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A collection of Galilean satellite eclipse observations, 1652–1983: Part I

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Summary. The most complete collection of extant Galilean satellite eclipse observations since 1652 has been assembled. Since many of the old data exist only in manuscript form or in archaic forms (e.g. apparent time, local time, sidereal time, Julian calendar, etc.), they have been reduced to a modern proleptic Universal Time (UT) system (where the day begins at midnight) on the Gregorian calendar. Many of the data had been presumed to be lost for more than a century and since they are very valuable for discussion of long-term effects on the satellites, I present them here for present as well as future generations of astronomers. The data are invaluable for long-term studies of Galilean satellite motion and for the determination of physical parameters.

Key words: Planets and satellites – Jupiter – Galilean satellites – eclipes — ephemerides — celestrial mechanics — observational methods —

1. Introduction

Since the 19th century a well-known but "non-existent" set of eclipse observations of the Galilean satellites made prior to the 19th century was referred to as the "Delambre collection." J.-B. Delambre (1749–1822) constructed tables of the satellites' motion in 1792 (Lalande, 1792) and 1817 (Delambre, 1817) which were widely used at the time. In the construction of those tables he analyzed approximately 6000 observations. Since the early 19th century those reductions had disappeared and most astronomers (Tisserand, 1896, p. 84) believed them irretrievably lost.

It has been only recently that the "pedigree" of this lost collection has been clarified. J.N. Delisle (1688–1768), an avid student of historical and positional astronomy (which in those days placed great emphasis on eclipse observations of the Galilean satellites for purposes of longitude determinations), had widespread contacts and collected eclipse observations of the satellites. Another French cleric-astronomer, A.-G. Pingré (1711–1796) probably made extensive use of Delisle's manuscript collection and over a period of 30 yr developed his monumental treatise on 17th century astronomy, Annales Célestes du dix-septième siècle, whose publication the French Academy authorized in 1791. Pingré's historical work placed great emphasis on the listing of eclipse observations for determination of longitudes. However, due to Pingré's death in 1796 and due to consequences of the French Revolution, the manuscript was not published and the printer's proofs were apparently destroyed. Delambre probably had access to these manuscripts and his human calculators reduced them for Delambre's use in developing his tables of satellite motion.

Near the close of the 19th century a set of proofs for Pingré's treatise was found and the French Academy in 1898 again authorized the publication of Pingre's work which was edited by Bigourdan (1901). Subsequently many of the original manuscripts for Pingré's treatise and Delisle's collection were rediscovered (Bigourdan, 1897), having been hurriedly and frequently mistakenly filed in Paris at the time of the French Revolution. Bigourdan was astronomer-in-chief at the Paris Observatory from 1897 to 1925 and he became the first director of the Bureau International de l'Heure (BIH) in 1919. To my knowledge no one has employed the rich source of data contained in Pingré's treatise until now.

Sampson (1910) apparently made a thorough search for the "lost" Delambre collection which according to Delambre (Sampson, 1910, p. 216) contained 3439 eclipse observations of Satellite I, 1100 of II, 590 of III, and 334 of IV made prior to circa 1808. After extensive effort Sampson was able to locate the "computer" records of observations of Satellite II and some of Satellite IV (but without reference to their place of observation) which he then published. These "records" are similar to the one depicted by Arlot et al. (1984) in their Fig. 1. The records contain reductions of original data apparently made for Delambre, but they are not the original observations and sometimes have been altered. Arlot et al. recently published a valuable paper which contained rediscovered "Delambre" records for Satellite I from 1775 to 1802 and state: "It seems that the observations, collected by Delambre, covering the years 1775 to 1802, were not at Sampson's disposal and it turns out that no useful observations made during that period were available to him ...."

While it in no way lessens the importance and value of the data for Satellite I which were published by Arlot et al., their statement regarding Sampson is not entirely correct. Sampson *was* aware of the Delambre reductions for Satellite I, but he elected to ignore them, feeling that his own discussion (Sampson, 1909) of the Harvard eclipses 1878–1903 adequately answered any questions about the motion of Satellite I. The Harvard series of eclipses were originally published only in residual form and

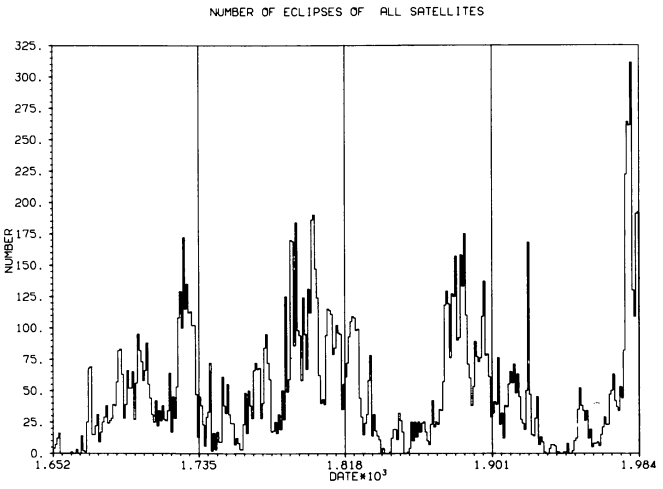

Fig. 1. Number of eclipse observations contained in the collection as a function of year

were reconstructed by Lieske (1978). In his discussion of the old Delambre data which he had found, Sampson (1910, p. 199) states (my comments are contained in brackets [ ]):

"I suppose this determination [that of Delambre] may now at length be considered generally superseded by discussion of photometric eclipses in the Harvard Annals, vol. lii, but it is not mere curiosity that would impel an inquiry into its [i.e. Delambre's collection of 6000 eclipse observations] value. It has a bearing upon three elements requisite for determining the masses of the satellites and the ellipticity of Jupiter. These elements are the motion of the node of Satellite II, the motion of the apse of Satellite IV, and that part of the equation of the centre of Satellite III which refers to the apse of IV."

In other words, Sampson was primarily interested in obtaining further information about $\dot{\omega}_2$, $\dot{\pi}_4$ and the coefficient of $l_3 - \pi_4$, using the notation of his theory (1921) or that of Lieske (1977). He then points out (p. 200) that the determination of the motion of ω_2 and π_4 "require a compact set of ancient observations ... to fix the positions of node and apse ... at a remote epoch," but that the determination of the coefficient of $l_3 - \pi_4$ requires a long dedicated series of observations.

Furthermore, in his discussion of the Delambre reductions which he rediscovered, Sampson (p. 216) states:

"... The Bureau des Longitudes, where such observations as existed would naturally repose, on learning my purpose, caused a search to be made, and most courteously placed at my disposal a mass of papers which proved when I examined them to contain among other matters a complete set of Delambre's collection of eclipses for Satellite II and Satellite IV.

"These papers are the work of two computers, made at the direction of Delambre .... The earlier and less important part [in the sense of Sampson who was interested in ω_2 and π_4] is referred to by the other calculator as 'les calculs que Monsieur Delambre a anciennement fait faire en ville.' They are computations of the time of occurrence of eclipses made with Delambre's Tables of 1792 .... There are about 500 eclipses of Satellite I, dating from 1775 to 1802, probably including the complete collection of picked eclipses of this satellite upon which the Tables of 1792 were founded, but the numbers for the other satellites are mere fragments of the whole.

"The work which remains of the second calculator [and which Sampson published in his paper] refers exclusively to Satellite II and Satellite IV. There are 1100 eclipses of II, and, after rejection of defective cases, 464 of IV."

So the data which Sampson published in his 1910 paper are the "Calculator II" records for Satellites II and IV, while the data published recently by Arlot et al. (1984) are probably the "Calculator I" records. Of the 845 observation records of Satellite I published by Arlot et al. I had already located approximately 30% in other sources.

Another source which has recently been examined is the collection (Bigourdan, 1897) of Delisle manuscripts contained in the Paris observatory in Manuscripts A-5-1 through A-5-8. J.N. Delisle was a French astronomer who in 1721 received an invitation to go to Russia for four years and help found the observatory in St. Petersburg. He went there in 1725 and remained for 22 yr. Delisle collected eclipse observations from widespread sources, many of them via correspondence, and his hand-written manuscript is the richest source of early observations extant.

These latter two forgotten treasures contain listings of the original observations as obtained from manuscripts and correspondence and they generally include the observations which ultimately also are given in the "computer records" published by Sampson (1910) and by Arlot et al. (1984). Similar computer records are contained in the Delisle manuscripts, so they all probably belong to the reductions which were done for Delambre. We now have more than 7000 observations prior to 1800 recovered from the literature and from manuscript collections and have probably reconstituted the lost "Delambre collection" which properly ought to be called the Delisle and Pingré collections.

The attempt to reconstruct the "Delambre" collection began in 1980 when I visited the Paris Observatory library and was able to examine the manuscript collection of J. Delisle. After initial examination and confirmation that when reduced to a modern UT system [by accounting for the difference between apparent and mean time, local time, and by using some form of the difference between Ephemeris Time (ET) and Universal Time (UT)] I found that the data were quite accurate, I endeavored to locate as many of the old eclipse observations as possible. A description of some of the detective work involved is described in Lieske (1982, 1983).

Since the observations were presented in an inhomogeneous manner with numerous peculiarities and since they are so valuable for obtaining a long span of earth-based data that in many respects rivals the accuracy of the derived parameters from modern spacecraft-based results, it was decided to reduce them to a uniform UT system so that future researchers might more readily have access to these invaluable data. The compilation of eclipse observations is outlined in this paper and the detailed listings are given in an accompanying paper in the Supplement series.

2. Sources of data

The early data are largely contained in manuscript form in the works mentioned earlier by Delisle and by Pingré. No data were taken from the "computer records" (since they often did not indicate where the observations were made and what the observing conditions were like) unless the original data were not available from other sources. Another valuable source for early observations is the data contained in the compilations which appeared in the annual volumes of the Berliner Astronomisches Jahrbuch, edited by J. Bode until his retirement in 1825 (the last issue edited by Bode was that of 1829, published in 1826). A list of the observers (or editors in some instances) of the data contained in the present collection is given in Table 1. The Table contains an Index which arbitrarily has been assigned to each source of observations. [The initial publication was labeled PA for "Publication *A*" and then the alphabet was wrapped-around from ZZ to AA after many other observations were found]. The table also gives the journal and its year of publication, the author of the paper and the number of observations contained in the collection. The table is sorted by authors in order that one might readily find the active observers in different time intervals. Tables in the Supplement paper present the same data but they are sorted by Index number or by journal, so that from the observations given in the Supplement paper one can easily determine who observed the eclipses. The initial literature survey conducted by Pierce (1974a,b) for locating observations of the Galilean satellites was supplemented by searches through other journals and manuscript collections.

As given in the table, there are 418 different sources and the total number of observations referenced is 16802 (including 1091 excluded observations). As will be noted later, some duplicate observations (notably published data which also appear in the generally unreferenced Sampson records of Calculator II or in the Arlot et al. compilation of Calculator I) are listed and marked as duplicates, while others are listed but marked as not useful for analysis until further information is obtained about them.

During the 17th century there was a great effort worldwide to make observations of eclipses of the Galilean satellites and they often formed the basis of early maps of the world, since a given event as observed at two different longitudes on the earth will yield the longitude difference between the observing sites. Most early observations were recorded in local apparent time and it often requires a bit of detective work to determine the modern location of an old observing site. Many names were spelled phonetically so that Otaheite is the modern Tahiti, Ulyssipone is the modern Lisbon, Hoai-Ngan (or Hoyaingan) is Hwaian, China, etc.

In Table 2 I present a listing of the observing sites for the present collection of eclipses. Each location is assigned an Index (so that duplicate data could more readily be identified), initially starting at value LA (for "Location *A*"), then LB etc., but again the alphabet was wrapped-around after ZZ in defining indices for each site. The longitude of the observing site is also given, as is the name of the location. The comments field in the table gives further details about certain sites, such as when the modern name and the old name are different. The final column of the table contains the number of observations from that observing site in the collection. The 16802 observations contained in the collection were made at 432 different sites. The paper in the Supplement series gives the actual observations and also lists the observing sites shown in Table 2 but sorted by Index and by longitude.

Modern observations of eclipses are largely made by amateur astronomers who contribute significantly to the valuable series of observations. In Fig. 1 we present a histogram showing the number of observations made in each year for all of the satellites. The histogram contains many historically important effects, such as the founding of the Paris observatory in 1667, the Greenwich observatory in 1675 and the early efforts of Ole Rømer in the 1670s to employ the eclipses to determine the finite speed of light (Nielsen, 1944). Also apparent are the increase in data upon Delisle's move to St. Petersburg in 1725 and the decrease during the French Revolution, during which many of the earlier manuscripts were hurriedly filed away and "misplaced" for a century or more. The extended paper in the Supplement series contains similar histograms for each satellite. Retirements (such as that of Bode in 1825, after which the Berliner Astronomisches Jahrbuch no longer contained an annual listing of observations) and the effects of wars are also evidenced.

3. Reduction of data

Most of the old observations were recorded in local apparent time. Hence in order to derive a mean time or Universal Time of the observation one needs to know the longitude of each observing site. Generally I obtained the longitude from *The Times Atlas of the World* (Comprehensive Edition of 1980), supplemented by old almanacs for established observatories, primarily the American Ephemeris of 1905 or the Berliner Astronomisches Jahrbuch. Although modern observations are recorded ab initio in UT, I still retained the longitudes and identification of observing sites so that duplicates could more readily be traced and removed.

As outlined in the Supplement paper, the local apparent times were reduced to proleptic Universal Times by the algorithm given in Smart (1931). It is only when calculating residuals (i.e., when computing the predicted time of an event in ET and comparing that prediction with the observed time of the event recorded in UT) that one requires the knowledge of the relationship between ET and UT. That introduces the problem of finding a good table of ΔT values valid for more than 3 centuries, and brings in a discussion of lunar tidal dissipation, since most tables of ΔT are based upon the analysis of the motion of the Earth's moon. The work of Brouwer (1952) is generally the standard for old observations, since it utilizes the tidal term $\dot{n}_{\mathrm{Moon}} = -22.44$ arcsec per century^2 of Spencer-Jones (1939), but Brouwer's results are not very accurate prior to 1850. Martin (1969) extended the Brouwer analysis prior to 1850 and the "Brouwer-Martin" values of ΔT are perhaps the best representation of the classical Brouwer approach using the Spencer-Jones tidal term of $\dot{n}_{\mathrm{Moon}} = -22''.44$.

The most accurate determination of ΔT (leaving aside the question of what the lunar tidal deceleration ought to be) is probably that of Morrison (1979a,b, 1980) and of Morrison and Stephenson (1981) since they carefully reduced the data and determined values of ΔT using a lunar tidal term of $\dot{n}_{\mathrm{Moon}} = -26''.0$ derived by Morrison and Ward (1975). Ten years ago there was great disparity in the determination of lunar tidal terms, with values ranging from the Spencer-Jones value of $\dot{n}_{\mathrm{Moon}} = -22''.44$ up to about $-50\,\mathrm{arcsec}/cy^2$. Each second of arc difference in the adopted lunar tidal term will produce about one second of time per century squared difference in the ΔT values, so it is important to get good values of ΔT, especially since one of the potential uses of the Galilean satellite eclipse data would be to investigate the possibility of tidal dissipation in the Galilean satellites as it might be evidenced in effects on their motion.

Table 1. Observer list (sorted by author)

Index	Year	Journal	Volume	Author	No. Obs.
PH	1965	*Sterne*	**41**: 32–34	Ahnert, P.	24
PI	1966	*Sterne*	**42**: 214–218	Ahnert, P.	57
PJ	1969	*Sterne*	**45**: 19–22	Ahnert, P.	82
FG	1972	*Sterne*	**48**: 34	Ahnert, P.	88
FH	1976	*Sterne*	**52**: 39	Ahnert, P.	103
FI	1978	*Sterne*	**54**: 45	Ahnert, P.	68
AJ	1833	*Mem. R. Astron. Soc.*	**5**: 379	(Airy?)	46
AK	1833	*Mem. R. Astron. Soc.*	**6**: 186	(Airy?)	65
AL	1836	*Mem. R. Astron. Soc.*	**9**: 265	(Airy?)	26
SG	1869	*Mon. Not. R. Ast. Soc.*	**29**: 253	(Airy)	12
SH	1870	*Mon. Not. R. Ast. Soc.*	**30**: 176	(Airy)	11
SI	1872	*Mon. Not. R. Ast. Soc.*	**32**: 78	(Airy)	12
SJ	1873	*Mon. Not. R. Ast. Soc.*	**33**: 158	(Airy)	23
SK	1874	*Mon. Not. R. Ast. Soc.*	**34**: 121,308	(Airy)	14
SL	1875	*Mon. Not. R. Ast. Soc.*	**35**: 238	(Airy)	10
SM	1876	*Mon. Not. R. Ast. Soc.*	**36**: 97	(Airy)	8
SN	1877	*Mon. Not. R. Ast. Soc.*	**37**: 116	(Airy)	0
SP	1878	*Mon. Not. R. Ast. Soc.*	**38**: 301	(Airy)	2
SQ	1879	*Mon. Not. R. Ast. Soc.*	**39**: 178	(Airy)	8
SR	1880	*Mon. Not. R. Ast. Soc.*	**40**: 150	(Airy)	12
SS	1881	*Mon. Not. R. Ast. Soc.*	**41**: 123	(Airy)	14
ST	1882	*Mon. Not. R. Ast. Soc.*	**43**: 242,286	(Airy)	11
SU	1884	*Mon. Not. R. Ast. Soc.*	**44**: 98	(Airy)	16
SV	1885	*Mon. Not. R. Ast. Soc.*	**45**: 159	(Airy)	18
SW	1886	*Mon. Not. R. Ast. Soc.*	**46**: 139	(Airy)	13
SX	1887	*Mon. Not. R. Ast. Soc.*	**47**: 111	(Airy)	15
SY	1888	*Mon. Not. R. Ast. Soc.*	**48**: 126	(Airy)	5
SZ	1889	*Mon. Not. R. Ast. Soc.*	**49**: 134	(Airy)	4
TA	1890	*Mon. Not. R. Ast. Soc.*	**50**: 120	(Airy)	5
TB	1891	*Mon. Not. R. Ast. Soc.*	**51**: 149	(Airy)	10
TC	1892	*Mon. Not. R. Ast. Soc.*	**52**: 171	(Airy)	11
TD	1893	*Mon. Not. R. Ast. Soc.*	**53**: 138	(Airy)	13
TE	1894	*Mon. Not. R. Ast. Soc.*	**54**: 148	(Airy)	14
TF	1895	*Mon. Not. R. Ast. Soc.*	**55**: 156	(Airy)	9
TG	1896	*Mon. Not. R. Ast. Soc.*	**56**: 139	(Airy)	16
TH	1897	*Mon. Not. R. Ast. Soc.*	**57**: 184	(Airy)	17
TI	1898	*Mon. Not. R. Ast. Soc.*	**58**: 101	(Airy)	3
TJ	1899	*Mon. Not. R. Ast. Soc.*	**59**: 174	(Airy)	3
TK	1902	*Mon. Not. R. Ast. Soc.*	**62**: 214	(Airy)	1
RQ	1912	*Astron. Nachr.*	**196**: 33–36	Amann, M., Rozet, C.	9
RR	1877	*Mon. Not. R. Ast. Soc.*	**37**: 259–260	Arcimis, A.	27
RS	1840	*Astron. Nachr.*	**18**: 135	Argelander, F.	4
FS	1984	*Astron. Astrophys.*	**136**: 142	Arlot, J. *et al.*	584
PK	1948	*Astron. J.*	**54**: 87–88	Ashbrook, J.	17
PL	1949	*Astron. J.*	**55**: 148–149	Ashbrook, J.	24
PM	1953	*Astron. J.*	**58**: 195	Ashbrook, J.	13
EY	1977	*Sky Telesc.*	**53**: 230	Ashbrook, J.	134
EZ	1977	*Sky Telesc.*	**54**: 153	Ashbrook, J.	104
FB	1978	*Sky Telesc.*	**55**: 265	Ashbrook, J.	95
FC	1978	*Sky Telesc.*	**56**: 170	Ashbrook, J.	132
FD	1979	*Sky Telesc.*	**57**: 310	Ashbrook, J.	51
FE	1979	*Sky Telesc.*	**58**: 377	Ashbrook, J.	264
FF	1980	*Sky Telesc.*	**60**: 258	Ashbrook, J.	147
TL	1906	*Astron. J.*	**25**: 46	Baker, R.	29

