Babylonian Astronomy and Its Legacy

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Dès que les premières tablettes astronomiques de Babylone furent déchiffrées, il devint évident que certains éléments de l'astronomie grecque ne furent pas uniquement anticipés par les Babyloniens mais carrément influencés par la tradition babylonienne. Maintenant que nous disposons d'un corpus beaucoup plus vaste de documents littéraires, incluant les "Agendas babyloniens" et plusieurs autres papyrus astronomiques de l'Egypte romaine, nous avons appris, par ces derniers, qu'une transmission massive de concepts et de méthodes s'est produite depuis la Mésopotamie vers le monde hellénistique durant le deuxième siècle de notre ère: notamment des techniques avancées relatives à l'observation et aux mathématiques astronomiques de même qu'aux augures célestes et à l'horoscope personnel.

We have known since the 1880s that the civilizations of Mesopotamia possessed an advanced, technical astronomy. Hundreds of tablets with astronomical contents, the remains of an archive at Babylon, were acquired by the British Museum about this time, a few through excavation but the greater part purchased. Many of these tablets were examined and copied by one of the Museum staff, T. G. Pinches, but his splendid copies were destined to lie unexamined for decades. The labours of the Jesuit assyriologist J. N. Strassmaier were to bear earlier fruit. Taking advantage of the old museum rules that gave outside scholars easy access to uncatalogued tablets, Strassmaier also copied numerous astronomical texts, but he went further by persuading Fr Josef Epping, a fellow Jesuit competent in astronomy, to study the texts. Epping and his successor, Fr F. X. Kugler, made great strides in analysing the mathematical methods underlying the Babylonian tables of computed lunar and planetary phenomena. In six years we will reach the centenary of Kugler's *Babylonische Mondrechnung*, the landmark study that revealed not only the priority of the Babylonians over the Greeks in discovering accurate periods of restitution for the principal elements of the moon's motions, but also that the Greeks actually *learned* these periods from the Babylonians.

The name inseparably associated with the subsequent study of Babylonian mathematical astronomy is that of O. Neugebauer. Applying sophisticated methods of numerical analysis to a much enlarged corpus of tablets, Neugebauer succeeded in establishing the relationships not just between fragments of single tablets, but also among whole series of tablets widely separated in date but united by a continuity of methods of computation. His comprehensive edition, *Astronomical Cuneiform Texts*, has become a paradigm for editions of scientific texts, and its acronym (*ACT*) is now the conventional name for the variety of texts that it embraces. Neugebauer's colleague, A. J. Sachs, began a comparable project to identify, organize, and publish the still larger corpus of texts recording astronomical observations. After Sachs' death this ambitious project was taken on by Hermann Hunger, and to date two large volumes of the astronomical Diaries have appeared.

Neugebauer's researches on the history of astronomy took in an astonishing spectrum of languages and cultures, and one of the principal themes of his work was the tracing of concepts and methods from one culture to another. Concerning the relationship between Babylonian and Greek astronomy he was through the course of his life profoundly cautious, a manifestation of his general disdain for ambitious historical reconstructions, or as he liked to call them, 'fantasies', extrapolated from scanty data. Yet he and his collaborators were able to supplement Kugler's lunar periods with many other instances of technical details of unquestionable Babylonian origin in Greek astronomy. Babylonian astronomy seemed about to take its place in the historiography of science, not merely as a scientific practice of intrinsic interest (a sort of 'ethno-science'), but as the true root of the complex tradition in the exact sciences that leads from the Greeks to Copernicus, Kepler, and the scientific revolution.

Yet outside of the publication of specialists this has not happened. Science still begins with the Greeks in the latest textbooks. True, they now will have a few pages prefixed on the Near East, but these are worse than nothing since they propagate misconceptions and half-truths about the allegedly empirical and mythological character of

Babylonian and Egyptian science, contrasted (unfavourably) with an idealized Aristotelean conception of Greek science as a rational pursuit of causes. Historians whose admiration for the Greeks is exactly coextensive with their perception of the Greeks as the originators of Western civilization—and I may add that they are seldom classical scholars—are now under attack from a party that, valuing evidence less than ideology, would confer the same status on Egypt. Advocates of Mesopotamia's more modest claims can expect little sympathy from either side.

