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The Cuneiform Conception of Celestial Space and Time

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The significance to the modern world of Mesopotamian celestial divination and astronomy cannot be overstated. The names and the 'ominous' values assigned to the heavenly bodies by the Mesopotamians underlie Western astrology, and have also influenced Indian astrology. Many of the key features in the astronomy of Hipparchus and Ptolemy, which later passed into the astronomy of the medieval world, were borrowed from the astronomers of Babylon and Uruk. The zodiac, the Metonic cycle, horoscopy, and a variety of astrological techniques are all first attested in Mesopotamia. The same goes for units, notably those divisions of space and time which are now used throughout the world (such as 60 minutes in an hour and 360° in a circle) which can be traced back to cuneiform antecedents.

Clay tablets dating to the last three millennia BC indicate the variety of ways in which the ancient scribes divided up space and time. This article considers the evidence for the units used in these endeavours, and makes particular effort to understand the cognitive background to the work of these diviners and astronomers. We may begin from the proposition that the earliest units were derived from:

a. the magnitudes of natural phenomena observed in the southern alluvial plain of Mesopotamia;
b. a series of ratios derived from the number of months in a year; and
c. a constant of speed (walking pace).

From a very early period an ideal year was reckoned to be 360 days long. This began as an approximation, for administrative simplicity, but soon came to have a far greater significance for celestial diviners. An ideal interval provided a standard against which diviners could judge and interpret reality. Celestial divination had such tremendous importance in the life of the Mesopotamian kings that it came ultimately to determine the manner in which distances in space were described. It was this ability to describe spatial distances which permitted the full flowering of cuneiform astronomy in the last few centuries BC.

The major developments in the measurement of celestial distance took place in the eighth and seventh centuries BC. This was the time when the Mesopotamian scribes were beginning to record and predict certain celestial phenomena with unprecedented accuracy. The strategies employed in this revolutionary activity owed a great deal to the art of divination, for divination had great need of more accurate prediction. Divination also provided the model of the universe which underpinned cuneiform astronomy — a model which cuneiform astronomy is often said to have lacked.

At the core of the present study is the scholarly class of ancient Mesopotamia, for it is their cognitive processes, not those of ancient Mesopotamia as a whole, that we are attempting to reveal. *Scholar* was a term used by Oppenheim (1969) to describe the experts in divination and other arts at the court of the Neo-Assyrian kings in the eighth and seventh centuries BC. The Neo-Assyrian scholars came from families of experts whose association with the kings went back generations. Their expertise took many years to acquire and constituted a wisdom which they claimed was rooted in earlier, even mythical times. The texts which they used were arranged in a standard form towards the end of the second millennium BC though many of them had precursors in the Old Babylonian period (*c.* 1900–1600 BC) or before.

These texts formed part of the Mesopotamian 'stream of tradition' (a term now endemic to Assyriology: Oppenheim 1964, 13) which had been

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formed into a corpus during the early second millennium BC. The corpus became an essential part of scribal training in the Old Babylonian schools and continued to be taught and transmitted until the end of cuneiform usage. The 'stream of tradition' included a number of texts that dealt with the measurement of time and celestial space. This part of the stream was based on still older material.

Amongst the scholars most interested in celestial divination in the Neo-Assyrian court were the scribes of the 70-tablet series, *Enūma Anu Ellil*,[1] the exorcists, and the chanters. These titles recur amongst the authors of astronomical texts written in southern Mesopotamia during the Late Babylonian period (*c.* 750–0 BC). Celestial divination played a key role in protecting the king against the vagaries of fortune, and involved the interpretation of signs sent by the gods. This may have been partly for propagandist purposes — omens used to justify royal behaviour (see Borger 1956, Bab A ii 24f.) — but it was presented as a religious function. The scholars drew inspiration from their scribal ancestors, and their writings demonstrate a strongly conservative attitude towards the established corpus of texts. Thus the élite or expert scribes who wrote the texts which deal in units of celestial space and time considered *themselves* part of a continuous enterprise devoted largely to the preservation and elaboration of a standard repertoire.

The famous mathematical astronomical texts dating to the last three centuries BC employ the zodiac, which appears only to have been invented in the fifth century BC. The complexity of the texts has suggested to some modern commentators that there must have been a new departure in thinking at that time, perhaps the result of foreign influence (Waerden 1974, 178; Neugebauer 1975, 2–4). This is unlikely, however, since accurate prediction of the very same celestial phenomena had been attempted without the use of the zodiac as early as the late Neo-Assyrian period (*c.* 750–600 BC). The techniques used were then in their infancy, but the fact that they were clearly related to the later ones suggests that the system underwent gradual development from the seventh century BC. The first accurate and systematic records of celestial phenomena date from the same period (see Pinches *et al.* 1955 texts 1413f.; Hunger & Sachs 1988; Walker 1997; Brown 2000, ch. 4). There is a clear continuity between the aims of scholars from the Neo-Assyrian (*c.* 750–600 BC) to the Hellenistic period (*c.* 300–0 BC). The phenomena they predicted were those considered ominous, and there can be little doubt that the effort to know as much as possible of what was portended in the skies provided the prime motivation for the writing of the astronomical texts.

The mathematical astronomical texts thus fall firmly within the same cultural context as Neo-Assyrian celestial divination. Yet, while the mid-eighth century BC saw the first systematic attempts to predict celestial phenomena accurately, the origins of the units used in that endeavour can be traced back to the early third millennium BC. The specific manner in which they were used, however, was an innovation of the late Neo-Assyrian period.

If we wish to cast light on the apparent *mentality* of the authors of these texts, we must first endeavour to make our assumptions explicit. The ways in which time and space can be measured will provide the starting point. It is essential that we seek to analyze the Mesopotamian units of time and space in their original context, without resorting to more general ideas about the need to regulate the calendar or the development of western science. All developments can better be explained as *choices* made from the class of what is possible through the pressure of needs and forces internal to the particular cultural milieu. The units may thus be interpreted as rationalizations of space and time in terms of the phenomena and objects available to the scribes — the reeds or barley grains, the areas large enough to sustain a family, the universally experienced passages of the sun, parts of the body such as cubits and fingers and so forth. These rationalizations were modified by:

a. the application of the underlying sexagesimal base system (base 60); and
b. the intimate relationship that existed between astronomy and the art of divination.

Fundamental concepts

Modern physics fixes the speed of light through the relationship between spatial and temporal units, in terms of metres per second. A *second*, a term derived from *secunda minuta* (describing the second operation of the sexagesimal system), is 1/3600th of a degree, or of an hour. In both cases the Mesopotamian origins are clear, though the manner of borrowing was by no means straightforward. The modern second was first defined as 1/86,400th of a mean solar day, but was replaced in 1967 by a definition based on the duration of radiation corresponding to the transition between levels of the ground state of the caesium 133 atom. The original meaning of the word second as a fraction of the 24-hour cycle of day and night has been lost, but a second is still defined in terms of a recurring phenomenon. The

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metre, the fundamental Système International unit of length, was first defined as a fraction, 10^{-7}, of the distance from the North Pole to the Equator. It was later defined by two marks on a platinum bar, then in 1960 by the wavelength of ^{86}Kr, and in 1983 by the length travelled by light in a vacuum in 1/299,792,458 seconds. Today, then, the constant of the speed of light fixes the relationship between our fundamental units of time (the second) and space (the metre). In Mesopotamia, the key relationship centred on the **dana**, which was both a unit of distance and of time — a double-hour.

Units of celestial space and time

Units of spatial distance have at different periods been defined by scratches on metal bars, by body parts, by objects in the real world, or even by the world itself. The same is true of the earliest such units attested in Mesopotamia. By the time a more or less consistent scheme was achieved (Table 2), it was a mixture of things in the world and abstractions drawn from particular situations, adjusted according to the demands of the sexagesimal number base. Although the units varied over both area and era, there is no evidence that at any given point their values changed with increasing number. The first finger of a distance was as long as the tenth, and so forth. To this extent they were homogeneous.

Units of time must be fractions or multiples of the continuously and systematically evolving, or the systematically repeating. The units do not always vary with time, though they often do so in practice: over the seasons, for example, or during the running of a timing device such as a water clock. In short, they may or may not be homogeneous. Mesopotamian water clocks surviving from the beginning of the second millennium BC measured time in terms of weight units (**gun**, **mana**, **gín**, **še**)[2] (see Powell 1987–90, 508–17). They were designed, pretty much, to measure equal intervals of times by equal weights or heights (see Brown *et al.* forthcoming; for a contrary view, see Neugebauer 1947, 39; 1975, 708). The **gun** and its fractions were thus homogeneous units of time (Table 1).