i

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
TM	1909	*Astron. Nachr.*	**181**: 55	Baranow, W.	8
TN	1886	*Astron. Nachr.*	**114**: 405	Battermann, H.	29
TP	1925	*Astron. Nachr.*	**226**: 251	Battermann, H.	66
ZK	1848	*Mon. Not. R. Ast. Soc.*	**8**: 189	Bayfield, Capt.	10
ZL	1822	*Astron. Nachr.*	**1**: 176,208,302,423,485	Beaufoy, M.	22
ZM	1824	*Astron. Nachr.*	**2**: 90,347,439	Beaufoy, M.	27
ZN	1825	*Astron. Nachr.*	**3**: 173,235	Beaufoy, M.	23
ZP	1826	*Astron. Nachr.*	**4**: 43,171,475	Beaufoy, M.	28
CE	1826	*Mem. Ast. Soc. London*	**2**: 129	Beaufoy, M.	58
ZQ	1827	*Astron. Nachr.*	**5**: 383	Beaufoy, M.	3
CA	1827	*Mem. Ast. Soc. London*	**3**: 75	Beaufoy, M.	11
TR	1871	*Astron. Nachr.*	**77**: 267	Becker, E.	6
FA	1981	*Obs. Astron. Antares*		Beserra, U.	51
ZR	1822	*Astron. Nachr.*	**1**: 217	Bianchi, J.	2
ZS	1832	*Astron. Nachr.*	**10**: 290	Bianchi, J.	16
CI	1734	*Philos. Trans. Abridg.*	**6(I)**: 236	Bianchini, [PT#407]	87
BG	1809	*Philos. Trans. Abridg.*	**6**: 92	Bianchini, [PT#340]	5
BK	1809	*Philos. Trans. Abridg.*	**7**: 165	Bianchini, [PT#396]	7
BC	1901	*An. Célest. 17. Siècle*	*Gauthier-Villars, Paris*	Bigourdan, M. ["Pingré"]	1033
TS	1877	*Mon. Not. R. Ast. Soc.*	**38**: 71	Bixby, W.	5
CZ	1784	*Astron. Jahr. Berlin*	147	Bode, J.[ed] [publ: 1781]	4
DA	1786	*Astron. Jahr. Berlin*	161,173	Bode, J. [publ: 1783]	39
DB	1787	*Astron. Jahr. Berlin*	163	Bode, J. [publ: 1784]	20
DC	1788	*Astron. Jahr. Berlin*	167	Bode, J. [publ: 1785]	6
DD	1789	*Astron. Jahr. Berlin*	129,155,156	Bode, J. [publ: 1786]	58
DE	1790	*Astron. Jahr. Berlin*	147	Bode, J. [publ: 1787]	4
DF	1791	*Astron. Jahr. Berlin*	128,153,179,240	Bode, J. [publ: 1788]	90
DG	1792	*Astron. Jahr. Berlin*	132,250	Bode, J. [publ: 1789]	46
DH	1793	*Astron. Jahr. Berlin*	109,210,231	Bode, J. [publ: 1790]	59
DI	1794	*Astron. Jahr. Berlin*	92,111,139,256	Bode, J. [publ: 1791]	107
DJ	1795	*Astron. Jahr. Berlin*	102,137,204	Bode, J. [publ: 1792]	42
DK	1796	*Astron. Jahr. Berlin*	108,155,212	Bode, J. [publ: 1793]	49
DL	1797	*Astron. Jahr. Berlin*	104,121	Bode, J. [publ: 1794]	28
DM	1798	*Astron. Jahr. Berlin*	127,200	Bode, J. [publ: 1795]	14
DN	1799	*Astron. Jahr. Berlin*	163,182,190,230	Bode, J. [publ: 1796]	67
DP	1800	*Astron. Jahr. Berlin*	229	Bode, J. [publ: 1797]	8
DQ	1801	*Astron. Jahr. Berlin*	99,184	Bode, J. [publ: 1798]	22
DR	1802	*Astron. Jahr. Berlin*	152,213,247	Bode, J. [publ: 1799]	35
DS	1803	*Astron. Jahr. Berlin*	169,173,179,183,196	Bode, J. [publ: 1800]	72
DT	1804	*Astron. Jahr. Berlin*	108,129,158,181	Bode, J. [publ: 1801]	64
DU	1805	*Astron. Jahr. Berlin*	127,159,176	Bode, J. [publ: 1802]	44
DV	1806	*Astron. Jahr. Berlin*	137,143,165	Bode, J. [publ: 1803]	52
DW	1807	*Astron. Jahr. Berlin*	146,171	Bode, J. [publ: 1804]	21
DX	1808	*Astron. Jahr. Berlin*	96,123,127	Bode, J. [publ: 1805]	33
DY	1809	*Astron. Jahr. Berlin*	105,148	Bode, J. [publ: 1806]	11
DZ	1810	*Astron. Jahr. Berlin*	134,170,190	Bode, J. [publ: 1807]	34
EA	1811	*Astron. Jahr. Berlin*	103,109,131,194	Bode, J. [publ: 1808]	43
EB	1812	*Astron. Jahr. Berlin*	104,115,146,216	Bode, J. [publ: 1809]	67
EC	1813	*Astron. Jahr. Berlin*	100,125,166	Bode, J. [publ: 1810]	27
ED	1814	*Astron. Jahr. Berlin*	97,104,126,165	Bode, J. [publ: 1811]	77
EE	1815	*Astron. Jahr. Berlin*	125,133,141,166,173,222	Bode, J. [publ: 1812]	77
EF	1816	*Astron. Jahr. Berlin*	126,129,146,150,162,210	Bode, J. [publ: 1813]	123
EG	1817	*Astron. Jahr. Berlin*	100,141,148,241	Bode, J. [publ: 1814]	52
EH	1818	*Astron. Jahr. Berlin*	118,138,159,214,260	Bode, J. [publ: 1815]	70

ii

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
EI	1819	*Astron. Jahr. Berlin*	102,121,147,175	Bode, J. [publ: 1816]	66
EJ	1820	*Astron. Jahr. Berlin*	99,150,168,194	Bode, J. [publ: 1817]	93
EK	1821	*Astron. Jahr. Berlin*	99,132,156,168,178	Bode, J. [publ: 1818]	33
EL	1822	*Astron. Jahr. Berlin*	114,124,139,169	Bode, J. [publ: 1819]	39
EM	1823	*Astron. Jahr. Berlin*	125,142,147,153,234	Bode, J. [publ: 1820]	42
EN	1824	*Astron. Jahr. Berlin*	139,145,171,199	Bode, J. [publ: 1821]	48
EP	1825	*Astron. Jahr. Berlin*	129,138,178	Bode, J. [publ: 1822]	48
EQ	1826	*Astron. Jahr. Berlin*	104,143,155,174,216	Bode, J. [publ: 1823]	45
ER	1827	*Astron. Jahr. Berlin*	109,115,128,189,198	Bode, J. [publ: 1824]	92
ES	1828	*Astron. Jahr. Berlin*	114,121,137,180,181*	Bode, J. [publ: 1825]	39
ET	1829	*Astron. Jahr. Berlin*	100,147	Bode, J. [publ: 1826]	17
EU	1981	*Personal Commun.*		Bretones, P.	15
CK	1734	*Philos. Trans. Abridg.*	**6(I)**: 241	Carbone, J. [PT#401]	19
CL	1734	*Philos. Trans. Abridg.*	**6(I)**: 244	Carbone, J. [PT#404]	2
BH	1809	*Philos. Trans. Abridg.*	**7**: 55	Carbone, J. [PT#385]	11
BJ	1809	*Philos. Trans. Abridg.*	**7**: 143	Carbone, J. [PT#394]	10
ZT	1831	*Astron. Nachr.*	**9**: 377	Cerquero, J.	30
ZU	1831	*Astron. Nachr.*	**9**: 387	Cerquero, J.	194
CT	1755	*Philos. Trans.*	**48**: 546	Chevalier, J.	2
BS	1809	*Philos. Trans. Abridg.*	**10**: 567	Chevalier, J. [PT **48**: 546]	3
BT	1809	*Philos. Trans. Abridg.*	**11**: 158	Chevalier, J. [PT **50**: 374]	7
RT	1860	*Mon. Not. R. Ast. Soc.*	**20**: 19	(Christy)	10
RU	1860	*Mon. Not. R. Ast. Soc.*	**20**: 85	(Christy)	3
RV	1860	*Mon. Not. R. Ast. Soc.*	**20**: 260	(Christy)	7
RW	1860	*Mon. Not. R. Ast. Soc.*	**20**: 291	(Christy)	4
RX	1861	*Mon. Not. R. Ast. Soc.*	**21**: 166	(Christy)	2
RY	1861	*Mon. Not. R. Ast. Soc.*	**21**: 184	(Christy)	4
RZ	1861	*Mon. Not. R. Ast. Soc.*	**21**: 213	(Christy)	2
SA	1861	*Mon. Not. R. Ast. Soc.*	**21**: 239	(Christy)	2
SB	1862	*Mon. Not. R. Ast. Soc.*	**22**: 50,87,165,238,274,290	(Christy)	9
SC	1863	*Mon. Not. R. Ast. Soc.*	**23**: 195,249	(Christy)	13
SD	1865	*Mon. Not. R. Ast. Soc.*	**26**: 287	(Christy)	11
SE	1866	*Mon. Not. R. Ast. Soc.*	**27**: 82	(Christy)	4
SF	1867	*Mon. Not. R. Ast. Soc.*	**28**: 172	(Christy)	12
CF	1826	*Mem. Ast. Soc. London*	**2**: 285	Colebrooke, R.	40
PN	1921	*Mon. Not. R. Ast. Soc.*	**82**: 58	Cooke, W.	4
FJ	1982	*Personal Commun.*		Correa, O.	7
TU	1875	*Mon. Not. R. Ast. Soc.*	**36**: 41	Crossley, E.	4
PD	1973	*Icarus*	**20**: 7–17	Cruikshank,D., Murphy,R.	16
ZW	1832	*Astron. Nachr.*	**10**: 127,215,297	David, Prof.	25
TV	1884	*Mon. Not. R. Ast. Soc.*	**44**: 270	Davidson, G.	2
CP	1747	*Philos. Trans. Abridg.*	**8(I)**: 180	DeLisle, J. [PT#441]	10
BP	1809	*Philos. Trans. Abridg.*	**7**: 335	DeLisle, J. [PT#407]	40
BB	1978	*Roemer et..vit lumière*	143–157	Debarbat, S. (R. Taton, Ed)	2
EW	1981	*Personal Commun.*		Debarbat, S.	9
FN	1982	*Personal Commun.*		Debarbat, S.	16
CY	?	*Paris Obs. Manuscripts*	**A 5 1–A 5 8**	Delisle Manuscripts	1973
CH	1734	*Philos. Trans. Abridg.*	**6(I)**: 225	Derham, W. [PT#402]	140
TW	1881	*Astron. Nachr.*	**100**: 199	Doberck, W.	13
TX	1890	*Astron. Nachr.*	**124**: 183	Doberck, W.	8
TY	1885	*Astron. Nachr.*	**110**: 375	Doolittle, C.	92
TZ	1915	*Astron. Nachr.*	**202**: 49	Dressler, E.	7
UA	1896	*Astron. Nachr.*	**140**: 361	Dubiago, A.	16
UB	1900	*Astron. Nachr.*	**152**: 379	Dubiago, A.	42

iii

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
UC	1904	*Astron. Nachr.*	**166**: 293	Dubiago, A.	6
UD	1905	*Astron. Nachr.*	**168**: 294	Dubiago, A.	9
PP	1968	*Říše hvězd Roč (Czech)*	**49**: 11–13	Dujnic, M.	21
BE	1803	*Trans. Am. Phil. Soc.*	**6**: 61,113	Ellicott, A.	33
BF	1810	*Trans. Am. Phil. Soc.*	**1**: 93 [*New Ser*]	Ellicott, A.	12
BD	1725	*Hist. Coel. Brit.*	**I**(*2 Ed*): 351–360	Flamsteed, J.	12
PG	1974	*Icarus*	**23**: 431–436	Frans, O., Millis, R.	4
ZX	1826	*Astron. Nachr.*	**3**: 458	Gambart,	27
BR	1809	*Philos. Trans. Abridg.*	**10**: 3	Gaubil, A. [PT#494]	6
UE	1898	*Astron. Nachr.*	**147**: 329	Geelmuyden, H.	9
ZY	1846	*Astron. Nachr.*	**25**: 47	Gerling,	5
UF	1874	*Mon. Not. R. Ast. Soc.*	**35**: 98	Gledhill, J.	12
UG	1880	*Mon. Not. R. Ast. Soc.*	**40**: 287	Gledhill, J.	5
UH	1881	*Mon. Not. R. Ast. Soc.*	**41**: 283	Gledhill, J.	15
UI	1882	*Mon. Not. R. Ast. Soc.*	**42**: 425	Gledhill, J.	6
UJ	1883	*Mon. Not. R. Ast. Soc.*	**43**: 448	Gledhill, J.	10
UK	1885	*Mon. Not. R. Ast. Soc.*	**45**: 166	Gledhill, J.	18
UL	1886	*Mon. Not. R. Ast. Soc.*	**46**: 150	Gledhill, J.	7
UM	1891	*Mon. Not. R. Ast. Soc.*	**51**: 358	Gledhill, J.	7
UN	1892	*Mon. Not. R. Ast. Soc.*	**52**: 159	Gledhill, J.	12
UP	1893	*Mon. Not. R. Ast. Soc.*	**53**: 144	Gledhill, J.	12
UQ	1894	*Mon. Not. R. Ast. Soc.*	**54**: 443	Gledhill, J.	18
UR	1895	*Mon. Not. R. Ast. Soc.*	**55**: 391	Gledhill, J.	18
US	1896	*Mon. Not. R. Ast. Soc.*	**56**: 489	Gledhill, J.	20
UT	1897	*Mon. Not. R. Ast. Soc.*	**57**: 653	Gledhill, J.	2
UU	1898	*Mon. Not. R. Ast. Soc.*	**58**: 506	Gledhill, J.	6
CB	1827	*Mem. Ast. Soc. London*	**3**: 106	Goldingham, J.	90
UW	1883	*Mon. Not. R. Ast. Soc.*	**43**: 115	Goldney, G.	9
UX	1920	*Astron. Nachr.*	**212**: 165	Graff, K.	4
PC	1971	*Boeing Research Lab.*	**D180**–14193–1	Greene, T. *et al.*	5
UY	1915	*J. des Obs.*	**5**: 35	Guillaume, J.	49
PQ	1922	*J. des Obs.*	**5**: 63–67	Guillaume, J.	94
ZZ	1846	*Astron. Nachr.*	**24**: 130	Hackel,	4
PT	1930	*Astron. J.*	**40**: 119–120	Hall, A. *et al.*	29
PR	1922	*Astron. J.*	**34**: 30	Hall, A., Bower, E.	9
PS	1923	*Astron. J.*	**35**: 107	Hall, A., Bower, E.	9
AA	1825	*Astron. Nachr.*	**4**: 143,360	Hallaschka,	23
AB	1827	*Astron. Nachr.*	**5**: 137,469	Hallaschka,	5
AC	1829	*Astron. Nachr.*	**7**: 191,351	Hallaschka,	7
AD	1830	*Astron. Nachr.*	**8**: 62,359	Hallaschka,	7
AE	1832	*Astron. Nachr.*	**10**: 63	Hallaschka,	2
PB	1961	*Planets and Satellites*	**3**: 328	Harris, D. (Kuiper, Ed)	8
PU	1955	*Astron. J.*	**60**: 115–117	Hasegawa, I.	77
PV	1975	*Personal Commun.*		Hasegawa, I.	53
CV	1771	*Philos. Trans.*	**60**: 502	Heberden, T.	24
CG	1826	*Mem. Ast. Soc. London*	**2**: 288	Hodgson, J.	24
BZ	1826	*Mem. Ast. Soc. London*	**2**: 439	Hodgson, J.	19
CC	1829	*Mem. Ast. Soc. London*	**3**: 344	Hodgson, J.	98
UZ	1857	*Astron. Nachr.*	**45**: 217	Hoek, M.	7
VA	1879	*Astron. Nachr.*	**95**: 151	Holetschek, J.	11
BX	1809	*Philos. Trans. Abridg.*	**13**: 526	Holland, S. [PT **64**: 171]	28
AZ	1741	*Operum Math.-Phys.*	*Works* **III**	Horrebow, P.	80
AF	1834	*Astron. Nachr.*	**11**: 379	Hussey, T.	10
RG	1909	*Mon. Not. R. Ast. Soc.*	**69**: 512–539	Innes, R.	12

iv

1986A&A...154...61L

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
RH	1909	*Mon. Not. R. Ast. Soc.*	**70**: 28–47	Innes, R.	18
RI	1910	*Transvaal Obs. Circ.*	**5**: 49	Innes, R.	60
RJ	1911	*Transvaal Obs. Circ.*	**12**: 103	Innes, R.	39
RP	1920	*Union Obs. Circ.*	**50**: 67	Innes, R.	66
RK	1912	*Union Obs. Circ.*	**3**: 23	Innes, R., Wood, H.	33
RL	1913	*Union Obs. Circ.*	**12**: 87	Innes, R., Wood, H.	47
RM	1915	*Union Obs. Circ.*	**23**: 177	Innes, R., Wood, H.	31
RN	1916	*Union Obs. Circ.*	**34**: 261	Innes, R., Wood, H.	41
QY	1922	*Union Obs. Circ.*	**55**: 140–146	Innes, R., Wood, H.	112
QZ	1922	*Union Obs. Circ.*	**56**: 162–163	Innes, R., Wood, H.	32
RA	1925	*Union Obs. Circ.*	**64**: 299–300	Innes, R., Wood, H.	17
RB	1926	*Union Obs. Circ.*	**67**: 334–335	Innes, R., Wood, H.	28
RC	1926	*Union Obs. Circ.*	**72**: 400–404	Innes, R., Wood, H.	25
PX	1934	*Astron. Nachr.*	**252**: 81–84	Jaschek, W.	2
QW	1934	*Astron. Nachr.*	**258**: 389–390	Jaschek, W.	3
CQ	1747	*Philos. Trans. Abridg.*	**8(I)**: 183	“Jesuits” [PT#468]	47
BN	1809	*Philos. Trans. Abridg.*	**7**: 274	“Jesuits” [PT#405]	16
VB	1881	*Mon. Not. R. Ast. Soc.*	**41**: 281	Johnson, S.	13
VC	1893	*Mon. Not. R. Ast. Soc.*	**53**: 449	Johnson, S.	12
VD	1869	*Mon. Not. R. Ast. Soc.*	**29**: 171	Joynson, J.	11
VE	1864	*Astron. Nachr.*	**61**: 270	Kaiser, F.	69
VF	1864	*Astron. Nachr.*	**63**: 153	Kaiser, F.	6
VG	1869	*Astron. Nachr.*	**73**: 297	Kaiser, F.	14
RD	1961	*Astron. Circ., Russian*	**218**: 22	Kalinkov, M.	8
TQ	1916	*Harvard Annals*	**80**: 153–190	King, E.	220
CM	1734	*Philos. Trans. Abridg.*	**6(I)**: 246	Koegler, I. [PT#416,420,424]	161
BM	1809	*Philos. Trans. Abridg.*	**7**: 273	Koegler, I. [PT#405]	21
RE	1955	*Astron. Circ., Russian*	**163**: 10–11	Kosik, C.	18
RF	1956	*Astron. Circ., Russian*	**173**: 7–8	Kosik, C.	28
VH	1886	*Astron. Nachr.*	**115**: 261	Lakits, F.	5
AG	1826	*Astron. Nachr.*	**5**: 251	Lang, A.	2
AH	1833	*Astron. Nachr.*	**10**: 263	Lang, A.	16
EV	1981	*Personal Commun.*		Loader, B.	39
FP	1982	*Personal Commun.*		Loader, B.	47
FU	1984	*Personal Commun.*		Loader, B.	80
WN	1875	*Mon. Not. R. Ast. Soc.*	**35**: 391	Lucas,	5
CJ	1734	*Philos. Trans. Abridg.*	**6(I)**: 240,**8**: 180	Lynn, G. [PT#393,440]	22
PY	1972	*Contr. Obs. Volongo*	**II**: Nr. 10–14	Machado, L.	41
VI	1872	*Mon. Not. R. Ast. Soc.*	**32**: 311	Main,	11
VJ	1873	*Mon. Not. R. Ast. Soc.*	**33**: 488	Main,	18
VK	1874	*Mon. Not. R. Ast. Soc.*	**34**: 417	Main,	8
VL	1877	*Mon. Not. R. Ast. Soc.*	**37**: 344	Main,	6
CN	1747	*Philos. Trans. Abridg.*	**8(I)**: 179	Manfredi, E. [PT#429]	14
BL	1809	*Philos. Trans. Abridg.*	**7**: 265	Manfredi, E. [PT#404]	11
CU	1770	*Philos. Trans.*	**59**: 399	Maskelyne, N.	4
CW	1774	*Philos. Trans.*	**64**: 184	Maskelyne, N.	16
BW	1809	*Philos. Trans. Abridg.*	**12**: 671	Maskelyne, N. [PT 59: ..]	15
BA	1915	*K. Danske Viden. Sels.*	*7 Raek.,Afd.* **12**: 106	Mayer, K.	3
FL	1982	*Aust. Planetary Obser.*		McNamara, G.	71
FT	1984	*Iris [NAPO Australia]*	**2**: Nr. 2	McNamara, G.	112
VM	1881	*Astron. Nachr.*	**101**: 135	Meyer, M.	8
PF	1974	*Icarus*	**23**: 425–430	Millis, R. *et al.*	15
PE	1974	*Personal Commun.*		Millis, R., Lockwood, G.	11
BQ	1809	*Philos. Trans. Abridg.*	**7**: 418	“Missionaries” [PT#414]	47

