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The Tal-Qadi Sky Tablet

There is an updated and more comprehensive German version of this Wikibook available here: Die Himmelstafel von Tal-Qadi

The Tal-Qadi sky tablet in a showcase of the National Museum of Archeology in Valletta (Malta).

From an astronomical point of view, the present text deals with the archaeological discovery of a roughly 4500-year-old limestone tablet from Malta, which obviously shows a section of the starry sky.

The described results of academic research follow two main hypotheses:

1. The Tal-Qadi Sky Tablet displays parts of the starry sky.
2. The five fan-shaped segments display a contiguous section of the starry sky (from left to right):
    1. Parts of today's constellation Orion.
    2. The head of today's constellation Taurus.
    3. The ecliptic.
    4. The open star cluster of the Pleiades.
    5. The brightest stars that rise before the Pleiades at the Eastern horizon.

In this Wikibook it is shown that the sky tablet of Tal-Qadi can be aligned to the Golden Gate of the Ecliptic in the constellation Taurus in order to measure the ecliptical latitude of the moon and planets. This was possible thousands of years ago as it is today without any further equipment. With the appropriate observations, not only can the sidereal and draconian periods as well as the Meton cycle of the moon be determined, but also star coverages and lunar and solar eclipses can be predicted.

Following the results of the academic research described below, the sky tablet gives many indications about the outstanding astronomical knowledge and skills already possessed by the Neolithic inhabitants of the island of Malta.

Scale replica of the Tal-Qadi sky tablet made of beech wood.

Preface

In ancient times, humans could only look at the night sky with the naked eye. In doing so, however, they have already been able to determine that the approximately 5000 visible fixed stars form an eternally fixed geometric constellation with one another, only that a slightly different section of the universe can be seen at different times of the day and year. The impression of looking at the Milky Way, the open star cluster of the Pleiades or the Andromeda Galaxy has certainly always been experienced as sublime and mysterious. The brightest fixed stars can be counted on a few hands and were not only relatively easy to impress but were even given proper names for identification or communication with other people.

Furthermore, even today, there were often unpredictable events, such as the appearance of novae, comets or falling stars, which were certainly processed mythically. Between these very regular and seemingly completely random looks when looking at the night sky, the first people certainly noticed that seven special moving stars move regularly and also perpetually in relation to the fixed star sky, above all the sun and the moon. Sometimes even two or three of you meet in one place in heaven, and this strange, mystical, and then completely inexplicable behaviour certainly captivated some of our ancestors in ancient times, and more and more myths have finally grown out of it.

Later in the Middle Ages, astronomy, along with arithmetic, geometry and music, was one of the four high arts of the quadrivium. The processes in the sky are indeed quite abstract and complex and can only be understood and related to each other with extensive prior knowledge. Unfortunately, this knowledge is increasingly being lost, as the night sky hardly allows comprehensive observation due to the strong light pollution and interest in it decreases accordingly. Perhaps these explanations here help to arouse interest in the subject or to deepen existing knowledge.

This Wikibook is a rough translation of the appropriate German-speaking Wikibook. Archaeoastronomy is a comparatively young science that has hardly been able to establish itself, particularly in German-speaking countries. The results presented here may also help to advance this discipline a little and to bring interested circles closer to the astronomical fundamentals for the assessment of archaeoastronomical facts.

Introduction

Tal-Qadi on Malta was already used by people in 4000 BC, the first temple buildings of Tal-Qadi were built between 3300 and 3000 BC and were then in use for a long time. The period from 3000 to 2500 BC is called the island's Tarxien phase.

During the excavations started in 1927, a fan-like limestone plaque with incisions was found in the temple complex. Most of the markings are clearly reminiscent of the depiction of stars, which makes the find one of the oldest archaeoastronomical objects.

The stars have always had a prominent place in the myths of all peoples. They were often viewed as manifesting manifestations or as the heavenly "locations" of deities. While the stars of the fixed star sky were of great importance for the navigation of seafarers or desert hikers, the celestial objects that were movable compared to the fixed star sky were often used for astrological interpretations.