The nychthemeron[3] (a complete cycle of night and day) is a repetitive phenomenon of near-constant periodicity, and an obvious unit with which to measure time. Direct fractions of the nychthemeron are attested as early as the late fourth millennium BC (Englund 1988, 168, text W20363). Fractions such as the **dana**, **UŠ**, and **nindan** were probably used in the Old Babylonian period (*c.* 1900–1600 BC). They are the units of time most commonly used in cuneiform

Table 1. *An approximate chronological overview of the units of celestial space and time used in Mesopotamia.*

	Celestial space *homogeneous units, but different values on earth and in space*	**Celestial time** *homogeneous units*	*non-homogeneous units*
3rd millennium BC/ 'Sumerian'		- Nychthemeron (**ud**) and fractions - Years (**mu**) of 12 or 13 months (**itu**) or 360 days (**ud**) - Months of 29 or 30 days	- Daylight (**ud**) or night-time ($\mathbf{ge_6}$) and their fractions (watches?)
2nd millennium BC/ 'EAE and Mul.Apin* divination'	- **dana** and its fractions (**UŠ**, **nindan**, **kùš**)?	-Weight of fluid in a device in units of **gun** and its fractions (**mana**, **gín**, **še**) - Nychthemeron and its fractions, **dana**, **UŠ**, and **nindan**	- Daylight/night-time and and fractions - Watches (**en.nun**)
1st millennium BC/ 'Non-mathematical astronomical texts'	- Cubit (**kùš**) and its fractions (**šu.si**, **še**) - **UŠ** and its fraction (**nindan**)	- Nychthemeron and its fractions, **dana**, **UŠ** and **nindan**	- Watches - Seasonal hours? (**si.man**) - Daylight (**me**)
1st millennium BC/ 'Mathematical astronomical texts'	- **dana**, **UŠ**, and **nindan** for for longitudes - **šu.si** and **še** for latitudes and eclipses	- Nychthemeron and its fractions - Month (**itu**) and its fractions (*tithis* = **ud** and smaller)	- Daylight (**me**)

* A two-tablet divination series dating to the second millennium BC concerned with the periodic phenomena of the heavens, published by Hunger & Pingree (1989).

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astronomy and divination.

The year is another cyclical phenomenon used as a unit by the Mesopotamian scribes. The term **mu** referred either to the period of 12 months (**itu**), or to the period of 13 months which was used to re-synchronize the lunar and solar calendars. It also referred to the 360-day year. **Mu** and its fractions are known from the early third millennium BC (Englund 1988, 136–64). In later times, subdivisions of the year were almost always expressed in terms of months and their fractions. The month once again derived from a cyclical celestial phenomena. One-thirtieth of a synodic month, a term known from Indian astronomy as a *tithi*, was also used as a unit. The Mesopotamian scribes simply referred to it by the same term they used for a 'day': **ud**. The relationships established between the **ud** or nychthemeron and the year were complicated and only rarely made explicit. By extension, the same applies to the **dana** and the **UŠ**.

Non-homogeneous time units were also used in Mesopotamia. Time could be expressed in fractions of daytime and night-time, or as the three watches (**en.nun** or *maṣṣartu*) of the day and night.[4] The length of the watches varied with the seasons. So did the **si.man** or *simanu*, a term interpreted as meaning 'seasonal hour' (Rochberg 1989b), and derived by the division of daylight and night into 12 intervals each. Thus both homogeneous (constant) and non-homogeneous (or seasonally variable) time units were used side-by-side, and it is by no means clear which of the two appeared first, though Neugebauer (1941, 15) asserted that seasonal units were the earlier (cf. Englund 1988, 164–80).

Absolute values

The scribes located an event in the sky in terms of time and distance. This poses the question as to where in the sky they began their measurements.

In non-zodiacal astronomy, celestial distances were often measured from other heavenly bodies. Particularly useful was a group of stars lying on the ecliptic (the path in the sky followed by the moon, the sun and the planets) known as 'normal' stars. At other times, distances were measured from the horizon. The daily rotation of the heavens meant that such distances could also be construed as times before setting or after rising, and the distinction was often not made clear. In the case of another group of stars called '*ziqpu* stars', which pass directly overhead, intervals were measured from the meridian, the north–south line (Box 1).

As 360° divided by the twelve zodiac signs equals 30°, distances were calculated from the start of each 30° band or sign in zodiacal astronomy. A particular phenomenon was calculated to occur, say, at x° of the sign Taurus. The zodiac itself can be fixed against the background stars by locating a 'normal' star at some particular point, or longitude, in the zodiac. This was done in a unique text published by Sachs (1952), which he dates to around 350 BC (cf. Huber 1958; Walker & Britton 1996, 49). Alternatively, the vernal equinox, or some other seasonal phenomenon, could be assigned a particular point in the zodiac. This is what is done nowadays. The longitude Aries 0° is where the sun is located at the vernal equinox. Since this so-called 'vernal point' varies slowly with precession backwards through the stars, a date is also required to fix the origin. In the mathematical astronomical texts from Babylon and Uruk the vernal point was fixed either at 10° or 8° of Aries.

Time-periods longer than a year were marked with reference to the start of dynasties (e.g. 'year x of the Seleucid Era'), of kings (e.g. 'year y of king z'), or sometimes simply by a count of years with specific

Box 1. *The angle subtended by a celestial distance versus right ascension.*

Some modern commentators (e.g. Hunger & Sachs 1988, 23f.; Rochberg 1988, 59; 1993, 11) translate the distances between a *ziqpu* star and the meridian in degrees. This needs further clarification, because the *ziqpu* stars do not lie on a 'great circle' and the unit in question, the **UŠ**, was also a unit of time. Some length in the sky, say two lunar diameters, will subtend an angle of 1°. A celestial body, however, may describe a small circle in the sky, and we might say that it has moved through 360°, when this is not a perceived distance 360 times as great as two lunar diameters. In these two instances the *degrees* in question differ. This is easy to see in the case of the circumpolar stars. In one 24-hour period they will (seemingly) revolve in what appears to be a small circle around the north star — their so-called 'right ascension' will change by 360° — but they will not draw out an arc as long as that described by an equatorial star. The same applies to the *ziqpu* stars. While an equatorial star is seen to move two lunar diameters, say, so a *ziqpu* star will move less. Only for great circles — the equator, the ecliptic, the horizon, the meridian etc. — will 1/360th equate with the perceived length of arc that 1° subtends. Mostly, one revolution of *ziqpu* stars was equated with 360 **UŠ**, but this meant 360 degrees of right ascension, or 360 time intervals. Translations such as 'the point 3° behind star x culminated' should read 'the point 3° of right ascension behind star x culminated' and perhaps 'the point 12 minutes behind star x culminated'.

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names (named after events or officials). The years themselves were broadly seasonal. From earliest times certain month names also designated seasonal events.

The Mesopotamian year, being lunar, officially started with the first appearance of the moon in month 1, but the timing of this event may have borne some relationship to the vernal equinox. In certain texts, particularly those from the Old Babylonian period, the 15th of month 12 was *ideally* the equinox, yet in others, particularly those we believe were composed later, the equinox *ideally* fell on the 15th of month 1. When the calendar was finally made consistent, the beginning of the year entered into a *systematically varying* relationship with the vernal equinox.

The beginning of a month occurred on the day when the first sliver of the moon became visible in the west just after sunset. The nychthemeron (or 24-hour period) began at sunset. Intervals shorter than a day were measured from sunset or sunrise. In astronomical texts from the last few centuries BC intervals were measured as so many **dana** and **UŠ** before or after sunset and sunrise (see Neugebauer & Sachs 1967, 212). The system of **en.nun** (watches) and the **si.man** (seasonal hours) also began and ended at sunrise and sunset. This contrasts with the present-day practice, in which the time of day is fixed from the time when the sun, in its lower transit, crosses the meridian (i.e. midnight). In ancient Mesopotamia, something close to this concept of the meridian was known, and was calculated by aid of the *ziqpu* stars (cf. Neugebauer 1975, 492–7). It would appear, however, that the scholars considered sunrise and sunset to be the key celestial events from which times were to be recorded and demarcated. Sunset marked the beginning of the day, and so was an obvious zero-point from which to measure times, but the divinatory texts also indicate that phenomena at both the eastern and western horizons had a particular significance in Mesopotamia. It is no surprise, then, that the timings of many celestial phenomena were calculated from the moment when the sun crossed these horizons (e.g. the 'lunar six': Hunger & Sachs 1988, 20f.).

Table 2. *The 'standard system' of length measure in Mesopotamia. (Based on Powell 1987–90, 485f.)*

	še	**šu.si**	**šudua**	**zipaḫ**	**kùš**	*nikkas*	**gi**	**nindan**	**½ÉŠ**	**éše**	**UŠ**	**dana**
še / *uṭṭetu* / 'barleycorn'	1											
šu.si / *ubānu* / 'finger'	6	1										
šu.dù.a / *šizu* 'stacked fists?'	60	10	1									
zipaḫ, **ŠU.BAD** *ūṭu* / 'open hand'	90	15	3/2	1								
kùš / *ammatu* / 'forearm, cubit'	180	30	3	2	1							
nikkas / 'half reed'	540	90	9	6	3	1						
gi / *qanû* / 'reed'	1080	180	18	12	6	2	1					
nindan / *nindānu* 'rod'	2160	360	36	24	12	4	2	1				
½ÉŠ / *ṣuppu* / 'half rope'	10,800	1800	180	120	60	20	10	5	1			
éše / *ašlu* / 'rope'	21,600	3600	360	240	120	40	20	10	2	1		
UŠ / *šūš?* / '60?'	129,600	21,600	2160	1440	720	240	120	60	12	6	1	
dana / *bēru* / 'stage?'	3,888,000	648,000	64,800	43,200	21,600	7200	3600	1800	360	180	30	1

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A developmental analysis

The standard system

The Sumerian and Babylonian units of length shown in Table 2 make up what Powell (1987–90, 458) terms the *standard (scientific) system*. The numbers describe the ratios between the various units. Thus 6 **še** = 1 **šu.si**. Most of the units were used in the early third millennium BC and it is likely that the system was fixed in the Presargonic period, before *c.* 2350 BC. This system came to be used in the Old Babylonian mathematical and divinatory texts, and ultimately in the Neo-Assyrian and Late Babylonian astronomical texts. It was used not only by scholars, but in many other contexts including economic transactions.