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
PW	1959	*Mem. Jpn. Astr. Assoc.*	**2**: 57–62	Mitani, T.	82
VN	1886	*Astron. Nachr.*	**114**: 139	Morize, H.	12
VP	1879	*Astron. Nachr.*	**94**: 131	Niesten, L.	7
VQ	1895	*Astron. Nachr.*	**138**: 317	Nijland, A.	3
VR	1896	*Astron. Nachr.*	**141**: 413	Nijland, A.	14
WU	1896	*Astron. Nachr.*	**141**: 413	Nijland, A.	0
VT	1898	*Astron. Nachr.*	**146**: 73	Nijland, A.	11
VU	1900	*Astron. Nachr.*	**152**: 193	Nijland, A.	17
VV	1901	*Astron. Nachr.*	**156**: 203	Nijland, A.	2
VW	1904	*Astron. Nachr.*	**166**: 139	Nijland, A.	7
VX	1905	*Astron. Nachr.*	**169**: 203	Nijland, A.	13
VY	1855	*Astron. Nachr.*	**39**: 219	Oudemans, J.	5
VZ	1855	*Astron. Nachr.*	**42**: 162	Oudemans, J.	7
WA	1856	*Astron. Nachr.*	**43**: Nr. 1015	Oudemans, J.	5
FK	1982	*Personal Commun.*		Owen, W.	4
PZ	1922	*Astron. Nachr.*	**217**: 30–32	Palisa, J.	21
WB	1873	*Mon. Not. R. Ast. Soc.*	**33**: 426	Perry, S.	12
WC	1874	*Mon. Not. R. Ast. Soc.*	**34**: 413	Perry, S.	8
WD	1877	*Mon. Not. R. Ast. Soc.*	**38**: 72	Perry, S.	7
WE	1879	*Mon. Not. R. Ast. Soc.*	**39**: 177	Perry, S.	3
WF	1881	*Mon. Not. R. Ast. Soc.*	**41**: 134	Perry, S.	11
WG	1882	*Mon. Not. R. Ast. Soc.*	**42**: 122	Perry, S.	13
WH	1882	*Mon. Not. R. Ast. Soc.*	**43**: 282	Perry, S.	8
WI	1884	*Mon. Not. R. Ast. Soc.*	**44**: 263	Perry, S.	15
WJ	1885	*Mon. Not. R. Ast. Soc.*	**45**: 345	Perry, S.	7
WK	1886	*Mon. Not. R. Ast. Soc.*	**46**: 315	Perry, S.	6
WL	1888	*Mon. Not. R. Ast. Soc.*	**49**: 35	Perry, S.	13
AI	1837	*Astron. Nachr.*	**18**: 77	Petersen,	2
PA	1907	*Harvard Annals*	**52**: *Part 1*, 1–148	Pickering, E.	665
WM	1882	*Mon. Not. R. Ast. Soc.*	**42**: 113	Pogson, N.	66
WP	1897	*Astron. Nachr.*	**144**: 141	Ristenpart, F.	2
QA	1944	*J. des Obs.*	**27**: 25–27	Rougier, G.	11
AM	1823	*Astron. Nachr.*	**1**: 313, **4**: 107	Ruemker,	5
AY	1910	*Mem. R. Astron. Soc.*	**59**: 26	Sampson, R. [“Delambre”]	1505
CR	1756	*Philos. Trans. Abridg.*	**10(I)**: 121	Sarmento, J. deC. [PT#490]	24
QB	1923	*J. des Obs.*	**4**: 74	Schaumasse, A.	12
QC	1923	*J. des Obs.*	**6**: 23	Schaumasse, A.	6
QD	1924	*J. des Obs.*	**7**: 84	Schaumasse, A.	6
QE	1934	*Astron. Nachr.*	**256**: 29–32	Schembor, F.	4
QF	1936	*Astron. Nachr.*	**259**: 253–258	Schembor, F.	7
QG	1936	*Astron. Nachr.*	**262**: 455–458	Schembor, F.	6
QH	1937	*Astron. Nachr.*	**266**: 133–138	Schembor, F.	1
QI	1938	*Astron. Nachr.*	**268**: 259–268	Schembor, F.	0
WQ	1856	*Astron. Nachr.*	**43**: 53	Schmidt, J.	7
WR	1858	*Astron. Nachr.*	**48**: 183	Schmidt, J.	13
WS	1850	*Astron. Nachr.*	**31**: 249	Schoenfeld, E.	7
AN	1837	*Astron. Nachr.*	**19**: 323	Schumacher, R.	68
AP	1848	*Astron. Nachr.*	**27**: 52	Schumacher, R.	44
AQ	1851	*Astron. Nachr.*	**31**: 49	Schumacher, R.	50
AR	1851	*Astron. Nachr.*	**31**: 381	Schumacher, R.	10
QX	1886	*Astron. Nachr.*	**114**: 133–134	Schur, W.	8
VS	1896	*Astron. Nachr.*	**141**: 413	Schur, W.	11
WT	1896	*Astron. Nachr.*	**141**: 413	Schur, W.	1
AS	1826	*Astron. Nachr.*	**4**: 59,489	Schwarzenbrunner, B.	9

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
AT	1833	*Astron. Nachr.*	**10**: 119	Schwarzenbrunner, B.	4
CD	1829	*Mem. Ast. Soc. London*	**3**: 368	Slawinski, M.	8
CS	1822	*Quart. J. Sci., London*		South, J.	4
WV	1882	*Mon. Not. R. Ast. Soc.*	**42**: 245	Stone, E.	6
WX	1883	*Mon. Not. R. Ast. Soc.*	**43**: 437	Stone, E.	22
WY	1884	*Mon. Not. R. Ast. Soc.*	**44**: 419	Stone, E.	9
WZ	1886	*Astron. Nachr.*	**115**: 299	Stuyvaert, E.	18
XA	1888	*Astron. Nachr.*	**119**: 75	Stuyvaert, E.	10
XB	1897	*Astron. Nachr.*	**143**: 301	Stuyvaert, E.	22
XC	1862	*Mon. Not. R. Ast. Soc.*	**22**: 287	Talmage, C.	4
XD	1885	*Astron. Nachr.*	**113**: 57	Tatlock, J.	14
XE	1867	*Mon. Not. R. Ast. Soc.*	**28**: 215	Tebbutt, J. [A.N.**71**: 169]	39
XF	1871	*Mon. Not. R. Ast. Soc.*	**32**: 61	Tebbutt, J. [A.N.**78**: 377]	10
XG	1874	*Mon. Not. R. Ast. Soc.*	**34**: 421	Tebbutt, J. [A.N.**86**: 11]	28
XH	1875	*Mon. Not. R. Ast. Soc.*	**36**: 100	Tebbutt, J.	14
XI	1876	*Astron. Nachr.*	**89**: 57	Tebbutt, J.	17
XJ	1878	*Astron. Nachr.*	**92**: 75	Tebbutt, J.	8
XK	1879	*Astron. Nachr.*	**95**: 119	Tebbutt, J.	26
XL	1880	*Astron. Nachr.*	**97**: 37	Tebbutt, J.	22
XM	1883	*Astron. Nachr.*	**106**: 323	Tebbutt, J.	18
XN	1886	*Astron. Nachr.*	**113**: 387	Tebbutt, J.	15
XP	1886	*Mon. Not. R. Ast. Soc.*	**47**: 30	Tebbutt, J.	23
XQ	1888	*Mon. Not. R. Ast. Soc.*	**48**: 129	Tebbutt, J.	24
XR	1889	*Mon. Not. R. Ast. Soc.*	**49**: 329	Tebbutt, J.	28
XS	1890	*Mon. Not. R. Ast. Soc.*	**50**: 335	Tebbutt, J.	8
XT	1891	*Mon. Not. R. Ast. Soc.*	**51**: 420	Tebbutt, J.	19
XU	1892	*Mon. Not. R. Ast. Soc.*	**52**: 598	Tebbutt, J.	9
XV	1893	*Mon. Not. R. Ast. Soc.*	**54**: 32	Tebbutt, J.	3
XW	1895	*Mon. Not. R. Ast. Soc.*	**55**: 517	Tebbutt, J.	13
XX	1896	*Mon. Not. R. Ast. Soc.*	**57**: 26	Tebbutt, J.	16
XY	1898	*Mon. Not. R. Ast. Soc.*	**58**: 464	Tebbutt, J.	11
XZ	1900	*Mon. Not. R. Ast. Soc.*	**59**: 620	Tebbutt, J.	11
YA	1905	*Mon. Not. R. Ast. Soc.*	**66**: 14	Tebbutt, J.	15
YB	1875	*Astron. Nachr.*	**83**: 265	Tisserand, M.	22
YC	1875	*Astron. Nachr.*	**87**: 59	Tisserand, M.	35
YD	1877	*Mon. Not. R. Ast. Soc.*	**37**: 284	Todd, C.	21
YE	1878	*Mon. Not. R. Ast. Soc.*	**39**: 2	Todd, C.	17
YF	1880	*Mon. Not. R. Ast. Soc.*	**40**: 170	Todd, C.	12
YG	1886	*Mon. Not. R. Ast. Soc.*	**46**: 353	Todd, C.	19
YH	1875	*Astron. Nachr.*	**85**: 155	Todd, D.	18
YI	1877	*Astron. Nachr.*	**89**: 297	Todd, D.	48
YJ	1878	*Astron. Nachr.*	**92**: 43	Todd, D.	32
YK	1879	*Astron. Nachr.*	**94**: 379	Todd, D.	28
YL	1879	*Astron. Nachr.*	**95**: 201	Todd, D.	16
YM	1880	*Astron. Nachr.*	**96**: 347	Todd, D.	35
QJ	1933	*Astron. Nachr.*	**259**: 397–398	Tscherny, S.	2
QK	1921	*Astron. J.*	**33**: 202	Van Biesbroeck, G.	8
QM	1926	*Astron. Nachr.*	**229**: 31–32	Vocca, P.	2
QN	1927	*Astron. Nachr.*	**233**: 263–264	Vocca, P.	1
QP	1928	*Astron. Nachr.*	**235**: 105–106	Vocca, P.	0
QR	1929	*Astron. Nachr.*	**235**: 175–176	Vocca, P.	4
QS	1929	*Astron. Nachr.*	**235**: 315–316	Vocca, P.	3
QT	1929	*Astron. Nachr.*	**236**: 13–14	Vocca, P.	3
QU	1929	*Astron. Nachr.*	**236**: 163–164	Vocca, P.	1

Table 1. Continued

Index	Year	Journal	Volume	Author	No. Obs.
CX	1777	*Philos. Trans.*	**67**: 162	Wargentin, P.	464
BU	1809	*Philos. Trans. Abridg.*	**12**: 352	Wargentin, P. [PT **56**: 278]	46
YN	1884	*Astron. Nachr.*	**107**: 221	Weinek, L.	2
YP	1884	*Astron. Nachr.*	**107**: 336	Weinek, L.	3
YQ	1885	*Astron. Nachr.*	**110**: 233	Weinek, L.	14
YR	1886	*Astron. Nachr.*	**114**: 409	Weinek, L.	23
YS	1888	*Astron. Nachr.*	**119**: 210	Weinek, L.	28
YT	1906	*Astron. Nachr.*	**172**: 260	Weinek, L.	18
YU	1907	*Astron. Nachr.*	**175**: 297	Weinek, L.	15
FM	1982	*Assoc. Lun. Plan. Obs.*		Westfall, J.	32
FQ	1983	*Assoc. Lun. Plan. Obs.*		Westfall, J.	122
EX	1981	*Personal Commun.*		Wieth-Knudsen, N.	143
FR	1982	*Personal Commun.*		Wieth-Knudsen, N.	15
YV	1897	*Astron. Nachr.*	**144**: 281	Wilhelm, A.	8
BV	1809	*Philos. Trans. Abridg.*	**12**: 670	Wilson, [PT **59**: 402]	12
YW	1881	*Astron. Nachr.*	**99**: 197	Winkler, W.	11
YX	1884	*Astron. Nachr.*	**108**: 243	Winkler, W.	20
YY	1887	*Astron. Nachr.*	**117**: 5	Winkler, W.	7
YZ	1893	*Astron. Nachr.*	**134**: 15	Winkler, W.	12
ZA	1895	*Astron. Nachr.*	**138**: 13	Winkler, W.	15
ZB	1896	*Astron. Nachr.*	**140**: 267	Winkler, W.	8
ZC	1897	*Astron. Nachr.*	**143**: 95	Winkler, W.	7
ZD	1898	*Astron. Nachr.*	**146**: 293	Winkler, W.	3
ZE	1899	*Astron. Nachr.*	**148**: 251	Winkler, W.	5
ZF	1875	*Astron. Nachr.*	**86**: 146	Winnecke, A.	25
ZG	1876	*Astron. Nachr.*	**88**: 308	Winnecke, A.	5
ZH	1878	*Astron. Nachr.*	**91**: 349	Winnecke, A.	8
ZI	1878	*Astron. Nachr.*	**93**: 341	Winnecke, A.	24
ZJ	1880	*Astron. Nachr.*	**96**: 371	Winnecke, A.	16
QV	1926	*Bull. Ast. Inst. Neth.*	**4**: 15	Witlox, A.	13
BY	1809	*Philos. Trans. Abridg.*	**13**: 528	Wright, T. [PT **64**: 190]	17
ZV	1849	*Astron. Nachr.*	**28**: 363	d’Arrest, H.	7
UV	1885	*Astron. Nachr.*	**110**: 267	de Glasenapp, S.	13
AU	1835	*Astron. Nachr.*	**16**: 313	de Slavinski, P.	4
AV	1836	*Astron. Nachr.*	**17**: 247	de Slavinski, P.	9
AW	1837	*Astron. Nachr.*	**19**: 235	de Slavinski, P.	5
AX	1838	*Astron. Nachr.*	**20**: 269	de Slavinski, P.	4
QL	1927	*Bull. Ast. Inst. Neth.*	**3**: 265–272	van der Bilt, J. *et al.*	26
TT	1896	*Astron. Nachr.*	**141**: 119	von Boinik, B.	2

Table 2. Observation sites (sorted by location)

Index	Longitude		Location	Country	Comments	No. Obs.
PY	22.28	E	Åbo	Finland	[Turku]	3
BV	94.03	W	Adel, Iowa	USA		3
NW	138.58	E	Adelaide, S. Aust.	Australia		71
UF	78.00	E	Agra	India		4
CW	105.95	W	Alamogordo, N. Mex.	USA		16
TN	12.67	E	Albano	Italy	(Lasiale)	12
TK	36.08	E	Alexandrette	Turkey	[İskenderun]	3
SX	29.54	E	Alexandria	Egypt		7
YW	77.10	W	Alexandria, Va.	USA		3
XY	151.17	E	Allawah, N.S.W.	Australia	near Sydney	48
YP	75.50	W	Allentown, Pa.	USA		12
CV	81.40	W	Altamonte Spr., Fla.	USA		13
PK	9.94	E	Altona	Germany		176
MQ	72.52	W	Amherst, Mass.	USA		93
PZ	4.89	E	Amsterdam	Netherlands		22
WS	13.52	E	Ancona	Italy		1
SE	7.07	E	Antibes	France		2
CX	4.42	E	Antwerpen	Belgium		1
MK	2.34	E	Aoste, Obs. d'	Italy		9
WV	40.67	E	Archangel	USSR	[Arkhangel'sk]	2
YS	77.18	W	Arlington, Va.	USA		22
UP	12.62	E	Assisi	Italy		1
YX	82.10	W	Athens, Ohio	USA		2
VN	3.90	E	Aubenas	France	[Viverois]	19
RS	4.49	E	Avignon	France		2
ZE	63.58	W	Avonport	Nova Scotia	?near Halifax?	1
XI	12.13	E	Bäckefors	Sweden		1
ZW	83.28	W	Bainbridge, Ohio	USA		3
QA	59.62	W	Barbados	Barbados		18
TC	2.11	E	Barcelona	Spain		5
DC	153.	E	Bardon, Queensland	Australia		13
UD	78.12	E	Barkot	India	?	6
AM	117.02	W	Barstow, Ca.	USA		13
BW	95.98	W	Bartlesville, Okla.	USA		4
WD	0.70	W	Bayeux	France		8
RW	1.29	W	Bayonne	France		4
PN	0.29	W	Bedford	England		15
YI	63.68	W	Bedford	Nova Scotia		3
NU	89.03	W	Beloit, Wisc.	USA		14
AQ	?	W	Belvidere, Tenn.	USA		4
VM	5.33	E	Bergen	Norway		14
ZI	74.02	W	Bergenfield, N.J.	USA		2
MS	13.42	E	Berlin	Germany	[Wm. Förster]	507
PM	0.17	W	Biggleswade	England		26
YV	8.43	E	Birmenstorf	Switzerland		55
AT	1.83	W	Birmingham	England		3
ZX	86.92	W	Birmingham, Ala.	USA		3
XX	173.97	E	Blenheim	New Zealand		99
QB	11.35	E	Bologna	Italy		172
TM	11.59	E	Bolsena	Italy		1
MM	7.10	E	Bonn	Germany		6
LZ	0.53	W	Bordeaux	France		11
TG	2.40	E	Bourges	France		3
YN	76.77	W	Bowie, Md.	USA		12

i

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
AN	10.13	E	Brabrand	Denmark		7
QC	17.04	E	Breslau	(Poland)	[Wrocław, Poland]	55
RT	4.29	W	Brest	France		5
NH	2.46	W	Bridgeport	England		12
CP	153.00	E	Brisbane, Queensland	Australia		14
BF	95.78	W	Broken Arrow, Okla.	USA		11
VV	16.67	E	Brünn	Czechoslovakia	[Brno]	3
NN	4.36	E	Brussels	Belgium		57
VW	14.71	E	Buchholz	Germany	?bei Drossen?	14
QD	19.05	E	Buda	Hungary	[Budapest]	111
NJ	18.96	E	Budapest	Hungary		5
WB	14.50	E	Budweis	Czechoslovakia	[České Budějovice]	2
WA	58.50	W	Buenos Aires	Argentina		2
DF	152.35	E	Bundaberg, Q'land	Australia		42
PB	0.34	W	Bushey Heath	England	near Stanmore	172
DD	152.	E	Cabramatta, N.S.W.	Australia		4
ML	6.30	W	Cádiz	Spain		28
TJ	9.08	E	Cagliari	Sardinia		1
SY	31.28	E	Cairo	Egypt	(LeCairé)	4
VG	1.87	E	Calais	France		1
UK	88.21	E	Calcutta	India		31
BS	81.85	W	Callahan, Fla.	USA		3
PQ	0.09	E	Cambridge	England		6
LA	71.13	W	Cambridge, Mass.	USA	Harvard Obs.	885
XV	47.04	W	Campinas	Brasil	Obs. Astr. Orion	18
WN	25.13	E	Candia	Crete	[Iráklion]	1
WH	24.02	E	Canea	Crete	[Khaniá]	2
SS	113.16	E	Canton	China	[Guangzhou]	9
XP	69.90	W	Cape Francis	Dominican Rep.	[Cabrera]	2
PS	18.47	E	Cape of Good Hope	South Africa		59
WZ	75.55	W	Cartagena	Colombia		22
WL	78.75	W	Cayos de Ana Maria	Cuba		2
RP	4.25	E	Cette	France	[Celles (Aube)]	3
QE	88.37	E	Chandernager	India	[Chandannagar]	9
PA	63.12	W	Charlotte Town	Prince Edward Isl.		11
YZ	87.75	W	Chicago, Ill.	USA	(Palos Hills, Worth)	38
VE	0.05	E	Chislehurst	England		12
UL	88.38	E	Chouringhy	India	near Calcutta	64
DG	172.67	E	Christchurch	New Zealand		9
NC	10.72	E	Christiania	Norway	[Oslo]	18
BG	81.87	W	Clinton, S. C.	USA		1
BE	82.30	W	Clyde, Ohio	USA		2
AW	83.05	W	Columbus, Ohio	USA		1
XT	73.05	W	Concepción	Chile		9
WU	28.58	E	Constantinople	Turkey	[İstanbul]	2
CQ	148.05	E	Cootamundra, N.S.W.	Australia		15
LN	12.56	E	Copenhagen	Denmark	(Hatniensi, Hauniae)	229
XU	71.42	W	Coquimbo	Chile		3
WR	12.60	E	Coriano	Italy		3
TH	2.22	E	Croc en Auvergne	France	[Crocq]	1
QG	18.67	E	Danzig	(Poland)	[Gdańsk, Poland]	14
XQ	88.17	W	Dauphin Isl., Ala.	USA		1
UA	78.03	E	Dehrah	India	[Dehra Dun]	7
UH	77.14	E	Delhi	India		4

