Mediterranean Archaeology and Archaeometry, Special Issue, Vol. 6, No 3, pp. 215-222

The Astronomical Inscription from Keskintos, Rhodes

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Received: 10/06/2006
Accepted: 15/10/2006

Abstract

A Greek astronomical inscription from about 100 B.C. found near Lardos, Rhodes in the late 19th century contains a table of numbers associated with various kinds of periodic behaviour of the planets. The inscription might have accompanied a votive object, perhaps representing the heavenly bodies in some manner. The underlying conception of celestial phenomena is significantly different from the tradition propagated by Ptolemy's Almagest. A long common period is assumed in which all periodicities of all planets are supposed to repeat exactly. This period was constructed as a product of the smallest whole factors, 2, 3, and 5. The relationships subsisting among many of the numbers in the inscription also reflect an assumption that small whole numbers underly the apparent complexity of planetary motion.

Keywords: *Rhodes, Keskintos, Great Year, planets, astronomy.*

Introduction

In 1893 a broken and weathered block of marble containing a Greek inscription on one of its faces was found at a site named Keskintos (Κέσκιντος) in the hill country southwest of Lardos, Rhodes, about 8 kilometres from Lindos. A Lindian antiquarian named Diakos Adelphiu made a "squeeze" (pressed paper impression) of the inscription and sent it to the German epigrapher Friedrich Hiller von Gaertringen, who had recently visited Rhodes in search of inscriptions to include in what was to be the first installment of volume 12 of the series *Inscriptiones Graecae* (Hiller von Gaertringen 1895). Recognizing from some of the vocabulary that the inscription's contents concerned astronomy, Hiller circulated a transcription of it among several astronomers and specialists in Greco-Roman science with the intention of gaining some understanding of what it meant-fruitlessly, until in September 1894 he approached the great French historian of mathematics Paul Tannery. Almost at once Tannery discerned through the noise of errors and gaps in Hiller's preliminary transcription that an arithmetical pattern prevails among the two columns of numbers that run down the first thirteen of the inscription's surviving fifteen lines: the number on the right of each line is always exactly ten times the number on the left. This relation made it possible to correct or restore many of the digits; and by December Tannery had worked out in its main lines the astronomical meaning of the text (Tannery 1895). Notwithstanding a couple of further insights due to Norbert Herz (Herz 1894) and Otto Neugebauer (Neugebauer 1975, v. 3, 698-705), little progress has been made on explaining the Keskintos Inscription and establishing its place in the evolution of Greek astronomy since Tannery's publications. Every serious historian of ancient astronomy is aware of its existence, but no one says much about it.

The edition that Hiller published as text no. 913 in *Inscriptiones Graecae* vol. 12 part 1 did not have the benefit even of Tannery's first round of corrections, which Hiller had to report in an addendum to the volume. Moreover all the scholarship on the inscription has depended on Adelphiu's squeeze; for although Hiller arranged to have the stone itself sent to Berlin, no one appears to have taken the trouble to examine it. As any reader of the four excellent pages of discussion that Neugebauer devoted to the inscription in his 1975 *History of Ancient Mathematical Astronomy* will see, an unsatisfactory element of uncertainty has adhered to both the readings and the astronomical interpretation. In the hope of obtaining a more secure text and addressing some of the remaining questions, I undertook a new edition, working directly from the stone in its present home, the basement of the Pergamon Museum of the Staatliche Museen zu Berlin. A critical edition and detailed study will appear in volume 7 of the journal *SCIAMVS: Sources and Commentaries in Exact Sciences*, probably in late 2006 (Jones 2006). In the present brief report emphasis will be chiefly on the cultural and conceptual aspects of the inscription rather than the details of the very interesting and enigmatic planetary theory that underlies it.

Description

The inscription is on a block of grey marble of dimensions 77 cm width by 31.5 cm height by 14 cm depth (Fig. 1). The two sides and the bottom are dressed faces, but the top surface is broken, and from the contents of the text it can be inferred that 12 cm or more-perhaps considerably more-is lost there. A large piece is also broken off the lower left corner, and the inscribed surface is weathered and chipped. The text is written in letters of approximately 0.8 cm height, except for the final, dedicatory line which has letters of approximately 1.4 cm height. Hiller, who had made a careful study of the development of lettering styles in Rhodian inscriptions, estimated the date of writing to be within a half century either way of 100 B.C.