It is apparent from Table 2 that base 60 was important in determining the ratios between units. All the ratios are either multiples of 60 (underlined), simple factors of 60, or multiples of simple factors of 60. The fact that the ratios are not exclusively multiples of 60 suggests that this name base had been imposed upon an earlier system or systems. The variable ratio of cubits to reeds, for example, was fixed by recourse to the number 6 in order to suit calculations in sexagesimal. Simplification of calculations was also effected by scholars interested in celestial phenomena, and played a significant role in determining the units used. It is too simplistic to state that base 60 was the original Mesopotamian base, since the earliest texts reveal a particularly complex situation (cf. Green & Nissen 1987, 117–66; Nissen *et al.* 1993, 25–9, 125–51; Box 2). Nevertheless, sexagesimal was very ancient and was dominant in calculations, especially those concerning astronomy.

Some of the units in Table 2 derive from parts of the human body. The **kùš** (cubit) and the **šu.si** (finger) are in a ratio (30:1) that broadly corresponds to reality, though it too conforms to the strictures of base 60. Surviving artefacts (Powell 1987–90, 462) indicate that the length of the cubit was *c.* 50 cm. The standard ratio 30:1 was maintained until the end of cuneiform writing, particularly in astronomical texts.

In the standard system, 180 **še** (barleycorn) equalled one cubit. A barleycorn is not a sphere, and what it is that constitutes its length is not obvious. Powell (1987–90, 459 & 508) suggests that 180 was the closest approximation that a multiple of 60 grains of barleycorn (i.e. 3×60) could make to the already established *weight* of the **gín** (shekel) (see note 2), and that this ratio of 180:1 was borrowed by the system of length measure in the mid-third millennium or earlier. That is, once a desire to weigh more accurately had emerged, the natural phenomenon of the barley grain was combined with the strictures of base 60 to establish a ratio of **še** to **gín** of 180:1. This ratio was then adopted by those scholars who wished to measure lengths more accurately, and was later applied to the measurement of celestial space.

The **nindan** or rod plays a pivotal role in the standard system for measuring both length and area, since 1 **nindan**^{2} = 1 **s**/**šar**. The **šar** or **sar**, known from the early third millennium, was a garden plot of a size capable of supporting the needs of an individual or family. Hence it may be regarded as a unit determined by both environmental and cultural factors. The nindan itself was about 6 metres in length. Powell (1987–90, 479) suggests that the **šar** may have first been thought of as four square reeds. His idea is that in the fourth millennium BC or earlier, river reeds averaging some three metres in length were used to measure and share out irrigable land in groups of four squares. The **nindan** was the name

Box 2. *Prehistoric and early historic counting as influenced by early adminstrative practice.*

Nissen *et al.* (1993, 11f.) argue that the earliest written records from Mesopotamia indicate the existence of an already complex system of economic bookkeeping. They suggest that, prior to this, 'great memory capacity such as is known from preliterate societies most probably enabled the ancient Babylonians to control (economic) data without recourse to written records'. As a result of the increasing quantity and complexity of economic transactions, ways had to be found by which 'objective' control was guaranteed. This included the use of counting symbols of varying shapes called *tokens*, which, in the period directly before the emergence of writing, were bundled together in *bullae* in order to describe high numerical quantities of particular products. A certain number of tokens of one shape were made equivalent to one token of another shape. These and other 'bundling rules' characterize some of the oldest known texts. In these texts (Nissen *et al.* 1993, 25f.) some 60 numerical signs are known. Many of these signs have different values depending on what it is they quantify — several different numerical systems coexisted at this time. One system was used to count areas, for example, whereas another (which shared some of the same symbols though with different values) was used to count discrete objects. The number of numerical systems and also the quantity of signs for numbers diminished over time. Clearly this evidence bears significantly on our understanding of the growth of human cognition of numbers as abstract entities. It is noteworthy that in all of the numerical systems thus far reconstructed for the early literate period the ratios between the signs are all simple fractions of 60.

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assigned to the sides of the area formed as a large square. The name chosen was probably taken from a standard measure of capacity (Box 3).

The **nindan** was the most common unit of calculation in the Old Babylonian mathematical texts but was still used in Late Period astronomical texts. The continued employment of such an ancient unit has a bearing on the cognitive decisions made by the scholars who wrote the astronomical texts. Continuity in names was important, as was the *relative* value of that unit as compared to other units, even in cases where the *absolute* value attached to the name had completely changed.

The **UŠ** is the unit that concerns us most in this discussion. It was used for measuring length and time, and ultimately for celestial distances also. If it could be read, its reading would cast additional light on the mentality which lay behind its origin. Powell (1987–90, 45–6) offers four possible readings, the most plausible being a connection with the Akkadian *šūš* 'sixty' since an **UŠ** is indeed equivalent to 60 **nindan**.[5] In terrestrial distance it was equivalent to some 360 metres, but it also came to describe four minutes of time, and the celestial distance subtended by 1°.

The **dana** is equated with Akkadian *bēru*, which appears to mean something akin to the distance marched between rest stops, or a stage. This makes very good sense, for a **dana** in the standard system was equivalent to about 10.8 km in length (21,600 cubits of *c.* 50 cm). A very ancient term, it was rationalized as 60^2 reeds in the standard system. If marching pace in the flat lands of southern Mesopotamia was pretty much what it is today, then each **dana** would have taken some two hours to complete. Whether it was the period of time or the distance measure that came first is immaterial. Indeed, the **dana** could well have been a unit both of time and distance from its inception. At some point scholars concluded that twelve **dana** fitted into one **ud** (night + day). The pressure to comply with the sexagesimal base must have played some part in the choice of number, excluding numbers such as 11, 13, and 14. But walking ten or fifteen stages in a day is not inconceivable and walking distance alone cannot explain the choice of the number 12. One other possibility is that the number 12 was borrowed from the twelve-month year.[6] The **dana** and the month are associated in several ways. In one **dana** of time the sun moves through a distance in the sky which is more or less equal to the distance moved by its rising point in one month (particularly near the equinoxes). From a terrestrial point of view, each day the sun travels through 360° plus a modest additional distance due to the fact that the earth has moved in that time. In a single ideal month the sun performs 30 revolutions plus the distance it moves in one **dana**. In twelve such months it will have undertaken 360 revolutions plus virtually one entire additional revolution. In other words, in a solar year the sun completes one revolution more than the number of days, since in that time the earth itself has completed one full orbit.

As the year is divided into twelve months, so the scholars divided this additional revolution into twelve. The additional revolution was, of course, simply one 24-hour period, or in Mesopotamian terminology one nychthemeron. The result of this twelve-fold division was to produce intervals that were in a sense the months of the nychthemeron. Crucially, this linked the measurement of celestial distance with the measurement of time and of terrestrial distance. It lay behind all subsequent cuneiform astronomical measurement. Each of those twelfths became a stage of time — a **dana** — which also generated a distance on earth through the natural walking pace of humankind. That resultant length was finally squeezed sexagesimally into the standard system. At a later date, each twelfth was subdivided into 30 segments, just as an ideal month was divided into 30 days, and in this way the **UŠ** (each equivalent to *c.* 360 metres) were generated. This

Box 3. Nindan: *the early 'standard measure' of capacity.*

'The earliest capacity norms must have arisen out of customary sizes for containers' writes Powell (1987–90, 492–3). The cuneiform sign for the **nindan** was used in the archaic period (*c.* 3000 BC) to describe a particular capacity measure — in particular a daily ration of food (see Nissen *et al.* 1993, 15, fig. 12; Englund 1988, 162–4). Nissen (Green & Nissen 1987, 153–4) also suggests that the sign was a pictogram of a bevelled-rim bowl, an artefact characteristic of the late Uruk and Jemdet Nasr periods in Mesopotamia (*c.* 3300–2900 BC). An excavated example is illustrated in Nissen *et al.* (1993, 14). Archaeological findings indicate that bevelled-rim bowls were of a standard size — around 0.8 litres. It is important from a psychological perspective that the sign for this fundamental administrative unit, the daily ration of food, was also used for a length unit corresponding to the side of an area of land considered sufficient to meet the needs of an individual or family. The 'standard measure', so far as the administration's feeding of its workers went, was adopted into length mensuration as a 'standard' length unit. This is probably reflected in the reading of Akkadian *middatu* 'measure' for the Sumerian **nindan**.

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ideal link between days and **UŠ** lies at the very heart of cuneiform astronomy, and is explicitly referred to in the text Mul.Apin I iii 49–50:

> The stars move backward into the night in the morning 1 UŠ each day.
> The stars move forward into the day in the evening 1 UŠ each day.

