The problem of decipherment the Babylonian "astrolabes"

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Abstract. The present work is devoted to the study of the Babylonian "astrolabes", which are believed by historians to be one of the earliest species of the star calendar. This calendar represents a list of stars and constellations, which have heliacal rising in a certain month of the year whereas three rising stars belong to different parts of the sky corresponding to each month; therefore, the "astrolabes" contain a set of 36 objects.

Verification the contents of the "astrolabes" and matching astronomical phenomena to the logic of designing a star calendar leads to two simple alternatives: 1) "astrolabes" were not used as a calendar, but were cult texts; and 2) the "astrolabes" were star calendars, but our identification of the Babylonian constellations has a large number of errors. In this case, it is necessary to question the reliability of identification and other Babylonian astronomical texts related to that time.
Key words: Babylonian "astrolabes", star calendars, archeoastronomy

Introduction

The most ancient documents of astronomical origin are the so-called Babylonian "astrolabes", which appeared in Mesopotamia at the end of the II millennium BC. It should be noted that the term "astrolabe" is not strictly correct and it is not related to the famous medieval astronomical device. It was introduced by British archaeologists in 1874, who referred to some type of discovered cuneiform texts as "astrolabes". Although archaeologists had chosen an unfortunate term from an astronomical point of view, it firmly rooted in the literature, with reference to a certain type of ancient Babylonian texts and is now generally accepted.

There are two types of "astrolabes", round and rectangular. The most ancient species are round "astrolabes" in the form of a disk, divided by three nested circles and twelve sectors forming 36 fragments (Van der Waerden, 75-77). Only two fragments of round "astrolabes" from the library of Ashurbanipal have survived up to our time. The latter types of documents are rectangular "astrolabes", which represent tables containing three columns and twelve lines. Among them, the earliest text is "Berlin's astrolabe" or "astrolabe B", which comes from Ashur and dates back to about 1100 BC.

The rows of the table match the calendar months, and the columns the sky regions which are called Ea, Anu and Enlil. According to Bezold's and Schaumberger's estimates, the stars located in the sector of about $\pm 17°$ from the celestial equator relate to Anu, above this band are the stars of Enlil (ie, the northern stars), and the stars below the band of Anu relate to the stars of Ea (southern stars). Each column contains 12 stars, which correspond to certain Babylonian months. Researchers believe that the objects mentioned in each column are stars or constellations that have heliacal rise during the corresponding month in three sectors of the sky: Ea, Anu and Enlil. If this is true, the Babylonian "astrolabes" are star calendars.

So-called lists of stars of Elam, Akkad and Amurru, are associated with the "astrolabes". Each of these lists contains only one column of stars. According to the content and order of enumeration, the lists coincide with the individual columns of the astrolabe stars, and their order exactly corresponds to the order of twelve months. There is a suggestion that these lists of stars are the precursors of "astrolabes", and the latter are their improved form. Whether this suggestion is true or not, the lists of stars and "astrolabes" represent a related category of texts, which we shall further consider as one.

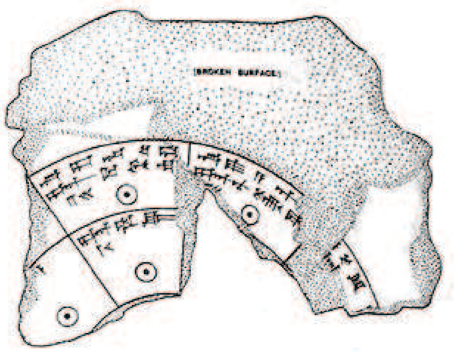

Fig. 1. Fragment of a Round "Astrolabe"

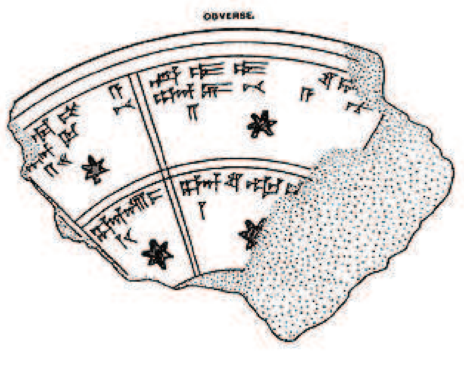

Fig. 2. Fragment of a Round "Astrolabe"

Fig. 3. A reconstruction of a Round "Astrolabe"

In Table 1 the Acadian words are written phonetically and marked in italics; the Sumerian words and ideograms are represented by capital letters in accordance to the Gesman dictionary.
If "astrolabes" are indeed star calendars, then they must reflect the real astronomical situation at the time of their creation. That is, the stars should be correctly distributed across the sky sectors (Ea, Anna and Enlil) and have heliacal rising at the right time. To verify this judgment, we need to identify the contents of the "astrolabe" and after that, evaluate the possibility of using it as a calendar.