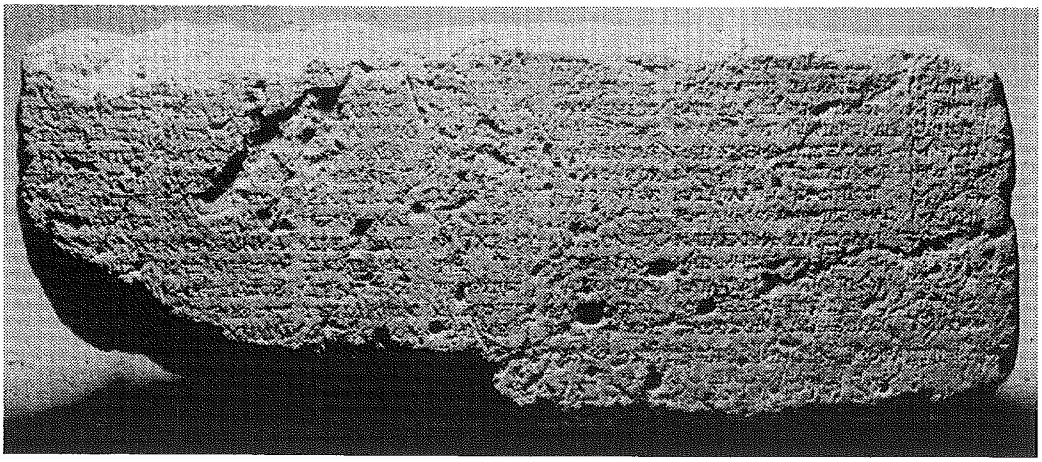

Fig.1: *The Keskintos Inscription (Staatliche Museen zu Berlin, Preußischer Kulturbesitz, Antikensammlung, Photo Johannes Laurentius).*

The text of the inscription, so far as it is preserved, is in three parts (cf. the text and translation in Figs. 2-3). The first thirteen lines belong to a table listing numbers of periods of four kinds associated with the planets Mercury, Mars, Jupiter, and Saturn (in that order). Only the fourth line devoted to Mercury survives. It can hardly be doubted that a set of periods for Venus was given in the lost preceding lines; whether there were also periods associated with the sun and moon is an open question. The format of each line of the table is uniform. Each line consists of two structurally identical halves, each half comprising the planet's name, a prepositional phrase qualifying the kind of period, a noun or adjective specifying the period, and a number. In each line the left and right halves are identical except for the numbers. The names of the planets are not the theophoric expressions "star of Hermes," "star of Ares," etc. familiar from Ptolemy but the descriptive names *Stilbôn* ("Twinkler"), *Pyroeis* ("Fiery one"), etc. that are frequently attested in Hellenistic and Roman period astronomical and astrological texts. Some of the terminology for the periods is familiar from other Greek texts, while some is unique to the inscription.

Following the planetary table, the fourteenth line defines two units of division of a circle (or cycle), the *moira* ("degree") and the *stigmê*