It should be noted that the ratios between the **dana**, the **UŠ** and the **nindan** remained constant throughout the millennia of their use and regardless of the context in which they were used.

***The early period* (c. *1750–750* BC)**

The first celestial omens date from the Old Babylonian period. They are of the form:

> If the eclipse begins and clears in the south: the downfall of Ubar and Akkad.
> (Old Babylonian text BM 22696:8 quoted in Rochberg 1989a, 21).

It is also from this time that the earliest schemes concerning the lengths of daylight or the measurement of time are attested. The length of daylight and other schemes that modelled the times between celestial phenomena were tied in with celestial divination. Indeed, one of their fullest expositions is to be found in Tablet 14 of *Enūma Anu Ellil*. The foremost aspect of such schemes is their ideal nature. In the ideal scheme of daylight-length, a 360-day year is divided into twelve 30-day months, the equinoxes and the solstices are evenly spaced and the ratio of the longest to the shortest day is 2:1 (Old Babylonian text BM 17175+ in Hunger & Pingree 1989, 163–4). The 360-day year facilitated administration (Box 4), but it also came to have, or perhaps always had, significance beyond mere expediency. For example, in the Middle Babylonian Epic of Creation the god Marduk is said to have established the lengths of the months at 30 days and the year at 360 days. Other examples show that some scholarly circles considered the universe to have been created ideal. One of these circles, I suggest, included scribes concerned with celestial divination. It is important to note that the authors of these divinatory texts did not believe that the year actually lasted 360 days or that a month really lasted 30 days. Records of celestial omens make it quite apparent that months were known to last 29 or 30 days.

The same texts indicate that diviners considered it possible to derive auspicious or inauspicious interpretations depending on whether observed reality corresponded with the ideal. A month that lasted 30 days boded well, whereas a 29-day month boded ill (cf. Brown 2000 ch. 3). The 'ideal' year derived from an administrative background, but other 'ideal' schemes were derived from notions of symmetry and simplicity which had nothing to do with bureaucracy, and everything to do with aiding diviners. These schemes predicted the ideal intervals between celestial phenomena, and opened the way for the real intervals to be given different interpretations. The evidence from creation myths appears to indicate that an ideal interval corresponded with a belief in how the universe was when first created.

The pervasive nature of the 'ideal' schemes strongly influenced the systems of celestial units which were used in the latest astronomical texts to be written in cuneiform. The year, as defined by the movement of the sun, continued to be divided into 360 (**UŠ**) and the months into 30 days even when the

Box 4. *The ideal or administrative year of twelve months and 360 days and base 60.*

A solar year comprises twelve full lunations and a partial lunation. In ancient Mesopotamia, however, a year was defined not by a number of days, but by a count of either 12 or 13 months, each of which was either 29 or 30 days long. At the same time, and from at least as early as the fourth millennium BC, an approximation to the solar year was used. This was the 360-day, 12-month year. Englund (1988) discusses its use in administrative contexts in the third millennium BC, arguing that it was produced by 'a mixture of the sexagesimal system with a heritage of natural cycles' and 'an increasingly involved organisational control faced with the necessary conversions of time units into counted things — in particular rations' (p. 122). He thus calls it the 'administrative year', suggesting (p. 124) that it at once simplified calculations and increased the state's demand on labour (by a factor dependent on the difference between 29.5 and 30 days). He regards these fourth- and third-millennium BC time notations as symptomatic of 'a related shift in consciousness imposed by administration, akin to the medieval adaptation to the clock-tower' (p. 182). Clearly, the nearest round number to 365 (days in a solar year) that is divisible by 12 (months) *is* 360. I suggest further that this approximation to the natural phenomenon of a year, brought about by the growing pressures of administation, may have played a critical role in determining which number base was most commonly used in all quantifying contexts — namely base 60. Since the time component involved in any given transaction was described in fractions of 360 (days) and 30 (months) (e.g. in the Ur III period, workdays were divided sexagesimally), it is probable that the weight, length, or capacity components would have been divided similarly. No doubt the ease with which 60, with its many factors, can be divided, also helped in this context.

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accurate prediction of celestial phenomena was the aim. The scholars remained deeply influenced by the idea that the universe was once as ideal in its behaviour as the Old Babylonian schemes imply. The scholars who devised the methods underpinning cuneiform astronomy made a cognitive decision to select units for the measurement of celestial phenomena that harked back to that description of the universe which was implied by divination. In other words, they attempted to model the behaviour of the universe in units that confirmed and assumed its originally ideal nature.

Measuring time

By *c.* 1700 BC, time was being measured in both the fixed units **UŠ**, **nindan**, **mana** and **gín**, and in the seasonally varying units daylight, night and watches. Ideal months had been defined as 30 nychthemeron in duration since at least the end of the fourth millennium BC, and ideal years as including twelve months. Real years had long since been thought of as either twelve or thirteen months, and this did not change in the early period. The administratively useful 'ideal' year of 12 **itu** and 360 **ud** was shadowed in the division of the ud into 12 **dana** and 360 **UŠ**. The weight units, **mana** and **gín**, were given a fixed ratio to the **UŠ** and **nindan** in order that any expression of time in sexagesimal would be correct in both systems.[7]

The evidence from texts dating to the centuries following the Old Babylonian period does not change this picture. Texts which are at least as old as the end of the second millennium continue to mention **UŠ**, **nindan**, **mana** and **gín**.

Measuring celestial distance

The only evidence for celestial distances before the eighth century BC comes from the text HS 245, formerly HS229 (Rochberg 1983; Horowitz 1993). This is a mathematical exercise concerning irregular numbers and bears little relationship to actual celestial configurations. Nevertheless, the units **dana**, **UŠ**, **nindan** and **kùš** are used to express distances between stars. HS 245 is at latest Middle Babylonian, and is very likely Old Babylonian in date. Calculations in the text show that 12 **kùš** = 1 **nindan**, 60 **nindan** = 1 **UŠ** and 30 **UŠ** = 1 **dana**. These ratios are identical to those in Table 2.

In later texts, the **dana** described an arc of the ecliptic or zodiac equivalent to the distance subtended by 30°. One hundred and twenty **dana** (the total distance in HS 245) would thus amount to 3600° or 10 complete revolutions. If this were a measurement of time, 120 **dana** would last 10 days. It seems very unlikely that the **dana** in HS 245 were meant in either of these senses, especially since the heavenly bodies mentioned in the text lie broadly across only 180° of the sky.[8] The **dana** and other units used in this text were not the same as those used in the later texts, and the distances described were not thought of as radial (Rochberg 1983, 213). We may conclude that in HS 245, a **dana** marked out an *actual* distance in the sky corresponding to a celestial arc somewhere in the region of $1^{1}/_{2}°$ (i.e. 180°/120).

In summary, there is evidence that in the period before 750 BC, celestial distances were at most very rarely, and perhaps never, described in fractions of a circle, as they were in the late period.[9]

The late period (c. 750–0 BC)

Dramatic changes in the measurement of time and celestial space came about during the late period, coinciding with a sudden increase in the accuracy with which celestial phenomena were recorded.

Measuring time

The fixed units of time based on the **UŠ** and **mana** were commonly used in the late period. New developments were limited to *tithis*, first attested in BM 36731 dating to the end of the seventh century BC (Neugebauer & Sachs 1967, 183f.), and to accurate values for the length of the year and the month derived largely from the intervals between lunar eclipses. Also, the *ziqpu* stars play an increasingly prominent role in celestial timing in the centuries following 750 BC. Texts that list them or describe their relationship to arcs of the ecliptic are not attested before the Neo-Assyrian period, but the *ziqpu* stars themselves are found in Mul.Apin (see Table 1) and may be as old as the Old Babylonian period.[10]

Ziqpu stars moved more or less overhead; their declination (distance from the celestial equator) was approximately equal to the observer's latitude,or approximately 35°N for southern Mesopotamia. In the Neo-Assyrian and Late Babylonian periods, these stars were used to measure times at night (cf. Parpola 1993, 149:r.1 & 134:8; Rochberg 1983, n. 9). Once it was ascertained which *ziqpu* star was culminating (standing directly overhead) at the beginning of the night, any subsequent time during that night could be determined by the *ziqpu* star then culminating, provided the time between culminations was already known. This time-keeping procedure complemented that of the water clock. Indeed, in some texts,[11] water clock weights and times between the culminations of particular stars were recorded side by side. It is possible that the intervals between culminations of

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different *ziqpu* stars were determined directly by using a water clock.[12]

In Mul.Apin, *ziqpu* stars are cited in connection with the risings of other stars. The numbers of days between their successive culminations at sunrise throughout the year are also given. This two-fold aspect appears to lie behind the two main types of *ziqpu*-text we find during and after the late Neo-Assyrian period:

