Before the Zodiac: Astronomy and Mathematics as Ancient Culture

Humanities Signature Course

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Tues. and Thurs., 12:30 – 1:50 pm

Taking as its central theme the cultural situatedness of the earliest systems of mathematics and astronomy—from their origins in ancient Mesopotamia (Iraq, *c.* 3400 BCE) until the Common Era (CE)—this signature course explores topics in mathematical language and script, metrology, geometry and topology, music theory, definitions of time, models of stars and planets, medical astrology, and pan-astronomical hermeneutics in literature and an ancient board game. Pushing against boundaries separating the humanities and social and physical sciences, students discover how histories of science and mathematics could be decisively shaped not merely by sensory experience or axiomatic definition, but also by ideas and imagery derived from the cultures, societies, and aesthetics of their day.

Assigned readings are all written in or translated into English, and prior familiarity with ancient languages or civilizations is not a prerequisite for undergraduate enrollment. Similarly, the course does not require knowledge of mathematics and astronomy beyond what any college student may be expected to know.

Students will be graded on class participation (20%) and the quality of their Project (40%) and Class Presentation (40%). Extra penalties will accrue in cases of unexcused absences from class. There will be no quizzes or mid-term or final examinations.

Updated 17 Feb 2019

Week 1 [Tues, 2 Apr 2019] – Writing Words and Numbers

An introduction to the geography and society of Mesopotamia *c.* 3400–3000 BCE, with an emphasis on the invention and development of cuneiform writing in the city and region of Uruk. We discuss problems with the popular model by Schmandt-Besserat, which posits the evolution of cuneiform writing from tokens impressed into clay. What evidence is there for the use of an abacus? To what extent were categories of script and language applicable to numerical and mathematical systems? Were abstract conceptions of number (e.g., the number 3) nonisolable from the objects counted (e.g., 3 fish) as has been repeatedly claimed, and what were the implications of the relationship between the two? We consider how embodied experience contributed to perceptions of certain numbers as being 'whole' or 'natural.'

Week 1 [Thurs, 4 Apr 2019] – *Tour of the Oriental Institute Museum*

Students will gather by 12:30pm just inside the entrance of the Mesopotamian Gallery of the Oriental Institute Museum (1155 E. 58th St., Chicago, IL 60637). The guided tour will focus on texts and artifacts illustrating the nature of cuneiform script, ancient scribal education, practices of measurement, and ways of doing mathematics and astronomy.

Week 2 [Tues, 9 Apr 2019] – Numeral Systems and Prototypes for Metrology

Sexagesimal (base 60), bisexagesimal (base 120), and a variety of numeral systems and scripts were each tailored to different commodities in the course of the 3rd millennium BCE (3000–2001 BCE). Why was the sexagesimal system preferred when standardization occurred during Sargonic (*c.* 2300–2150 BCE) and Ur III (*c.* 2100–2000 BCE) periods? An introduction to the Old Babylonian (*c.* 1750–1600 BCE) scribal school, with its elementary mathematical curriculum involving the use and likely memorization of metrological and arithmetic tables. Analogous to numeral systems, metrology was closely tied to the forms and relationships of prototypical objects and scenarios, instead of describing quantities such as weight, length, area, and volume in exclusively abstract terms. What benefits or disadvantages might result from coherence between numeral systems (e.g., our base 10 decimal system) and metrological systems (e.g., 1 meter = 10×10 centimeters, as opposed to 1 yard = 36 inches)?

Week 2 [Thurs, 11 Apr 2019] – Mathematical Exercises of the Old Babylonian School

A progression to intermediate and advanced stages of the Old Babylonian (*c.* 1750–1600 BCE) mathematical curriculum, with a survey of exercise problems on dividing fields, volumes of trenches and bricks, weighing stones, poles-and-walls, etc. We consider the status of learned coefficients (e.g., π in our own culture) as technical constants specific to the culture and pragmatics of Babylonian bureaucracy. Clay tablets containing rough work by ancient students often consist of a scattering of numbers, unpredictably positioned in relation to each other and without explanation of their uses (much like the case with modern students) – how do we make sense of such artifacts, and what special insight do they provide about the ways ancients solved mathematical problems?