Identification of the names of objects mentioned in the astrolabes

To identify stars and constellations, we used the fundamental study of G.E. Kurtik [2007], and in some cases, we turned to the Russian translation of Van der Waerden's book [1991]. This translation was made according to the English edition of 1974 and it reflected in the references of G.E. Kurtik as Waerden [1974]. However, we can assume that the Russian edition contains more detailed information because an object in Russian translation is sometimes identified to the accuracy of a particular star, not a group of stars. Therefore, we shall occasionally refer to this publication.

1. The stars of Ea (Southern stars).

1.1 IKU=^{mul}Ik*û* -"Field", part of the constellations Pegasus and Andromeda. Van der Waerden identifies IKU as quadrangle [large square] of Pegasus (α, β, γ) and α Andromeda. The declinations of these stars in the 11th century BC are in the range of $-1°$ to $+13°$ and refer to the Anu stars, but not Ea.

	Month	Stars of Ea	Stars of Anu	Stars of Enlil
1	Nisan	IKU	DIL.BAT	APIN
2	Iyar	MUL.MUL	SHU.GUI	*A-nu-ni-tum*
3	Sivan	SIBA.ZI.AN.NA	UR.GU.LA	MUSH
4	Tammuz	KAK.SI.DI	MASH.TAB.BA	SHUL.PA.E
5	Ab	BAN	MASH.TAB.BA.GAL.GAL	MAR.GID.DA
6	Elul	*ka-li-tum*	UGA	SHU.PA
7	Tishrei	NIN.MAH	*zi-ba-ni-tum*	EN.TE.NA.MASH.LUM
8	Cheshvan	UR.IDIM	GIR.TAB	LULGAL
9	Kislev	*sal-bat-a-nu*	UD.KA.DUH.A	UZA
10	Tebeth	GU.LA	*al-lu-ut-tum*	A^{mushen}
11	Shebat	NU.MUSH.DA	SHIM.MAH	DA.MU
12	Adar	KUA	^{d} Marduk	KA.A

Table 1. The content of an "Astrolabe".

1.2 MUL.MUL - Pleiades. The Pleiades declination on the prospective date of the creation of the "astrolabes" is $\delta = +10°$, therefore they cannot be attributed to Ea stars either.

1.3 SIBA.ZI.AN.NA=^{mul}SIPA.ZI.AN.NA - "The Righteous Shepherd Anu". Identification: the constellation of Orion [Waerden 1949, 1952-53, Weidner 1957-59, Koch 1989]. The declinations of the stars of the contour of the constellation in the 11th century BC were within the range from $-17°$ (Rigel) to $+1°$ (Betelgeuse), therefore they belong to the Anu region, not Ea. However, the name "Righteous shepherd Anu" itself suggests that the constellation should be located in the region of Anu, and not somewhere else.

1.4 KAK.SI.DI=^{mul}KAK.SI.SA$_2$=GAG.SI.SA$_2$=*šukūdu* - "Arrow". Identification: Sirius+$\varepsilon + \eta$ CMa, Sirius [Weidner 1957-59], Sirius + Procyon [Papke 1978, Waerden 1984], Sirius + Betelgeuse [Koch 1989]. Thus, there are many identification variants of the stars in the constellation. With a degree of certainty, one can only assert that Sirius was a part of the Mesopotamian constellation of the Arrow. This star is in the Ea region in any historical epoch, if the observer was in Mesopotamia.

1.5 BAN=$^{mul/d}$BAN=$^{mul(giš)}$PAN=*gaštu* - "Bow", Canis Major stars without Sirius + part of the stars of Puppis [Waerden 1949, Weidner 1957-59, 1974, Hunger, Pingree 1999. There are no disagreements in this identification.

1.6 *Ka-li-tum*=^{mul}*Kalītu(m)*=^{mul}BIR - constellation or star within Puppis, although the identification of the object is ambiguous. Variants: Canopus(?) [Weidner 1957-59], $\gamma, \delta, \kappa, \lambda$ Vela + ε, ι Pupis [Koch 1989], β Andromeda [Huger, Pingree 1989]. If we exclude the last option, this object can be identified as a star of Puppis, which automatically corresponds to the area of Ea.

