A COLLECTION OF GALILEAN SATELLITE ECLIPSES 1652-1982

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I. INTRODUCTION

It is known that early (i.e. 17th-18th century) visual observations of Jupiter's Galilean satellites are approximately as accurate as modern visually observed eclipses (Lieske 1982). In the early days the clocks were the primary source of error while in present days problems related to the Earth's and Jupiter's atmospheres have become the primary limiting factor. The early observations were generally made in local apparent time (i.e. related to the real hour angle of the sun). After the development by Huygens in 1656 of the pendulum clock, these early observations, when reduced to a modern UT system, have been shown to be quite accurate.

The early data are of great interest, both historically and scientifically. From the historical standpoint, the data are of interest: for example, in exploring the work of Ole Roemer and his determination of the finite speed of light; or, in the observations of Neptune by Galileo (Kowal and Drake 1980). Also, many of the early geographical charts were developed by employing satellite eclipses to determine longitudes. The problem of Galilean satellite eclipses was one of the great areas of research in 17th century astronomy.

Scientifically, the early data are still of great interest because of the long time-base of observations with essentially uniform accuracy. These data could be used to explore questions related to ΔT (Ephemeris Time minus Universal Time) in the early days. Current investigations of ΔT (e.g. Morrison, 1979 Morrison, et al 1981) generally employ lunar occultations and must deal with the secular deceleration of the moon. Galilean satellite eclipses do not depend on the lunar tidal terms and should provide a useful independent check for 17th century values of ΔT, although there may be tidal effects from the Jupiter system which must be considered.

The evolution of the Laplace commensurability and of the periods of the satellites is also of great current interest. The studies by

V. V. Markellos and Y. Kozai (eds.), Dynamical Trapping and Evolution in the Solar System, 51–59.

Peale et al (1979, 1980), Greenberg (1980), Yoder (1979), and Yoder and Peale (1981) all present scenarios which would benefit greatly from analyses which can only effectively be done by employing the old data over a long time-span.

So the value of old eclipse observations is readily apparent. The question is: do they still exist? The purpose of this paper is to introduce two treasures (in the true sense of the word) which still exist and which do contain the old data which for many years were thought to have disappeared.

II. THE DELAMBRE COLLECTION

It is generally believed that Delambre (1749-1822) collected over 6000 eclipse observations of the Galilean satellites prior to approximately 1808. Sampson (1910), who initiated an exhaustive study of manuscripts at the Bureau des Longitudes found part of the "computer" records (the personal computers of those days were humans, rather than Apple II's), for Satellites II and IV. These records formed part of the "Delambre" collection which Sampson described as:

> ". . . forming part of Delambre's great collection, which, so far as I know, astronomers have hither to supposed to be lost. Probably no such collection could now be made nor would anyone attempt it with so much thoroughness. Much of it seems to have been gathered from correspondents. [p. 200]
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> . . . But the original achievement of Delambre, who collected and reduced some 6000 observations . . . fully deserves Laplace's [1749-1827] praise as 'un des principaux titres de ce savant illustre à la reconnaissance des astronomes.' [p. 199]
>
> Delambre regarded his collection as exhaustive; in his Tables of 1817 (Introduction, p. i) he says, 'j'ai donc receulli soigneusement tout ce que les éphémerides, les collections académiques, les ouvrages des astronomes et ma correspondence m'ont fait connaître; and further (pp. liv, lv) he mentions that this collection of eclipses consisted of 3439 eclipses of I, 1100 of II, 590 of III, and 334 of IV. If those could be recovered, it was clear that they would form a more valuable collection than any that could now be made. Tisserand, who was in a position to know, seems to imply that they were lost: 'le travail dans lequel Delambre avait discuté plus de 6000 observations, et dont Laplace parle à plusiers reprises, a malheureusement été pardu' (Méc. Cél., t. iv, p. 84). [p. 215]."

These partial records for Satellites II and IV, which were found by Sampson, have been shown (Lieske 1982) to be quite accurate

especially for Satellite II (for which the records contained the observer's location). Hence, I became interested in pursuing the possibility of locating further old documents and looking for the lost "Delambre" collection.