ii

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
YR	105.00	W	Denver, Colo.	USA	Louisville, Lakewood	16
RN	1.29	W	Derby	England		2
ZS	95.58	W	Des Moines, Iowa	USA		5
SB	1.08	E	Dieppe	France		3
VU	26.73	E	Dorpat	(USSR)	[Tartu, Estonia]	13
QH	13.74	E	Dresden	Germany		25
RY	2.22	E	Dunkirk	France		4
NE	1.58	W	Durham	Scotland		9
ZQ	78.90	W	Durham, N. C.	USA		7
PT	3.18	W	Edinburgh	Scotland		18
BQ	113.42	W	Edmonton, Alberta	Canada		6
CL	138.60	E	Edwardstown, S.Aust.	Australia		27
ZD	114.88	W	Ely, Nevada	USA		1
XZ	151.03	E	Engadine, N.S.W.	Australia	SW of Sydney	17
SV	41.17	E	Erzeroum	Turkey	[Erzurum]	0
YJ	124.17	W	Eureka, Ca.	USA		1
BR	3.52	W	Exeter	England		3
AX	13.10	E	Falkensee	Germany	-Finkenkrug	26
VZ	38.96	W	Feira de Santana	Brasil	Obs. Astr. Antares	51
LE	111.66	W	Flagstaff, Ariz.	USA	Lowell Obs.	14
TA	11.26	E	Florence	Italy	[Firenze]	6
LB	104.02	W	Fort Davis, Tex.	USA	McDonald Obs.	8
BU	97.33	W	Fort Worth, Tex.	USA		1
VI	10.92	E	Fredrikstad	Norway	(Frederikstein)	11
UX	16.92	W	Funchal	Madeira Isl.		18
TW	79.38	E	Futty Ghur	India	[Fatehgarh]	19
CF	?	E	Galliera	Italy		12
YT	96.62	W	Garland, Tex.	USA		20
TS	64.30	W	Gaspee, Quebec	Canada	[Gaspé]	9
WQ	8.93	E	Genes	Italy	[Genova]	16
NL	6.15	E	Geneva	Switzerland		22
AE	77.27	W	Gettysburg, Pa.	USA		1
TP	4.15	W	Glasgow	Scotland		12
NG	2.23	W	Gloucester	England	(Abbenhall Rectory)	13
XH	12.00	E	Göteborg	Sweden	(Gothenburg)	1
NM	9.94	E	Göttingen	Germany		13
NY	12.37	E	Gohlis	Germany	bei Leipzig	38
SC	16.40	E	Gorée	Chad		2
QI	10.71	E	Gotha	Germany		1
QJ	51.58	W	Gothaab	Greenland		17
AP	93.42	W	Green Forest, Ark.	USA		24
AR	79.83	W	Greensboro, N. C.	USA		3
MN	0.00		Greenwich	England		980
AL	121.70	W	Gridley, Ca.	USA		23
SD	61.35	W	Guadeloupe	Guadeloupe		1
CZ	148.08	E	Gundagai, N.S.W.	Australia		3
DB	152.	E	Gymea, N.S.W.	Australia		2
MX	63.35	W	Halifax	Nova Scotia	(Bermerside Obs.)	172
NF	10.24	E	Hamburg	Germany	Bergedorf	11
BZ	86.97	W	Hartselle, Ala.	USA		2
VR	82.42	W	Havana	Cuba		7
CJ	98.72	W	Helotes, Tex.	USA		3
BH	25.00	E	Helsinki	Finland		12
CR	5.17	E	Herk-de-Stad	Belgium		7

iii

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
UG	75.75	E	Hisar	India	(Haryana)	6
SQ	119.11	E	Hoai-Ngan	China	[Hwaian (Kiangsu)]	27
NA	114.17	E	Hong Kong	Hong Kong		8
VK	6.13	E	Hyer	France	[Hyères]	8
QK	11.42	E	Ingolstadt	Germany	(Bibourg)	100
WY	11.42	E	Innsbruck	Austria		7
SH	0.06	W	Islington	England		3
NZ	11.59	E	Jena	Germany		50
LY	28.08	E	Johannesburg	South Africa		498
YB	12.92	E	Karl-Marx-Stadt	Germany		4
NR	8.40	E	Karlsruhe	Germany		2
WP	9.50	E	Kassel	Germany		36
TY	85.19	E	Katmandu	Nepal	[Kathmandu]	8
MR	48.82	E	Kazan, RSFSR	USSR	Engelhardt Obs.	81
BY	119.13	W	Kennewick, Wash.	USA		7
PI	0.01	E	Kent	England		10
AG	74.20	W	Keyport, N. J.	USA		15
MI	36.23	E	Khar'kov	USSR	Ukrainian SSR	8
SL	111.27	E	Kiang-Chen	China	[Kianghsien]	9
MB	30.50	E	Kiev	USSR	[Kiyev] Ukrainian SSR	2
TT	70.42	W	Kittery Point, Me.	USA		3
MT	20.50	E	Königsberg	(Prussia)	[Kaliningrad, USSR]	73
UE	77.29	E	Kotgarh	India		3
QF	19.96	E	Kraków	Poland		113
PW	14.13	E	Kremsmünster	Austria		50
CU	3.53	E	Kruishouten	Belgium		1
DH	175.75	E	Kuaotunu	New Zealand		13
LU	135.79	E	Kyōto	Japan	Kwasan Obs.	82
YE	4.49	E	La Barbanche	France	(St. Étienne)	1
RV	0.05	W	La Fleche	France		3
XM	16.32	W	La Laguna, Tenerife	Canary Islands		4
LG	70.81	W	La Serena	Chile	(Cerro Tololo Obs.)	6
CE	25.67	E	Lahti	Finland		13
QL	21.98	W	Lambhuus	Iceland		36
VF	76.30	W	Lancaster, Pa.	USA		45
LM	12.10	E	Langenwetzendorf	Germany		17
ZL	115.17	W	Las Vegas, Nev.	USA		4
CT	113.50	W	Leduc, Alberta	Canada		2
AZ	1.58	W	Leeds	England		8
MU	4.48	E	Leiden	Netherlands		124
PE	12.39	E	Leipzig	Germany		18
MF	107.38	E	Lembang	Indonesia		13
XE	73.77	W	Les Cayes	Haiti		7
WC	5.58	E	Liège	Belgium		3
QM	8.91	E	Lilienthal	Germany		21
VY	77.05	W	Lima	Peru		10
TD	9.13	W	Lisbon	Portugal		61
YK	121.77	W	Livermore, Ca.	USA	(Fremont, Dublin)	13
NI	3.07	W	Liverpool	England		13
RR	0.17	W	London	England		8
AH	105.10	W	Longmont, Colo.	USA		14
XD	16.53	W	Loratava	Canary Islands	La Orotava, Tenerife	2
ZU	118.25	W	Los Angeles, Ca.	USA	Van Nuys, Northridge	102
UZ	59.93	W	Louisburg	Nova Scotia	Cape Breton Island	9

iv

1986A&A...154...61L

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
SI	100.31	*E*	Louveau	Siam	[Bangkok, Thailand]	14
WT	1.18	*E*	Louviers	France		1
QN	13.19	*E*	Lund	Sweden		23
QP	6.55	*E*	Lund	Norway		2
LR	4.51	*E*	Lyon	France		161
DA	149.17	*E*	Mackay, Queensland	Australia		11
ZN	89.37	*W*	Madison, Wisc.	USA		9
NQ	80.25	*E*	Madras	India		228
QR	3.69	*W*	Madrid	Spain		38
SR	102.16	*E*	Malacca	Malaysia	"Malaca prison"	4
ZV	72.52	*W*	Manchester, Conn.	USA		3
NT	8.77	*E*	Marburg, a.d. Lahn	Germany		12
BT	4.45	*E*	Marcinelle	Belgium		1
MZ	8.45	*W*	Markree	Ireland	County Sligo	13
PF	5.39	*E*	Marseilles	France		337
SF	61.00	*W*	Martinique	Martinique		24
LD	155.47	*W*	Mauna Kea, Hawaii	USA		19
ZY	85.82	*W*	McMinnville, Tenn.	USA		9
YL	80.50	*W*	Merritt Island, Fla.	USA		2
YD	6.15	*E*	Metz	France		18
VP	99.17	*W*	Mexico City	Mexico		8
QS	9.19	*E*	Milan	Italy		17
WG	24.42	*E*	Mflos	Greece		1
CG	87.93	*W*	Milwaukee, Wisc.	USA		1
QT	23.73	*E*	Mittau	(USSR)	[Jelgava, Latvia]	64
MH			*Mixture*		Union Obs. Circ. 55	84
PC	10.93	*E*	Modena	Italy		20
YC	4.17	*E*	Monistrol-sur-Loire	France		6
QU	1.35	*E*	Montauban	France		3
AI	100.33	*W*	Monterrey	Mexico		33
QV	3.53	*E*	Montpellier	France		22
DE	153.	*E*	Mt. Gravatt, Q'land	Australia		2
ZR	122.33	*W*	Mt. Shasta, Ca.	USA		1
BB	91.43	*W*	Mt. Vernon, Iowa	USA		3
US	13.03	*E*	Muceria	Italy	[Muccia?]	1
BP	11.42	*E*	Muris	Italy	(?Murci long.?)	18
UB	77.18	*E*	Nahun	India	[Nahan]	5
SK	118.47	*E*	Nanking	China	[Nanjing]	13
RU	1.33	*W*	Nantes	France		2
PH	14.42	*E*	Neustadt	Czechoslovakia	bei Prag	47
LP	72.92	*W*	New Haven, Conn.	USA	Yale Univ. Obs.	54
TL	74.00	*W*	New York, N. Y.	USA		0
CA	87.42	*W*	Newburgh, Ind.	USA		2
MA	7.30	*E*	Nice	France		28
SJ	121.31	*E*	Ning-Po (Liang-Po)	China	[Ningbo, Che-Kiang]	1
YQ	76.30	*W*	Norfolk, Va.	USA		6
VB	75.33	*W*	Norriton, Pa.	USA	(Norristown)	10
TE	11.04	*E*	Nürnberg	Germany		34
TZ	90.23	*E*	Nusseerabad	E. Pakistan	[Nasirabad, Mymens.]	16
AD	122.25	*W*	Oakland, Ca.	USA		1
VJ	8.02	*E*	Oderoe	Norway	[Flekkerøy]	1
VH	19.05	*E*	Ofen	Hungary	near Budapest	27
WW	143.25	*E*	Okhotsk	USSR		1
NS	17.28	*E*	Olmütz	Czechoslovakia	[Olomouc]	20

v

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
XJ	38.18	*E*	Onega	USSR		3
PL	2.54	*W*	Ormskirk	England		14
VC	149.57	*W*	Otaheite	Tahiti	[Papeete, Tahiti]	7
UN	12.48	*E*	Otricoli	Italy		1
AB	?	*W*	Ottsville, Pa.	USA		4
NK	1.26	*W*	Oxford	England	Radcliffe Obs.	85
DK	172.18	*E*	Oxford	New Zealand		5
WX	156.50	*E*	Ozernovskiy	USSR		10
CC	11.88	*E*	Padua	Italy	[Padova]	1
XL	13.35	*E*	Palermo	Sicily		1
RL	13.46	*E*	Palme	Sicily	Palma di Montechiaro	39
YA	175.65	*E*	Palmerston North	New Zealand		1
LC	116.86	*W*	Palomar Mtn., Ca.	USA	Mt. Palomar Obs.	5
PV	151.00	*E*	Paramatta, N.S.W.	Australia		5
PX	2.34	*E*	Paris	France		1693
AF	?	*W*	Parlin, N. J.	USA		11
WJ	0.37	*W*	Pau	France		18
QW	116.25	*E*	Pekin	China	[Beijing]	541
SZ	28.58	*E*	Péra	Turkey	[İstanbul]	3
QX	7.67	*E*	Perinaldo	Italy		47
LF	116.14	*E*	Perth	Australia		7
XF	72.85	*W*	Petit-Goave	Haiti		7
YG	?	*E*	Pfaffstätten	Austria		13
VA	75.17	*W*	Philadelphia, Pa.	USA		12
ZH	112.05	*W*	Phoenix, Ariz.	USA		1
QY	10.40	*E*	Pisa	Italy		17
CS	90.50	*W*	Pleasant Valley, Ia.	USA		2
MW	13.84	*E*	Pola	Italy		10
SM	79.50	*E*	Pondichéry	India	[Pondicherry]	4
AU	82.47	*W*	Port Huron, Mich.	USA		12
PU	76.51	*W*	Port Royal	Jamaica		3
BI·	51.17	*W*	Pôrto Alegre	Brasil		45
XR	48.55	*W*	Pôrto Belo	Brasil		1
TU	70.47	*W*	Portsmouth, N. H.	USA		11
NX	14.40	*E*	Prague	Czechoslovakia		638
ZM	74.67	*W*	Princeton, N. J.	USA		7
UJ	95.14	*E*	Prome	Burma		2
VQ	11.15	*E*	Quedlinburg	Germany		2
ZF	122.52	*W*	Quesnel, B. C.	Canada		2
XG	78.50	*W*	Quito	Ecuador		8
LK	10.03	*E*	Randers	Denmark		6
CY	12.12	*E*	Ratisbon	Germany	[Regensburg]	1
VT	12.20	*E*	Ravenna	Italy		1
LX	43.19	*W*	Rio de Janeiro	Brasil	Obs. do Valongo	54
YM	77.17	*W*	Rockville, Md.	USA		25
YU	103.73	*W*	Rocky Ford, Colo.	USA		33
ZC	14.72	*E*	Rønne	Denmark	Bornholm	2
QZ	12.48	*E*	Rome	Italy		203
RZ	1.05	*E*	Rouen	France		9
RX	1.01	*W*	Royan	France		1
NB	75.38	*W*	S. Bethlehem, Pa.	USA		97
VD	109.67	*W*	S. Joseph	Mexico	[San José del Cabo]	4
SA	2.01	*W*	Saint Malo	France		2
RA	57.25	*W*	St. Cosmo	Paraguay	(?S. Ignacio?)	54

vi

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
PJ	64.69	*W*	St. Croix	Virgin Islands		18
SW	14.31	*E*	St. Elme	Malta	(Valletta)	5
UW	57.00	*W*	St. Ignatius	Paraguay	[San Ignacio]	21
TR	71.19	*W*	St. Lewis, Quebec	Canada		9
UY	1.25	*W*	St. Michel-en-l'Herm	France		2
WK	4.77	*E*	St. Paul-Trois-Chat.	France		3
ND	30.30	*E*	St. Petersburg	(USSR)	[Leningrad]	172
XN	5.70	*E*	St. Pilon	France	St. Paul-lès-Durance	1
BM	31.08	*E*	Salisbury	Rhodesia		1
BL	111.92	*W*	Salt Lake City, Ut.	USA		27
BD	122.40	*W*	San Bruno, Ca.	USA		32
AJ	117.17	*W*	San Diego, Ca.	USA		6
PD	6.21	*W*	San Fernando	Spain		224
MY	122.43	*W*	San Francisco, Ca.	USA		69
XK	55.53	*W*	San Ignacio	Argentina	*Cf. RA* in Paraguay	25
WM	57.60	*W*	San Miguel	Argentina		2
UT	11.60	*E*	San Quirico d'Orcia	Italy		3
XA	74.17	*W*	Santa Marta	Colombia		2
BA	46.37	*W*	Santos	Brasil		6
PP	0.09	*E*	Saville Row	England	(Cambridge)	4
UC	77.33	*E*	Seharunpur	India	[Saharanpur]	7
PG	14.02	*E*	Senftenberg	Germany		4
SP	121.25	*E*	Shanghai	China		4
CH	1.50	*W*	Sheffield	England		1
YY	114.42	*W*	Shoshone, Idaho	USA		5
SN	108.36	*E*	Si-ngan-fu	China	[Qinxian]	8
UU	11.19	*E*	Sienna	Italy		1
CD	3.68	*E*	Sleidinge	Belgium		13
VL	0.60	*W*	Slough	England		22
TI	27.09	*E*	Smyrne	Turkey	[İzmir]	1
LH	11.19	*E*	Sonneberg	Germany		116
TV	63.36	*W*	Southwest Point	Canada	Anticosti Island	9
UV	0.48	*W*	Southwick	England	near Oundle	22
LJ	20.34	*E*	Spišská Nová Ves	Czechoslovakia		49
BX	?	*W*	Stansbury Park, Ut.	USA		1
LL	?	*E*	Stenbro	Norway		6
VS	12.87	*E*	Stifte Tepl	Czechoslovakia	[Teplá]	19
RB	18.06	*E*	Stockholm	Sweden		149
NP	2.47	*W*	Stonyhurst	England		103
MG	7.77	*E*	Strasbourg	France		81
ST	120.37	*E*	Su-cheu-fu	China	[Suzhou]	1
UI	95.38	*E*	Suddeeah	India	[Sadiya]	6
TQ	0.11	*W*	Surry-street	England	(Mr. Short's house)	5
ZZ	1.80	*W*	Sutton Coldfield	England		1
LQ	151.20	*E*	Sydney, N.S.W.	Australia		4
BJ	76.17	*W*	Syracuse, N. Y.	USA		2
LI	20.12	*E*	Szolnok	Hungary		27
ZA	122.50	*W*	Tacoma, Wash.	USA		7
CN	117.60	*E*	Tambellup, W. Aust.	Australia		4
ZG	82.63	*W*	Tampa, Fla.	USA		8
MJ	69.29	*E*	Tashkent	USSR	Uzbek SSR	46
WF	22.97	*E*	Thessaloníki	Greece		1
VX	3.28	*E*	Thury	France		32
YF	12.10	*E*	Tisvildeleje	Denmark		246

vii

Table 2. Continued

Index	Longitude		Location	Country	Comments	No. Obs.
LT	139.67	*E*	Tōkyō	Japan	Tanakami Obs., etc.	130
AV	78.80	*W*	Tonawanda, N. Y.	USA		4
SG	5.56	*E*	Toulon	France		73
MP	1.46	*E*	Toulouse	France		58
TX	96.01	*E*	Tounzemahn	Burma	[Amarapura]	9
TB	0.41	*E*	Tours	France		18
AC	146.80	*E*	Townesville	Australia		7
RC	79.85	*E*	Tranquebar	India	near Pondicherry	4
SU	39.43	*E*	Trébizonde	Turkey	[Trabzon]	1
DJ	175.0	*E*	Trentham	New Zealand		3
WI	13.20	*E*	Tripoli	Libya		1
RD	10.37	*E*	Trondjem	Norway	[Trondheim]	13
CB	80.80	*W*	Troy, W. Va.	USA		2
ME	7.70	*E*	Turin	Italy	Pino Torinese Obs.	29
RE	17.59	*E*	Tyrnau	(Czechoslovakia)	[Trnava]	84
CK	47.95	*W*	Uberaba	Brasil		7
ZP	81.55	*W*	Univ. Heights, Ohio	USA	near Euclid	1
QQ			*Unknown*		Sampson-d'Alembre	515
RF	0.25	*E*	Upminster	England		127
DI	175.10	*E*	Upper Hutt	New Zealand		7
AA	76.75	*W*	Upper Marlboro, Md.	USA		3
RG	17.62	*E*	Uppsala	Sweden		62
RM	12.72	*E*	Uranibourg	Denmark	(Uraniborg)	8
UR	12.63	*E*	Urbino	Italy		1
MD	5.13	*E*	Utrecht	Netherlands		93
WE	15.65	*E*	Uttersberg	Sweden		4
XS	71.67	*W*	Valparaiso	Chile		1
AK	97.02	*W*	Victoria, Tex.	USA		10
BK	82.40	*W*	Vidalia, Georgia	USA		1
LW	16.38	*E*	Vienna	Austria		514
ZJ	75.98	*W*	Virginia Beach, Va.	USA		1
YH	119.30	*W*	Visalia, Ca.	USA		6
RI	4.68	*E*	Viviers	France		182
TF	2.02	*E*	Vouzon	France	(Orleans)	1
ZK	?	*W*	Wadesville, Ind.	USA		1
RJ	0.04	*W*	Wanstead	England	(Wansted)	6
LS	77.05	*W*	Washington, D. C.	USA	U. S. Naval Obs.	160
ZT	82.38	*W*	Wayne, Mich.	USA		2
AY	3.88	*E*	Wetteren	Belgium		12
BN	1.03	*E*	Whitstable	England		4
ZB	8.25	*E*	Wiesbaden	Germany		1
MV	77.05	*W*	Willets Point, N. Y.	USA		5
MC	88.56	*W*	Williams Bay, Wisc.	USA	Yerkes Obs.	8
PR	25.29	*E*	Wilna	(USSR)	[Vilnius, Lithuania]	111
AS	71.08	*W*	Winchester, Mass.	USA	near Boston	11
UM	0.63	*W*	Windsor	England		21
NV	150.84	*E*	Windsor, N.S.W.	Australia		377
XC	12.65	*E*	Wittenberg	Germany		8
CM	149.13	*E*	Woden, A.C.T.	Australia		4
RK	1.07	*W*	York	England		6
BC	80.67	*W*	Youngstown, Ohio	USA		9
XB	16.88	*E*	Zábřeh	Czechoslovakia		7
CI	4.50	*E*	Zoetermeer	Netherlands		14

viii

Nowadays most analysts obtain values of the lunar tidal dissipation somewhere between the Spencer-Jones value of $\dot{n}_{\rm Moon} = -22''.44$ and the Morrison value of $\dot{n}_{\rm Moon} = -26''.0$. Since these two competing models differ by about 3.5 arcsec, then the appropriate ΔT values differ by about $3^{\rm s}.24\,T^2$ – or by about 30 s of time over three centuries. If the old data are accurate to that level, then one at least can discriminate between the two values for lunar tidal dissipation in tables of ΔT. Upon adopting some values of ΔT we can employ the old Galilean eclipses to investigate the possible existence of secular changes in their periods as mentioned by Goldstein (1975) and by Yoder and Peale (1981), or one can estimate corrections to the adopted ΔT tables.