1.7 NIN.MAH=^{muld}NIN.MAH=^{muld}NIN.TU -"The Great Lady" - asterism or a star in the constellation of Vela. All identification variants differ only in the size of the asterism: Vela(?) [Weidner 1957-59], γ Vela [Reiner, Pingree 1981], part of the Vela, most of the Vela [Hunger, Pingree 1989]. In any case, this asterism refers to the southern stars.

1.8 UR.IDIM=$^{mul/d}$UR.IDIM - "The Mad Dog". Identification is not straightforward. Variants of identification: Head of the Serpens [Waerden, 1949], Serpens or Head of the Serpens [Waerden, 1974], Serpens [Weidner, 1957-59], Lupus [Weidner, 1957-59], Lupus + ζ Scorpius. The Russian edition of Van der Waerden's book identifies it as the δ Serpens. In the case of identification of UR.IDUM with part of Serpens, it leads to the fact that the asterism belongs to the northern stars, and in case of its identification as a part of the constellation Lupus, to the south.

1.9 *Sal-bat-a-nu*=$^{mul/d}$*Salbatānu* is unambiguously the planet Mars.

1.10 GU.LA=^{mul}GU.LA=*rabû* -"The Great Giant" - part or the entire constellation of Aquarius, [Waerden 1949, 1952-3, 1974, Weidner 1957-59, Reiner, Pingree 1981, Hunger, Pingree 1999]. In this period, Aquarius belongs to the region of Ea.

1.11 NU.MUSH.DA=$^{mul/d}$NU.MUS.DA=*nammaššû* - "herds of wild animals". The identifications are different: a group of stars from α and β Sagittarius to α Phoenix; constellation Grus [Weidner 1957-59]; η or κ Centauri [Huger, Pingree 1989]. Note that α Phoenix itself is not visible at the latitude of Babylon even at the beginning of the 1st millennium BC. The same applies to the bright star α Grus, which culminates at a height of 1 degree and could hardly be observed. Therefore, the only possible identifications of this constellation are the stars of the fourth magnitude α, β, θ and ι Sagittarius, or even fainter stars of the constellation Microscope. Perhaps the most reasonable identification is the star of the Grus, but its visible brilliance at the latitude of Babylon does not exceed 4^m in different models of the atmosphere. Therefore, we suppose that the identification of this constellation is questionable.

1.12 KUA=^{mul}KU$_6$=*mūnu* - "Fish". All researchers identify this constellation as the modern constellation of Piscis Austrinus or directly with the surroundings of Fomalhaut.

Stars of Anu (The band near the celestial equator).

2.1 DIL.BAT=$^{mul/d}$*Dilbat*=^{mul}*Dilibat*=^{mul}DIL.BAD is the planet Venus. This identification does not cause doubts among researchers and is considered reliable.

2.2 SHU.GUI=^{mul}$\check{S}$U.GI - "Old Man" - a constellation in the southern part of Perseus, which stretched to the northern stars of Taurus. Identification variants: Perseus + northern part of Taurus [Waerden 1949], Perseus + northern stars Hyades [Weidner 1957], Perseus [Waerden, 1952, 1954]. Van der Waerden identifies it as the star γ Perseus.

2.3 UR.GU.LA=^{mul}UR.GU.LA - "Lion" or "big Dog", corresponds to the modern constellation of Leo. This identification does not cause any disagreement.

2.4 MASH.TAB.BA=^{mul}MA$\check{S}$.TAB.BA is usually an abbreviation of ^{mul}MA$\check{S}$H.TAB.BA.GAL.GAL - "Big Twins". It was identified as the α

and β Gemini [Schaumberger 1952]. In the era of the 11th century BC all these stars belonged to the region of Anu.

2.5 MASH.TAB.BA.GAL.GAL=^{mul}MAŠH.TAB.BA.GAL.GAL - "Great Gemini". Identification: Gemini [Waerden 1949, 1952-3, 1974], α and β Gemini [Weidner 1957-9], [Koch 1989, 1993]. This identification means that the constellation of Gemini is included twice in the list of heliacal rising constellations.

2.6 UGA=*mul*UGA^{mušen}=^{mul}UG$_5$=^{mul}UG.GA=^{mul}DUG$_2$.GA - "Raven" is a constellation corresponding to the modern Corvus. All the identifications are approximately the same: Raven (Waerden 1949, 1974), [Weidner 1957-59], [Koch 1989]. Belongs to Anu.

2.7 *Zi-ba-ni-tum*=^{mul}*Zibānītum* -"Libra", corresponds to the modern constellation of Libra. There is no discrepancy in the identification variants: [Waerden 1949, 1952-3, 1974], [Weidner 1957-59], [Koch 1989].