III. THE PINGRÉ TREASURE

While staying in 1980 at the Astronomisches Rechen-Institut in Heidelberg as an Alexander von Humboldt Senior American Scientist awardee, I was able to further investigate the possible sources and existence of old data. From L. Morrison of the Royal Greenwich Observatory, I received a clue to examine a Pingré book. This volume, A.-G. Pingré: Annales Célestes du dix-septième siècle by Bigourdan (1901), [hereafter referred to as Pingré] proved to be extremely interesting. Alexandre-Gui Pingré (1711-1796) was a French cleric and astronomer who for 30 years collected and compiled a history of seventeenth century astronomy. According to Gillispie (1970 X, p. 615):

> "In 1791 Le Monnier and Lalande persuaded the Academy to vote a large sum for its publication but the printer was slow and Pingré's death in 1796, coupled with devaluation the preceding year, led the printer to abandon the project and to sell the printed sheets as waste paper. Worse still, the manuscript was lost. Almost a century later, however, a Parisian bibliophile found in a country town what turned out to be LeMonnier's set of sheets and the remainder of the manuscript was discovered in the archives of the Paris observatory. In 1898, at the instigation of C. G. Bigourdan, the Academy again decided to publish; and the volume appeared in 1901."

This work, which had been thought lost for 100 years contains comments on 17th century astronomy, as well as observations. It makes for extremely interesting reading. Since the Galilean satellites were a prime focus of 17th century astronomy, eclipse observations of them occur with regularity. Some interesting examples are as follows. We find the entry for September 1689:

> "Sept. 21 11^h 39' . . . émersion du 1^{er}. Malaca. les P. Comille et de Bèze. Anc. Mém t VII, p. 756.
>
> . . .
> . . .
>
> 28 13 37 . . . émersion du 1^{er}:: Malaca, les mêmes que le 21.ibid. Les observateurs étoiant en prison; il ne leur étoit quères possible de s'assurer de l'heure avec quelque précision." [p. 469].

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This series of observations (there are others) were made at Malaca, Malaysia in 1689 by two people who were in prison and, hence, couldn't accurately set up a clock! However, when reduced from apparent time to universal time and compared with the E-2 ephemeris (Lieske 1980), the observations are quite good. The moral here might be that everyone can make a valuable contribution to science and humanity!

Another example from the same year (1689) is found:

"Nov. 1 6^h 1'20" . . . suivant la correction du P. Gouye. Anc. Mém. t. VII, p. 783. Le P. Noël remarque que ses observations ont été faites dans la partie orientale de Hoai-Ngan, grande ville. . . La lunette du P. Noël portoit un objectif de 13 1/2 pieds, et un oculaire de 2 1/2 pouces: elle étoit, dit-il, excellente" [p. 470].

This particular example is interesting for the following reason. As has been mentioned, one of the prime objectives of 17th century astronomy was the determination of longitudes. A difficulty that a modern analyst frequently finds is that the names of cities (and countries) have changed over the centuries. In addition, the Pingré book generally contains French phonetic spellings of place-names. One needs to know the longtiude of the locality in order to make the reduction from apparent to universal time. When I first consulted my Chinese colleagues regarding "Hoai-Ngan" they immediately informed me that that was not a Chinese name (because of the "ng"). Since I had 100 of these observations and they all were excellent, giving the same residuals for an assumed location in Vietnam (where I was told the combination "ng" occurs in spelling), I applied the modern ephemerides to the 17th century task of determining observatory longitude. From the residuals I calculated a longitude correction which led me to a longitude of $119^\circ.11$ East where I found Hwaian (Kiangsu, China) and which my Chinese colleagues pronounced in the same manner as my French colleagues pronounced "Hoai-Ngan" or "Hoyaingan" as it also is spelled in some of the Delisle manuscripts. This gives an idea of some of the difficulties and also the rewards of reducing the old data.

The Pingré work is certainly the main source for Delambre's 17th century collection. It is quite remarkable that Sampson, who published his research on the old data in 1910, was not aware of this treasure which was published in 1901! I highly recommend the Pingré book to anyone interested in historical astronomy and scientific attitudes during the 17th century.