1. lists of *ziqpu* stars giving the number of **dana** and **UŠ** (and water clock weights) between their successive culminations. These were undoubtedly units of time, but may also have been thought to describe celestial distances. Hunger & Pingree (1989, 143–4) compare the number of days between successive culminations of *ziqpu* stars given in Mul.Apin with the number of **UŠ** given in text AO 6478 for the same events. The principle is straightforward. If one star culminates at dawn 10 days after another, then since the sun will have moved through 10/365ths of its annual revolution during this time, the stars will be approximately 10/360ths of a nychthemeron apart, that is 10 **UŠ** of time or 10° of right ascension.
2. *ziqpu*-texts that relate the crossings of the meridian by the stars to the risings of segments of the ecliptic.[13] These texts post-date the invention of the zodiac and apparently derive from the reference in Mul.Apin: by which you observe the rising and the setting of the stars at night. The movement of the *ziqpu* stars is assigned the term **zi** or *nisḫu*, which means something like travelled distance or velocity. It is given in units of **UŠ**. The portions of the zodiac are all $2^1/_2$ **UŠ** segments (or twelfths of a sign), and were referred to by the term **ḫa.la** or *zittu*. The first **ḫa.la** or $2^1/_2$ **UŠ** of the sign Aries rises (according to this theory) as the corresponding culminating star (somewhere in Cygnus) moves past the meridian by $1^2/_3$ **UŠ**. In this type of *ziqpu* text, **UŠ** are used explicitly to describe *distances* along the ecliptic, and to correlate these distances with distances between *ziqpu* stars, even though the latter lie on a parallel of declination that is not a great circle. This suggests that the intervals between the *ziqpu* stars in the lists may also have been thought of as distances, and not just as times (Box 5).

Measuring celestial distance[14]

Almost all texts from the Neo-Assyrian period that use **UŠ** and **dana** apply them as time units in the manner familiar from the Early Period. An exception are texts from the Neo-Assyrian capital Nineveh published by Pingree & Reiner (1975). These contain lines which read 'Mercury became visible in the east in Month MN on day X (and) the sun was 10 **UŠ** to the left (**gùb**)'. The 10 **UŠ** in this text, as the term 'left' indicates, probably describe a *distance* along the ecliptic rather than simply a *time* between successive risings.

A second example is offered by text BM 76738+ (Walker forthcoming) line 22: '[Year 11, month 8, day] ⌜15⌝ above (*e-lat*) LISI (= the star Alpha scorpii) ⌜$6^1/_2$ **UŠ**⌝, first appearance with reference to LISI, a little in front'. Calculations show that this records an observation of Saturn on 13th November 637 BC when the planet had a longitude of 212.9° and a latitude of 2° and Alpha scorpii had a longitude of 213.2° and a latitude of –4.4°. Comparing longitudes, the remark 'a little in front' is very appropriate. As to latitudes, 2° + 4.4° is indeed very close to the $6^1/_2$ **UŠ** by which the text says Saturn is above LISI. If *e-lat* truly refers to a distance from the ecliptic (or even if it referred to a vertical distance) this text (if restored correctly) indicates that **UŠ** were being used to describe celestial distances equivalent to 1° as early as the seventh century BC.

In the mathematical astronomical texts of later centuries the **UŠ**-system (Table 3) was used repeatedly and exclusively to describe *calculated* distances along the zodiac.

The Neo-Assyrian period was a time of further innovation in the use and adaptation of units. Foremost amongst these was the use of the **kùš** or cubit to describe celestial distances of either 2° or $2^1/_2$° (Table 3). This is in stark contrast to its use in the Middle Babylonian text HS 245 described earlier. Similarly, the unit **šu.si**, or finger, was used to describe celestial distances of 1/12°.[15]

In the Neo-Assyrian and Neo-Babylonian Letters and Reports written by the scholars to the kings Esarhaddon and Assurbanipal in the eighth and seventh centuries BC, **šu.si** were used to describe the magnitude of eclipses (Parpola 1993, 148:7 & 149:r.5; Hunger 1992, 104:4; Huber 1973) and the distances

Table 3. *The two systems of celestial distance measure used in Mesopotamia after the Neo-Assyrian period.*

UŠ-system of celestial distance measure	1 **dana** = 30° = 30 **UŠ**	1 **UŠ** = 1° = 60 **nindan**	1 **nindan** = 1/60°
kùš-system of celestial distance measure	1 **kùš** = 2° or $2^1/_2$° = 30 or 24 **šu.si**	1 **šu.si/si/u** = 1/12° = 6 **še**	1 **še** = 1/72°

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Box 5. *The influence of* ziqpu *stars on the emergence of celestial distance measure.*

One might suspect that the celestial equator was marked out spatially before the ecliptic. This is because the assocation between: a) the distance moved as a result of the rotation of the earth by a celestial body lying on the equator, or on a parallel of declination; and b) the time taken to move, is direct. In each **UŠ** of time a body moves 1/360th of the way around the equator. This is not the case on the ecliptic because of its obliquity. Its division into 360 parts represents a further level of abstraction. At no point in cuneiform astronomy, however, was the celestial equator ever demarcated by stars. What was marked out in this way was a *parallel of declination*. The *ziqpu* stars lay along a parallel of declination and the directly proportional relationship of the distances between them to the time differences between their culminations would have been apparent in a way that was not the case for the sun. A large part of the circle of *ziqpu* stars is visible on any clear night, and it is obvious how the distances between them are proportional to the intervals between the culminations. The daytime path of the sun is not marked out in such a way as to demonstrate the same. I suggest that the system of time measure using *ziqpu* stars revealed how a circle in the sky could be divided *spatially* as well as *temporally* into 360 **UŠ**, which paved the way for dividing another circle in the sky, the ecliptic, into the same. In this way the *ziqpu* texts are intermediate between the system of time measure we find in celestial divination based on notions of the ideal year, and the system of space measure used in the zodiac which made possible the later developments in cuneiform astronomy.

One text, dated by its editors (Pingree & Walker 1988) to between the seventh and fifth centuries BC, bears this out. It lists stars lying along lines of the same right ascension (a distance along the equator from the vernal point) in strings (called **gu**) from the north to the south, commencing in each case with a *ziqpu* star. These strings are in effect meridian lines and the authors suggest (p. 318) that a device with strings held out in such a way as to link the stars may even have been used to determine ecliptic longitudes directly. Meridian lines are orthogonal to the equator, and they also cross the ecliptic. It would seem that in this pre-zodiacal stage of cuneiform astronomy the scholars assumed that a spatial division by meridian lines would suffice to locate objects lying on the ecliptic. For our purposes it is relevant that in this text *ziqpu* stars were in effect used to divide up the equator *spatially*.

between planets (Hunger 1992, 82:8 & 489:r.7; Parpola 1993, 47:r.7). **Kùš** are found in one report describing the distance between Saturn and Venus. Both units are found in the first attested Astronomical Diary dating to 652 BC, and in all subsequent Diaries,[16] describing both distances between heavenly bodies and the magnitudes of eclipses. In all cases those distances recorded in cubits and fingers appear to have been the result of observations.

In the mathematical astronomical texts the **še** was used to describe the calculated magnitudes of eclipses, attesting to a high degree of perceived precision in the astronomy of the period.

In ordinary distance measurement a finger measured approximately $1^{2}/_{3}$ cm (i.e. close to the width of a human digit). In order to make this correspond to a length in the sky subtended by 1/12°, the finger would have had to be about 11.5 metres away. Any device that measured celestial distances so as to make the terrestrial and celestial finger or cubit correspond would clearly have been unfeasible. A celestial distance of one finger did not remotely correspond to the arc subtended at the eye by a finger held at arm's length. As celestial distance units, the finger and the cubit bore little or no relationship to the dimensions of a human being, unlike their older, terrestrial counterparts. Although bearing the names and ratios attested in the millennia-old standard system of length measure (Table 2), they no longer bore any direct relationship to things in the world. These units were used in the new endeavour of accurately recording the locations of certain celestial phenomena with a mind to their prediction. The ancient names and ratios no doubt legitimated their use, and made the results seem appropriate for the art of celestial divination. Although employed to record the empirical data upon which the mathematical astronomical theories were based, the celestial cubit and finger were assigned absolute values not on the basis of empiricism, but as a result of the specific relationships they bore to the other system of celestial measure created during the late Neo-Assyrian period, the **UŠ**-system (Box 6). This, rather than the **kùš** system, came to be employed in astronomical prediction, as opposed to in the mere recording of celestial data.

Conclusion

What can this analysis of the development of the various units tell us about the mentality of the scribes and scholars who practised divination and predicted celestial phenomena? The units that made up the standard system (Table 2) included those derived from the observation and organization of the natural phenomena of the environment which surrounded

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Box 6. *The numerical relationships between the* **UŠ** *and the* **kùš***-systems of celestial measure.*

It is probable that a fixed distance in the sky was assigned a particular value in terms of cubits and/or fingers as the basis for measurement in the **kùš**-system. This particular value appears to have been determined largely by parallel with the **UŠ**-system. Perhaps 144 = 12^2 cubits of 30 fingers were made equal to the length of a great circle on the basis of an analogy with 12 **dana**. Neugebauer (1975, 592) describes a first- or second-century AD papyrus from Egypt which shows Mesopotamian influence. This papyrus contained a scheme in which 720 solar diameters covered the length of the ecliptic, and in which one so-called 'solar cubit' comprised 30 fingers. The scheme suggests that the Mesopotamian 30-finger cubit of celestial measure may have been defined against the solar diameter, in which case it would have been defined as 5 solar diameters. If assigning 720 solar diameters to the ecliptic is also Mesopotamian, then a close connection with 360 **UŠ** in a revolution is clear. It is worth noting that 720 = 12,0;0 solar diameters = 12;0 **dana** (noted by Thureau-Dangin 1931a, 25; Powell 1987–90, 461) and that 720 **kùš** = 1 **UŠ** in the standard system. If the 30-finger celestial cubit were indeed thought of as five solar diameters, then it would appear to follow that one solar diameter would be six fingers in length. A solar diameter is indeed close to $^1/_2°$, so this would also be fairly accurate.