2.8 GIR.TAB=^{mul}GIR$_2$.TAB=*zuqaqīpu* - "Scorpion", corresponds to the modern constellation of Scorpio. Variants of identification: Scorpio [Waerden 1949, 1952-3, 1974], [Weidner, 1957-9], Hunger, Pingree 1989, Scorpio + part of Libra [Koch, 1989]. The constellation belongs to the region of Anu.

2.9 UD.KA.DUH.A=^{mul}UD.KA.DU$_8$.A=^{mul}U$_4$.KA.DU$_8$.A - "Demon with gaping mouth", corresponds to the modern constellations of Cygnus and part of Cepheus. Variants of identification: Cygnus and stars of nearby constellations - Lacerta, Cepheus, parts of Pegasus and Andromeda [Gössmann 1950], Cygnus + $\alpha, \xi, \iota, \delta, \zeta, \mu$ Cepheus [Waerden 1949], Cygnus + part of Cepheus [Waerden, 1974], Cygnus + part of Cepheus [Weidner 1957-59], Cygnus, Lacerta, parts of Cassiopaea and Cepheus [Hunger, Pingree 1989]. Identified as δ Cygnus by van der Waerden. In all identifications and in any historical epoch this constellation refers to the region of Enlil (the northern stars).

2.10 *Al-lu-ut-tum*=^{mul}AL.LUL=^{mul}AL.LU$_5$=^{mul}AL.LUB - "Crab", a constellation within the constellation of Cancer. Identification variants: the Beehive Cluster (M44) [Schaumberger, 1952], $\gamma, \delta, \varepsilon$ (= Crab), η, θ, ι Cancer [Koch 1993, 1995].

2.11 SHIM.MAH=^{mul}SIM.MAH=^{mul}ŠIM.MAH=*sinuntu* - "Swallow" is a constellation within the Pisces and the western part of Pegasus. Variants of identification: the southwestern part of the Pisces + stars to the ε Pegasus [Waerden 1949, 1952-3, 1974], the western part of Pisces [Weidner 1957-9], the western part of Pisces with some stars of Pegasus [Reiner, Pingree 1981], $\varepsilon, \zeta, \theta$ Pegasus, α Equuleus and western Fish in the modern constellation of Pisces [Hunger, Pingree 1999].

2.12 ^{d}Marduk=^{muld}AMAR.UD - Marduk is the supreme deity of Babylon, identified as Jupiter or Mercury [Reiner, Pingree 1981], [Brown 2000]. Van der Waerden [1991] referring to Schaumberger identifies Marduk as Jupiter.

The stars of Enlil (Northern stars).

3.1 APIN=^{mul}APIN=*epinnu* - "Plow" - constellation within Triangle and Andromeda. Identification variants: Triangle + γ Andromeda [Waerden 1949, 1974, Weidner 1957-59, Reiner, Pingree 1981], Triangle including 41, χ, β, γ Andromeda [Koch 1989], part of Andromeda [Koch-Westenholz 1995], α, β Triangle + γ Andromeda.

3.2 *A-nu-ni-tum*=$^{mul/d}$*An(n)unītu(m)* is a constellation corresponding to the eastern fish in Pisces. Variants of identification: the northeastern part of the Pisces [Gössmann 1950], the northeastern part of the Pisces + the middle part of the Andromeda [Waerden 1952-53, 1974], the eastern fish in the constellation Pisces to ν Andromeda, [Weidner 1957-59], $\tau, \upsilon, \varphi, \chi, \psi$, 64 Pisces + γ Pegasus [Koch 1989].

3.3 MUSH=$^{mul(d)}$MU*Š* - "Snake" - a constellation within the modern Hydra. Variants of identification: Hydra + β Cancer [Waerden 1949, 1974, Gössmann 1950], Hydra [Weidner 1957-59], Hydra's head - δ Hydra, $\alpha, \beta, \gamma, \delta$ Crater - Hydra's tail end [Reiner, Pingree 1981, Koch 1995], and van der Waerden [1991] identifies MUSH as δ Cancer. Note that the all identifications do not allow for referring the considered asterism to the stars of Enlil (the northern stars).

3.4 SHUL.PA.E=$^{mul/d}$*Š*UL.PA.E_3 - "young man appearing with brilliance" - the planet Jupiter [Gössmann 1950]. Starting from the Old Babylonian period, it is identified as Marduk in its astral meaning of Jupiter. The astronomical meaning fixed in the Newasserian texts is Jupiter during the heliacal rising [Reiner, Pingree 1998] . Thus, Jupiter has already been included twice in the astrolabe, and its new position is very different from the previous one. Such a displacement of Jupiter cannot be accomplished within a year.