In this paper, the emphasis is less on the archaeological aspects of the find. Rather, the following explanations represent an attempt to interpret the representations on the stone tablet based on the previous findings from an astronomical, geometrical and geographical point of view and thus possibly to contribute to being able to classify the find in an expanded context. Based on the celestial phenomena that have been observed without telescopes for thousands of years, many basic terms of astronomy are mentioned, explained and related to one another.

The Tal-Qadi sky tablet matched to the starry sky with ecliptic line.


Badly damaged and alienated state of the ruins of Tal-Qadi in 2014.

Location of the Tal-Qadi temple

The temple complex of Tal-Qadi is located ten kilometres northwest of the capital Valletta in the northern part of the island republic near today's small town Sàn Pawl il-Baħar. The location is at 35 ° 56'12 "north latitude and 14 ° 25'14" east longitude. The height above sea level of the Mediterranean is around 16 meters.

If visibility is good, Etna in Sicily can be seen in a northerly direction over the narrow bay with salt pans located one and a half kilometres east of Sàn Pawl il-Baħar in a good 200 kilometres. Only in this direction can the Mediterranean Sea be seen from the temple complex from a position raised by a few meters.

The alignment of the temple complex from west to east is unusual in comparison to all other Maltese temple complexes, as these are largely aligned along the main axis of the island from northwest to southeast. The building was around 30 meters long in the north-south direction and around 25 meters in the east-west-east direction. Itis no longer possible to clearly determine where the entrance to the temple was.[1]

The azimuth (horizontal angle) of the still recognizable axis in the temple points east to 76 degrees of arc (direction to sunrise on April 18 and August 24) or in the opposite direction to the west to 256 degrees (direction to sunset on February 17 and on October 24). In Malta there are good astronomical observation conditions due to the dry and balanced Mediterranean climate. There, lunar eclipses were regularly observed, but also total solar eclipses, such as the solar eclipse in the morning hours of May 18, 2146 BC, with high probability.[2]

The special but largely irregular phenomena in the fixed star sky include meteors, supernovae and comets. On average, a supernova could be seen with the naked eye approximately every 200 years over the past 2000 years. The Halley comet is documented in China as early as 240 BC.[3] The last perihelion passage of the periodic comet C2020 F3 (NEOWISE) is likely to have taken place during the island's Tarxien phase.


Relief map of Malta with the location of Tal-Qadi.

Reference of the temple to the sky system

Various examples are known from archaeology of how in ancient times the directions of the sky could be determined and the rising and setting of the stars could be determined and predicted. Examples include the Goseck circular moat in Saxony-Anhalt (4900 BC) [4], the Nebra sky disc (around 2000BC) or the Belchen system of the Celts in the Vosges, where the four Belchen are seen from Alsace other, more eastern Belchen in the region have a calendar function with regard to the sunrises.[5]

Seen from the Tal-Qadi temple ruins, towards the west (270 degrees of arc, the direction towards sunset at the beginning of spring and autumn), there is a clearly recognizable path of a natural valley, towards the east there is a hill over 50 meters high that covers the horizon.

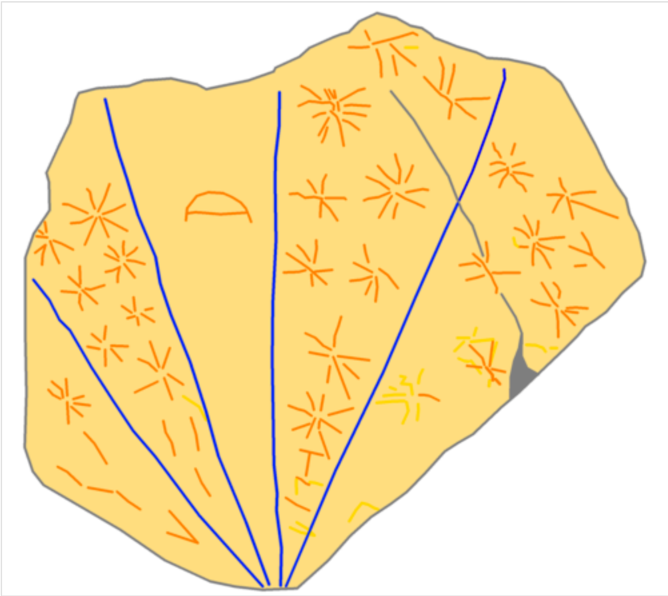
The celestial north pole was and is an important reference point in the northern hemisphere for orientation in the night sky. In ancient times, because of the precession of the Earth's axis, the North Star was not at the point of the celestial north pole and could therefore not be used directly to determine the north direction. This can easily be identified from the temple complex by sighting the sea bay in the direction of Etna. This was all the easier when the volcano was active and creating a large column of smoke that could be seen from afar, and even at night when the corresponding column of fire was noticeable. Such events are documented in the traditions from ancient times for geographical orientation, such as the exodus of the Israelites from the slavery of Pharaoh in Egypt between 1500 and 1000 BC (compare Exodus 13.21 + 22).