This otherwise satisfactory basis for the relationship between the **UŠ** and the **kùš** systems of celestial measure is complicated, however, by the fact that in the Eclipse Reports an eclipse measures 12 fingers — approximately twice reality. The value for a lunar or solar diameter of 1° even appears explicitly in one late text and was not resolved in the mathematical astronomical texts. Neugebauer (1975, 551) writes: 'not only is it difficult to understand how direct observation could result in so gross an error; neither should its consequences for the theory of eclipses have escaped astronomers who developed the most sophisticated methods for the computation of lunar ephemerides'. The importance of dividing up celestial distances into packets of twelve, as in 12 **dana** = 12^2 **kùš** = 12,0;0 solar diameters, while maintaining the antique ratio of 30 fingers to 1 cubit, was perhaps considered to be of greater significance than correspondence with reality.

the scholars — their own body parts, the reeds in the marshes, the grains of barley in the storage jars. The measure referred to as the rod or **nindan** derived directly from the dimensions of a particular area of land that the agrarian community in Mesopotamia considered fundamental. Its name may well have been borrowed from a unit that was intimately connected with the economic realities of the day — the volume of a daily ration of food (Box 3). The discovery that twelve lunations occurred during one passage of the seasons gave rise to a twelve-fold division of the nychthemeron. That interval, combined with walking pace (a constant of speed in many ways analogous to our use of the speed of light) gave rise to the **dana**. This measure of distance, a stage, was associated from earliest times with the rest stops of marching armies or trading parties.

Given all the phenomena which the scholars could have used to divide up their universe, this list is intriguing. What sheds most light on the cognitive processes involved, however, is the manner in which these phenomena were manipulated into an elaborate system of lengths, covering spans from a fraction of a centimetre to many kilometres. Also revealing is the way in which the system was employed for the timing and positioning of celestial events.

The factor which forced the early units into the fully developed standard system of measurement was essentially the base 60. It was the usefulness of base 60 that lay behind adoption of the 360-day year as an approximation to the solar year (Box 4). The use of the approximation simplified calculations in an ever-expanding bureaucracy. Under sexagesimal influence, traditional ratios were varied, many units were dropped and some added. The unit **UŠ** was added in between the **nindan** and the **dana**, equating to 60 of the former and a thirtieth of the latter. The **nindan** itself measured two reeds in length, and a reed was defined as 6 **kùš** (cubits). Cubits were tied to the smallest unit **še** by borrowing a ratio from the system of weighing. A cubit was also made equal to 30 fingers. In this way, the entire system of length measure was fixed by ratios of round sexagesimal numbers. This simplified any calculations concerning commodity transactions. It would have further assisted the accountants, and no doubt made easier the regulation of an empire. Hardly surprising, then, that it was under the Akkadian and Ur III empires of the late third millennium BC that the standard system became firmly established. Units which had been closely linked to natural phenomena and the peculiarities of alluvial living were made subject to the ambitions of centralized administration. The importance of this conscious cognitive decision to control administration and facilitate calculations cannot be overstated.

At the same time, the significance to the diviners of the ideal year and ideal month owed much to their notions of primeval symmetry. It is apparent that something more than accounting efficiency lay behind their adoption of these particular units. The

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ideal year (and its derivatives) constituted a powerful divinatory tool. Interpretations of observed reality depended on whether or not the observations corresponded with the ideal. It was for this reason that celestial diviners always used those units which related to the ideal year. The ideal 30-day month probably influenced the decision to make a **dana** equal to 30 **UŠ**, though it was only one among several possible units which could have been intercalated between the **nindan** and the **dana**, all of them equally efficient in sexagesimal terms. Just as the **dana** mirrored celestial phenomena in being the month of the nychthemeron, so the **UŠ** became the nychthemeron of the nychthemeron. This association continued until the very end of cuneiform writing. In the mathematical astronomical texts, data such as the length of the day, that had once been expressed as functions of 360-nychthemeron, continued to be expressed as functions of 360 **UŠ**. By being the nychthemeron of the nychthemeron, a **UŠ** was made equal to 60 **nindan** by default, and the probable reading of its name as *šūš* (sixty) reflects this. Its relationship to the units of a system of time measure derived from a water clock may have reinforced this reading. Alternatively, the reading may have determined the ratio in those devices between the weight of fluid in **mana** and the time measured in **UŠ**.

It is noteworthy that in the second millennium BC, and in areas peripheral to Babylonia, the smaller units of the standard system were sometimes changed to accommodate new administrative needs. The larger units never varied. The **dana**, **UŠ**, and **nindan** were fixed by the astronomical fact of twelve months to a year and by a conservatism that is perhaps common to theological belief, for in at least one strand of religious thinking it was the gods who established that there should be 30 days in a month. Such conservatism characterizes the power of tradition, and explains a great deal about the shape of the written record in later periods of Mesopotamian history. It also applies to systems of time and space.

In the late Neo-Assyrian period, the particular power structures that confronted scholars drove them for the first time to attempt to predict celestial phenomena accurately. In this quest they employed the oldest ratios and units. We know that they thought themselves part of a scribal tradition dating back at least a millennium, and that they considered the divinatory series to have been of antique inspiration. In trying to convince their employer, the king, of their relevance (or in order to protect their sovereign against malign influences), such an appeal to antiquity would have been of great assistance. At the same time, to compete with their colleagues, these scholars began to make accurate records of ominous celestial phenomena so as to be able to predict their occurrence. For the recording of night-time events they used, amongst other things, the *ziqpu* stars. The distances between the *ziqpu* stars were proportional to the times between their successive culminations, and it was most likely this observation that led to the extension of the system of time-reckoning to record celestial locations. Given the number of ways in which celestial space could be divided using a sexagesimal base, the scholars' use of 360 **UŠ** is revealing of the strongly conservative mentality which sought legitimation for innovations through the association of such innovations with existing norms. From that point on, the celestial distance units no longer bore any direct relationship to things in the real world. They testify to a mental leap which linked the daily passage of the heavens with fractions of the circumference of a circle. This leap stands at the very beginning of what we term spherical astronomy.

Neither was the **kùš**-system of celestial distance units a measure of the heavens based on physical apparatus. Instead, the **kùš**-system probably developed from numerical associations with the **UŠ**-system (Box 6). It too represented an abstraction from units once based on things in the world, and it too appears to have emerged out of the revolutionary ferment of the late Neo-Assyrian period. Both systems, although new in their approach to celestial distances, employed the names of ancient units, even

Box 7. *Fractions-of-a-circumference distance as opposed to angular measure.*

I have been careful not to describe the celestial distances given by the **UŠ**- or **kùš**-systems as 'angles', even though I have used 'degree' frequently. This is not to say that I believe that the Mesopotamian scribes regarded the celestial intervals as straight-line distances. It is apparent from the circular astrolabes and from what may be a circular zodiac from Sippar that the ecliptic and the celestial equator were regarded as circles. There is no evidence, however, from any period in Mesopotamia of the use of 'angle', as we might understand it — as the divergence from a centre of two lines. Nevertheless, in the late period, distances between bodies were given in terms of circle fractions. These should be conceived of as fractions of the circumference of a standard *length* of 12 **dana** or 360 **UŠ**, hence, I suggest, the use of units *already* conceived of as marking distances. Ultimately, through Greek and medieval intermediaries, this resulted in our using 360° in *any* circle.

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to the point of confusing temporal and spatial **UŠ**. Indeed, the **kùš**-system may have come about partly to circumvent this confusion. Only the oldest possible names were employed, even if those same names had been and were still being used with quite different meanings, as was the case in the text HS 245 (see section on celestial distance measure in the early period p. 111). By using names and ratios found in *Enūma Anu Ellil*, scholars intellectualized that the discoveries resulting from using the new units would continue to be suitable for divinatory purposes.

The highest levels of abstraction came about with the use of the *tithi* (called by the same name for a day, **ud**) and of the fraction-of-a-circumference systems for a great circle that was not parallel to the daily rotation of the heavens — the **UŠ**-system of celestial distance measure (Table 3). Although both were used in the late Neo-Assyrian period, they were used most effectively in the mathematical astronomical texts of the last few centuries BC. There the zodiac of twelve signs simply reiterated the twelve-fold **dana** division of the nychthemeron and the twelve months in a year. The zodiac not only used ancient ratios, but combined these with ancient and equally legitimating constellation names for the twelve signs. With the aid of the zodiac, it became possible to express the annual passage of the sun through the primeval and ideal universe in 360 days as a passage through 360 **UŠ** of the ecliptic. The *tithi*, by the same token, by being defined as 1/30th of a lunation, harked back to the ideal month. Both units maintained a tradition of mensuration which was already at least two thousand years old.