3.5 MAR.GID.DA=$^{mul(giš)}$MAR.GID_2.*DA* -"Wagon" - a constellation in the Ursa Major. Variants of identification: Ursa Major [Waerden, 1949, 1974, Gössmann 1950, Weidner 1957-59, Reiner, Pingree 1981],
stars $\alpha, \beta, \gamma, \delta, \varepsilon, \zeta, \eta$ Ursa Major [Koch 1989].

3.6 SHU.PA=$^{mul/d}$*Š*U.PA=^{mul}*Š*U_4.PA - "Magnificent, brilliant" - according to interpretations it is the constellation within Bootes [Reiner, Pingree 1981] with Arcturus [Waerden, 1949, 1974, Gössmann 1950, Weidner 1957-59] as the main star of asterism.

3.7 EN.TE.NA.BAR.HUM=^{mul}EN.TE.NA.BAR.GUZ/LUM/HUŠ - "shaggy winter star" (Sumerian name), "mouse-like" (Akkadian name), constellation within the Centaurus [Gössmann 1950, Reiner, Pingree 1981]. Van der Waerden refers to as EN.TE.NA.MASH.LUM. The latter is identified as the star γ Centaurus or its neighborhood. This constellation corresponds to the region of Ea in any historical epoch, but is placed in the zone of Enlil.

3.8 LUGAL=$^{mul/d}$LUGAL=*šarru* - "The King", α Lion (Regulus)
Gössmann 1950
. Also the identifications are given in [Waerden 1949, 1974], [Koch, 1989].

3.9 UZA=^{mul}UZ_3=^{mul}UD_5 - "Goat". Identification: Lyra, also identified with ^{mul}GASHAN.TIN and ^{muld}gula [Gössmann 1950], Lyra [Waerden 1949, 1974], Lyra + some external stars [Weidner 1957-59, Reiner, Pingree 1981], Lyra + stars from Hercules [Koch 1989].

3.10 A^{mushen}=^{mul}$A_2^{mušen}$=^{mul}TE_8/$TI_8^{mušen}$=*erû*=*arû* - "Eagle" - a constellation within the modern constellation of the Aquila [Gössmann 1950, Weidner 1957-59, Reiner, Pingree 1981]. Van der Waerden [1991] identifies the star ζ Aquila as the center of the asterism, although this basically does not change anything.

3.11 DA.MU=$^{mul/d}$*Damu* -"The Pig". There are no identification versions, although the constellation is mentioned in many astronomical texts: Astrolabe P, Astrolabe B, BM34713, BM82923, MUL.APIN and etc.

3.12 KA.A=^{mul}KA$_5$.A=^{mul}LUL.A=^{mul}KA$_{10}$=*šēlebu* - "fox" - a constellation in the Ursa Major(?). Identification: g Ursa Major [Gössmann 1950, Weidner 1957-59, 1959-60], 80-86 of the Ursa Major(?) [Reiner, Pingree 1981, 1989], part of the Ursa Major [Koch-Westenholz 1995]. In the Great Star List it is identified as one of the names of Mars: ^{mul}KA.A=^{d}min(=^{d}*sal-bat-a-nu*) "Fox" = Mars.

We shall now substitute the decoded names of the constellations in the original table. In case of multiple identification we shall choose the most suitable identification, or leave it "as is". All identification variants, in which one of several nearby stars are proposed as the center of the asterism, will be considered as identical.

Analysis of the contents of the "astrolabes" from astronomical point of view

1. Planets in the "astrolabes". The first observation that catches the eye after decoding the contents of the "astrolabes" is the presence of planets: Venus (2.1), Mars (1.9) and (3.12?), Mercury or Jupiter (2.12?), and Jupiter (3.4). [Here, the first number denotes the band of the sky: 1 - Ea, 2 - Anu, 3 - Enlil. The second number denotes the number of the month. For example, record "2.1" corresponds to the object, which has heliacal rising in the band of Anu and in the month of Nisan.] Positions 2.12 and 3.12 are not uniquely identified, therefore we cannot confidently establish whether Jupiter is present twice or whether entry (2.12) describes the appearance of Mercury, and (3.4) - the heliacal rising of Jupiter. Similarly, we do not know exactly whether record (3.12) is accurately identified as Mars, the constellation Ursa Major or as something else.

As the planets move, the dates of their heliacal risings cannot be associated with specific months. If Jupiter passes one zodiacal constellation within one year, then Mercury, Venus and Mars manage to pass several zodiacal constellations within the same time.Thus, the presence of planets undermines the internal logic of the "astrolabes" as a star calendar. This fact may be considered as a sufficient condition for rejecting the hypothesis that "astrolabes" were star calendars.