i	ii	iii	iv	v	vi	vii	viii
Σ[τίλβοντος]	[κατὰ σχῆμα]	[διέξοδοι]	. . . .	Στίλβ[οντος]	[κατὰ] σχῆμα	διέξοδο[ι]	[ϙα] M [ʹ]ηυ[ ]
Πυ[ρόεντ]ος	κατὰ μῆκ[ο]ς	[ζωι]διακοὶ	α M ʹευϙβ —	Πυρόεντος	κατὰ μῆκος	ζωιδια[κοὶ]	ιε M ʹδϡκ
Πυρόεντος	κατὰ πλάτ[ος]	[τρο]πικοὶ	α M ʹευλς [—]	Πυρόεντος	κατὰ πλάτος	τρ[ο]πικοὶ	ιε M ʹδτξ
Πυρόεντος	κατὰ βά[θος]	[περι]δρομαὶ	δ M ϡξ . —	Πυρόεντος	κατὰ βάθος	περιδρομαὶ	μ M ʹαχν
Πυρόεντος	κατὰ σχ[ῆμα]	[διέ]ξοδοι	α M ʹγ[χμ]η —	Πυρόεντος	κατὰ σχῆμα	διέξοδοι	ιγ M ʹϛυπ
Φαέθοντος	κατὰ [μῆ]κος	[ζ]ωιδιακοὶ	[ʹ]βυν —	Φαέθοντος	κατὰ μῆκος	ζωιδιακοὶ	β M ʹδφ
Φαέθοντος	κατ[ὰ πλ]άτος	τροπικοὶ	ʹβυνς —	Φαέθοντος	κατὰ πλάτος	τροπικοὶ	β M ʹδφξ
[Φαέ]θοντος	κατὰ βάθος	περιδρομαὶ	β M ʹδσξ —	Φαέθοντος	κατὰ βάθος	περιδρομαὶ	κδ M ʹβχ
[Φαέθ]οντος	κατὰ σχῆμα	διέξοδοι	β M ʹϛχϙ —	Φαέθοντος	κατὰ σχῆμα	διέξοδοι	κϛ M [ʹϛϡ]
[Φαίνο]ντος	κατὰ μῆκος	ζωιδιακοὶ	ϡϙβ —	Φαίνοντος	κατὰ μῆκος	ζωιδιακοὶ	[ʹ]θϡκ
[Φαίνοντος]	κατὰ πλάτος	τροπικοὶ	ϡπθ σις	Φαίνοντος	κατὰ πλάτ[ος]	τροπικοὶ	ʹθωϙς
[Φαίνοντος]	κατὰ βάθος	περιδρομαὶ	β M ʹζρος —	Φα[ίνο]ντος	κα[τ]ὰ βάθος	περιδρομαὶ	κζ M ʹαψξ
[Φαίνοντος]	[κατὰ] σχῆμα	διέξοδοι	β M ʹηρμη —	Φαίνοντος	κατὰ σχῆμα	διέξοδοι	κη M ʹαυπ

] . [. . . .] . . . ὁ κύκλος μο(ιρῶν) τξ, στιγμῶν [ʹ]θψκ. ἡ μοῖρα στιγμῶν κ[ζ.]

] . . αις χαριστήριον

***Fig.2:** Text of the Keskintos Inscription (bracketed letters are restored, underdotted letters are uncertain).*

	Mercury	[In relative position]	[passages]	xxxx	Mercury	In relative position	passages	[91]84xx
	Mars	In length	zodiacals	15492	Mars	In length	zodiacals	154920
3	Mars	In breadth	tropicals	15436	Mars	In breadth	tropicals	154360
	Mars	In depth	revolutions	40*96*x	Mars	In depth	revolutions	40*165*0
	Mars	In relative position	passages	13648	Mars	In relative position	passages	136480
6	Jupiter	In length	zodiacals	2450	Jupiter	In length	zodiacals	24500
	Jupiter	In breadth	tropicals	2456	Jupiter	In breadth	tropicals	24560
	Jupiter	In depth	revolutions	24260	Jupiter	In depth	revolutions	242600
9	Jupiter	In relative position	passages	26690	Jupiter	In relative position	passages	266900
	Saturn	In length	zodiacals	992	Saturn	In length	zodiacals	9920
	[Saturn]	In breadth	tropicals	989 216	Saturn	In breadth	tropicals	9896
12	[Saturn]	In depth	revolutions	27176	Saturn	In depth	revolutions	271760
[]	[Saturn]	In relative position	passages	28148	Saturn	In relative position	passages	281480
	]... A circle comprises 360 degrees or 9720 points. A degree comprises 2[7] points.							
15	] to ... a thank-offering.							