The lunar-solar cycle and other periodic relationships employed in the mathematical astronomical texts gave improved values for the year and the month. The parameters which underpinned these texts were in large part derived from data recorded in the non-mathematical astronomical texts such as the Diaries and Eclipse Records, with very little further empirical input. What is important to note is that the new and improved units did not come about through detailed confrontation with the observed universe in the Hellenistic period, but derived from data recorded in a manner established in the eighth and seventh centuries BC. Scholars modelled the periodicities noticed in this data base through mathematical techniques, but in order to reduce the number of calculations to manageable proportions they used units drawn from the fractions-of-a-circumference system and the *tithi*. Thus the **UŠ**-system for longitudes and the *tithi*-system for times can both be attributed to the scholars' need for efficiency in their calculations and to their desire to use old forms.

In the mathematical astronomical texts, both temporal and spatial locations were calculated to a high degree of precision. Although the predictions were also accurate by ancient standards, they were not as accurate as their apparent precision would imply. Nor was the precision of the calculations necessary to the ultimate divinatory purpose of the texts. Times calculated in *tithis* were simply equated to calendar dates, at which point any precision in the calculated time was immediately lost. In the same way, an accurately calculated longitude was used simply to locate the position of the forthcoming phenomenon to the nearest few degrees. Predicted dates and times at this level of accuracy were sufficient for the needs of the celestial diviner, because all such phenomena still had to be watched for in order that their full significance could be gleaned.

The precision with which the times and locations of phenomena were calculated was an artefact of the unit systems used, and does not reflect a background of highly accurate observations. Since any given celestial phenomenon was predicted by a number of different systems, all of which gave precise, but slightly different values for the expected time and/or location, it is apparent that the results of the calculations were rarely checked against reality with any precision. The non-appearance of predicted eclipses would have indicated that problems were afoot with a given mathematical scheme, but in general even the least accurate schemes were not abandoned. They continued to be used alongside the more effective ones. The detailed testing of the predictions was apparently of no interest to the scholars. Provided the mathematical astronomical texts fulfilled their divinatory purpose, and predicted celestial events to the nearest day and to within a few degrees, that was sufficient for the scholars. It was never their intention to model the universe as precisely as possible.

It is also perhaps surprising to us that the units of position used in the observational texts differed from those used in the predictive texts, just as the times observed in days differed from the times calculated in *tithis*. Clear and important differences therefore exist between the modern and the cuneiform approaches. In the latter, calculations were more precise than was necessary; several schemes co-existed, each giving slightly different predictions; observations were sometimes recorded in units different to those used in the calculations; and the predicted phenomena still had to be watched for to be interpreted fully. These differences can be explained, we

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argue, by the fact that the predictions of the mathematical astronomical texts were not intended to account for the behaviour of the universe, but to assist in the retrospective interpretation of that behaviour. It is accordingly unsurprising that the maintenance of antique forms, names, and ratios was considered to be of significance in that endeavour.

The units used for recording celestial space and time in Mesopotamia were not only the result of the demands of calculating efficiency, or of environmental determinism. They also attest to the power of an imperial enforcement of standards, and to the encouragement of competition between diviners; to the belief in a universe created simply and symmetrically, and to the importance of attaching even the newest discoveries to antique norms. It is sometimes asserted that cuneiform astronomy contains no underlying picture of the universe, and that this distinguishes it from Greek or modern astronomy (Swerdlow 1998, 27; Walker & Britton 1996, 51). Although it was used for the purposes of divination, however, cuneiform astronomy used units which ensured that the description of the behaviour of the heavenly bodies closely mirrored how it was believed the universe was when first created (i.e. its 'ideal' form). Just as various Greek astronomers devised mathematical schemes for predicting celestial behaviour on the basis that the heavenly bodies moved in circles, so cuneiform astronomers devised schemes in which the year was comprised of 12 and 360 units, the month of 30 units, eclipse magnitudes of 12 units, and so forth.

These units were created by individuals, and were regulated and adapted to new ends by scribal scholars. The scholars employed them in pursuit of one of the most important intellectual activities of that time, divination. The influence of divination pervaded the entire astronomical endeavour. Even the most sophisticated of the mathematical astronomical texts, written in the last centuries of the first millennium BC, reveal that for their authors, the interpretation of the predictions was all-important. This mentality is shown most clearly by the particular use they made of the units. When making the inevitable comparison between the achievements of early Mesopotamian science and late twentieth-century Western science, the differences in cognitive approaches must be recognized as fundamental. At no point has it been argued that what was present in Mesopotamia is an instance of some universal cognitive-processual development. On the contrary, it may well be unique to the literate minority who wrote the texts that have here been considered.

Notes

1. Only about one third of this series is published, see Weidner 1941/44; 1954/56; 1968/69; Rochberg 1989a; Van Soldt 1995; Reiner & Pingree 1975; 1981; 1998; George & Al-Rawi 1991/92; Largement 1957.
2. The system of weight units in Mesopotamia is straightforward. 1 **gu(n)**/*biltu*/'talent' = 60 **mana**/*manû*/'mina'. 1 mina = 60 **gín** 'axes', a Sumerian term rendered into Akkadian by *šiqlu* 'shekel'. 1 shekel = 180 **še** 'grain'. Thousands of Mesopotamian weights are to be found in the world's museums, dating from the Presargonic period and later. Some of these have the amounts marked upon them. Most of the examples incorporate mina norms in the region of 480–510 g.
3. We use the term 'nychthemeron' rather than 'day' to avoid confusion with the period of daylight. By it we mean simply the period of a night plus the following day (much as the Greek origin of the word implies), without suggesting that anything more precise than this was meant. The Mesopotamians used the term **ud**, which was as ambiguous in meaning as our 'day' is, since it described both daylight and the interval between successive sunsets (and later even *tithis*).
4. 'Watches' are at least as old as the Old Babylonian period (see Englund 1988, n.40). **Sag.ge$_6$** 'twilight' (see Koch 1997) and **ki šú** *šamaš* 'with sunset' are attested in the Diaries (Hunger & Sachs 1988, 15). The length of these intervals is not known.
5. In a text from the city of Lagaš dating to before the Old Akkadian period the units of distance increase from the *rope* to the **dana**. Where we might expect a **UŠ**, however, instead we find 60 **nindan** (see Powell 1987–90, table vii). This suggests that the **UŠ** was introduced at a later date. It has also been suggested by Smith (1969, 74) that the **UŠ** may have been derived from a term for one-sixtieth of a watch on an equinoctial day. Such days last 12 hours, so each of the three watches would last four hours, one-sixtieth of which is four minutes. This is indeed the length of time of one **UŠ**. A sixtieth would be *šušu'û* or similar in Akkadian and is another possible resolution of **UŠ**. Since 'watches' are seasonal and the **UŠ** is an homogeneous unit of time, however, this interpretation is unlikely.
6. Powell (1987–90, 467) proposes that during marches on equinoctial days it was observed that between stages the sun moved through $^1/_6$th of the sky. Thus a nychthemeron was made 12 **dana** in length. To my mind, the distance between rest stops is not *a priori* about 11 km. The number 12 should be sought elsewhere. It is likely to be earlier. See also Thureau-Dangin (1928, 187) who suggests an origin based on 12 months in a year, but without explanation. Human walking pace is pretty much a constant, so given two hours, 11 km follow.
7. For details see Brown *et al.* forthcoming. 2,0;0 in sexagesimal equals 120 (2 × 60); but in cuneiform, 2,2,0;0 or for that matter 0;0,0,2 (2.60^{-3}), were all written simply as '2'. In texts such as BM 17175+ where

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the units are not specified, it is thus not clear from the writing '2' whether 2 **mana** or 120 **UŠ** were meant. The ratio between **UŠ** and minas of 60:1 provides another reason for reading the sign **UŠ** as *šūš* 'sixty'.