For this reason, let us assume that the four positions (2.1), (1.9), (2.12), and (3.4) associated with the planets, were mistakenly identified, and in fact, relate to stars rather than planets. We identify the position (3.12) with part of constellation the Ursa Major, since there is such an alternative for it. In this case, the "astrolabes" will have five unidentified stars or constellations [this list also includes the record (3.11)], but the hypothesis that the "astrolabe" is a star calendar will be preserved.

	Month	**Stars of Ea**	**Stars of Anu**	**Stars of Enlil**
1	Nisan	α, β, γ Peg	***Venus***	Tri + γ And
2	Iyar	Pleiades	γ Per	β And
3	Sivan	Orion	δ Leo	δ Can (?); Hya?
4	Tammuz	α CMa	α and β **Gem**	***Jupiter***
5	Ab	δ CMa	α and β **Gem**	Ursa Major
6	Elul	part of Puppies	γ Crv	α Boo
7	Tishrei	γ Vel	α Lib	γ Cen (?!)
8	Cheshvan	δ Ser or part of Lupus	Scorpio	α Leo
9	Kislev	***Mars***	δ Cyg+Lac+Cep	α Lyr
10	Tebeth	β Aqr	Cancer	ζ Aql
11	Shebat	from α and β Sag to α Phe	ε Peg	**not identified**
12	Adar	α PsA	***Jupiter*** or ***Mercury***	part of Ursa Major or ***Mars***

Table 2. Decoding result of "astrolabes".

2. The presence of duplicates. The presence of duplicates in the "astrolabes" also works against the hypothesis of their identification as star calendars, as it violates the integrity of its logical structure. At the same time, if the "astrolabe" is a cult text, there are no strict requirements to its structure.

Formally, we can only discuss one duplicate: MASH.TAB.BA (2.4) and MASH.TAB.BA.GAL.GAL (2.5), which is identified as the Gemeni or their heads (Castor and Pollux). It is possible that the first record corresponds to the entire constellation, while the second one is its more detailed version (the heads of Gemini in particular). However, such version contradicts the fact that the stars in cells 2.4 and 2.5 must have heliacal rising in different months. It is evident that the heliacal rising of α and β Gemini and other stars of this constellation occurred within few days, but not in a month. That is why it is most reasonable to consider one of the entries (2.4) and (2.5) to be incorrect. Although such consideration will remove the semantic and astronomical consistency in the structure of the "astrolabe", it comes at a cost. First, the number of unidentified objects will increase to six. Second, if one of the records (2.4) or (2.5) is incorrect, it is unclear 1) why it occurred in all documents at once, 2) where is the original that led to this error, 3) if "astrolabes" were actually used for calendar purposes, why were they not corrected? Unfortunately, the definitive answers to these questions are unlikely to be obtained.

In addition to the problem of the presence of duplicates in the astrolabes themselves, there are certain doubts related to the accuracy of our translations from the Sumerian and Acadian languages, and the correctness of identification of the constellations. However, this remark is valid only if the hypothesis that the "astrolabe" is a star calendar is true. If this is so, then our identifications of positions (3.5) and (3.12) as the constellation Ursa Major become contradictory, and therefore we must abandon one of them.

3. The belonging of the stars to certain stripes of the sky. Because the structure of the star calendar, to which we refer the astrolabe, imposes specific limitations, it is important to consider the question of the belonging of the stars / constellations of the "astrolabe" to the southern (Ea), equatorial (Anu) and northern star (Enlil) bands. As we have mentioned above, there is an estimate according to which the Anu belt included a bar of stars near the celestial equator in the declinations range $\delta = \pm 17°$. Correspondingly, the stars of Enlil are located to the south of Anu, and the star Ea is located to the north . We will use this estimate, assuming a possible deviation of up to 5-7 degrees in either direction.

When we cited the identification of objects of the "astrolabe" in section 2, we made estimates of the affiliation of the stars of a particular region of the sky. The results of this estimation are presented in Table 3, where the problem items are marked in bold.