I have initially adopted the Spencer-Jones value for tidal friction, $\dot{n}_{\rm Moon} = -22''.44$ arcsec/cy^2 (the effect in lunar longitude is $\frac{1}{2}\,\dot{n}_{\rm Moon}\,T^2$), but I have employed the Morrison data because of their inherent superiority. In Fig. 2 I present a diagram of the ΔT values as obtained by Morrison (1980) and by Morrison and Stephenson (1981) for the interval 1650 to the present which were communicated to me by Morrison (1980) prior to publication. In the figure one obtains the value of ΔT by differencing the "observed" drift in time of the Moon for zero tidal acceleration [Z in the diagram] and the adopted tidal acceleration [F in the figure] to produce the appropriate value of ΔT [T in the figure]. Hence, one can employ Morrison's data (which essentially yield the Z curve) and the Spencer-Jones tidal acceleration for the F curve to produce the equivalent ΔT values for the Spencer-Jones model but using the raw data of Morrison. The algorithm for calculating ΔT from Morrison's data for arbitrary $\dot{n}_{\rm Moon}$ is

$$\Delta T(\dot{n}_{\rm Moon}) = \Delta T_{\rm Morrison} - 0^{\rm s}.911\,(\dot{n}_{\rm Moon} + 26''.0)T^2 \qquad (1)$$

where $\dot{n}_{\rm Moon}$ is measured in arcsec/cy^2 and where T is measured in centuries from 1955.5. For the Spencer-Jones tidal acceleration of $\dot{n}_{\rm Moon} = -22''.44$ the correction to Morrison's values of ΔT is $-3^{\rm s}.24T^2$. There is no correction after 1955.5 since those values are based upon atomic time measurements and in that case there is no intermingling of lunar tidal acceleration effects with determinations of ΔT.

The resultant values of ΔT are plotted in Fig. 3 using the Spencer-Jones model ($\dot{n}_{\rm Moon} = -22''.44$) of tidal acceleration of the Moon. In the Supplement paper I present plots of the Morrison versus Brouwer-Martin values reduced to a common lunar tidal acceleration. Essentially, the Morrison data are more smooth than the less-accurate Brouwer-Martin data. In Fig. 4 I present a plot of the difference in ΔT values in the sense of ΔT based upon the Spencer-Jones model of lunar acceleration ($\dot{n}_{\rm Moon} = -22''.44$) minus the value of ΔT based upon the Morrison model of lunar acceleration ($\dot{n}_{\rm Moon} = -26''.0$). If the old Galilean eclipse observations clearly prefer one model over the other it should be evident in the residual plots which will be given later. If the Morrison value of $\dot{n}_{\rm Moon}$ for tidal acceleration of the Moon as it occurs in values of ΔT is better than the Spencer-Jones value, then the satellite eclipse residuals ought to cluster about the curve given in Fig. 4 which would represent the zero-residual curve for the Morrison value of $\dot{n}_{\rm Moon}$.

4. Eclipse residuals

There are currently two accurate ephemerides which recently have been published in the literature and which are useful for analyzing and predicting the positions of the Galilean satellites based upon my 1977 improvement of Sampson's (1921) theory of their motion. The first set of parameters labeled E-2 was published by Lieske (1980) and was based upon an analysis of 1753 eclipse observations from 1878–1972, together with 85 mutual events from 1973 and with 2964 photographic observations from 1967–78. The other commonly available set of parameters was published by Arlot (1982) and labeled G-5. It resulted from an analysis of 8656 photographic observations from 1891 to 1978.

Since numerous scientists have requested a listing of the series coefficients for ephemerides E-2 and for G-5 in an easily readable form similar to that presented for the original theory (Lieske,

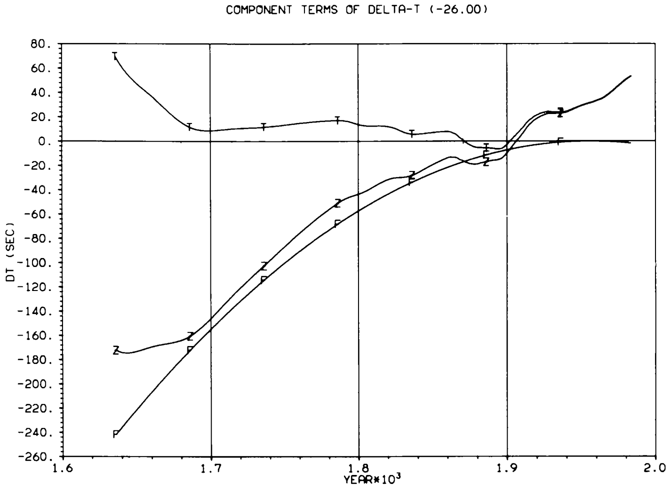

Fig. 2. Components of Morrison's ΔT determination. Z represents the observed lunar longitude drift in the absence of a tidal acceleration component. F represents the effect of Morrison's $\dot{n}_{\rm moon} = -26$ arcsec/cy^2 and $T = Z - F$ represents the value of ΔT for the given $\dot{n}_{\rm moon}$. All units in the ordinate are expressed in sec while the abscissa contains the year

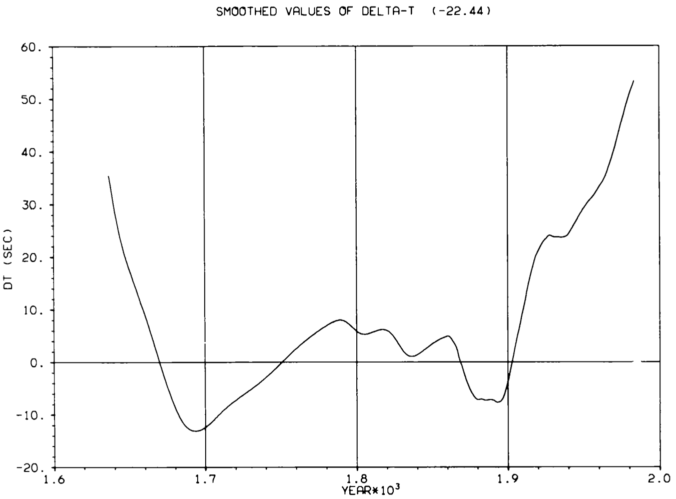

Fig. 3. Plot of ΔT from Morrison's data using the Spencer-Jones values of $\dot{n}_{\rm moon} = -22.44$ arcsec/cy^2. The curve represents the initially adopted value of ΔT for calculation of residuals

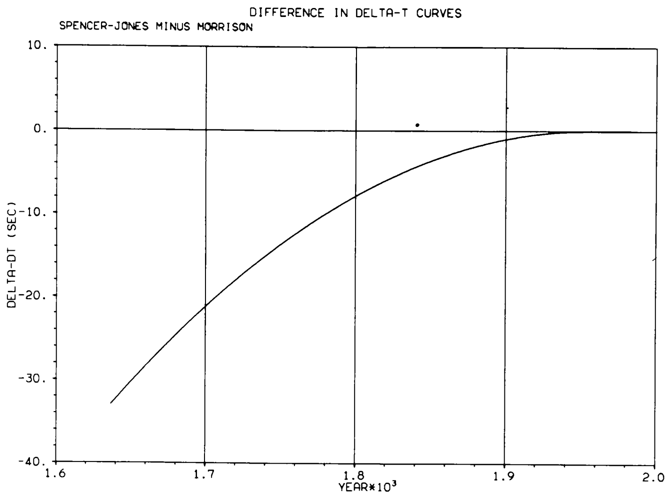

Fig. 4. The difference between ΔT values based upon Spencer-Jones' $\dot{n}_{\mathrm{moon}} = -22.44$ arcsec/cy^2 versus that based upon Morrison's $\dot{n}_{\mathrm{moon}} = -26$ arcsec/cy^2 is plotted as a function of the year. The curve is based upon Morrison's data

1977) in order that they more readily may program the ephemerides on diverse computers, I present the fundamental epsilon-beta parameterrs for E-2 and for G-5 in Table 3, along with the error estimates originally published by the two authors. See the subsequent discussion for the interpretation of the error estimates. In Table 4 the series coefficients for the components in radial direction, longitude and latitude are presented for the two ephemerides for all four satellites. The application of these coefficients to the generation of ephemerides is described in the earlier paper by Lieske (1977).

In Arlot's analysis he compares the "error" estimates of E-2 and of G-5 and suggests that G-5 is more accurate than E-2, although the sum-of-squares of residuals for a common set of data which Arlot employs do not differ by much – indicating that the two published estimates for errors are not really comparable. In fact, Lieske's E-2 attempted to give "realistic errors" based upon consideration of non-estimated parameters such as the masses of the satellites and the pole of Jupiter [which had been obtained from Null (1976)] upon the 24 epsilon-beta orbital parameters (which correspond roughly to the 24 arbitrary constants of integration which one must determine in discussing the initial values for 4 satellites) which were estimated. Arlot's stated errors, on the other hand, were the formal errors obtained in estimating only the 24 orbital parameters from his data set. As is evidenced by the closeness in the sum-of-squares which either E-2 or G-5 yields in analyzing a common set of data (viz. that of Arlot), the real error estimates of the two parameter sets must be very similar. Arlot's Table 3 (Arlot, 1982 p. 309) suggests that they differ by less than 0.5%.

Whichever way one wishes to go (either using consider-covariance errors or the formal errors based upon the 24 orbital parameters) the two sets are related approximately by a factor of 3, so that Lieske's E-2 "realistic errors" are about 3 times the

Table 3. Theory parameters for E2 (Lieske) and G5 (Arlot)

Epsilon Parameter		E2 value (dimensionless)	G5 value (dimensionless)
1	δm_1	$+0.041590 \pm 0.0098$	$+0.041590$
2	δm_2	-0.002461 ± 0.0200	-0.002461
3	δm_3	-0.023189 ± 0.0076	-0.023189
4	δm_4	$+0.256938 \pm 0.0084$	$+0.256938$
5	$\delta S/J$	$(+206.7082138 \pm 9.5) \cdot 10^{-6}$	$+206.7082138 \cdot 10^{-6}$
6	δn_1	$(+5.6763 \pm 3.69) \cdot 10^{-9}$	$(-1.835945 \pm 0.8513) \cdot 10^{-9}$
7	δn_2	$(+10.9655 \pm 5.79) \cdot 10^{-9}$	$(+11.054947 \pm 0.5523) \cdot 10^{-9}$
8	δn_4	$(-2.44689 \pm 2.87) \cdot 10^{-8}$	$(-5.5560148 \pm 0.15354) \cdot 10^{-8}$
9	λ_A	$(+11.4663 \pm 2.21) \cdot 10^{-4}$	$(+14.9959 \pm 0.86918) \cdot 10^{-4}$
10	δn_J	$(+16.2 \pm 6.3) \cdot 10^{-6}$	$+16.2 \cdot 10^{-6}$
11	δJ_2	-0.007778 ± 0.00054	-0.007778
12	δJ_4	-0.275934 ± 0.024	-0.275934
13	δR_J	-0.000308 ± 0.00060	-0.000308
14	δP_J	$(+0.095 \pm 2.8) \cdot 10^{-4}$	$+0.095 \cdot 10^{-4}$
15	$\delta 3(C-A)/2C$	$0. \pm 0.15$	$0.$
16	δe_{11}	-0.793261 ± 0.424	-0.473172 ± 0.098801
17	δe_{22}	$+0.116719 \pm 0.266$	$+0.463707 \pm 0.108628$
18	δe_{33}	-0.031160 ± 0.019	-0.043680 ± 0.004671
19	δe_{44}	-0.005380 ± 0.004	-0.003586 ± 0.000542
20	δe_J	$+0.002781 \pm 0.0005$	$+0.002781$
21	δc_{11}	$+0.479780 \pm 0.409$	$+0.492066 \pm 0.060640$
22	δc_{22}	$+0.001049 \pm 0.025$	-0.006578 ± 0.002110
23	δc_{33}	$+0.041111 \pm 0.049$	$+0.050194 \pm 0.003248$
24	δc_{44}	-0.066572 ± 0.109	-0.070668 ± 0.001315
25	δI_J	$+0.005384 \pm 0.011$	$+0.005384$
26	δJ	-0.000133 ± 0.00011	-0.000133
27	$\delta \epsilon$	$0. \pm 4.7 \cdot 10^{-6}$	$0.$
28	δn_S	$0. \pm 1.0 \cdot 10^{-6}$	$0.$

Beta Parameter		E2 value (deg)	G5 value (deg)
1	$\Delta\ell_1$	$+0.048170 \pm 0.0176$	$+0.046245 \pm 0.004819$
2	$\Delta\ell_2$	-0.013693 ± 0.0039	-0.014445 ± 0.000877
3	$\Delta\ell_3$	[−0.0446245	−0.0447900]
4	$\Delta\ell_4$	-0.062787 ± 0.0049	-0.066536 ± 0.000443
5	$\Delta\phi_\lambda$	$+184.415351 \pm 20.3$	$+182.797225 \pm 0.005084$
6	$\Delta\pi_1$	$+77.868511 \pm 73.8$	$+62.231560 \pm 7.608520$
7	$\Delta\pi_2$	$+54.429883 \pm 15.5$	$+86.403965 \pm 4.320290$
8	$\Delta\pi_3$	$+12.691861 \pm 0.92$	$+14.181513 \pm 0.236000$
9	$\Delta\pi_4$	-0.717416 ± 0.13	-0.747260 ± 0.028121
10	$\Delta\Pi_J$	$+0.166755 \pm 0.05$	$+0.166755$
11	$\Delta\omega_1$	$+65.628689 \pm 18.5$	$+60.834877 \pm 3.490252$
12	$\Delta\omega_2$	$+5.153378 \pm 1.1$	$+6.075500 \pm 0.125467$
13	$\Delta\omega_3$	-6.237802 ± 2.5	-5.450563 ± 0.210661
14	$\Delta\omega_4$	$+4.854064 \pm 2.4$	$+4.903778 \pm 0.077832$
15	$\Delta\psi$	-0.233589 ± 0.19	-0.233589
16	$\Delta G'$	$0. \pm 0.4$	$0.$
17	ΔG	-0.140391 ± 0.03	-0.140391
18	$\Delta\phi_1$	$+15.610 \pm 3.1$	$+15.610$
19	$\Delta\phi_2$	$+5.135 \pm 4.2$	$+5.135$
20	$\Delta\phi_3$	-1.719 ± 2.1	-1.719
21	$\Delta\phi_4$	-7.784 ± 1.8	-7.784
22	$\Delta\Omega_J$	$+0.044280 \pm 0.007$	$+0.044280$

i

Table 3. Continued

Index		E2 angle (deg)	G5 Angle (deg)	E2 rate (deg/day)	G5 rate (deg/day)
1	ℓ_1	106.078590000	106.076665000	203.4889553630643	203.4889538344055
2	ℓ_2	175.733787000	175.733035000	101.3747245566245	101.3747245656922
3	ℓ_3	120.561385500	120.561220000	50.31760915340462	50.31760993133556
4	ℓ_4	84.4558230000	84.4520740000	21.57107087517961	21.57107020450808
5	ϕ_λ	184.415351000	182.797225000	0.17356902	0.17354439
6	π_1	82.3802310000	66.7432800000	0.16102275	0.16075291
7	π_2	128.960393000	160.934475000	0.04645644	0.04681876
8	π_3	187.550171000	189.039823000	0.00712408	0.00712296
9	π_4	335.309254000	335.279410000	0.00183939	0.00183940
10	Π_J	13.4703950000	13.4703950000	0.	0.
11	ω_1	308.365749000	303.571937000	−0.13280610	−0.13280633
12	ω_2	100.438938000	101.361060000	−0.03261535	−0.03261574
13	ω_3	118.908928000	119.696167000	−0.00717678	−0.00717675
14	ω_4	322.746564000	322.796278000	−0.00176018	−0.00176018
15	ψ	316.500101000	316.500101000	$-2.480 \cdot 10^{-6}$	$-2.480 \cdot 10^{-6}$
16	G'	31.9785280244	31.9785280244	0.033459733896	0.033459733896
17	G	30.2380210168	30.2380210168	0.08309256178969453	0.08309256178969453
18	ϕ_1	188.443270647	188.443270647	0.	0.
19	ϕ_2	52.1445966929	52.1445966929	0.	0.
20	ϕ_3	257.461000000	257.461000000	0.	0.
21	ϕ_4	149.336611731	149.336611731	0.	0.
22	Ω_J	99.9975400000	99.9975400000	0.	0.
	a_1	$2.819347 \cdot 10^{-3}$ a.u.	$2.819347 \cdot 10^{-3}$ a.u.		
	a_2	$4.485872 \cdot 10^{-3}$ a.u.	$4.485873 \cdot 10^{-3}$ a.u.		
	a_3	$7.155352 \cdot 10^{-3}$ a.u.	$7.155352 \cdot 10^{-3}$ a.u.		
	a_4	$1.2585436 \cdot 10^{-2}$ a.u.	$1.2585438 \cdot 10^{-2}$ a.u.		

Substitution Values for E2+. [Otherwise identical with E2]

Parameter	Value for E2+	Parameter	Value for E2+	Parameter	Value for E2+
ϵ_8	$-7.8066 \cdot 10^{-9}$	ϵ_{10}	$-5.417 \cdot 10^{-3}$	β_4	-0.06449
ℓ_4	84.45412	n_4	21.57107123460327	a_4	$1.2585435 \cdot 10^{-2}$ a.u.
υ_1	#14 −5595 $\pi_3 - \pi_4$				
υ_2	#35 +3450 $\ell_2 - \pi_4$				
ξ_3	#7 −7893 $\ell_3 - \pi_4$	υ_3	#35 +15799 $\ell_3 - \pi_4$		
ξ_4	#9 −73326 $\ell_4 - \pi_4$	υ_4	#41 +146668 $\ell_4 - \pi_4$		

ii

1986A&A...154...61L

Table 4. Series coefficients for E2 (Lieske) and G5 (Arlot)