IV. THE DELISLE TREASURE

The second treasure which I would like to mention is the manuscript collection of J. N. Delisle (1688-1768), which is probably the basic source for both Pingré and for the "Delambre" collection of Galilean satellite eclipses. Delisle (also spelled De l'Isle) was a student astronomer of Maraldi who collected reports of eclipses and occultations for the Mémoires. According to Gillispie (1970, IV, p. 22-25),

> "Delisle's growing reputation brought him, in 1721, an offer from Peter the Great to found an observatory and an associated school of Astronomy in Russia . . . . Planned for four years, Delisle's stay in Russia lasted twenty-two years. . . . One of Delisle's long-standing activities had been the amassing of vast amounts of geographical and astronomical material through an extraordinarily extensive correspondence, through inheritance, and through laborious copying."

After his return to Paris

> ". . . he obtained a new observatory at the Hôtel de Cluny. It was there, in 1759, that his pupil and assistant, Charles Messier, observed the return of Halley's comet."

Pingré became associated with the project headed by Delisle to observe the transit of Venus in 1761. It is, therefore, quite probable that the original source of the Pingré collection of eclipses and the "Delambre" collection is Delisle.

While visiting the Paris observatory, I mentioned my interest in old manuscripts to Mme A-M. de Narbonne, Conservateur of the Observatory of Paris Library. She showed me several volumes of the Delisle manuscripts and made it possible for me to study them. In the Inventaire Général by Bigourdan (1897) they are classified under the heading A 5 1 through A 5 8 and described on pages F11-F12 of the Inventaire Général. Again it is surprising that Sampson was unaware of this publication.

The inscription in Delisle's handwriting on one page of his collection is reproduced in Figure 1. It reads: "Eclipses of the satellites of Jupiter observed in Paris after my return from Russia in 1747 where the apparent times have been, for the most part, calculated by Mr. Messier for my journal."

The "Mr. Messier" referred to here is the same Charles Messier mentioned earlier. A second moral to this paper might be that today's assistant will become tomorrow's leader since Messier became famous in his own right.