In the Ea band, at least three positions (1.1), (1.2) and (1.3) are problematic, because they belong to the Anu region in any historical period. Let us note that the correctness of identification of the Pleiades and Orion is reliable. Also, the identification of the record (1.8), which most researchers identify with the Serpens's head, is not unambiguous. If such identification

	Month	Stars of Ea	Stars of Anu	Stars of Enlil
1	Nisan	α, β, γ **Peg** $-1^\circ \div +14^\circ$	**?**	Tri + γ And $+13^\circ \div +26^\circ$
2	Iyar	**Pleiades** $+10^\circ$	γ **Per** $+38^\circ$	β And $+19^\circ$
3	Sivan	**Orion** $-17^\circ \div +1^\circ$	δ **Leo** $+35^\circ$	δ Can (?); Hya? $+13^\circ \div +23^\circ$
4	Tammuz	α CMa -17°	α **and** β **Gem** $+29^\circ \div +31^\circ$	**?**
5	Ab	δ CMa -26°	α **and** β **Gem** $+29^\circ \div +31^\circ$	Ursa Major $+52^\circ \div +75^\circ$
6	Elul	part of Puppies $\sim -40^\circ$	γ Crv -1°	α Boo $+47^\circ$
7	Tishrei	γ Vel $\sim -40^\circ$	α Lib 0°	γ **Cen (?!)** -32°
8	Cheshvan	δ **Ser** $+24^\circ$ or Lupus $-36^\circ \div -20^\circ$	Scorpio $-35^\circ \div -10^\circ$	α Leo $+23^\circ$
9	Kislev	**?**	δ **Cyg** $+41^\circ$	α Lyr $+40^\circ$
10	Tebeth	β Aqr -15°	Cancer 23°	ζ Aql $+14^\circ$
11	Shebat	from α and β Sag to α Phe $-50^\circ \div -40^\circ$	ε Peg 0°	**?**
12	Adar	to α PsA -42°	**?**	part of UMa $+52^\circ \div +75^\circ$

Table 3. Assessment of the correspondence of constellations to the certain zones of the sky.

is correct, then this position does not correspond to the zone Ea and contradicts the logic of a star calendar. Identification of record (1.8) as a part of the constellation Lupus corrects this error. Adhering to the concept of "astrolabe" as a star calendar, we shall assume that position (1.8) corresponds to the constellation of Lupus, but the number of erroneous identifications increases by one.

In the Anu band, we find an obvious discrepancy in cells (2.1), (2.2) and (2.9), which can be attributed to Enlil without any reservations. We have already discussed the fact that one of the positions (2.4) or (2.5) [most likely the last], is likely to be duplicate. That is, instead of two records we have one. In case of identification of this constellation as Gemini's heads, its belonging to the Enlil area is beyond doubt. If we associate the Babylonian constellation MASH.TAB.BA (.GAL.GAL) with the entire modern constellation of Gemini, then we can assume with a little reservation that this constellation belongs (or partly belongs) to Anu.

The Enlil band contains only one error in record (3.7). At the same time, we remember that one of the positions (3.5) or (3.12) is erroneous, but we shall not consider this question yet.

Thus, from a formal point of view, 7 out of 32 objects do not fit with the logic of a star calendar design. In addition to the fact that the "astrolabes" contain planets, this is a serious argument against the hypothesis that "the "astrolabe" is a star calendar. Therefore, we have solid arguments to reject this hypothesis. However, it is possible to find some compromise by making the following assumption. The "astrolabe" really is a star calendar with the dates of heliacal rising, but we have to consider its columns separately from each other. We have already mentioned that the content of the "astrolabe" coincides with the lists of the stars of Elam, Akkad and Amurra. We can assume that the list of stars of each city is a star calendar, in which a certain month corresponds to the rising of one star or a constellation. Then, the lists of stars were combined for political or religious reasons in a single document. Since under this assumption there is no requirement that an ascending star belongs to a certain band of sky (Ea/Anu/Enlil), it can be anywhere. This allows us to preserve the astronomical meaning behind the "astrolabes", although in this case, they are not a single whole document, but they represent three separate and independent lists of stars.

4. Ordering by longitude. If the "astrolabes" or their fragments (individual columns) indeed represent a calendar of the rising of stars and constellations, then all objects should follow the order of increasing longitudes (or straight ascents). Let us verify this by writing down the deciphered names of the constellations of the Ea region: The verification shows that the constellations attributed to the Ea strip go in the order of the longitudes: "Pegasus Big Square" $\to$ Pleiades $\to$ Orion $\to$ α CMa $\to$ δ CMa $\to$ part of Puppies $\to$ γ Vel $\to$ Serpent's head or Lupus's part $\to$ (?) $\to$ β Aqr $\to$ region from α Sag to α Phe $\to$ α PsA.

With the Anu stars, the situation is worse, because here we can identify two violations: (?) $\to$ γ Per $\to$ δ **Leo** $\to$ α and β Gem $\to$ α Gem $\to$ γ Crv $\to$ α Lib $\to$ Scorpio $\to$ δ Cyg $\to$ **Cancer** $\to$ ε Peg $\to$ (?). "Not in its place" is the neighborhood of the star δ Leo, which in fact should follow Gemini. In addition, the constellation of Cancer for some reason is between

Cygnus and Pegasus, which is certainly not the case. The origin of these errors remains incomprehensible, although one can assume a poor precision of our translation.