Index	E2	G5	Argument	Ratio n/n_{sat}
XI-1: Series coefficients for $\xi_1 = (\rho_1 - a_1)/a_1$ (cosine)				
1	170	170	$\ell_1 - \ell_2$	.50181707
2	106	106	$\ell_1 - \ell_3$	.75272560
3	−96	−245	$\ell_1 - \pi_1$	.99920869
4	−2	−2	$\ell_1 - \pi_2$	.99977170
5	−395	−389	$\ell_1 - \pi_3$	.99996499
6	−214	−214	$\ell_1 - \pi_4$	.99999096
7	−63	−63	$\ell_1 + \pi_3 - 2\Pi_J - 2G$	.99921833
8	−41279	−41279	$2\ell_1 - 2\ell_2$	1.00363413
9	3	3	$2\ell_1 - 2\ell_3$	1.50545120
10	−130	−130	$4\ell_1 - 4\ell_2$	2.00726827
V-1: Series coefficients for $\upsilon_1 = \nu_1 - \ell_1$ (sine)				
1	−27	−27	$-2\Pi_J + 2\psi - 2G$	-.00081670
2	−456	−456	$-2\Pi_J + 2\psi$	-.00000002
3	−746	−708	$-2\Pi_J + \omega_3 + \psi - 2G$	-.00085196
4	93	93	$-\omega_2 + \psi$	.00016027
5	−72	−72	$-\omega_3 + \psi$	.00003526
6	−49	−49	$-\omega_4 + \psi$	.00000864
7	−324	−324	G	.00040834
8	69	69	$2G$	.00081668
9	−33	−33	$5G' - 2G + \phi_2$	.00000547
10	−27	−27	$\omega_3 - \omega_4$	-.00002662
11	146	146	$\omega_2 - \omega_3$	-.00012501
12	30	30	$\omega_2 - \omega_4$	-.00015163
13	−38	−38	$\pi_4 - \Pi_J$	.00000904
14	−5596	−5897	$\pi_3 - \pi_4$	.00002597
15	292	287	$\pi_2 - \pi_3$	.00019329
16	156	156	$\pi_2 - \pi_4$	.00021926
17	−39	−39	$\pi_1 - \pi_3$	.00075630
18	−26	−26	$\pi_1 - \pi_4$	.00078227
19	−26	−26	$\pi_1 + \pi_4 - 2\Pi_J - 2G$	-.00001633
20	−2198	−3848	$\pi_1 + \pi_3 - 2\Pi_J - 2G$	.00000964
21	1321	1728	ϕ_λ	.00085297
22	39	39	$3\ell_3 - 7\ell_4 + 4\pi_4$	-.00018336
23	−32	−32	$3\ell_3 - 7\ell_4 + \pi_3 + 3\pi_4$	-.00015739
24	−1157	−1160	$\ell_1 - 2\ell_2 + \pi_4$	.00364317
25	−1940	−1907	$\ell_1 - 2\ell_2 + \pi_3$	.00366914
26	−791	−1040	$\ell_1 - 2\ell_2 + \pi_2$	.00386243
27	292	694	$\ell_1 - 2\ell_2 + \pi_1$	.00442544
28	−617	−617	$\ell_1 - \ell_2$	.50181707
29	−270	−270	$\ell_1 - \ell_3$	.75272560
30	−26	−26	$\ell_1 - \ell_4$	.89399390
31	192	490	$\ell_1 - \pi_1$	.99920869
32	5	5	$\ell_1 - \pi_2$	.99977170
33	791	781	$\ell_1 - \pi_3$	.99996499
34	459	460	$\ell_1 - \pi_4$	.99999096
35	147	144	$\ell_1 + \pi_3 - 2\Pi_J - 2G$	.99921833
36	21	21	$2\ell_1 - 4\ell_2 + \omega_2 + \omega_3$	.00707272
37	−200	−200	$2\ell_1 - 4\ell_2 + 2\omega_2$	.00694771
38	82363	82363	$2\ell_1 - 2\ell_2$	1.00363413
39	−35	−35	$2\ell_1 - 2\ell_3$	1.50545120
40	−3	−3	$3\ell_1 - 4\ell_2 + \pi_3$	1.00730328
41	275	275	$4\ell_1 - 4\ell_2$	2.00726827

i

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
LAT-1: Series coefficients for $\varsigma_1 = z_1/a_1$ (sine)				
1	46	46	$\ell_1 - 2\Pi_J + \psi - 2G$	.99918331
2	7038	7096	$\ell_1 - \omega_1$	1.00065265
3	1835	1821	$\ell_1 - \omega_2$	1.00016028
4	329	332	$\ell_1 - \omega_3$	1.00003527
5	93	93	$\ell_1 - \omega_4$	1.00000865
6	−311	−311	$\ell_1 - \psi$	1.00000001
7	75	75	$3\ell_1 - 4\ell_2 + \omega_2$	1.00710799
XI-2: Series coefficients for $\xi_2 = (\rho_2 - a_2)/a_2$ (cosine)				
1	−18	−18	$\omega_2 - \omega_3$	-.00025094
2	−27	−27	$2\ell_3 - 2\Pi_J - 2G$	.99106591
3	553	553	$\ell_2 - \ell_3$	.50364739
4	45	45	$\ell_2 - \ell_4$	.78721451
5	−102	−102	$\ell_2 - \pi_1$	.99841161
6	−921	−1208	$\ell_2 - \pi_2$	.99954174
7	−3187	−3143	$\ell_2 - \pi_3$	.99992973
8	−1738	−1741	$\ell_2 - \pi_4$	.99998186
9	−15	−15	$\ell_2 - \Pi_J - G$	.99918034
10	−64	−64	$2\ell_2 - 2\ell_4$	1.57442901
11	166	164	$2\ell_2 - 2\omega_2$	2.00064346
12	18	18	$2\ell_2 - \omega_2 - \omega_3$	2.00039253
13	−54	−54	$5\ell_2 - 5\ell_3$	2.51823695
14	−30	−30	$\ell_1 - 2\ell_2 + \pi_4$	.00731292
15	−67	−67	$\ell_1 - 2\ell_2 + \pi_3$	.00736505
16	93748	93748	$\ell_1 - \ell_2$	1.00729478
17	48	48	$\ell_1 - 2\ell_3 + \pi_4$	1.01460770
18	107	107	$\ell_1 - 2\ell_3 + \pi_3$	1.01465983
19	−19	−19	$\ell_1 - 2\ell_3 + \pi_2$	1.01504782
20	523	523	$\ell_1 - \ell_3$	1.51094217
21	30	30	$\ell_1 - \pi_3$	2.00722450
22	−290	−290	$2\ell_1 - 2\ell_2$	2.01458956
23	−91	−91	$2\ell_1 - 2\ell_3$	3.02188434
24	22	22	$4\ell_1 - 4\ell_2$	4.02917912
V-2: Series coefficients for $\upsilon_2 = \nu_2 - \ell_2$ (sine)				
1	102	102	$-2\Pi_J + 2\psi - 2G$	-.00163936
2	−1158	−1158	$-2\Pi_J + 2\psi$	-.00000005
3	1715	1628	$-2\Pi_J + \omega_3 + \psi - 2G$	-.00171013
4	26	26	$-2\Pi_J + \omega_2 + \psi - 2G$	-.00196107
5	32	32	$-\omega_2 + \psi$	.00032171
6	255	257	$-\omega_3 + \psi$	.00007077
7	219	218	$-\omega_4 + \psi$	.00001734
8	−1846	−1846	G	.00081966
9	−263	−263	$2G$	.00163932
10	18	18	$2G' - 2G + \phi_4$	-.00097920
11	19	19	$2G' - G + \phi_1$	-.00015954
12	−15	−15	$5G' - 3G + \phi_1$	-.00080867
13	−150	−150	$5G' - 2G + \phi_2$	.00001098
14	102	102	$\omega_3 - \omega_4$	-.00005343
15	55	55	$\omega_2 - \omega_3$	-.00025094
16	72	72	$\pi_4 - \Pi_J$	.00001814
17	2397	2311	$\pi_3 - \pi_4$	.00005213
18	−21	−21	$\pi_3 - \pi_4 + \omega_3 - \omega_4$	-.00000130
19	−74	−45	$\pi_2 - \pi_3$	.00038799
20	−35	−35	$\pi_2 - \pi_4$	.00044012

ii

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
21	−31	−31	$\pi_1 - \pi_2$	.00113013
22	32	76	$\pi_1 - \pi_3$	.00151812
23	107	101	$\pi_1 - \pi_4$	.00157025
24	−431	−575	$\pi_1 + \pi_3 - 2\Pi_J - 2G$	.00001935
25	−3172	−4149	ϕ_λ	.00171215
26	55	55	$2\ell_3 - 2\Pi_J - 2G$	.99106591
27	−110	−111	$3\ell_3 - 7\ell_4 + 4\pi_4$	-.00036805
28	91	91	$3\ell_3 - 7\ell_4 + \pi_3 + 3\pi_4$	-.00031592
29	−25	−25	$3\ell_3 - 7\ell_4 + 2\pi_3 + 2\pi_4$	-.00026379
30	−1993	−1993	$\ell_2 - \ell_3$	.50364739
31	−137	−137	$\ell_2 - \ell_4$	.78721451
32	39	102	$\ell_2 - \pi_1$	.99841161
33	1844	2417	$\ell_2 - \pi_2$	.99954174
34	6394	6305	$\ell_2 - \pi_3$	.99992973
35	3451	3458	$\ell_2 - \pi_4$	.99998186
36	30	30	$\ell_2 - \Pi_J - G$	.99918034
37	−18	−18	$2\ell_2 - 3\ell_3 + \pi_4$	.51096031
38	−39	−39	$2\ell_2 - 3\ell_3 + \pi_3$	.51101244
39	98	98	$2\ell_2 - 2\ell_4$	1.57442901
40	−166	−164	$2\ell_2 - 2\omega_2$	2.00064346
41	−18	−18	$2\ell_2 - \omega_2 - \omega_3$	2.00039253
42	72	72	$5\ell_2 - 5\ell_3$	2.51823695
43	30	30	$\ell_1 - 2\ell_2 - \pi_3 + 2\Pi_J + 2G$	.00886382
44	4159	4169	$\ell_1 - 2\ell_2 + \pi_4$	.00731292
45	7571	7476	$\ell_1 - 2\ell_2 + \pi_3$	.00736505
46	−1491	−1955	$\ell_1 - 2\ell_2 + \pi_2$	.00775304
47	−469	−1181	$\ell_1 - 2\ell_2 + \pi_1$	.00888317
48	−185640	−185641	$\ell_1 - \ell_2$	1.00729478
49	−111	−111	$\ell_1 - 2\ell_3 + \pi_4$	1.01460770
50	−205	−202	$\ell_1 - 2\ell_3 + \pi_3$	1.01465983
51	39	39	$\ell_1 - 2\ell_3 + \pi_2$	1.01504782
52	−16	−16	$\ell_1 - 2\ell_3 + \pi_1$	1.01617795
53	−803	−803	$\ell_1 - \ell_3$	1.51094217
54	−19	−19	$\ell_1 - \pi_2$	2.00683651
55	−75	−75	$\ell_1 - \pi_3$	2.00722450
56	−31	−31	$\ell_1 - \pi_4$	2.00727663
57	−9	−9	$2\ell_1 - 4\ell_2 + \omega_3 + \psi$	.01451874
58	4	4	$2\ell_1 - 4\ell_2 + 2\omega_3$	.01444797
59	−14	−14	$2\ell_1 - 4\ell_2 + \omega_2 + \omega_3$	.01419703
60	150	150	$2\ell_1 - 4\ell_2 + 2\omega_2$	.01394610
61	−11	−11	$2\ell_1 - 4\ell_2 + 2\Pi_J + 2G$	.01622887
62	−9	−9	$2\ell_1 - 4\ell_2 + \pi_3 + \pi_4$	.01467798
63	−8	−8	$2\ell_1 - 4\ell_2 + 2\pi_3$	.01473011
64	915	915	$2\ell_1 - 2\ell_2$	2.01458956
65	96	96	$2\ell_1 - 2\ell_3$	3.02188434
66	−18	−18	$4\ell_1 - 4\ell_2$	4.02917912
LAT-2: Series coefficients for $\varsigma_2 = z_2/a_2$ (sine)				
1	17	17	$\ell_2 - 2\Pi_J + \psi - 3G$	.99754100
2	143	143	$\ell_2 - 2\Pi_J + \psi - 2G$	.99836066
3	−143	−143	$\ell_2 - \omega_1$	1.00131005
4	81575	80954	$\ell_2 - \omega_2$	1.00032173
5	4512	4551	$\ell_2 - \omega_3$	1.00007079
6	1164	1159	$\ell_2 - \omega_4$	1.00001736
7	−19	−19	$\ell_2 - \psi - G$	.99918037
8	−3286	−3286	$\ell_2 - \psi$	1.00000002
9	35	35	$\ell_2 - \psi + G$	1.00081968

iii

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
10	−28	−28	$\ell_1 - 2\ell_3 + \omega_3$	1.01451876
11	273	271	$\ell_1 - 2\ell_3 + \omega_2$	1.01426783
XI-3: Series coefficients for $\xi_3 = (\rho_3 - a_3)/a_3$ (cosine)				
1	24	24	$-\omega_3 + \psi$	.00014258
2	−9	−9	$\omega_3 - \omega_4$	-.00010765
3	10	10	$\pi_3 - \pi_4$	.00010503
4	294	294	$\ell_3 - \ell_4$	.57130175
5	18	18	$\ell_3 - \pi_2$	.99907674
6	−14691	−14502	$\ell_3 - \pi_3$	.99985842
7	−7894	−7907	$\ell_3 - \pi_4$	.99996344
8	−23	−23	$\ell_3 - \Pi_J - G$	.99834864
9	−20	−20	$\ell_3 + \pi_4 - 2\Pi_J - 2G$	.99673383
10	−51	−51	$\ell_3 + \pi_3 - 2\Pi_J - 2G$	.99683886
11	39	39	$2\ell_3 - 3\ell_4 + \pi_4$	.71394181
12	−1758	−1758	$2\ell_3 - 2\ell_4$	1.14260350
13	−11	−11	$2\ell_3 - 2\pi_3$	1.99971684
14	−10	−10	$2\ell_3 - \pi_3 - \pi_4$	1.99982186
15	−27	−27	$2\ell_3 - 2\Pi_J - 2G$	1.99669728
16	24	24	$2\ell_3 - 2\omega_3$	2.00028526
17	9	9	$2\ell_3 - \omega_3 - \omega_4$	2.00017761
18	−24	−24	$2\ell_3 - \omega_3 - \psi$	2.00014268
19	−16	−16	$3\ell_3 - 4\ell_4 + \pi_4$	1.28524356
20	−156	−156	$3\ell_3 - 3\ell_4$	1.71390526
21	−41	−41	$4\ell_3 - 4\ell_4$	2.28520701
22	−11	−11	$5\ell_3 - 5\ell_4$	2.85650876
23	6333	6333	$\ell_2 - \ell_3$	1.01469677
24	9	9	$\ell_2 - \pi_3$	2.01455519
25	39	39	$2\ell_2 - 3\ell_3 + \pi_4$	1.02943009
26	70	70	$2\ell_2 - 3\ell_3 + \pi_3$	1.02953512
27	10	10	$\ell_1 - 2\ell_2 + \pi_4$	.01473332
28	20	20	$\ell_1 - 2\ell_2 + \pi_3$	.01483835
29	−153	−153	$\ell_1 - \ell_2$	2.02939354
30	155	155	$\ell_1 - \ell_3$	3.04409031
31	11	11	$2\ell_1 - 2\ell_2$	4.05878707
V-3: Series coefficients for $\upsilon_3 = \nu_3 - \ell_3$ (sine)				
1	10	10	$-\pi_3 + \pi_4 - \omega_3 + \psi$	.00003755
2	27	27	$-2\Pi_J + 2\psi - 2G$	-.00330282
3	−1488	−1488	$-2\Pi_J + 2\psi$	-.00000010
4	−161	−152	$-2\Pi_J + \omega_3 + \psi - 2G$	-.00344540
5	14	14	$-\omega_2 + \psi$	.00064814
6	411	415	$-\omega_3 + \psi$	.00014258
7	346	345	$-\omega_4 + \psi$	.00003493
8	−2338	−2338	G	.00165136
9	−66	−66	$2G$	.00330272
10	10	10	$G' - G + \phi_3$	-.00098639
11	22	22	$2G' - 2G + \phi_4$	-.00197278
12	26	26	$2G' - G + \phi_1$	-.00032142
13	11	11	$3G' - 2G + \phi_2 + \phi_3$	-.00130781
14	9	9	$3G' - G + \phi_1 - \phi_2$	.00034355
15	−19	−19	$5G' - 3G + \phi_1$	-.00162923
16	−208	−208	$5G' - 2G + \phi_2$	.00002213
17	159	160	$\omega_3 - \omega_4$	-.00010765
18	21	21	$\omega_2 - \omega_3$	-.00050556
19	120	120	$\pi_4 - \Pi_J$	.00003656
20	6558	6592	$\pi_3 - \pi_4$	.00010503

iv

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
21	−57	−57	$\pi_3 - \pi_4 + \omega_3 - \omega_4$	-.00000262
22	−91	−89	$\pi_2 - \pi_3$	.00078168
23	−72	−72	$\pi_2 - \pi_4$	.00088671
24	−26	−26	$\pi_1 - \pi_3$	.00305854
25	−9	−9	$\pi_1 - \pi_4$	.00316357
26	16	16	$\pi_1 + \pi_4 - 2\Pi_J - 2G$	-.00006604
27	523	1148	$\pi_1 + \pi_3 - 2\Pi_J - 2G$	.00003899
28	314	410	ϕ_λ	.00344947
29	−10	−10	$\ell_4 - \pi_4$	.42866169
30	−100	−100	$\ell_3 - 2\ell_4 + \pi_4$	.14264006
31	83	83	$\ell_3 - 2\ell_4 + \pi_3$	.14274509
32	−943	−943	$\ell_3 - \ell_4$	.57130175
33	−37	−37	$\ell_3 - \pi_2$	.99907674
34	29387	29007	$\ell_3 - \pi_3$	.99985842
35	15800	15827	$\ell_3 - \pi_4$	.99996344
36	7	7	$\ell_3 - \pi_4 + \omega_3 - \omega_4$	.99985580
37	46	46	$\ell_3 - \Pi_J - G$	.99834864
38	51	51	$\ell_3 + \pi_4 - 2\Pi_J - 2G$	.99673383
39	11	11	$\ell_3 + \pi_3 - 2\Pi_J - 3G$	.99518750
40	99	98	$\ell_3 + \pi_3 - 2\Pi_J - 2G$	.99683886
41	1	1	$\ell_3 + \pi_1 - 2\Pi_J - 2G$	.99989740
42	−101	−101	$2\ell_3 - 3\ell_4 + \pi_4$	.71394181
43	13	13	$2\ell_3 - 3\ell_4 + \pi_3$	.71404684
44	3218	3218	$2\ell_3 - 2\ell_4$	1.14260350
45	29	29	$2\ell_3 - 2\pi_3$	1.99971684
46	25	25	$2\ell_3 - \pi_3 - \pi_4$	1.99982186
47	37	37	$2\ell_3 - 2\Pi_J - 2G$	1.99669728
48	−24	−24	$2\ell_3 - 2\omega_3$	2.00028526
49	−9	−9	$2\ell_3 - \omega_3 - \omega_4$	2.00017761
50	24	24	$2\ell_3 - \omega_3 - \psi$	2.00014268
51	−172	−173	$3\ell_3 - 7\ell_4 + 4\pi_4$	-.00074151
52	141	141	$3\ell_3 - 7\ell_4 + \pi_3 + 3\pi_4$	-.00063649
53	−55	−55	$3\ell_3 - 7\ell_4 + 2\pi_3 + 2\pi_4$	-.00053146
54	27	27	$3\ell_3 - 4\ell_4 + \pi_4$	1.28524356
55	226	226	$3\ell_3 - 3\ell_4$	1.71390526
56	53	53	$4\ell_3 - 4\ell_4$	2.28520701
57	13	13	$5\ell_3 - 5\ell_4$	2.85650876
58	42	42	$\ell_2 - 3\ell_3 + 2\ell_4$	-.12790674
59	−12038	−12038	$\ell_2 - \ell_3$	1.01469677
60	−24	−24	$\ell_2 - \pi_3$	2.01455519
61	−10	−10	$\ell_2 - \pi_4$	2.01466021
62	−78	−78	$2\ell_2 - 3\ell_3 + \pi_4$	1.02943009
63	−133	−131	$2\ell_2 - 3\ell_3 + \pi_3$	1.02953512
64	−662	−663	$\ell_1 - 2\ell_2 + \pi_4$	.01473332
65	−1246	−1234	$\ell_1 - 2\ell_2 + \pi_3$	.01483835
66	699	909	$\ell_1 - 2\ell_2 + \pi_2$	.01562003
67	90	90	$\ell_1 - 2\ell_2 + \pi_1$	.01789690
68	190	190	$\ell_1 - \ell_2$	2.02939354
69	217	217	$\ell_1 - \ell_3$	3.04409031
70	2	2	$2\ell_1 - 4\ell_2 + \omega_3 + \psi$	.02925086
71	−4	−4	$2\ell_1 - 4\ell_2 + 2\omega_3$	.02910828
72	3	3	$2\ell_1 - 4\ell_2 + 2\omega_2$	.02809716
73	2	2	$2\ell_1 - 4\ell_2 + \pi_3 + \pi_4$	.02957167
74	2	2	$2\ell_1 - 4\ell_2 + 2\pi_3$	.02967670
75	−13	−13	$2\ell_1 - 2\ell_2$	4.05878707