The limestone slab

Description

The plaque is on display in the National Museum of Archaeology in Valletta.[7]

It is unclear whether the limestone slab found is largely complete or just a fragment of a larger slab, but some of the sides are noticeably straight and smooth.[8] The limestone slab has the shape of an irregular hexagon, is 29 centimetres wide, 24centimeters high and approximately 5 centimetres thick. Limestone is not very hard and can therefore be easily worked and scratched, and numerous symbols and graphic elements are represented on the flat surface. However, there are also many natural bumps and it is not always possible to clearly identify whether the surface has natural, deliberately man-made, unintentional or damage-related structures. The provenance of the stone tablet has apparently not yet been investigated, for example based on the chemical analysis of the composition of the rock.


Sketch of the incisions on the Tal-Qadi sky tablet based on the Institute for Studies of the Study of the Ancient World at New York University.[6]

According to the dimensions, the stone tablet has an area of almost 500 square centimetres. With a density of 2.7 to 2.9 grams per cubic centimetre for limestone [9] the mass of the tablet is around six kilograms. This makes it portable and can be held in your hands for a few minutes with a corresponding effort.

The representation is divided radially into five roughly equal-sized segments with an angle of a good 20 arc degrees each by four straight lines. The lines have a common point of intersection a little outside the board and start radially from the corner point to the left of the longest and straight edge. Star-shaped symbols are shown in the two segments on the left and right. A single star symbol can be seen in the left segment, and several star symbols in the other three. The middle segment shows a semi-circular figure, the straight edge of which is perpendicular to the direction towards the centre of the radial rays and on the side to this centre. The two right segments are traversed by a much more pronounced furrow.

Interpretation

The three star groups depicted were associated with zodiac signs early on. It was speculated that the three asterisks stand for the three zodiac signs Scorpio, Virgo and Leo, or that the existing tablet is only a fragment of a larger tablet that has shown a moon-phase calendar. The symbol in the middle segment was associated with a crescent moon.[1]

It is possible that the sky region shown on the sky table with the stars that set here and there was observed from the temple of Tal-Qadi, especially in the evening and in a westerly direction.[10]

According to recent investigations by the archaeologist Peter Kurzmann, the seven-star-shaped representations directly to the left of the centre could be the star Aldebaran (α Tauri) with the stars γ, δ, ε and θ Tauri belonging to the open star cluster of the Hyades in today's constellation Taurus (Taurus) as well as the two tips of the bull horns and Tien Kuan (ζ Tauri) and Elnath (β Tauri) act. The star ε Tauri is also called Ain. The constellation to the right of the centre could be the seven main stars of the open star cluster of the Pleiades, also belonging to the constellation Taurus, and to the far right the constellation Perseus to the north represent. The single star on the left is associated with one of the three brightest stars in the northern sky south of the above-mentioned star clusters:[11]

- The distinctive red supergiant Betelgeuse in the constellation Orion (α Orionis), the shoulder of the sky hunter (also known as the left shoulder star because it is at the top left from the viewer).
- The brightest star in the constellation Orion Rigel (β Orionis), the opposite foot of the sky hunter.
- The brightest star of the starry sky Sirius (α Canis Majoris) in the neck and head area of the constellation Canis Major.