In the band of Enlil stars, the order of the longitudes breaks three times. γ **And** $\rightarrow \beta$ And $\rightarrow \delta$ Can or Hydra $\rightarrow$ (?) $\rightarrow$ UMa $\rightarrow \alpha$ Boo $\rightarrow \gamma$ Cen $\rightarrow$ α **Leo** $\rightarrow \alpha$ Lyr $\rightarrow \zeta$ Aql $\rightarrow$ (?) $\rightarrow$ **UMa**.

In fact, β And precedes γ And, but not vice versa. However, even if we correct for this discrepancy (e.g. we can replace these stars with each other), their heliacal risings occur within a week, but not a month, as it should be according to the model of a star calendar. Instead of β And a more appropriable option could be a bright star from Taurus or Auriga, but such identification had not been proposed, yet. The same remark applies to α Leo, which rises earlier than γ Cen and α Boo. Finally, we have already mentioned that one of the positions identified with Ursa Major is erroneous. Obviously, the last identification violates the order of following longitudes, so it should be ruled out. As above, we replace all excluded objects in the table with question marks.

5. Synchronization of the heliacal rises. Finally, let us consider the synchronization of the heliacal rises of stars and constellations for individual months. All three objects located on the same line (row) should ascend within one month.

Line 3: the heliacal rising of Orion occurs much earlier than that of Lion, head of Hydra or Cancer.

Line 5: the constellation of Ursa Major did not go beyond the horizon at the latitude of Babylon in the first millennium. Therefore, the event of "heliacal rising" was impossible for this constellation and consequently, it should not be in the star calendar. The heads of the Gemini had heliacal rising in the same month as Sirius, but were not in any way connected with δ CMa. Therefore, record (2.5) should be considered erroneous.

Line 7: The star γ Vel (or its vicinity) had heliacal rising a month earlier than that of α Lib and γ Cen.

Line 10: ζ Aql had heliacal rising much earlier than that of β Aqr. Thus, the logical structure of the astrolabe is violated.

Again, the only possible solution of this problem could be an assumption of three independent lists of the rising stars, which were combined into an astrolabe. In this case, the estimates obtained in part 5 lose their meaning and the contradiction is eliminated.

Conclusion

An analysis of the Babylonian "astrolabes" allows for assuming one of the four alternatives.

1. The mutual positions of stars and constellations established by us contradict the data structure of a star calendar. This is evidenced by the following facts: a) the lack of ordering of stars along longitudes, b) the lack of ordering of synchronicity of the events of heliacal risings for stars belonging to the same month, c) the lack of ordering according to declinations (or lack of ordering over the bands of the sky), d)the presence of planets. In

	Month	Stars of Ea	Stars of Anu	Stars of Enlil
1	Nisan	α, β, γ Peg	**?**	Tri + γ And
2	Iyar	Pleiades	γ Per	**?**
3	Sivan	**Orion**	*delta* Leo	δ Can or Hya
4	Tammuz	α CMa	α and β Gem	**?**
5	Ab	δ CMa	α and β **Gem**	**Ursa Major**
6	Elul	part of Puppies	γ Crv	α Boo
7	Tishrei	γ **Vel**	α Lib	γ Cen
8	Cheshvan	δ Ser or part of Lupus	Scorpio	**?**
9	Kislev	**?**	δ Cyg+Lac+Cep	α Lyr
10	Tebeth	β Aqr	**?**	ζ **Aql**
11	Shebat	from α and β Sag to α Phe	ε Peg	**?**
12	Adar	α PsA	**?**	**?**

Table 4. An estimation of synchronicity of heliacal risings. Problematic items are shown in bold.

practice, this means that the Babylonian "astrolabes" could not be used for calendar purposes.

2. The "Astrolabe" should be considered as three independent documents, each of which described the order of the rising stars. In this case, there will be less contradictions, since the requirement for the synchronism of the heliacal risings and the orderliness of the stars in declination disappears. Along with this, there remains the problem of the presence of planets, as well as the orderliness of declinations. In this sense, the ideal version of the calendar is a list of stars corresponding to the sector Ea.

3. The "Astrolabe" is a cult document, so it does not have to meet the astronomical requirements, which we expect for a star calendar.

4. Our decoding of the "astrolabe" is very inaccurate, which leads to numerous errors in identifications. One of the reasons for this may be the lack of unification of the designations of stars and constellations during the creation of "astrolabes".

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