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
——— LAT-3: Series coefficients for $\varsigma_3 = z_3/a_3$ (sine) ———				
1	37	37	$\ell_3 - 2\Pi_J + \psi - 3G$	.99504587
2	321	321	$\ell_3 - 2\Pi_J + \psi - 2G$	.99669723
3	−15	−15	$\ell_3 - 2\Pi_J + \psi - G$	.99834859
4	−45	−45	$\ell_3 - 2\Pi_J + \psi$	.99999995
5	−2793	−2772	$\ell_3 - \omega_2$	1.00064819
6	32387	32669	$\ell_3 - \omega_3$	1.00014263
7	6871	6840	$\ell_3 - \omega_4$	1.00003498
8	−45	−45	$\ell_3 - \psi - G$	.99834869
9	−16876	−16876	$\ell_3 - \psi$	1.00000005
10	51	51	$\ell_3 - \psi + G$	1.00165141
11	10	10	$2\ell_2 - 3\ell_3 + \psi$	1.02939349
12	−21	−21	$2\ell_2 - 3\ell_3 + \omega_3$	1.02925091
13	30	30	$2\ell_2 - 3\ell_3 + \omega_2$	1.02874535
——— XI-4: Series coefficients for $\xi_4 = (\rho_4 - a_4)/a_4$ (cosine) ———				
1	−19	-19	$-\omega_3 + \psi$	.00033259
2	167	167	$-\omega_4 + \psi$	.00008148
3	11	11	G	.00385204
4	12	12	$\omega_3 - \omega_4$	-.00025110
5	−13	−13	$\pi_3 - \pi_4$	.00024499
6	1656	1635	$\ell_4 - \pi_3$	.99966974
7	−24	−24	$\ell_4 - \pi_4 - 2\Pi_J + 2\psi$	.99991450
8	−17	−17	$\ell_4 - \pi_4 - G$	.99606269
9	−73328	−73461	$\ell_4 - \pi_4$	.99991473
10	15	15	$\ell_4 - \pi_4 + G$	1.00376677
11	30	30	$\ell_4 - \pi_4 + 2\Pi_J - 2\psi$	.99991496
12	−5	−5	$\ell_4 - \Pi_J - 2G$	.99229593
13	−89	−89	$\ell_4 - \Pi_J - G$	.99614796
14	182	182	$\ell_4 - \Pi_J$	1.00000000
15	−6	−6	$\ell_4 + \pi_4 - 2\Pi_J - 4G$	.98467712
16	−62	−62	$\ell_4 + \pi_4 - 2\Pi_J - 3G$	.98852916
17	−541	−542	$\ell_4 + \pi_4 - 2\Pi_J - 2G$	.99238120
18	27	27	$\ell_4 + \pi_4 - 2\Pi_J - G$	.99623323
19	6	6	$\ell_4 + \pi_4 - 2\Pi_J$	1.00008527
20	6	6	$\ell_4 + \pi_4 - \omega_4 - \psi$	1.00016699
21	−9	−9	$\ell_4 + \pi_3 - 2\pi_4$	1.00015972
22	14	14	$\ell_4 + \pi_3 - 2\Pi_J - 2G$	.99262619
23	13	13	$2\ell_4 - \pi_3 - \pi_4$	1.99958447
24	−269	−270	$2\ell_4 - 2\pi_4$	1.99982946
25	−25	−25	$2\ell_4 - 2\Pi_J - 3G$	1.98844389
26	−155	−155	$2\ell_4 - 2\Pi_J - 2G$	1.99229593
27	−12	−12	$2\ell_4 - \omega_3 - \omega_4$	2.00041430
28	19	19	$2\ell_4 - \omega_3 - \psi$	2.00033282
29	48	48	$2\ell_4 - 2\omega_4$	2.00016320
30	−167	−167	$2\ell_4 - \omega_4 - \psi$	2.00008171
31	142	142	$2\ell_4 - 2\psi$	2.00000023
32	−22	−22	$\ell_3 - 2\ell_4 + \pi_4$	.33272835
33	20	20	$\ell_3 - 2\ell_4 + \pi_3$	.33297334
34	974	974	$\ell_3 - \ell_4$	1.33264308
35	24	24	$2\ell_3 - 3\ell_4 + \pi_4$	1.66537143
36	177	177	$2\ell_3 - 2\ell_4$	2.66528616
37	4	4	$3\ell_3 - 4\ell_4 + \pi_4$	2.99801450
38	42	42	$3\ell_3 - 3\ell_4$	3.99792923
39	14	14	$4\ell_3 - 4\ell_4$	5.33057231
40	5	5	$5\ell_3 - 5\ell_4$	6.66321539

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
41	−8	−8	$\ell_2 - 3\ell_3 + 2\ell_4$	-.29836076
42	92	92	$\ell_2 - \ell_4$	3.69956847
43	104	104	$\ell_1 - \ell_4$	8.43341926
——— V-4: Series coefficients for $\upsilon_4 = \nu_4 - \ell_4$ (sine) ———				
1	8	8	$-\pi_3 - \pi_4 + 2\psi$	-.00041576
2	−9	−9	$-\pi_3 - \pi_4 + \omega_4 + \psi$	-.00049725
3	27	27	$-\pi_3 + \pi_4 - \omega_4 + \psi$	-.00016351
4	−407	−409	$-2\pi_4 + 2\psi$	-.00017077
5	309	309	$-2\pi_4 + \omega_4 + \psi$	-.00025226
6	−19	−19	$-2\pi_4 + \omega_3 + \psi$	-.00050336
7	8	8	$-\pi_4 - \Pi_J + 2\psi$	-.00008550
8	−5	−5	$-\pi_4 - \Pi_J + \omega_4 + \psi$	-.00016699
9	63	63	$-\pi_4 + \Pi_J - \omega_4 + \psi$	-.00000379
10	8	8	$-2\Pi_J + 2\psi - 3G$	-.01155634
11	73	73	$-2\Pi_J + 2\psi - 2G$	-.00770430
12	−4840	−4840	$-2\Pi_J + 2\psi$	-.00000023
13	16	16	$-2\Pi_J + \omega_4 + \psi - 2G$	-.00778579
14	−97	−97	$-\omega_3 + \psi$	.00033259
15	152	152	$-2\omega_4 + 2\psi$	.00016297
16	2074	2065	$-\omega_4 + \psi$	.00008148
17	−5605	−5605	G	.00385204
18	−204	−204	$2G$	.00770407
19	−10	−10	$3G$	.01155611
20	24	24	$G' - G + \phi_3$	-.00230090
21	11	11	$G' + \phi_1 - 2\phi_2$	.00155114
22	52	52	$2G' - 2G + \phi_4$	-.00460180
23	61	61	$2G' - G + \phi_1$	-.00074976
24	25	25	$3G' - 2G + \phi_2 + \phi_3$	-.00305066
25	21	21	$3G' - G + \phi_1 - \phi_2$	.00080138
26	−45	−45	$5G' - 3G + \phi_1$	-.00380041
27	−495	−495	$5G' - 2G + \phi_2$	.00005162
28	−43	−44	$\omega_3 - \omega_4$	-.00025110
29	5	5	$\pi_4 - \Pi_J - G$	-.00376677
30	234	234	$\pi_4 - \Pi_J$	.00008527
31	11	11	$2\pi_4 - 2\Pi_J - 2G$	-.00753353
32	−10	−10	$2\pi_4 - \omega_3 - \omega_4$	.00058485
33	68	67	$2\pi_4 - 2\omega_4$	.00033374
34	−13	−13	$\pi_3 - \pi_4 - \omega_4 + \psi$	.00032647
35	−6112	−6041	$\pi_3 - \pi_4$	.00024499
36	−42	−42	$\pi_3 - \pi_4 + \omega_3 - \omega_4$	-.00000612
37	−3318	−3276	$\ell_4 - \pi_3$	.99966974
38	48	48	$\ell_4 - \pi_4 - 2\Pi_J + 2\psi$	.99991450
39	10	10	$\ell_4 - \pi_4 - \omega_4 + \psi$	.99999621
40	33	33	$\ell_4 - \pi_4 - G$	.99606269
41	146673	146938	$\ell_4 - \pi_4$	.99991473
42	−31	−31	$\ell_4 - \pi_4 + G$	1.00376677
43	−6	−6	$\ell_4 - \pi_4 + \omega_4 - \psi$	.99983324
44	−61	−61	$\ell_4 - \pi_4 + 2\Pi_J - 2\psi$	.99991496
45	10	10	$\ell_4 - \Pi_J - 2G$	.99229593
46	178	178	$\ell_4 - \Pi_J - G$	.99614796
47	−363	−363	$\ell_4 - \Pi_J$	1.00000000
48	5	5	$\ell_4 + \pi_4 - 2\Pi_J - 5G' + 2G - \phi_1$	1.00003365
49	12	12	$\ell_4 + \pi_4 - 2\Pi_J - 4G$	.98467712
50	124	124	$\ell_4 + \pi_4 - 2\Pi_J - 3G$	.98852916
51	1085	1087	$\ell_4 + \pi_4 - 2\Pi_J - 2G$	.99238120
52	−55	−55	$\ell_4 + \pi_4 - 2\Pi_J - G$	.99623323

Table 4. Continued

Index	E2	G5	Argument	Ratio n/n_{sat}
53	−12	−12	$\ell_4 + \pi_4 - 2\Pi_J$	1.00008527
54	−13	−13	$\ell_4 + \pi_4 - \omega_4 - \psi$	1.00016699
55	6	6	$\ell_4 + \pi_4 - 2\psi$	1.00008550
56	17	17	$\ell_4 + \pi_3 - 2\pi_4$	1.00015972
57	−28	−28	$\ell_4 + \pi_3 - 2\Pi_J - 2G$	.99262619
58	−33	−33	$2\ell_4 - \pi_3 - \pi_4$	1.99958447
59	672	674	$2\ell_4 - 2\pi_4$	1.99982946
60	36	36	$2\ell_4 - 2\Pi_J - 3G$	1.98844389
61	218	218	$2\ell_4 - 2\Pi_J - 2G$	1.99229593
62	−5	−5	$2\ell_4 - 2\Pi_J - G$	1.99614796
63	12	12	$2\ell_4 - \omega_3 - \omega_4$	2.00041430
64	−19	−19	$2\ell_4 - \omega_3 - \psi$	2.00033282
65	−48	−48	$2\ell_4 - 2\omega_4$	2.00016320
66	167	167	$2\ell_4 - \omega_4 - \psi$	2.00008171
67	−142	−142	$2\ell_4 - 2\psi$	2.00000023
68	148	148	$\ell_3 - 2\ell_4 + \pi_4$	.33272835
69	−96	−94	$\ell_3 - 2\ell_4 + \pi_3$	.33297334
70	−390	−390	$\ell_3 - \ell_4$	1.33264308
71	9	9	$2\ell_3 - 4\ell_4 + 2\pi_4$	.66545670
72	−37	−37	$2\ell_3 - 3\ell_4 + \pi_4$	1.66537143
73	6	6	$2\ell_3 - 3\ell_4 + \pi_3$	1.66561642
74	−195	−195	$2\ell_3 - 2\ell_4$	2.66528616
75	6	6	$3\ell_3 - 7\ell_4 + 2\pi_4 + \omega_4 + \psi$	-.00198194
76	185	186	$3\ell_3 - 7\ell_4 + 4\pi_4$	-.00172968
77	−151	−150	$3\ell_3 - 7\ell_4 + \pi_3 + 3\pi_4$	-.00148469
78	53	52	$3\ell_3 - 7\ell_4 + 2\pi_3 + 2\pi_4$	-.00123970
79	−10	−10	$3\ell_3 - 7\ell_4 + 3\pi_3 + \pi_4$	-.00099471
80	6	6	$3\ell_3 - 6\ell_4 + 3\pi_4$	.99818505
81	−8	−8	$3\ell_3 - 4\ell_4 + \pi_4$	2.99801450
82	−41	−41	$3\ell_3 - 3\ell_4$	3.99792923
83	−13	−13	$4\ell_3 - 4\ell_4$	5.33057231
84	−44	−44	$\ell_2 - 3\ell_3 + 2\ell_4$	-.29836076
85	89	89	$\ell_2 - \ell_4$	3.69956847
86	105	105	$\ell_1 - \ell_4$	8.43341926
——— LAT-4: Series coefficients for $\varsigma_4 = z_4/a_4$ (sine) ———				
1	8	8	$\ell_4 - 2\Pi_J - \omega_4 + 2\psi$	1.00008137
2	8	8	$\ell_4 - 2\Pi_J + \psi - 4G$	.98459174
3	88	88	$\ell_4 - 2\Pi_J + \psi - 3G$	.98844377
4	773	773	$\ell_4 - 2\Pi_J + \psi - 2G$	.99229581
5	−38	−38	$\ell_4 - 2\Pi_J + \psi - G$	.99614785
6	5	5	$\ell_4 - 2\Pi_J + \psi$	.99999989
7	9	9	$\ell_4 - \omega_1$	1.00615668
8	−1	−1	$\ell_4 - \omega_2$	1.00151199
9	−5075	−5119	$\ell_4 - \omega_3$	1.00033270
10	−7	−7	$\ell_4 - \omega_4 - G$	.99622956
11	44300	44106	$\ell_4 - \omega_4$	1.00008160
12	7	7	$\ell_4 - \omega_4 + G$	1.00393364
13	−102	−102	$\ell_4 - \psi - G$	.99614808
14	−76493	−76493	$\ell_4 - \psi$	1.00000011
15	104	104	$\ell_4 - \psi + G$	1.00385215
16	−10	−10	$\ell_4 - \psi + 5G' - 2G + \phi_2$	1.00005174
17	−11	−11	$\ell_3 - 2\ell_4 + \psi$	.33264296
18	7	7	$\ell_3 - 2\ell_4 + \omega_4$	.33256148

"formal" error in Arlot's G-5. It should be pointed out, however, that the formal error given by Arlot for the phase of the libration ($\Delta\beta_5$ in the theory) almost certainly is incorrect and should probably be interpreted as the error in $\varepsilon_9 \Delta\beta_5$, since Arlot (using Lieske's software) undoubtedly employed the partial derivative with respect to $\varepsilon_9 \Delta\beta_5$ rather than simply the partial derivative with respect to $\Delta\beta_5$ alone.

At any rate, the only reliable way to compare two sets of predictions is to evaluate them with a common set of data. Arlot has performed such a comparison using photographic data and, as noted above, there is very little difference between the two ephemerides if one ignores Arlot's "error estimate" comparison and relies on the more meaningful difference in sum-of-squares of residuals for the common set of data.

In order to demonstrate the long-term comparison of the two sets of parameters E-2 and G-5, I have calculated the Observed minus Calculated times of observation for the collection of eclipses which is the subject of this paper. I have adopted the Spencer-Jones value for lunar tidal acceleration of $\dot{n}_{\rm Moon} = -22''.44$ in reducing Morrison's values of ΔT to the Spencer-Jones standard in relating ET for the predictions and UT for the observations. In the plots I also show the reference line for zero residuals if one adopts Morrison's value of $\dot{n}_{\rm Moon} = -26''.0$ for the lunar acceleration. It should be noted that no adjustment of either the E-2 or of the G-5 parameters has been made, but I have merely "extrapolated" the two ephemerides into epochs where neither had contained any data in the analyses which originally produced E-2 and G-5. In this comparison for the sake of consistency I have employed the same satellite radii as employed in the paper on eclipse predictions (Lieske, 1981) based upon the work of O'Leary and van Flandern (1972) for the radius of Io (1820 km) and that of Aksnes and Franklin (1976) for the other satellites (1533 km, 2608 km, and 2445 km). Future studies will of course utilize the IAU radii as given by Davies et al. (1983) or its successor.

The residuals for ephemeris E-2 are presented in Fig. 5 for the four satellites. In calculating the positions of Jupiter and of the Earth I have employed the JPL ephemeris DE-102 (Newhall et al.,

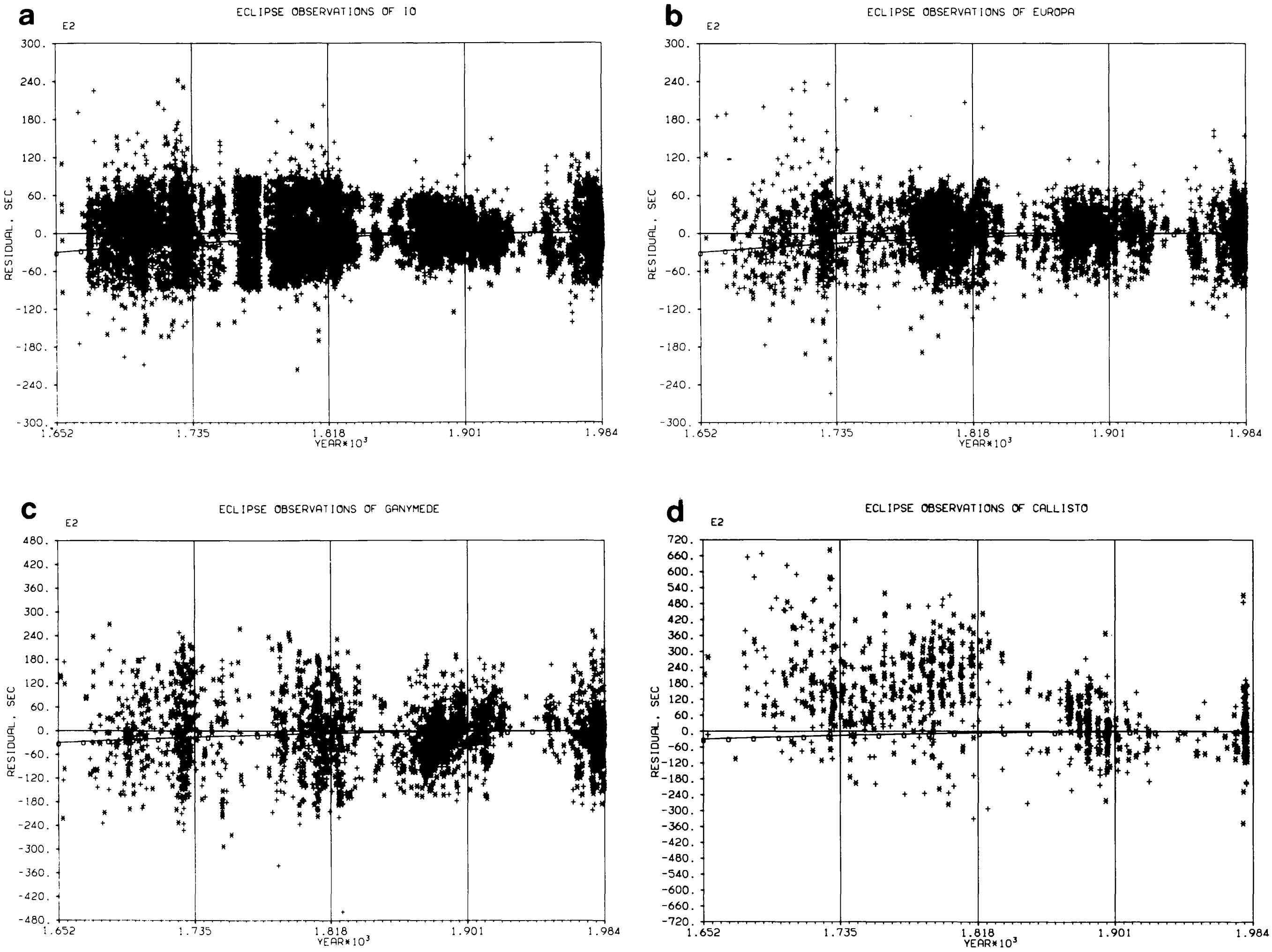

Fig. 5a–d. Extrapolated O-C eclipse residuals (for the data contained in the present collection) for Io (**a**), Europa (**b**), Ganymede (**c**), and Callisto (**d**) in sec as a function of year of observation is plotted for Ephemeris E-2 (Lieske, 1980). The abscissa is based upon Spencer-Jones' $\dot{n}_{\rm moon} = -22.44$ in the calculation of ΔT. The analogues x-axis of zero residuals for Morrison's $\dot{n}_{\rm moon} = -26$ arcsec/cy^2 is represented by the solid line ∘—∘—∘. No adjustment to the E-2 parameters have been made

1983). The O-C residuals are expressed in seconds of time, and disappearances are represented by an asterisk (*) while reappearances are represented by a plus sign (+). The reference axis for the ordinate is based upon the Spencer-Jones lunar tidal term of $\dot{n}_{\mathrm{Moon}} = -22''.44$ in ΔT, while the reference axis for zero-residuals for the Morrison and Ward lunar acceleration of $\dot{n}_{\mathrm{Moon}} = -26''.0$ is depicted as the reference value labeled as a ∘—∘—∘ curve. There is some evidence for Satellites I through III that a value for the lunar tidal acceleration should be between the Spencer-Jones (horizontal axis) and the Morrison and Ward (∘—∘—∘) values, although the residuals are remarkably flat for over three centuries without any adjustments to the orbital parameters. Satellite IV suggests evidence of a drift in the time prior to the 20th century where no data were employed in generating E-2. The residuals in seconds of time can be converted to approximate longitude residuals (measured in km) by multiplying the time-residuals by the negative of the velocity for each satellite: $18\,\mathrm{km\,s^{-1}}$ for Io, $14\,\mathrm{km\,s^{-1}}$ for Europa, $11\,\mathrm{km\,s^{-1}}$ for Ganymede and $8\,\mathrm{km\,s^{-1}}$ for Callisto.

Similar plots for Arlot's G-5 ephemeris (Arlot 1982), whose constants are given in Tables 3 and 4, are presented in Fig. 6. There are more pronounced drifts for the inner three satellites for ephemeris G-5.