Fig.3: *Translation of the Keskintos Inscription (bracketed words and digits are restored, italicized digits are doubtful, x represents digits in severe doubt).*

("point"). *Moira* is a well-attested term for a unit of arc equal to 1/360 of a circle from the second century B.C. on; the unit derives from two Babylonian conventions, the division of the day into 360 time units and the division of the twelve zodiacal signs into 30 units of zodiacal longitude. The term stigmê is only found referring to a unit of arc in this inscription. Inspection of the stone confirms that Hiller was correct in reading the text as asserting that a *stigmê* is 1/9720 of a circle, i.e. 1/27 of a degree (scholarship has generally acquiesced in Tannery's insistence that the number should be read as 720, not 9720).

The final line is a dedication: a *charistêrion* or thanks-offering to divinities that were specified in the lost first half of the line. All that we can be sure of is that these divinities, or some of them, were feminine: perhaps the Muses, or perhaps merely "all the gods and goddesses."

The site and its significance

Keskintos is a farm property situated on the northwest slope of a 300 metre high hill to the west of Lardos, which according to Hiller was called *Orthê* but is now identified on maps as *Stafilia* (Fig. 4).

One reaches it by taking the road from Lardos northwest towards the monastery *Moni Ipseni* for approximately 2.3 kilometres and then turning south on an unpaved road. After about a kilometre of pine forest one arrives at a level area, mostly

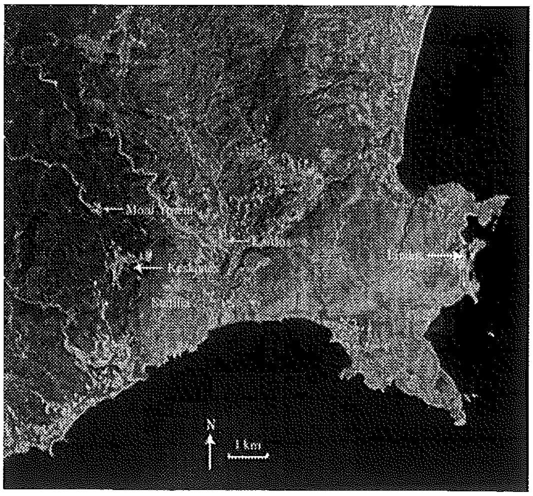

Fig.4: *Satellite photograph of vicinity of Lardos Bay.*

***Fig.5:** Keskintos, views towards east (top) and west (bottom).*

open except for a few olive trees, which is Keskintos. It is not marked on any map that I have seen except the one Hiller provided in Inscriptiones Graecae 12.1, where it is incorrectly placed northeast of the hill. (I was told how to find it by a café keeper in Lardos.) Hiller is correct in giving the name as "Keskintos" rather than "Keskinto," the form preferred for some reason by Tannery and most subsequent scholars.

No specifics of the circumstances under which the inscription was found are available; probably it was discovered accidentally by a local farmer and somehow brought to Adelphiu's attention. Hiller reports (presumably relying on information from Adelphiu) that ancient tombs were found in the vicinity, and infers that a community associated with Lindos existed there in antiquity. According to a brief archeological report published in 1994, remains of an early Christian church, other buildings, an olive press, ceramics, and tombs have been found at the site (Volanakis 1994).

Two explanations of how the inscription came to Keskintos are possible. The less exciting, but on the whole more probable, story is that it was moved from somewhere else to be recycled as building material during the middle of the first millennium A.D., the time of the known archeological remains on the site. An origin as far away as Lindos itself would then be conceivable. Alternatively, one is free to hypothesize that an estate or a small community already was present at Keskintos in the Hellenistic period, and that an astronomer lived there around 100 B.C. The place is not particularly well suited to astronomical observations of the kind one would expect in the Hellenistic context, for which a clearer and more level horizon would be desirable (Fig. 5). On the other hand, the author of the inscription may well have been a more speculative type of astronomer, exploiting received information rather than his own observations.

