Astronomical Computation in the Pre-Modern World
Methods – Tables – Accuracy

Workshop
11-12 April 2024

ZODIAC – Ancient Astral Science in Transformation (ERC)
Institute for the History of Knowledge in the Ancient World
Freie Universität Berlin

Fabeckstraße 23-25, room 2.2058

Organisers: Mathieu Ossendrijver, Thomas Peeters

Thursday 11 April 2024, 09:45-10:30
Alexander Jones (New York University)
Greco-Egyptian Sign-Entry Almanacs Beyond Van der Waerden: Questions of Accuracy and Derivation

Following Neugebauer's 1942 reedition of the Demotic sign-entry almanacs P.Berlin inv. 8279 and the Liverpool Stobart Tablets, Van der Waerden published papers in 1947 and 1960 presenting analytic arguments that the data in these almanacs had been computed by Babylonian, or at least Babylonian-style, arithmetical methods. Finally, in response to Neugebauer's 1969 criticisms of Van der Waerden's claims (in Neugebauer and Parker, *Egyptian Astronomical Texts* Volume 3), Van der Waerden restated and refined them in a 1972 paper. By now, the extensive presence of Babylonian and other arithmetical algorithms and methods in the astronomy of Greco-Roman Egypt has been established more directly and conclusively from other papyri and ostraca, both Greek and Demotic, but much remains uncertain about the details, especially with respect to the calculation of planetary positions. The sign-entry almanacs, being by far the largest corpora of computed planetary positions from the Greco-Egyptian tradition, are therefore still worth studying from the point of view of the derivation of their data. In this talk, I will try to build on Van der Waerden's analyses, focusing on whether there are detectable patterns in the errors of the almanac data in comparison with data computed by modern theory, and whether for Venus in particular one can go beyond Van der Waerden's attempt to identify the algorithm employed in the Stobart Tablets.

Thursday 11 April 2024, 11:00-11:45
John Steele (Brown University)
Calculating the Lunar Six: Evidence from Practice

The lunar six are a group of intervals between the rising and setting of the sun and moon measured on six specific occasions during the month. Several hundred reports of observations and predictions of the lunar six are preserved in Babylonian texts. Brack-Bernsen has identified a series of methods for calculating the lunar six intervals using data from 18 and 18½ years earlier. In this paper, I will present a large-scale analysis of preserved lunar six observations and predictions in order to examine how these methods were implemented in practice. In addition, I will discuss the role of predicted lunar six data in the determination of the length of the month and the prediction of eclipses.

Thursday 11 April 2024, 11:45-12:30
Lis Brack-Bernsen (Universität Regensburg)
The Usefulness of Computer Simulated Lunar Data

The Lunar Six time intervals have been observed and collected since 600 BC by the Babylonians. They are well observed, agreeing with astronomical calculations of the phenomena. Therefore, it is possible to generate "Observed Lunar data". The astronomical significance and utilisation of Lunar Four and their sums: The Goal-Year method and the calculation of the "lunar contribution" to the duration of the month. The sums ŠÚ+NA and ME+GE_6 as observational basis of the daylength schemes for System A and B. Analysis of the curves Σ and Φ: Φ is probably a tangential fit to Σ.

Thursday 11 April 2024, 14:00-14:45
Thomas Peeters (Freie Universität Berlin – ZODIAC)
Accuracy of Ancient Jupiter Tables Across Time and Place

Can accuracy of astronomical tables be used as a tool to shed light on the spread of astronomical knowledge between Mesopotamia, Greece and Egypt in the period 300 BCE - 300 CE? And how could one go about in quantifying this accuracy and creating this tool? In this contribution I present an approach to accuracy of ancient Jupiter tables, using both ancient tabulated data and modern, synthetic NASA JPL data. A couple of initial patterns will be unveiled, using modern digital tools for comparison of these data.

Thursday 11 April 2024, 14:45-15:30
Marc Chapuis (Brown University)
Computational Analysis of Chinese Astronomical Systems: Work-in-progress on Yixing's Great Expansion System

Chinese Astronomical Systems (li 曆) are procedures describing how to compute an astronomical almanac comprising of the lunisolar civil calendar, lunar and solar eclipse dates and timing, and planetary ephemerides. These systems possess three interesting characteristics: 1) they were designed as coherent units; 2) they are particularly long examples of pre-modern computation procedures; 3) they were made for practical use. The combination of these characteristics makes them a privileged locus for the investigation of how the practicality of computations conditions mathematical astronomy in practice. I will present work-in progress on my study of Yixing's Great Expansion System (adopted in 727 CE) procedures with a focus on what might be gleaned from considering the computations involved in detail.