The detailed analysis of the data contained in the present collection will be presented in a subsequent paper in which the satellite masses and Jupiter's pole will be estimated with an accuracy comparable to that of the spacecraft-based results of Campbell and Synnott (1985), but for the present study I made an initial investigation of the Satellite IV data and adjusted only the longitude (β_4), mean motion (ε_8) and eccentricity (ε_{19}) of Satellite IV in order to demonstrate how much of the drift present in Fig. 5 could be attributed to simple orbital effects. The resultant residuals for "E2+" for Callisto are depicted in Fig. 7 with the three changed parameters listed in Table 3. The other satellite residuals do not perceptibly change. Statistics of the graphical representations are given in Table 5. Again, it should be noted (with the exception of E2+) that no adjustments to the E-2 or the G-5 parameters have been made. In the table the maximum, minimum

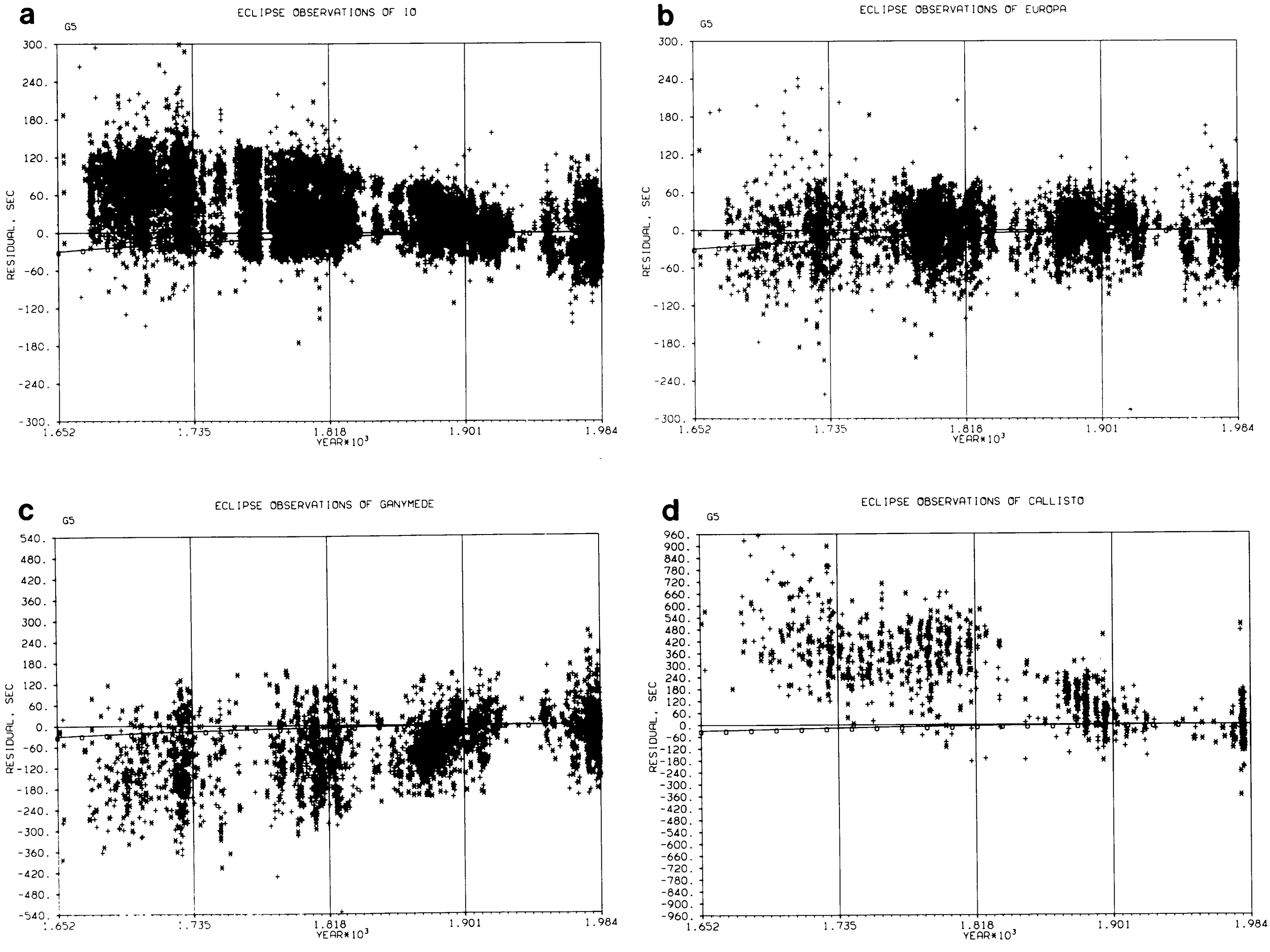

Fig. 6a–d. Extrapolated O-C residuals for the observations contained in the present collection are plotted for Ephemeris G-5 (Arlot, 1982). No adjustment of Arlot's G-5 parameters have been made. As in Fig. 5 the solid curve represents the zero-residual axis for Morrison's $\dot{n}_{\mathrm{moon}}$ in the calculation of ΔT. Time-residuals may be converted to longitude residuals by multiplication of each satellite's speed ($18\,\mathrm{km\,s^{-1}}$, $14\,\mathrm{km\,s^{-1}}$, $11\,\mathrm{km\,s^{-1}}$, $8\,\mathrm{km\,s^{-1}}$ for Io through Callisto, respectively)

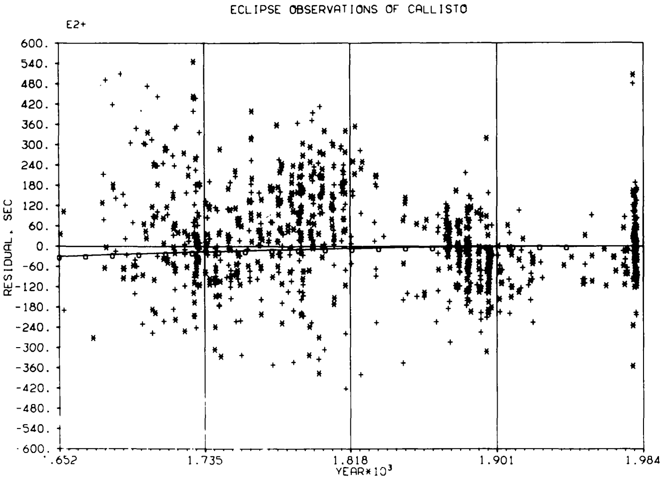

Fig. 7. Graph of Callisto O-C eclipse is plotted in sec of time as a function of year for Ephemeris E2+, which was derived from E-2 by adjusting only the longitude, mean motion and eccentricity of Callisto

Table 5. Statistics for ephemerides E2 (Lieske), G5 (Arlot) and E2+

Satellite	Max	Min	Mean	σ_0	σ	N	σ_a
Io							
E2	242^{s}	-216^{s}	$-1^{\mathrm{s}}.1$	$44^{\mathrm{s}}.4$	$44^{\mathrm{s}}.4$	8502	$43^{\mathrm{s}}.2$
G5	299	−175	+31.0	58.0	49.0	8502	43.2
E2+	242	−216	−1.1	44.4	44.4	8502	43.2
Europa							
E2	239	−254	+0.8	42.4	42.4	3966	44.2
G5	241	−261	−1.8	43.0	43.0	3966	44.2
E2+	239	−254	+0.8	42.4	42.4	3966	44.2
Ganymede							
E2	269	−458	−7.0	86.1	85.8	2394	78.4
G5	267	−534	−62.7	115.8	97.3	2394	78.4
E2+	269	−458	−7.0	86.1	85.8	2394	78.4
Callisto							
E2	682	−347	112.1	197.0	162.0	849	124.8
G5	952	−355	247.4	327.9	215.3	849	124.8
E2+	545	−422	24.9	148.8	146.7	849	124.8
All							
E2	682	−458	4.6	68.9	68.7	15711	53.2
G5	952	−534	20.1	100.7	98.6	15711	53.2
E2+	545	−458	−0.1	62.0	62.0	15711	53.2

and mean residuals are given, along with the standard deviation σ, the standard deviation from zero mean σ_o, the number of observations N and the average apriori uncertainty σ_a (discussed subsequently) for each satellite. The residual plot for Callisto depicted in Fig. 7 still suggests that some of the physical parameters of E-2 (e.g., the pole of Jupiter, the satellite masses, etc.) may need revision – or perhaps that the theory lacks a periodic term or perhaps that it contains one which it should not [such as Term 35 in υ_4 of Table 4: $-6112\,10^{-7}\sin(\pi_3-\pi_4)$ with a period of 186 yr].

5. Catalog of eclipse observations

The collection of eclipse observations 1652–1983 is more thoroughly described in the Supplement paper, but a sample page from the collection is presented here in Table 6. Each observation is assigned a reference number (NUMBER) and the Gregorian data of observation in a proleptic UT scale is given as YEAR, MONTH, DAY. The apriori uncertainty σ_a of the observation (SIGMA) is given in Field 5 in sec and is intended to be employed for weighting the individual observations in future analyses. It is to some extent arbitrary and is generally based upon a long series of observations by a given observer so that the weighted sum-of-squares is approximately equal to the number of observations. If a given observer normally observes "last speck" (at the beginning B of an eclipse) or "first speck" (at the end E of an eclipse) for disappearances (D) and reappearances (R), then often if he describes the observing conditions as being poor, his disappearances will be interpreted as D-times (half-brightness or mid-event for disappearance) and his reappearances will be R-times (half-brightness for reappearance). The suffix to the SIGMA field is either a V (for visual observation) or a P (for photometric). In the sixth field (SAT) the satellite number and type of event (e.g. 1D for a disappearance of Satellite I or 3R for a reappearance of Satellite III) is given.

All observations are reduced to the mid-event or half-brightness time of observation (see Peters, 1975, or Thuillot, 1983) using the T_Q values given in column 10 and described in an earlier paper (Lieske, 1981). T_Q represents the amount of time required for a satellite to move a distance equal to its radius in a direction normal to the eclipse cone and is thus approximately the difference in time between the "last speck" (B) and half-brightness time for a disappearance (D) or the difference between the "first speck" (E) and half-brightness time for a reappearance (R). There is some arbitrariness in my allocation: I assumed that an observer observed either the mid-event (D or R) or that he observed the last/first speck (B or E) rather than trying to interpolate to some ideal standard for each observer. If an observer determined the last/first speck at the beginning (B) or end (E) of an eclipse, then I reduced the observed times to the comparable mid-event times for disappearance (D) or reappearance (R). If he observed a mid-event D or R then I made no change in the observed time but inserted in the NOTES column of Field 9 the letter 'S' (for "switched") so that another analyst would be free to apply his own correction if desired.

The seventh field PUB of the table contains the index to the publication reference (see Table 1) and the eighth field LOC contains the index for the observatory site (see Table 2). The 9th field NOTES contains an 'S' if the original data were D/R rather than last(B)/first(E) speck reduced to mid-event. It usually is the result of use of a small-aperture telescope or the presence of adverse observing conditions. The NOTES field contains an asterisk (*) if the data should not be employed in an analysis and is probably due to its being a duplicate (in which case it is marked with an @ symbol) or from the abnormally large residual which probably is a result of a recording error or an misinterpretation of the observing site or method of recording time. If several observations were made for the same event at a single observing site, then they are combined into one pseudo-observation (the letter V plus the number of observations that went into the calculation of the "normal" point appears in Field 9) while the original data are marked as "duplicates" with the notation *@. The tenth field contains T_Q, the time in sec required for a satellite to traverse a distance equal to its radius into the eclipse cone. The "last speck" time of observation t_B at the beginning of an eclipse (B) is related to the half-brightness time of disappearance t_D by

$$t_B = t_D + T_Q \tag{2}$$

where T_Q is positive, while the reappearance (R) time of half-brightness t_R is related to the first speck (E) at the end of an

1986A&A...154...61L

Table 6. Sample page from collection of eclipses

Galilean satellite data and residuals for ephemerides E2 (Lieske), G5 (Arlot), and E2+

NUMBER	YEAR	MONTH	DAY	SIGMA	SAT	PUB	LOC	NOTES	TQ	E2	G5	E2+
1	1652	6	27.96845	50V	1D	BC	RL	*S	108	-1641	-1563	-1641
2	1652	9	24.84074	50V	2R	BC	RL	*S	-120	1401	1397	1401
3	1652	10	4.71094	150V	4D	BC	RL		349	214	510	36
4	1652	10	25.71205	105V	3R	BC	RL	*S	-253	-3491	-3640	-3491
5	1653	4	30.12432	105V	3R	BC	RL	*S	-241	2743	2587	2743
6	1653	5	7.10851	105V	3D	BC	RL		241	139	-15	139
7	1653	6	13.06137	150V	4D	BC	RL	*	300	1656	1951	1479
8	1653	6	19.10670	105V	3D	BC	RL	S	240	135	-19	135
9	1653	6	30.02288	150V	4R	BC	RL	*S	-300	1725	2019	1547
10	1653	7	17.01353	150V	4R	BC	RL	*S	-300	21892	22186	21715
11	1653	9	5.05242	150V	4R	BC	RL	*S	-302	1516	1809	1339
12	1654	5	31.08268	150V	4D	BC	RL	*S	381	6506	6799	6329
13	1654	5	31.13824	150V	4R	BC	RL	*S	-381	-2880	-2589	-3057
14	1654	7	3.97892	105V	3D	BC	RL	S	276	-222	-384	-222
15	1654	8	5.12825	50V	1D	BC	RL	*	108	356	434	356
16	1654	8	6.05843	150V	4D	BC	RL	*	435	527	820	351
17	1654	8	9.00838	105V	3R	BC	RL	*S	-284	5036	4879	5036
18	1654	8	22.82144	150V	4D	BC	RL	*	452	581	874	404
19	1654	8	22.95443	150V	4R	BC	RL	S	-452	-13	277	-190
20	1654	8	26.04900	50V	2R	BC	RL	*S	-119	5076	5078	5076
21	1654	10	28.87424	200V	4D	BC	RL		555	279	571	102
22	1654	12	8.66403	105V	3D	BC	RL	*S	316	-733	-895	-733
23	1654	12	8.79376	105V	3R	BC	RL	S	-316	-125	-277	-125
24	1655	7	1.13598	50V	2D	BC	RL		135	-7	-6	-7
25	1655	7	2.10650	50V	1D	BC	RL		113	46	123	46
26	1655	7	18.03588	50V	1D	BC	RL		113	110	187	110
27	1655	7	26.01296	50V	2D	BC	RL		136	125	127	125
28	1655	7	26.05065	105V	3D	BC	RL	S	406	-96	-265	-96
29	1655	7	26.14787	105V	3R	BC	RL	S	-406	174	20	174
30	1655	8	10.04242	50V	1D	BC	RL		113	-11	65	-11
31	1655	8	17.12629	50V	1D	BC	RL	*	113	373	450	373
32	1655	9	2.05118	50V	1D	BC	RL		113	35	112	35
33	1655	9	17.98630	50V	1D	BC	RL	*S	113	570	647	570
34	1655	9	20.88352	50V	2D	BC	RL	*S	140	1080	1085	1080
35	1655	9	25.05823	50V	1D	BC	RL	S	113	-93	-16	-93
36	1655	9	27.97839	50V	2D	BC	RL	S	140	-47	-42	-47
37	1655	10	2.13581	50V	1D	BC	RL	*S	113	-274	-197	-274
38	1655	10	5.08633	50V	2D	BC	RL		141	-59	-54	-59
39	1655	10	12.89557	105V	3D	BC	RL	S	436	119	-53	119
40	1662	5	17.94863	50V	2R	AY	QP	S	-140	185	187	185
41	1665	9	26.88687	100V	1R	CY	QZ	?	-106	-175	-102	-175
42	1665	10	5.74102	100V	1R	CY	QZ	S	-106	191	264	191
43	1665	10	5.76318	55V	2R	CY	QZ		-115	-48	-38	-48
44	1668	1	11.81347	50V	2D	AY	QB	*S@	131	-84	-90	-84
45	1668	1	11.81347	50V	2D	BC	QB	S	131	-84	-90	-84
46	1668	1	11.92322	50V	2R	AY	QB	*S@	-131	188	190	168
47	1668	1	11.92323	50V	2R	BC	QB	S	-131	189	191	189
48	1668	1	19.05626	50V	1D	BC	PX	S?	113	31	105	31
49	1668	10	15.85181	50V	1D	CY	TA	*S	113	267	340	267
50	1668	10	22.92825	50V	1D	BC	PX	S	113	11	85	11
51	1668	10	22.92826	50V	1D	BA	LN	S	113	12	85	12
52	1668	10	24.93140	50V	1R	CY	TA	**	-113	12272	12346	12272
53	1668	10	29.90338	50V	1R	CY	TA	**	113	-9001	-8928	-9001
54	1668	11	12.92737	105V	3D	AZ	LN	S	367	83	-70	83
55	1668	11	12.92737	105V	3D	BC	PX	S	367	83	-70	83
56	1668	11	20.09403	105V	3D	BC	PX	S	364	84	-68	84
57	1668	11	20.09403	105V	3D	AZ	LN	S	364	84	-68	84
58	1669	11	26.92051	50V	1D	AZ	LN	S	109	28	100	28
59	1669	11	26.92051	50V	1D	BC	PX	S	109	28	100	28
60	1670	5	31.85989	50V	1R	CY	PX		-106	-40	30	-40
61	1671	3	19.87516	50V	1R	BC	PX	S	-106	-18	51	-18
62	1671	3	19.87517	50V	1R	AZ	LN	S	-106	-17	51	-17
63	1671	3	31.83627	165V	4D	CY	PX	S	299	-104	182	-272
64	1671	3	31.83992	150V	4D	AY	QQ	**@	299	210	497	42
65	1671	4	27.81402	50V	1R	AZ	LN		-106	-127	-58	-127
66	1671	4	27.81469	50V	1R	BC	PX	S	-106	-69	0	-69
67	1671	4	27.84663	105V	3R	BC	PX	S	-242	-71	-227	-71
68	1671	4	27.84753	105V	3R	AZ	LN		-242	6	-149	6
69	1671	5	4.86177	105V	3D	BC	PX	S	242	-110	-267	-110
70	1671	5	4.86178	105V	3D	AZ	LN	S	242	-109	-266	-109
71	1671	5	4.89476	50V	1R	BC	PX	S	-106	-63	5	-63
72	1671	5	4.99601	50V	1R	AZ	LN		-106	44	113	44
73	1671	9	25.15774	50V	1D	CY	QG		106	-12	58	-12
74	1671	10	18.16237	50V	1D	BC	PX	S	106	-95	-24	-95
75	1671	10	18.16304	50V	1D	CY	RM	S	106	-38	33	-38
76	1671	10	25.24179	50V	1D	AZ	LN		107	-20	50	-20
77	1671	10	25.24235	50V	1D	BC	RM		107	27	98	27
78	1671	10	25.24302	50V	1D	BC	PX	S	107	85	156	85
79	1671	11	17.24720	50V	1D	BC	PX	S	107	6	78	6
80	1671	11	19.25131	50V	2D	AZ	LN	S	114	-6	-9	-6
81	1671	11	19.25175	50V	2D	CY	RM	S	114	31	28	31
82	1671	11	26.08980	50V	1D	CY	QG	*	107	-468	-396	-468
83	1671	12	12.02197	50V	1D	CY	RM	S	107	18	90	18
84	1671	12	14.02263	50V	2D	CY	RM	**	114	-9103	-9106	-9103
85	1671	12	14.12791	50V	2D	AZ	LN		114	-7	-10	-7
86	1672	1	4.02693	50V	1D	BC	PX	S	107	-7	63	-7
87	1672	1	4.02694	50V	1D	AZ	LN	S	107	-6	64	-6
88	1672	1	4.02737	50V	1D	BC	RM	S	107	30	102	30
89	1672	1	11.10517	50V	1D	BC	PX	S	108	-42	28	-42
90	1672	1	11.10518	50V	1D	AZ	LN	*S@	108	-41	29	-41
91	1672	1	11.10567	50V	1D	BC	LN	S	108	0	72	0
92	1672	1	12.87449	50V	1D	BC	PX	S	108	-70	0	-70
93	1672	1	12.87450	50V	1D	AZ	LN	*S@	108	-69	1	-69
94	1672	1	12.87499	50V	1D	BC	LN	S	108	-27	43	-27
95	1672	1	18.18454	50V	1D	CY	LN	S	108	14	85	14
96	1672	1	19.95432	50V	1D	BC	PX	S	108	24	95	24
97	1672	1	25.26312	50V	1D	BC	PX	S	108	-4	67	-4
98	1672	1	27.03311	50V	1D	BC	PX	S	108	22	93	22
99	1672	2	3.11177	50V	1D	BC	PX	S	108	1	73	1
100	1672	2	11.95432	50V	1D	BC	RN	*	108	-537	-466	-537

eclipse by

$$t_E = t_R + T_Q \qquad (3)$$

where T_Q is negative. The eleventh through thirteenth fields labeled E2, G5 and E2+ contain the O-C residuals (in sec) for ephemerides E-2 (Lieske, 1980), G-5 (Arlot, 1982) and E2+ (noted at the end of Table 3 of this paper).

6. Conclusions

The collection of eclipse observations presented here represents the most thoroughly documented series of observations of Jupiter's Galilean satellites extant. The 332-yr series of eclipse observations represents a fairly uniform set of data from which present and future generations of astronomers can draw inferences which could not be derived from any highly accurate local series of data. Although they by themselves do not represent the greatest accuracy currently available, the eclipse observations, by their uniform accuracy and sheer length of time covered, provide one of the most valuable sources of data for studies in the long-term motion of the satellites. It is hoped that this collection will provide a vital link to the past that will be required of future theories and analyses. Future analyses of these data should provide accuracies for the satellite masses and Jupiter pole parameters which are independent of and rival in accuracy the results of spacecraft-based studies.

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