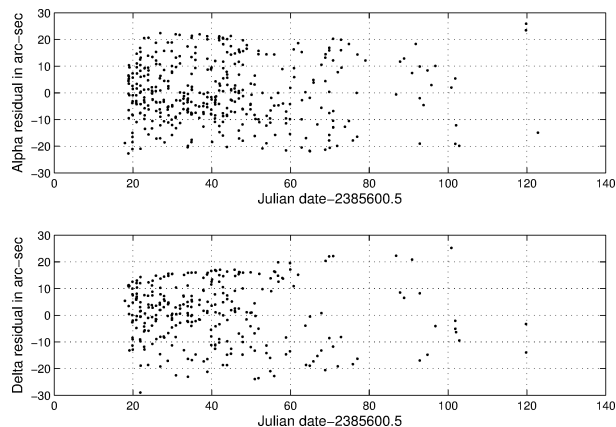st separation from the Earth on 18 Feb. 5044, but the separation will be 0.986 AU and thus no threat. It is also interesting to integrate the orbit backwards. On 4 June -2551 the comet passed within 0.790 AU from the earth. This date is close to the time of construction of the Great Pyramid in Egypt. Perhaps some Egyptian chronicles mention a new, bright star in the heavens. Or maybe Sumerian chronicles. This, however, is a question for experts in Near Eastern studies. I merely mention the possibility.

6. THE TRANSIT OF THE SUN

On 26 June 1819 the Great Comet transited the Sun. Hind (1876) has analyzed supposed observations, or perhaps better stated anomalies on the surface of the Sun because they occurred before it was known that a new comet had been discovered. Of these observations he credits that of Canon Stark as the one most probably identifiable as the comet. Stark observed the solar surface from Augsburg, Germany, and published in his *Meteorologisches Jahrbuch* that at 7^h15^m, presumably Augsburg mean time, he saw a remarkable spot $15'25''$ from the western limb and $14'30''$ from the northern. When he observed the Sun again at noon the spot had disappeared. I calculate, using the geographical coordinates of Augsburg, that the comet made first contact with the Sun's limb at $5^h21^m13^s$ GMT at position angle $171.°9$, last contact at $8^h56^m46^s$ and position angle $9.°1$, and closest approach of $2'23.''6$ at $7^h8^m53^s$ GMT. The Sun's semidiameter was $15'43.''9$.

Stark's measurements imply that the spot he observed was $1'15.''9$ from the Sun's center $31.^m4$ before the time of closest approach if we assume that he used Augsburg mean time and more than $1'$ closer than the angle of minimum separation. Although

these data do not agree closely, the fact that Canon Stark was not a trained astrometric observer (or why would he be publishing in a meteorological journal?) and that the spot he found had disappeared by noon, it seems likely that he indeed saw the comet as it transited the Sun. Hind (1876) arrives at a similar conclusion. But because of the lack of close agreement between his observation and the data given by computation, the observation unfortunately cannot be used to improve the orbit of the comet.

7. CONCLUSIONS

An orbit of the Great Comet of 1819 (C/1819 N1) has been calculated by use of 402 observations in α and 294 in δ made between July and October 1819. The orbit is a high eccentricity ellipse. The comet will not return for over 3,000 years and represents no threat to the Earth. It is possible that Near Eastern records around 2550 BCE may mention an earlier passage of the Great Comet. The comet transited the Sun on 26 June, before the first astronomical observation of 2 July, and was likely seen by at least one observer.

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