Thursday 11 April 2024, 16:00-16:45
Rob van Gent (Universiteit Utrecht)
Predicting Eclipses in the Late Medieval and Early Modern Period

My talk will be on predicting lunar and solar eclipses in the late medieval and early modern period. I will discuss how they were computed and how they were commonly tabulated in early printed ephemerides. As examples I will discuss a little-known list of solar eclipses predicted for the years 1366 to 1386 mentioned in a composite Latin manuscript in the Utrecht University Library (hs. 317, 14th century), the eclipses tabulated in the *Ephemerides* (1474) of Regiomontanus and the lunar and solar eclipses listed in the "Shepherd's Calendar" (*Le grant kalendrier et compost des bergers*, various editions and translations from 1491 onwards).

Thursday 11 April 2024, 16:45-17:30

Christián Carman (Universidad Nacional de Quilmes)

What Can We Learn From a Two-Page Manuscript of Tycho Brahe Full of Calculations?

When Tycho Brahe observed the latitude of Mars on August 10th and 24th, 1593, he noticed that they did not fit the Prutenic tables' predictions and wrote in his notebook: "The cause of this need to be looked into carefully". In the *Appendix ad Observationes anni 1593*, Dreyer published part of the drafts of calculations in which Brahe tried to solve this problem. Tycho starts by calculating the latitudes using the Prutenic tables but introduces corrections coming from his own models, observations, and parameters. The full calculations have not been published by Dreyer but are preserved in the manuscript. By looking at these calculations in detail we can learn the sophisticated way in which an astronomer like Tycho could combine outdated tables with his own values to obtain very precise values. In this talk, I will guide you in the winding tour of Tycho's calculations to show you how models, observations, and tables interact in a smart way to obtain those values.

Friday 12 April 2024, 09:30-10:15

Sajjad Nikfahm-Khubravan

The Empirical Foundation of Ptolemy's Oscillating Eccentrics in the *Almagest*

Based on his observations, Ptolemy concluded in the *Almagest* that the center of the epicycle of Venus always remains either on the ecliptic or above it, and that of Mercury either on the ecliptic or below it. He assumed that, for each lower planet, when the center of the epicycle is at the apogee or perigee of the eccentric, and the planet is in conjunction with the mean Sun, the center of the epicycle has some small latitude (0;10 above the ecliptic for Venus, and 0;45 below the ecliptic for Mercury). To fulfill this empirical condition, for these two planets, Ptolemy devised two oscillating eccentrics. But he never cited his observations, and he only implied that this assumption resulted from observing the planets either at conjunction, or at positions very close to conjunction. Pedersen and Neugebauer each tried to come up with an explanation for how Ptolemy determined the inclination of the eccentrics of the lower planets. Pedersen tried to determine this inclination by finding the conjunction of Venus with the mean Sun at a time observable to Ptolemy. But instead of a northern latitude for Venus, Pedersen found a southern latitude in such a conjunction, and he concluded that "how Ptolemy obtained his basic data remains a mystery". Neugebauer also could not reproduce Ptolemy's values for the inclination of the eccentrics of Venus and Mercury. Referring to the two earlier attempts by Pedersen and Neugebauer, Swerdlow said "I know of no correct explanation of just what it is that he", namely Ptolemy, "observed, what accounts for β_3", namely the maximum inclination of the eccentrics of the lower planets, "and will not trouble the reader with my own attempts". Swerdlow said that inferring such a small latitude "at conjunction when the planet can only be observed many days before or after, the latitude is changing the most rapidly across the line of sight, and is strongly affected by refraction near the horizon, seems very insecure". Following these unsuccessful attempts, we should either assume that for some unknown reason, Ptolemy invented these values, or that instead of using observations made near conjunctions, he used some other observations. In this paper, I shall argue in favor of the latter option and shall show that it is the key to finding the empirical bases for Ptolemy's assumption of oscillating eccentrics. Finally, I shall discuss the kinds of empirical and theoretical issues that arose when Ptolemy later changed his latitude theory, in the *Planetary Hypotheses*, where he devised eccentrics with fixed inclinations for Venus and Mercury.