The inscription as scientific publication and votive offering

In considering the purpose of the Keskintos Inscription, one would naturally look for illumination from other comparable inscriptions presenting scientific data; these are, however, exceedingly few even if one includes those that are known to us only through report. Easily the closest analogue is the so-called Canobic Inscription that Ptolemy erected at Canopus in Egypt in A.D. 146/147, which survives through a transcription made in late antiquity and reproduced in some medieval copies of Ptolemy's great astronomical treatise, the *Almagest* (Jones 2005). Like the Keskintos Inscription, the Canobic Inscription is dedicated to a divinity: its first line reads "To the Saviour God, Claudius Ptolemy [dedicates] the first principles and models of mathematics." (By "mathematics" Ptolemy meant astronomy.) The body of the text is a long list of numerical parameters defining the dimensions, rates of revolution, and orientations at an epoch date of all the components of the models of celestial motion that Ptolemy deduced in the *Almagest.* (The inscription in fact preceded the publication of the *Almagest*, and Ptolemy made a small number of revisions to his models in the intervening time.) There is no explanation of the structure of the models, however, although a corrupt geometrical diagram present in one of the manuscript copies might have formed part of the inscription.

The Canobic Inscription contains information corresponding to the table of planetary periods in the Keskintos Inscription, though in different form (section 7, lines 23-40), and like the Keskintos Inscription it has definitions of its units (section 3 lines 4-5 and section 5 line 7). The specification of the celestial motions in the Canobic Inscription was probably much more comprehensive, since if the Keskintos Inscription had contained dimensional data pertaining to components of models one would have expected this to *follow* the table of periods. The fact that both inscriptions are catalogues of (mostly numerical) facts without explanations of the terminology or theoretical framework means that they cannot have been intended to teach spectators about astronomy. Rather, they seem to be emblems imparting to the spectator the idea of the orderliness and knowability of the cosmos, while (at least in the case of the Canobic Inscription) asserting credit to the dedicator for the discovery of this knowledge.

With respect to the first of these functions, the inscriptions may be likened to the public display of maps of the world in the Hellenistic and Roman periods; one recalls especially Ptolemy's claim in *Geography* 1.1 that world maps serve to impress viewers with the form and place of the earth with respect to the cosmos and the place and scale of our habitations on its surface. As an assertion of credit, one may compare the pictorial representation of the theorems relating the volumes and surfaces of the sphere and cylinder that Archimedes arranged to have inscribed on his tomb, a variation on the more common Greco-Roman device of picturing on a funerary inscription the tools of one's profession (e.g. medical instruments for a physician).

The overt occasion for the Keskintos Inscription, according to its final line, is in connection with a votive offering. Votive offerings in ancient Greek society were motivated by many different circumstances, for example success in war, victory in games, recovery from illness, survival from calamity, coming of age, and receipt of public honours or offices. The offering consisted in an object of some kind, often but not always related to the reason behind the offering, and an inscription identified the dedicator, dedicatee, and sometimes the circumstances (Rouse 1902). What, then, was the offering of which the Keskintos Inscription is the record? In the case of Ptolemy's Canobic Inscription, the dedicatory line makes it clear that what is being offered is the knowledge recorded in the inscription itself. But this is highly unusual, indeed I do not know of any clear parallel, and it is not clear that we are entitled to assume that in the Keskintos Inscription too the inscription constituted the offering. One is tempted to hypothesize that it accompanied some handiwork exhibiting a planetary system or the cosmos as a whole, possibly even an example of *sphairopoiia*, a movable or mechanical display of the heavenly bodies. But this must remain a speculation.

The Great Year and the role of small whole numbers

I have already mentioned Tannery's first insight concerning the planetary table, that in each line referring to a particular planet and a particular kind of period, the number of periods given on the right side is ten times the number given on the left. Tannery's other principal insight, arising from his identification of the first and fourth periods associated with each planet as periods of revolution around the zodiac (i.e. longitudinal periods) and periods of revolution relative to the sun (i.e. synodic periods), was that the numbers on the left are to be interpreted always as the number of periods (of whichever kind) that take place in exactly 29140 solar years, while those on the right are the number of periods that take place in 291400 years. Since almost all the numbers on the left, and absolutely all those on the right, are whole numbers, it follows that 29140 years brings about an exact simultaneous recurrence of most of the periodic motions of all the planets, while 291400 years is a complete recurrence period, that is, a Great Year. (The double number written for Saturn's periods in "breadth" on the left is to be interpreted as 989 216/360.)