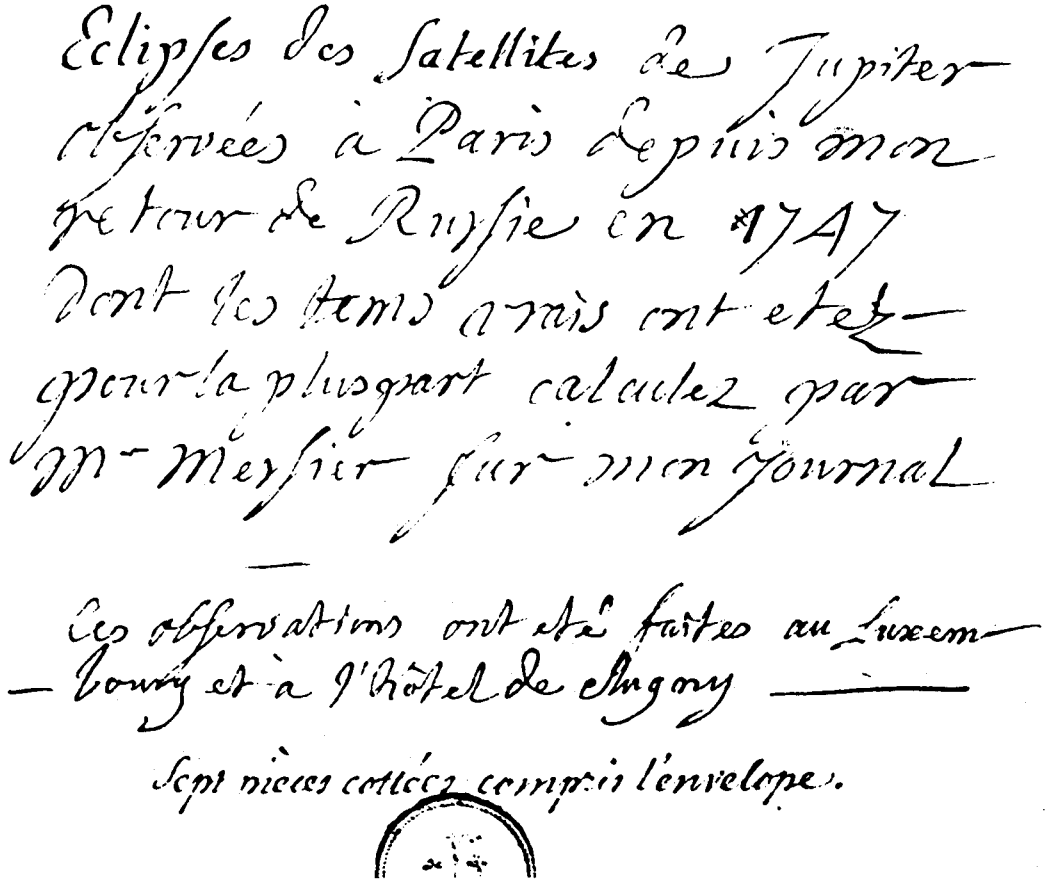

Figure 1. Inscription in Delisle Manuscript

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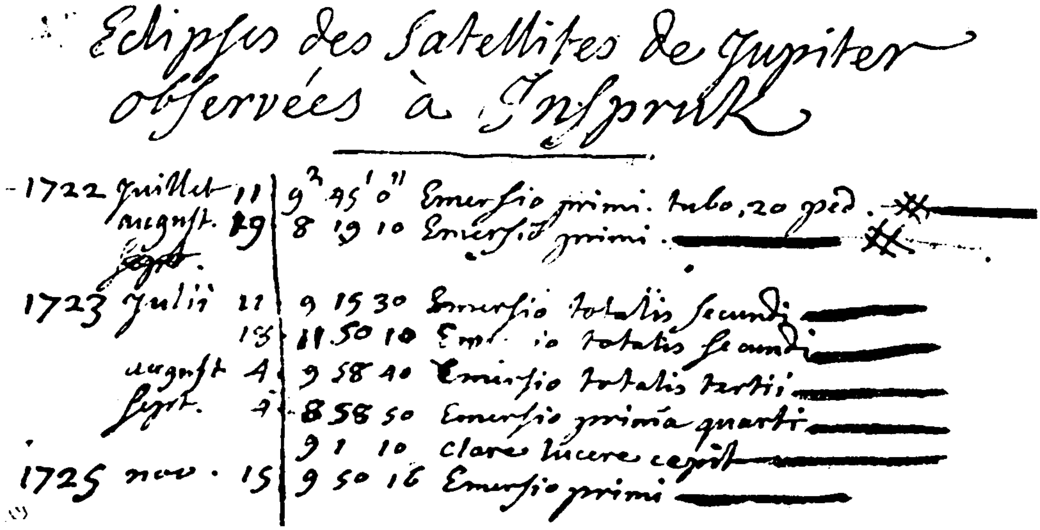
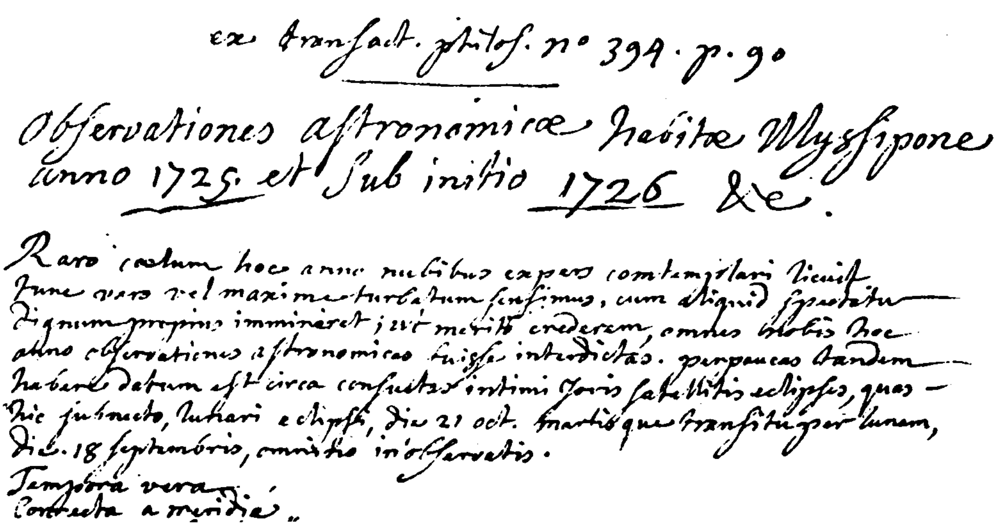