Nevertheless I think that the time is ripe to make the case once more that at least in this one domain of the sciences of the heavens, the contributions of such Greek astronomers as Hipparchus and Ptolemy cannot be seen in true perspective unless we pay at least as much respectful attention to their Babylonian as to their Greek predecessors. It is not merely that the number of Babylonian features recognized in Greek sources has continued to rise. We now have evidence of a new kind that is forcing us to revise our estimates of the manner and breadth of the contact between Babylonian and Greek astronomy. Hitherto, our knowledge of Greek astronomy has been based almost entirely on the treatises of Ptolemy and his later commentators, supplemented by gleanings from other more or less 'literary' works preserved through the Middle Ages. Now we can consult contemporary documents from classical Egypt on papyrus that are exact counterparts in Greek of the cuneiform texts.

About fifty astronomical papyri from disparate collections have been published to date, and most of these were studied, with several important historical results, by Neugebauer between the late 1940s and the 1980s. Far and away the largest identified body of these documents, however, remained untouched until quite recently. These were part—a very small part indeed—of the vast hoard of papyri excavated by B. P. Grenfell and A. S. Hunt at the site of the ancient town of Oxyrhynchus. I am at present editing these texts and tables, and later in this talk I will mention informally some of the more striking new insights that they give. It goes without saying that this substantial addition to the number of known astronomical papyri is also illuminating many obscurities in the already published material.

A large proportion of the astronomical papyri are datable by their contents, so that we have some index of their chronological distribution. The overwhelming majority are of the Roman period, with a peak in the second and third centuries of our era which perhaps merely reflects the generally high survival rate of papyri of all kinds from this period. The astronomical papyri from the Hellenistic period are not merely few but essentially different in genre from the main body. Most of the Roman-era papyri are numerical tables or instructions for the use of tables, and these were undoubtedly the papers of astrologers. We also have numerous personal horoscopes and fragments of astrological handbooks; these still await adequate study.

I should mention in passing that, although most of our astronomical papyri are written in Greek, there exist some Demotic papyri with contents exactly comparable to the Greek ones. The question of the relationship between the two languages as vehicles of astronomy in Egypt is a difficult one that I will only be able to touch lightly upon here.

I would like to review the current state of the question of Greek knowledge and exploitation of Babylonian astronomy, focussing on three aspects: observations, celestial divination and astrology, and theoretical astronomy. In conclusion, I will try to show that these are really facets of a single problem of transmission.

OBSERVATIONAL ASTRONOMY

By the term 'observation' I mean actual dated records of what a competent observer saw in the heavens on a particular night or day. Mesopotamian astronomy was founded on observations, and regular observing and record-keeping remained a leading component of astronomical activity until the time of the very latest tablets we have (from the A.D. 70s). The oldest systematic records that we have from Babylon are cycles of eclipse observations that almost certainly began with the year 747 B.C., the beginning of the reign of Nabu-Nasir. But the main medium for recording observations was the class of texts that Sachs named 'Diaries'. The oldest preserved fragment of a Diary dates from 652 B.C., but early Diaries are very thinly preserved until the 4th century, becoming quite dense in the Seleucid and Parthian periods. The Diaries contained the night-by-night records of the key stages of the lunar month; passages of the moon and planets near certain reference stars (which we call Normal Stars); appearances, disappearances, and stations of the five visible planets; and eclipses; as well as a wealth of meteorological and economic data and local and national news.

As we will see, Greek astronomy was very late in incorporating a genuine observational component, and its earliest debts to Mesopotamia were not observations. Meton of Athens' 19-year calendrical cycle in the late 5th century B.C. was most likely inspired by the 19-year intercalation cycle of the Babylonian calendar, which has now been traced back to the beginning of that century. And the scheme of constellations set out by Plato's contemporary Eudoxus incorporated many Mesopotamian figures, although the assignment of stars to constellations, when we are in a position to check, turns out not to be exactly the same.

It is not until the second half of the fourth century B.C. that we come to what looks like a reference to Babylonian observations in Greek hands. The philosophical commentator Simplicius tells us that Aristotle's protegé Callisthenes 'brought back' observations of the heavens from Babylon in the wake of Alexander the Great's conquest. To be sure, Simplicius is writing the better part of a millenium after the supposed event, and he does not make his story more plausible when he goes on to assert that the observations ranged over 31,000 years. Theon of Alexandria, writing about A.D. 370, says that another of Aristotle's circle, Callippus, obtained values for the number of days in a year and in a lunar month by comparing so-called Chaldean observations with observations from his own time; and this has been taken as corroboration that Callisthenes did indeed bring back observational records. However, the method of measuring periods by comparing widely spaced observations is almost certainly an anachronism for Callippus' time, and anyway the Babylonian records do not contain observations of solstices and equinoxes but only computed dates of these events. Theon's account is probably a misunderstanding engendered by the ambiguity of the Greek word *tereseis*, which we customarily translate as 'observations' but frequently seems to refer to the generalized fact (e.g. a periodicity) distilled from observations. Seen in this light, Simplicius' story about Callisthenes might also mean no more than that he obtained certain facts and numerical parameters from the Babylonian astronomers.