8. A brief calculation shows that, if true, the stars were thought by the author of HS 245 to be *c.* 400 km away. In the *ziqpu* text AO 6478, which dates to the period after *c.* 750 BC, 655,200 '**dana** in the sky' corresponded to '364 **UŠ** in the (stellar) portion'. This implies that the 'sky' was about 1 million km away. Both values are not inconceivable as estimates of the distance to the stars (see Horowitz 1994, 184–5).
9. In one Seleucid period *ziqpu* text from Uruk (VAT 16436), the ratio **kuš**:**UŠ** of 1:720 is still found in a celestial context (Schaumberger 1952, 216–17). The conservative nature of scribal activity sometimes meant that old and new systems were kept side by side and sometimes even reconciled.
10. Schaumberger (1952) dates their invention to the tenth century BC on the basis of a relationship to the vernal equinox. See, however, the text published by George (1991).
11. The best known is the text AO 6478 from Seleucid Uruk, treated by Thureau-Dangin (1913), Schaumberger (1952), and others cited in Rochberg (1983, n.8). A Neo-Assyrian version from Nineveh (K 9794) exists. The total **UŠ** in one revolution of the *ziqpu* stars is 364 in these texts. In the Late Babylonian text from Babylon, BM 38369+ (Horowitz 1994), the total **dana** in a revolution is 12 (line 20).
12. In AO 6478, 60 **UŠ** of time correspond to 10 **mana** of water flowing from a water clock. This is 10 times the normal number. Either a fast-flowing water clock was envisaged, or some reference is being made to the interval of 120 **dana** (also 10 times too big) in HS 245. See section on celestial distance measured in the early period, p. 111.
13. These texts were first discussed by Schaumberger (1955) who studied A 3427, U196 and Sp II 202+ (*LBAT* 1499). They were referred to briefly by Rochberg (1988, 58–9) and by Horowitz (1994) who published another very fragmentary example, BM 77242 from Sippar. Finally, Rochberg (forthcoming) produced a study which incorporated results from the otherwise unedited *LBAT* 1503.
14. Aaboe (Aaboe & Sachs 1980, 15) distinguishes between non-mathematical astronomical texts and mathematical astronomical texts. Both aimed to predict ominous celestial phenomena, but only the latter were free from the need to consult a record of observations.
15. The ratio in the standard system of units for measuring lengths on earth between a *finger* and a *cubit* was 1:30 (Table 2), but by the Late Babylonian period this ratio was commonly 1:24. The reasons for this change can perhaps be traced to the Kassite period (Powell 1987–90, 470). The 24-finger or 2° celestial distance cubit was commonly used in the non-mathematical astronomical texts, but the 1:30 ratio and the $2^{1}/_{2}$° cubit were used in the mathematical astronomical texts. One late text is known that converts the 24-finger cubit into the 30-finger one (Neugebauer & Sachs 1967, 200f.), so why were two different celestial cubits used simultaneously? I note, somewhat cautiously, that in any given time interval, a *ziqpu* star will move $^{4}/_{5}$ths the distance moved by an equatorial star. In 1 **UŠ**, say, an equatorial star will move 1° (or 1 **UŠ** in celestial distance units), but a *ziqpu* star will move 0.8 **UŠ**. In other words, while the *ziqpu* star moves half of a 24-finger **kùš**, the equatorial star moves half of a 30-finger **kùš**! Perhaps distances between phenomena recorded according to *ziqpu* timing were made in '*ziqpu* cubits', hence their use in the non-mathematical astronomical texts such as the Diaries. Equally, some distances noted in the mathematical astronomical texts were made using the 'great circle cubit', because of that cubit's strong numerical relationship with the **UŠ** system of timing and celestial distance measure (Box 6) — the system which the mathematical astronomical texts mainly employed.
16. The Diaries record observations of various celestial and some terrestrial phenomena. They occasionally include the results of some calculations. For the exceptional use of *rūṭu* or 'span' to describe celestial distances, cf. Hunger & Parpola 1983/84, 48.

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Appendix. *A Neo-Assyrian sinking water clock from Nimrud?*

I rediscovered this object in the British Museum via a reference in S. Smith (1969, 77) to an article by R. Smith in which a small photograph (Smith 1907, 327, fig. 2) is published and the following description given (Smith 1907, 332):

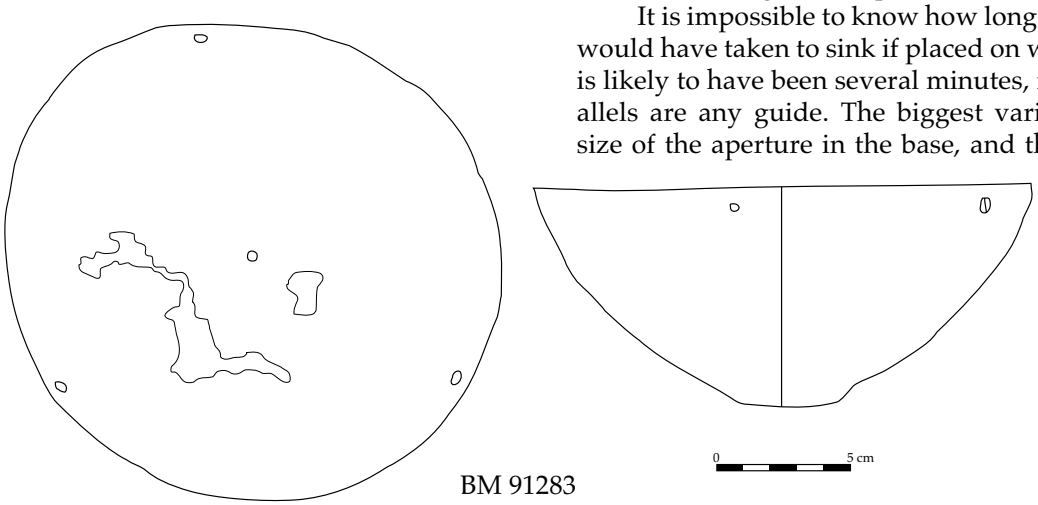
> Looking through the cases of Babylonian and Assyrian bronzes, we [Wallis Budge and Smith] found a corroded basin of copper (BM 91283), $7^1/_2$ inches in diameter, with a distinct round hole in the base, and three other perforations at equal distances round the rim, just as in the Shropshire specimen [Smith 1907, fig. 5, a possible sinking-type water clock]. Unhappily, this bowl was acquired before the days of systematic registration, and its history is unknown, but it probably comes from Nimrud, and may date to the ninth century BC.

BM 91283 was not worth photographing again, but I provide below a drawing made by Ann Searight, to whom I am extremely grateful. The bowl was treated with sodium sesquicarbonate, which accounts for its green colour. It was poorly made, and has no decoration. It is approximately 18 cm in diameter by about 9 cm deep. The holes referred to by Smith are quite distinct. They have been punched from the inside. The central hole is the smallest by far and is currently about 1 mm across. I have searched through the Museum's entire collection of bronze bowls (with the kind assistance of the Keeper, J. Curtis), but was unable to locate any others with holes in their bases. Another noteworthy aspect of the bowl is the line marking a change of colour which runs parallel with the rim on the inside (not marked on the drawing) some 12 mm below it. It is possible that this discolouration marks the extent of the substance held by the bowl.

The bowl's mass is 206 g. It is severely corroded and I estimate that about 80 cm^2 of the surface is missing. Assuming the bowl to be a hemisphere, by $2\pi r^2$ its surface area when complete was about 510 cm^2 and its original weight therefore about 250 g.

The design of the bowl is quite similar to known sinking-type water clocks from India and Sri Lanka (Smith 1907, 326), though in its current state the hole in the base is comparatively large. If placed on a reservoir of water the device would fill until the combined density of the bowl and fluid exceeded the density of water, at which point it would sink, marking some passage of time. It could have been calibrated by means of the holes near the rim, which would permit the rapid and balanced influx of water after a certain period and make the device sink almost immediately. Calculations also indicate that, for this device, the water would have filled up to the line marking the change of colour just before sinking.* This may explain the colour change at this point.

It is impossible to know how long this device would have taken to sink if placed on water, but it is likely to have been several minutes, if later parallels are any guide. The biggest variable is the size of the aperture in the base, and the fact that



BM 91283

* To sink: the weight of the bowl + weight of water up to depth h below the rim > weight of water displaced = volume of bowl times the density of water. Volume of bowl = $^2/_3\pi r^3$. Volume of water in bowl up to depth h is given by $^2/_3\pi r^3$ minus the integral of $(\pi r^2 - \pi x^2)$ from 0 to h. This = $^2/_3\pi r^3 - h\pi r^2 + \pi h^3/3$. This times the density of water will give the mass of water in the bowl up to depth h. This plus 250 g must exceed $^2/_3\pi r^3$ times the density of water, for the bowl to sink. Thus $(\pi h^3/3 - h\pi r^2)$ times the density of water + 215 g > 0. If we assume the density of water is 1 g/cm^3 then h will be in cm. So, $h^3/3 - 81h > 250/\pi$ which leads to a value of h around 1 cm.

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Appendix. *(cont.)*

corrosion makes it impossible to know its original extent. It is likely that the bowl came from Nimrud, as confirmed by Dr Curtis, though we cannot be sure and there is nothing in its style to help determine this one way or the other. Of course, the device may not have been a sinking water clock at all, but was perhaps used to drain fluid while suspended from the three other holes.

If, however, the bowl was a water clock, then it is noteworthy for being the unique example of a Mesopotamian device for measuring time that has survived. I would also note that if it measured short intervals, then its appearance during the Neo-Assyrian period would be entirely consistent with the improving accuracy in recording celestial data we see from that time. Finally, Oppenheim (1974) published a Neo-Assyrian text that referred to a timing device known as a *mašqû* (ll. 64–65) which was to be used to measure the length of the period of the moon's first visibility. This is quite a short interval. *Mašqû* is not a name usually used to refer to an out-flowing water clock. Etymologically the name means something like the place or instrument of drinking, thus a watering hole, a device for drinking, or possibly a device that drinks. It appears with the determinative **dug** or 'bowl' as early as the MB period, and in Oppenheim's text must describe a timing device shaped like a bowl which was either derived from a drinking vessel or which itself drank water, perhaps through a small hole in its bottom. Perhaps *mašqû* was the name of the sinking water clock.

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