The concept of the Great Year has a complex history in ancient thought, which we cannot adequately summarize here (de Callatay 1996). It apparently originated in Plato's discussion of the "Perfect Year" in Timaeus 39d, and was an element of Platonist, Peripatetic, and Stoic thought. For the Stoics it was linked to the theory of cyclic conflagrations of the cosmos. After the rise of Greek astrology (c. 100 B.C.) it became an occasional theme in astrological texts. In the context of Greek mathematical astronomy the Keskintos Inscription is as yet the only known document constructed on the assumption of a common recurrence period of all the heavenly bodies (or at least all the planets), but B. L. van der Waerden and G. J. Toomer have speculated (Toomer 1894, 422 note 12) that similar principles underlay the "Eternal Tables" that Ptolemy disparages in Almagest 9.2, and I am confident that evidence that this is correct will turn up in due course among the astronomical papyri from Greco-Roman Egypt. The yugas of Indian astronomy, though the basic idea of them preceded the influx of Greek astronomical methods and concepts into India, were likely also influenced by such Greek technical applications of the Great Year.

Various durations for the Great Year are attested in Greco-Roman sources, and although none of them is the same as that of the Keskintos Inscription, they help to explain how it was obtained. Several of the cited Great Years are expressed as numbers of Egyptian calendar years (which comprised exactly 365 days) rather than solar years, and the numbers are generally products of the smallest whole factors (2, 3, and 5), sometimes taken together with 365 or with 1461 (i.e. 4 times 365 1/4, the so-called Sothic Period). While 291400 is not a number that can easily be explained in terms of planetary periods or products of small whole numbers, if we consider it to be the presumed equivalent in solar years of 291600 Egyptian years, we can derive the number 291600 as $2^4 \times 3^6 \times 5^2$. (The fact that 291600 is also thirty times 9720, the number of *stigmê* divisions in the circle according to the metrological line of the inscription, is also surely not an accident.) 291400 turns out to be, rounded to the nearest integer, the number of solar years that would be equal to 291600 Egyptian years on the assumption that a solar year is exactly 365 1/4 days, so that it is evident that the author of the inscription was ignorant of, or unconvinced by, Hipparchus' distinction between a tropical year significantly less than 365 1/4 days and a sidereal year significantly greater than 365 1/4 days.

Small whole numbers also play a role in the specific numbers assigned to the planetary periods, at least in the case of Jupiter and Saturn. Rounded to whole numbers, the periods in which Jupiter and Saturn make one circuit of the zodiac are respectively 12 and 30 years. The zodiacal periods (periods in "length") implied by the inscription are more precise than these round numbers: for Jupiter, 29140/2450 yields a period of approximately 11.89 solar years, while for Saturn, 29140/992 yields approximately 29.38 solar years. However, as Neugebauer noted, if we take the difference between each planet's numbers of periods in "relative position" and in "depth" we obtain 2430 for Jupiter and 972 for Saturn (using the smaller numbers on the left side), in both cases 20 less than the inscription's numbers of zodiacal periods. In the present report space forbids discussing just what it means in terms of the underlying planetary theory that the numbers of periods in "length" and "depth" *nearly* add up to the periods in "relative position", or what the small difference of 20 (or 200 for the larger numbers) signifies. But the fact stands out that 2430 = 81 × 30 and 972 = 81 × 12, which means that these numbers that are embedded in the inscription's data though not explicitly stated are in the exact 30 to 12 ratio as well as being factors of the assumed Great Year (29160 or 291600 Egyptian years). The same 30 to 12 ratio subsists between the differences that we get by subtracting the periods in "length" from the periods in "breadth" for each of these planets.

This turns out to be a radically different approach to describing the periodicity of celestial phenomena from Ptolemy's. Ptolemy holds that the apparent complexity of the movements and other phenomena of the heavenly bodies can be analysed into a combination of simple and mathematically describable elements, for example eccentres and epicycles, but he accepts that the periodicities themselves are irreducibly "ugly" numbers (at least from the human point of view) with indefinitely many decimal places, so that the pursuit of exact recurrence periods is a pointless endeavour. The author of our inscription must have believed in the existence of an arithmetical structure in the cosmos, comparable to the arithmetical ratios that, with some success, Greek harmonic theorists employed to model the pitch intervals of music.

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