The frequent allusions to Babylonian and even Egyptian observations made over hundreds of thousands of years that we find in classical authors are of course no evidence of direct knowledge of the actual records. Such evidence is found, uniquely but abundantly, in Ptolemy's astronomical treatise, the *Almagest*, written about A.D. 150. In the first place, actual observations are cited: ten lunar eclipses and three planetary passages near fixed stars. We can learn something about the manner of transmission of these reports, first from Ptolemy's explicit remarks about the whole corpus of observations available to him, secondly from the way he uses them or that he tells us his predecessors used them, and thirdly from the terms of the reports themselves. Ptolemy started his tables with the beginning of the reign of Nabu-Nasir (or 'Nabonassar'), and he tells us expressly that this was the beginning of the observations available to him. The earliest eclipse that he actually uses is not much later, from 721 B.C., and it is remarkable that the only Babylonian observations older than the 3rd century B.C. in the *Almagest* are lunar eclipses. Several of these eclipse observations, as Ptolemy tells us, were used by Hipparchus, three centuries before Ptolemy. Hipparchus was reknowned as an astronomer in antiquity, but the loss of all but one of his writings has rendered him an enigmatic figure for us. The remarkable frequency of Babylonian elements in his work is one part of this puzzle to which I will recur.

As quoted by Ptolemy, the eclipse reports are quite far removed from the way they must have originally been recorded. The times of the eclipses are given only in a Greek unit, seasonal hours, which vary in length through the course of the year; and this can hardly be either Hipparchus' or Ptolemy's doing, since they had to convert these variable hours into constant hours for their analyses; and the original Babylonian time indications would have been more suited to their needs. All traces of the Babylonian lunar calendar have vanished from the eclipse reports, to be replaced in most cases by the Egyptian calendar and years since the Era Nabonassar. Three eclipses from the 380s that Hipparchus made use of are distinct in presentation from the rest. These are dated by months in a lunar calendar using Athenian month names, and the years are identified by the Athenian archon. Interestingly, Ptolemy cites Hipparchus as having described these three eclipses as being 'among those that were brought back from Babylon', a phrase that is not echoed for the other Babylonian eclipses in the *Almagest*. The evidence seems to point to more than one transmission of eclipse records before Hipparchus.

Still different is the case of the three planetary observations. These are practically straight translations of the kind of Normal Star passages regularly reported in the Diaries. The dates are given in the Seleucid Era and according to the Babylonian calendar, although the month names appear in Macedonian disguise. That someone had access to the Diaries, or comparable records, is also suggested by Ptolemy's remark that the greater part of the older planetary observations available to him were dates of appearances, disappearances, and stations.

For the theoretical work of Hipparchus and Ptolemy, the Babylonian observations were a prominent resource; and this is especially true of the eclipses because their great antiquity made it possible to measure periodic phenomena over a great span of time, ensuring high precision. However, we now know that Hipparchus' and Ptolemy's measurements of these periods were themselves only attempts to confirm or refine Babylonian values. Their methodology of extracting numerical parameters from the observations does not derive from Babylonian astronomy, but it could scarcely have been developed without access to a range and density of observational records that earlier Greek astronomy could not provide.

The earliest sustained programmes of observation in the Greek world that Ptolemy was able to draw upon were carried out in the 3rd century B.C. in Egypt. One series consisted of observations made at Alexandria by Timocharis of stellar passages and occultations by the moon and Venus. Another series, partly overlapping Timocharis' in date, consists of anonymous reports of stellar passages by the planets. One wonders whether these programmes of observation were inspired at some remove by the contemporary practice of observation in Mesopotamia. Babylonian influence is certainly felt in the use of 'digits', that is, units of 1/12 of the lunar or solar disk, in Greek observations of eclipses. But it must be stressed that we have no trace of any Greek observational programme extending over a longer span than the career or a single observer, comparable to the many centuries of Babylonian Diaries. Moreover not one of the papyri from the Roman period is an observational record.

OMENS AND HOROSCOPY

Mesopotamian celestial divination falls into two broad categories: the omen texts typified by the compendium *Enuma Anu Enlil*, that associate conspicuous 'events' in the heavens with outcomes, usually of national significance; and the later so-called 'horoscopes' that associate the disposition of the sun, moon, and planets in the sky at the time of birth of an individual with outcomes for that individual's life. The same two classes of prognostication, one driven by ominous events that choose their own time of occurrence, the other driven by the essentially arbitrary instant when someone is born, is inherent in Greek astrology. What part, then, did the Mesopotamian traditions play in the development of their Greek counterparts?