Friday 12 April 2024, 10:15-11:00
Benno van Dalen (Bayerische Akademie der Wissenschaften)
Calculation of the Equations of Mercury in al-Ṭūsī's Recension of the *Almagest*

While less than 20 manuscripts of three Arabic translations of Ptolemy's *Almagest* have survived, we know of nearly 200 manuscripts of its most important recension, the *Tahrīr al-Majisṭī* by Naṣīr al-Dīn al-Ṭūsī, written in 1249. In some tens of these manuscripts the *Taḥrīr* is followed by three appendices, which most probably stem from the environment of the Maragha observatory and especially from the circle of Quṭb al-Dīn al-Shīrāzī. The first of these appendices briefly explains the calculation of the equation of centre for Mercury and then provides twenty diagrams of the various relative positions of the Earth, the centre of the crank circle, the centre of the deferent, the epicycle centre and the planet itself. This is followed by three tables providing all intermediate results of the calculation of the equation of centre and the maximum equation of anomaly for a highly irregular set of arguments. I intend to show the results of a recomputation of all these data and try to explain possible errors in the values in the tables. These results will, if appropriate, be contrasted with techniques of calculation and approximation that have been recognised in "regular" planetary tables in Islamic astronomical handbooks.

Friday 12 April 2024, 11:30-12:15
Richard Kremer (Dartmouth College)
An Alfonsine Astrologer's Toolbox, or Computing Ephemerides 1442-73 in Paris, BnF lat. 7301

Many fifteenth-century Latin manuscripts contain the astronomical tables and texts required for computation and interpretation of horoscopes, but only a few such codices have been linked to known consulting astrologers. The astrological practices of Richard Trewythian in London (Sloane 428, horoscopes and ephemerides for 1442-58) and S. Belle in Moulins (Lisbon 1711, horoscopes and ephemerides for 1468-80) have been usefully analyzed, respectively, by Sophie Page (2001) and Helena Avelar de Carvalho (2021). In this paper, I will analyze another astrologer's toolbox, BnF lat. 7301, that contains only a few horoscopes but an extensive set of daily ephemerides for years from 1442-73, in at least six different hands. Unlike Page and Avelar de Carvalho, I will focus on the computational practices and the ephemerides in this codex, asking how they were computed and what their formats suggest about how they might have been used in astrological consultations.

Friday 12 April 2024, 12:15-13:00
Matthieu Husson (Université Paris Sciences et Lettres)
Probatio Operationis, Alfonsine Astronomers' Views on Accuracy and the Epistemological Values of Computation

In a student manuscript left by John of Saxony (Erfurt, 2° 377) we find a series of autograph notes providing some kind of mathematical rationale of shadows and sun altitude computations as described by John of Lignères' canons *Cujuslibet arcus*. This series of notes mention an intriguing *probatio operationis* of the same procedures. This *probatio operationis* is maybe to be found in a later extensive commentary John of Saxony made on the canons of his master John of Lignères consisting of long, slightly commented computed examples following the *Cujuslibet* instructions. I propose to analyse this small corpus and reflect on what a *probatio operationis* could be for John of Saxony and his milieu. This will be a means to understand historical actors' views on accuracy and the forms of reasoning they developed through and around computations.

Friday 12 April 2024, 14:30-15:15
Teije de Jong (Universiteit van Amsterdam)
Tablet U 98: The Remains of an Interesting Jupiter System B Ephemeris from Uruk

Listed as ACT No. 627, Neugebauer summarizes the contents of this fragment as “Jupiter, first stationary points for (at least) 12 years, system B”. In spite of the limited amount of information the preserved lines turn out to be datable to SE 179–192 (133–119 BC). In this paper I will present a reconstruction of the ephemeris and I discuss the choice of the initial longitude and the date of Jupiter at its first station and the possible connection of this ephemeris to other preserved Jupiter ephemerides. In the process we get a glimpse of an Urukian astronomer at work.

Friday 12 April 2024, 15:15-16:00
Mathieu Ossendrijver (Freie Universität Berlin – ZODIAC)
A Close Look at the Babylonian Jupiter Tables

With 47 computed tables, Jupiter is by far the best attested planet among the Babylonian planetary tables. In this contribution I present an overview and selected results of a new investigation of these tables. Topics that will be addressed include the archival context and initialization of the tables and mutual dependencies between tablets and between columns for different phenomena.

Friday 12 April 2024, 16:30-17:15
Anuj Misra (Max-Planck-Institut für Wissenschaftsgeschichte Berlin; Freie Universität Berlin)
Tabulating the Heavens: Astronomical Tables in Sanskrit

From the beginning of the second millennium CE, Sanskrit astronomers habitually composed text-tables (*sāraṇī*’s or *koṣṭhaka*’s) to explain the movement of the heavens. Their compositions provided a numerical basis to chart the cyclical journey of the celestial bodies through the zodiac, and in many ways, transformed the kinematics of heavenly motion into the arithmetics of earthly numbers. Insofar as form has bearing on content, the peculiarities of the scribal practices among Sanskrit table-makers also played its part in determining the mathematics used in the construction of these tables. In this talk, I explore these (and other) facets from the world of Sanskrit numerical tables to help situate the art of table-making within the science of astronomy.