Week 3 [Tues, 16 Apr 2019] – Shapes, Topology, and Geometrical Algebra

The same terminology designated both rudimentary shapes and lines that constituted the defining characteristic of the shape, e.g., the side for the square, the diagonal for the rectangle, the circumference for the circle, etc. We discuss how such definitions agree with or differ from our conceptions of these shapes. What topological principles were taught using problems involving labyrinths and knots? Is 'geometrical algebra' an accurate or appropriate label for the procedures observed in selected mathematical exercises (e.g., in tablet BM 13901)? We compare the fluidity between arithmetic and geometry in these exercises with that of mathematics today.

Week 3 [Thurs, 18 Apr 2019] – Pythagoras' Theorem and Plimpton 322

An extensive case study illustrating how similar mathematical forms may derive from different motivations and be employed for different purposes specific to particular mathematical cultures. We observe that Pythagoras' Theorem is related to calculations involving the lengths of a right-angled triangle, according to how it is portrayed in Euclid's *Elements* (I, 42). How did this model influence the views of early scholars on the cuneiform mathematical tablet 'Plimpton 322'? We discover that Mesopotamian procedures were intended, not so much for elucidating triangle lengths, but for generating pairs of reciprocal numbers. How did such procedures make sense of and respond to problems created by the unique way reciprocals were defined and employed in Mesopotamia?

Week 4 [Tues, 23 Apr 2019] – Mathematics in Acoustics and Music Theory

An exploration of how the geometry of sound holes in Mesopotamian harps reflected highly technical efforts at improving air resonant power efficiency while maintaining sound quality. We survey the handful of ancient manuscripts on music theory and how different scholars have interpreted them, particularly in light of the cuneiform mathematical tradition. How should we interpret the geometrical depiction of the relationships among 'strings' drawn on the Babylonian tablet 'CBS 1766'? If string lengths and ratios in music were indeed modeled after canonical numbers in reciprocal lists, what is implied about Babylonian views on the subjectivity or objectivity of aesthetics?

Week 4 [Thurs, 25 Apr 2019] – *Guest Lecture*

A guest lecturer will speak on a topic and provide additional perspectives in the historical study of ancient mathematics.

Week 5 [Tues, 30 Apr 2019] – The Babylonian Creation Myth and Month-Stars

An influential model linking time with celestial space was supplied by the Babylonian Creation Myth (*Enūma eliš*), which has been ascribed to the occasion of Nebuchadnezzar I's recovery of the god Marduk's cult statue from Elam (*c.* 1100 BCE). We examine the origins of the heavens and constellations according to the myth, including its implication of the 36 (= 12×3) month-stars, each of which were assigned to one of twelve months and one of three celestial paths. The tri-column tablet 'Astrolabe B' (*c.* 1100 BCE) portrays in its format the three paths, as well as the anchoring role of Marduk's star (i.e., the 'Ford star') that stands in the center of the paths and on the threshold between old and new years. We consider variations between the month-stars of Astrolabe B and those of the so-called *Zwölfmaldrei* tablet (BM 82923).

Week 5 [Thurs, 2 May 2019] – Mul-apin and Circular Star Maps

The astral compendium Mul-apin (*c.* 1000 BCE) was an edited product characteristic of scribal developments at the end of the 2nd millennium BCE, when other cuneiform text compositions were also standardized and serialized. Mul-apin introduces two additional categories of stars: (I) Heliacally rising stars, or stars at their first visibility, and (II) *Ziqpu*-stars, or stars that culminate at the sky's meridian. We explain how heliacally rising stars could have derived from month-stars, as well as how difficulties in detecting stars at their heliacal rising—due to celestial, atmospheric, and horizon phenomena—could have been resolved with the aid of *ziqpu*-stars. What may have inspired the development of circular astrolabes and, in turn, planispheres like 'K 8538' (*CT* 33, 10) and the so-called 'Sippar Planisphere'? To what extent do such circular artifacts imply knowledge of what scientists call 'spherical astronomy'?