The nearest approximation to the term 'omen' in the Greek technical literature is the word *episemasia*, which means 'sign' or 'indication'. It is used in a rather specialized sense for the weather prognostications associated with stellar risings in such weather calendars as Ptolemy's *Phases of the Fixed Stars*. But in the same author's treatise on astrology, the *Tetrabiblos*, *episemasia* refers to the general prognostications associated with the characteristics of eclipses. The *kinds* of outcome that Ptolemy associates with eclipses are like those of the eclipse omens of *Enuma Anu Enlil*, but Ptolemy's criteria for analysing an eclipse observation are somewhat different. In particular, he makes no use of the directions of obscuration of the eclipsed disk, which provide one of the most important variables in the omen texts. But it must be kept in mind that the *Tetrabiblos* sets out to reform and rationalize the science of astrology, and Ptolemy is not bound to reflect contemporary Greek practice in all respects. In fact in the *Almagest*, which he wrote before the *Tetrabiblos*, Ptolemy devotes a long section to the problem of predicting precisely these directions of obscuration, and he explains that this is necessary because people use them to determine *episemasiai*. This is further confirmed by a new papyrus fragment from the 1st century of our era. It presents part of a series of predictions of lunar eclipses, in which the directions of obscuration are set out using the same nomenclature that we find in the *Almagest*, together with other elements such as the fraction of the disk to be obscured and the duration of the eclipse, all potential factors for interpretation in a Mesopotamian omen text. I believe we are here seeing traces of an essentially Babylonian practice of eclipse omens transmitted into Greek, and subjected to much less alteration than we would have expected on the basis of Ptolemy's reworking in the *Tetrabiblos*.

But if some form of omen interpretation was present in Greek astrology, it was definitely less important in the practice of most astrologers than personal horoscopy. The papyrus record makes this imbalance manifest. Beside the one or two documents like this eclipse canon that pertain to *episemasiai* we can set a couple of hundred personal horoscopes. A typical horoscope simply states the date and time of birth, the positions of the sun, moon, and planets computed for that date, and the zodiacal sign or degree of the zodiacal circle that was rising at that moment (it is this ascending point, or *horoskopos*, that gives the horoscope its name). We have a few more elaborately written 'deluxe' horoscopes that include other astrologically significant data derived from the positions of the heavenly bodies, along with much fancy prose. The documentary horoscopes do not, however, discuss the outcomes for the concerned individual.

The Babylonian horoscopes that we possess have similar, though not quite identical, contents: the date and time of birth of an individual, the locations of the planets at that time, but not the ascending point of the zodiac, so that pedantically speaking the term 'horoscope' is not correct for these texts. Unlike the papyrus horoscopes, they sometimes also set out interpretations or forecasts. These show, firstly, that the technique of prognostication is not far removed from omen interpretation, and secondly, that one of the important factors was whether the heavenly bodies were above or below the horizon at the moment of birth, so that the ascending point is really involved even if it is not written down in the document.

One usually emphasizes the differences between Babylonian and Greek horoscopy; and they are indeed prominent. Not only was the Greek apparatus for interpretation that we know from the astrological handbooks much more complex than the simple schemes evident in the cuneiform texts, but this apparatus was founded upon a characteristically Greek, post-Aristotelean cosmology that related human lives to the celestial motions, as effects to causes, in a way that cannot have been in the Babylonian astrologer's mind. But if we look upon astrology as the Greeks did, as a physical science with practical applications, then the basic phenomenon with which that science attempted to deal was that human characters and lives could be predicted from the configuration of the heavenly bodies above and below the horizon at the moment of birth; and that phenomenon was certainly taken over by the Hellenistic inventors of Greek astrology from Babylonian horoscopy.

As I conceive it, Babylonian astrology (and in this I include both the omens and the horoscopes) metamorphosed into its Greek forms in two steps. First, the actual methods must have been transmitted in the sense that Greeks, or in any event non-Babylonians, came into close enough contact with the Babylonian techniques of celestial divination so that they were convinced that they worked and moreover grasped the details at the practical level, possibly even adopting them themselves. Only then would one have been in a position to take the further steps that led to Greek astrology as we know it: replacing the explanatory rationale of divination while leaving its methods intact, and thereafter deriving from the new rationale the numerous embellishments that made the astrology of the Roman period such an intricate affair.