Eclipses des Satellites de Jupiter observées à Inspruk

1722	Juillet 11	9h 45' 0"	Emersio primi. tubo, 20 pied.
	august. 19	8 19 10	Emersio primi.
	sept.		
1723	Julii 11	9 15 30	Emersio totalis secundi
	13	11 50 10	Emersio totalis secundi
	august 4	9 58 40	Emersio totalis tertii
	sept. 7	8 58 50	Emersio prima quarti
		9 1 10	clare lucere coepit
1725	nov. 15	9 50 16	Emersio primi

Figure 2. Observations from "Inspruk"



ex transact. philos. no 394. p. 90

Observationes astronomicae habitae Ulyssipone anno 1725 et sub initio 1726 &c.

Raro caelum hoc anno nubibus expers contemplari licuit. Tunc vero vel maxime turbatum sensimus, cum aliquid spectatu dignum propius immineret; ut merito crederem omnes nobis hoc anno observationes astronomicas fuisse interdictas. perpaucas tandem habere datum est circa consuetas intimi Jovis satellitis eclipses, quas hic subnecto, lunari eclipsi, die 21 oct. martisque transitu per lunam, die 18 septembris, omnino inobservatis.

Tempora vera

Correcta a meridie.

Figure 3. Observations from "Ulysʃipone"

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The handwritten manuscripts are generally in French or Latin and contain eclipse observations which Delisle made or recorded from his correspondence. There are numerous deciphering problems which occur, similar to that cited regarding Hoai-Ngan. In Figure 2 is shown a relatively easy one where Innsbruck, Austria is spelled Inspruk. In Figure 3 the more difficult Ulysſipone is Lisbon, Portugal upon close study.

V. SUMMARY

I have examined the Delisle manuscript and the Pingré book and have recorded and reduced the observations listed there. We now have more than 6800 eclipse observations before 1800 and over 16,000 prior to 1982. Hence, we may be certain that the lost "Delambre" collection has been found and that it probably should be called the Delisle-Pingré collection. It has been an exciting treasure hunt, and I hope to publish the reduced observations on microfiche so that these valuable data will not be lost to future generations.

The collected eclipse observations will become the basis for exploring the evolution of the Laplace commensurability as well as for determining ephemerides, masses, libration parameters, etc. for the upcoming Galileo mission.

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REFERENCES

Bigourdan, G., 1897, "Inventaire général et sommaire des manuscrits de la bibliothéque de l'observatoire Paris", Ann. de l'Obs. Paris 21, F1-F60.

Bigourdan, G., 1901, A.-G. Pingré: Annales Célestes du dix-septième siècle, Gauthier-Villars, Paris [Pingré book].

Gillispie, C. C. (ed), 1970, Dictionary of Scientific Biography, C. Scribner, NY.

Greenberg, R., 1980, "Orbital Evolution of the Galilean Satellites" in The Satellites of Jupiter, D. Morrison, ed., IAU Colloquium No. 57, Academic Press.

Kowal, C. T., Drake, S., 1980, Nature, 287, 311.

Lieske, J. H., 1980, Astron. Astrophys. 82, 340.

Lieske, J. H., 1982, Cel. Mech. 26, 257.

Morrison, L. V., 1979, Monthly Notices Roy. Astron. Soc. 187, 41.

Morrison, L. V., Lukac, M. R., Stephenson, F. R., 1981, R. Greenwich Obs. Bull., (in press).

Peale, S. J., Cassen, P., Reynolds, R. T., 1979, Science 203, 892.

Peale, S. J., Cassen, P., Reynolds, R. T., 1980, Icarus 44, 234.

Sampson, R. A., 1910, Mem. Roy. Astron. Soc. 59.

Yoder, C. F., 1979, Nature 279, 767.

Yoder, C. F., Peale, S. J., 1981, Icarus 47, 1.