Week 6 [Tues, 7 May 2019] – Measuring Time—Calendars and Water Clock

We consider the human experience of categories in Mesopotamian time-keeping, e.g., 'watches' of the day/night, sunset as the day's beginning (as opposed to sunrise, or even midnight as observed by the Romans), the notion of a 7-day week (as opposed to the 10-day week in ancient Egypt), phases of the moon, solstices and equinoxes, agricultural seasons, annual religious festivals, the tenure of kings/officials, etc., as well as Mesopotamia's tradition of menologies, hemerologies and lucky days. We examine the onomatopoetically named *dibdibbu* texts from the Old Babylonian school, which contained mathematical problems related to a water clock. What are the reasons for rejecting the older model of an outflow clock, in favor of an inflow clock? We observe how—in response to the growing prominence of the unit UŠ in the astral sciences—the water clock became calibrated so that 1 *shekel* of liquid would correspond to the passage of 1 UŠ (= 4 minutes) of time.

Week 6 [Thurs, 9 May 2019] – Early Planetary Theories and Eclipses

In addition to the sun and moon, the ancient Mesopotamians recognized five planets: Mercury, Venus, Mars, Jupiter, and Saturn. What phenomena might have inclined the ancient Mesopotamians to view instead the sun and planets as followers of the moon, which traveled along a 'Path of the Moon'? We analyze the planetary model underlying the so-called 'Venus Tablet of Ammi-ṣaduqa,' which allegedly depicts conditions during the reign of the Babylonian king Ammi-ṣaduqa (*c.* 1646–1626 BCE). Key planetary events known as *Greek Letter Phenomena* vary depending on whether their subject is an inner planet (Mercury, Venus) or outer planet (Mars, Jupiter, Saturn). How did ancient astronomers predict forthcoming eclipses, and at what point was it probable that they had knowledge of the 'Saros cycle' (i.e., a period of 223 synodic months separating eclipses of the same type)? We explore the cultural repercussions of eclipses as evident in the 'Substitute King Ritual' and the *Lunar Eclipse Myth*.

Week 7 [Tues, 14 May 2019] – Astronomical Professions, Omens, and Reports

An introduction to the five major scholarly professions in the Neo-Assyrian court (late 8th and 7th centuries BCE): the diviner (*bārû*), the physician (*asû*), the magician (*āšipu*), the lamentation priest (*kalû*), and the astronomer (*ṭupšarru* or *ṭupšar Enūma Anu Enlil*). Professionals operated within a system of patronage, whereby a scholar's recognition and livelihood was directly dependent upon the favor of the Assyrian monarch, so that fierce competition and one-upsmanship characterized their interactions. We consider how scholars made use of observations, the astronomical omen series *Enūma Anu Enlil* (EAE), extraneous texts, and 'mouth of the scholar' traditions in the crafting of astrological reports for the king. In Achaemenid and Seleucid times (*c.* 550 BCE and later), the title 'astronomer' became much more restricted, with magicians and lamentation priests increasingly engaged in astronomical scholarship, encouraged by their ties to Babylonian temple institutions that grew in importance as patrons of traditional scholarship under Persian and Hellenistic rule. Pan-astronomical hermeneutics characterized commentaries written by these professionals.

Week 7 [Thurs, 16 May 2019] – Astronomical Diaries, Almanacs, and Goal Year Texts

'Non-mathematical Astronomical Texts' (NMAT) such as Astronomical Diaries, Almanacs and Normal Star Almanacs, and Goal Year Texts describe the positions of planets in terms of distances—in 'cubits' and 'fingers'—from a set of reference stars called 'Normal Stars.' Astronomical Diaries (attested from 650 BCE) were compiled from daily observations of celestial events such as the positions of the moon and planets, solstices and equinoxes, Sirius phenomena, meteors and comets, and the weather, along with records on the prices of commodities, river levels, and significant historical events. By contrast, 'Mathematical Astronomical Texts' (MAT) such as the ephemerides and procedure texts depict planetary positions in terms of 'degrees' (UŠ) of a zodiacal sign. What were the advantages of or reasons for the production of NMAT even centuries after the invention of the zodiac?