MATHEMATICAL ASTRONOMY

And what of the relationship between Babylonian and Greek mathematical astronomy? Until less than a decade ago, the prevailing assumption was that the various traces of Babylonian concepts and parameters in Greek sources were the evidence of cross-fertilization between two scientific traditions that basically evolved independently. The essential nature of Greek astronomy was known, from such theoretical writings as Ptolemy's *Almagest*, to be physical and geometrical, explaining the apparent motions of the heavenly bodies as our view in perspective of paths in three dimensions, compounded out of circular revolutions. The characteristic stamp of a Greek astronomical table was its use of trigonometric functions describing the edge-on view of circular orbits. Its goal was to yield the position in the heavens of each body at any given time.

The Babylonian so-called *ACT* tablets, on the other hand, used strictly arithmetical manipulations of numbers without trigonometry, to predict in the first place sequential phenomena such as new moons or first appearances of planets, and only secondarily the positions of the moon or planet between these events. A typical tablet for the moon is a complex thing, with one row say for each successive new moon and fifteen to twenty columns of numbers tabulating the various elements involved in calculating the conditions of visibility. The tablets concerning the planets had a simpler structure, reflecting the smaller number of periodic components required to predict the pertinent phenomena. Their purpose was to reproduce the ever-varying intervals of time and progress through the zodiac between similar stages in a planet's looping path, for example between the successive stationary points at the extremities of each loop or 'retrogradation'.

We knew that certain numerical parameters built into the Babylonian lunar tables were familiar to Greek astronomers beginning with Hipparchus: a list of facts and numbers few enough to fit on a file card. For knowledge of the planetary tables we had scarce evidence indeed.

This hypothesis of a narrow and restricted transmission has now been completely overturned. In 1988, Neugebauer obtained a photograph of a scrap of papyrus in a private collection, the contents of which he recognized at once to be one of the columns of a Babylonian lunar table. The implication was obvious, that the whole technique of computing these tables was known in Egypt two centuries after it had last been seen in Babylon. Among the new Oxyrhynchus papyri there are several bits of what one can only describe as Babylonian planetary tables written in Greek, and it is now clear that practically the whole of Babylonian planetary theory was current knowledge in Roman Egypt, well after the publication of Ptolemy's writings and tables.

It will be some time before our notions of the development of Greek astronomy have adapted to take account of these discoveries. For example, we are now just beginning to recognize that the transmission of Babylonian mathematical astronomy into Greek was inevitably connected with the transmission of astrological concepts. Horoscopic astrology in particular simply could not exist without the possibility of calculating planetary positions, and the same people who brought the technique of interpreting horoscopes to the Hellenistic world must also have brought with them the tools without which a horoscope could not be computed.

Again, we now have to take a new look at the empirical base of Ptolemy's astronomy. Many of the phenomena that Ptolemy addresses, and for which he gives no specific demonstration from observations, turn out to be among the most readily noticed features of the Babylonian *ACT* schemes. In particular Ptolemy's familiarity with the kinds of variations exhibited by the planets in their progress through the sky can now be explained by reference to the Babylonian methods. And although the papyri only tell us directly about the practices of the Roman period, we have reason now to hunt for clues that imply that the wholesale transmission of the *ACT* schemes had begun early enough to be reflected in the work of Hipparchus in the second century B.C. If this turns out to be correct, then the fusion of numerical prediction with geometrical explanation of the phenomena that we associate with Hipparchus and Ptolemy was no less a Babylonian than a Greek science.

SELECTIVE BIBLIOGRAPHY

Jones, A. *Astronomical Papyri from Oxyrhynchus* (Philadelphie, American Philosophical Society, forthcoming).

— "On Babylonian Astronomy and its Greek Metamorphoses," in *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Pre-modern Science held at the University of Oklahoma*, F. J. Ragep and S. P. Ragep, eds (Leiden: Brill, 1996), 139-155.

Koch-Westenholz, U. *Mesopotamian Astrology* (Copenhagen: Museum Tusculanum, 1995).

Kugler, F. X. *Die Babylonische Mondrechnung* (Freiburg im Breisgau: Herder'sche Verlagshundlung, 1900).

Neugebauer, O. *Astronomical Cuneiform Texts* (London: Lund Humphries, 1955).

— *A History of Ancient Mathematical Astronomy* (Berlin: Springer, 1975).

— and H. B. van Hoesen. *Greek Horoscopes* (Philadelphia: American Philosophical Society, 1959).

Toomer, G. J. *Ptolemy's Almagest* (London: Duckworth, 1983).

Sachs, A., and H. Hunger. *Astronomical Diaries and Related Texts from Babylonia* (Wien, Verlag der Österreichischen Akademie der Wissenschaften, 1988).