Week 8 [Tues, 21 May 2019] – The Calendar Text System and Medical Astrology

Invented in the late 5th century BCE, the zodiac imposed a schematic Babylonian year of 360 days onto the sun's ecliptic of 360°, so that each month begins with the sun's movement into a new zodiacal sign, and the 30 days of a month correspond to the 30° of a zodiacal sign. The 360° circle was therefore of Babylonian origin, and later became foundational to Hellenistic astronomy and to its precursors of trigonometry. On the heels of this invention were the articulation of a Calendar Text system and its micro-zodiac of 13, which partitioned a single zodiacal sign into thirteen micro-zodiacal divisions, in an effort to synchronize the movements of sun and moon. Expanding upon earlier traditions of hemerology, dates in the Calendar Text system were correlated with plant, mineral, and animal ingredients that were imbued with healing efficacy for the day. What fundamental tenet of medical practice, however, was violated by such therapeutic uses of hemerology? What steps did the Babylonians take to mitigate the problem?

Week 8 [Thurs, 23 May 2019] – Scale Drawings on *Gestirn-Darstellungen* Tablets

The most striking features of *Gestirn-Darstellungen* tablets are their drawings of star constellations and planets in specific positions known as 'Houses of Secret.' We discover how such drawings were aligned with a horizontal scale, so that time differences in the dates of heliacal risings of stars could be translated into spatial distances between stars. While the *Gestirn-Darstellungen* tablets date to the Seleucid period (*c.* 2nd century BCE), similar principles of drawing seem to be attested already in a Kassite Star Calendar (VAT 15377) belonging to the later half of the 2nd millennium BCE. How did the 'Houses of Secret' of Mesopotamian planets later develop into the *hypsomata* of Hellenistic astrology, as well as into Zoroastrian ideas about the Horoscope of the World in the *Bundahishn*? What evidence suggests that the *Gestirn-Darstellungen* tablets, which utilized a micro-zodiac of 12, postdated the invention of the micro-zodiac of 13 in Calendar Texts?

Week 9 [Tues, 28 May 2019] – Lunar and Planetary Ephemerides

Two lunar systems account for the vast majority of mathematical astronomical tablets on the moon: (I) Lunar System A, which depicts the moon moving at a higher or lower constant speed throughout the year, and (II) Lunar System B, which depicts the moon moving at constant acceleration or deceleration between higher and lower limits throughout the year. How does the moon's speed (relative to an earth-bound observer) change throughout its elliptical orbit round the earth, from its position of apogee to perigee and vice versa? How were methodologies in Lunar Systems A and B applied to planetary ephemerides? We closely analyze an ephemeris of the planet Mercury—as recorded in Oriental Institute tablet 'A3425'—while elucidating each step of this complex procedure, showing how ancient observers depicted, in mathematical terms, changes in the planet's behavior at the *Greek Letter Phenomena*.

Week 9 [Thurs, 30 May 2019] – *Class Presentations*

TBD

Week 10 [Tues, 4 Jun 2019] – The Seleucid Game of Twenty Squares

The course ends on a fun note with a tablet of game rules written by the astronomer Itti-Marduk-balāṭu (II) and dated to Year 135 of Seleucus the king (i.e., 177/176 BCE). The game represents an adaptation of an old board game—the so-called 'Royal Game of Ur'—attested already in the 3rd millennium BCE, but with its board design, gaming tokens, knucklebone-die, etc., reinterpreted to express the zodiac circle, solstices and equinoxes, and star constellations at their heliacal rising or *ziqpu* position. We consider this board game within the context of pan-astronomical hermeneutics (introduced in an earlier lesson).

Week 10 [Thurs–Fri, 6–7 Jun 2019] – *College Reading Period*