In a further investigation it is pointed out that the edges of the stone tablet are not broken, but machined and in some cases quite straight, so that it can be assumed that the geometry of the stone tablet is intended and that it is not a fragment from a larger tablet should act. A pentagonal structure recognizable in the plaque has similarities with the floor plans of Maltese temples.[8]

In another temple complex on Malta, in the south temple of Mnajdra, there are indications of possible observation of the Pleiades in antiquity.[12]

Other researchers assume that the semi-circular symbol is a bird barge that the people of Malta used to sail the Mediterranean at the time. The star constellations are images of the Adriatic region, the eastern Mediterranean and the Black Sea.[13] If one follows this approach, the base of the stone tablet is not in the centre of the rays, but exactly opposite, so that the boat would be aligned correctly, namely swimming in the water. It is *The Chronology of Ancient Kingdoms Amended*[14] assumed that this would have postulated that constellations were used for navigation. In the Chronicle there are references to navigation with stars and to the use of constellations in ancient times, but this does not apply to the time 4500 years ago, nor are navigation and constellations brought into a direct relationship by Newton. Rather, he only points out that in antiquity, for navigation purposes, the rising and setting (morning first and morning last or evening first and evening last) of individual stars were observed (also called heliacal and acronychical rising and setting). Newton also does not speak of correspondences between constellations and geographical conditions.[15]

In the following, some of the celestial objects mentioned as well as some astronomical facts are described in more detail and brought into context.

Modern artistic background painting of the night sky with sections of the neighbouring constellations Orion and Taurus . Below left the arm and the bow of the hunter Orion and in the middle the head of the bull with Aldebaran and the Hyades and the body of the animal with the Pleiades further above on the right. The star Omikron Tauri (ο Tauri) is on the lower right in the left front hoof, and the two stars Tien Kuan (ζ Tauri) and Elnath (β Tauri) are on the upper left in the tips of the horns. Above the Pleiades on the edge of the picture a foot of the constellation Perseus with the two stars ζ Persei and Atik (ο Persei) can be seen.

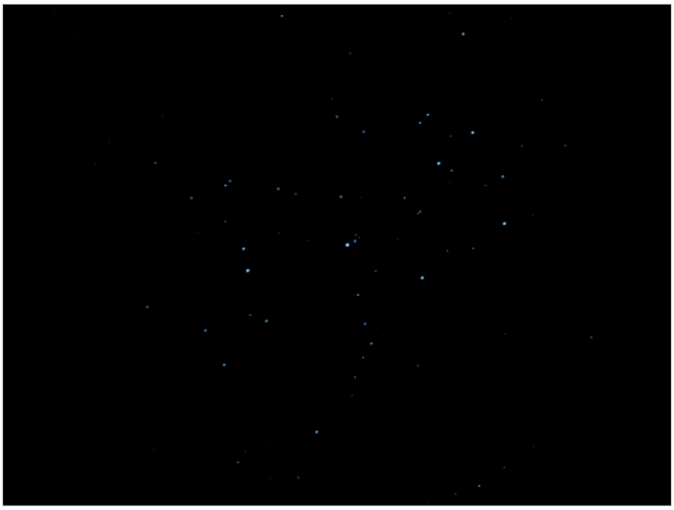
The Pleiades

After the moon and the five planets visible to the naked eye, the Pleiades are the most conspicuous objects in the night sky. They belong to an open star cluster and are not as large and as close to our solar system as the star clusters of the Hyades, which are only 153 light years away, but at a distance of around 400 light years they are still close enough that some of the brighter stars can be distinguished with the naked eye.

The Pleiades open cluster consists of over a thousand stars, of which the brightest seven main stars are listed below:

The seven main stars of the Pleiades

Proper name	Apparent brightness
Alcyone	$3{,}0^m$
Atlas	$3{,}5^m$
Electra	$3{,}5^m$
Maia	$4{,}0^m$
Merope	$4{,}0^m$
Taygeta	$4{,}0^m$
Pleione	$\approx 5{,}0^m$



The Pleiades with their main stars.

> **Note:** The numerical size class of the apparent magnitude is indicated by a subsequent and superscript m (for Latin *magnitudo* or, for shorter, *mag*). A number one size class higher means a decrease in the apparent brightness by a factor of around 2.5. The difference in brightness between the brightest star in the night sky Sirius (-1.5^m) and the darkest stars (6^m) that are barely visible to the naked eye is therefore a ratio of 1000 to 1. The apparent brightness says nothing about size, distance or absolute brightness of a star.

Two other, somewhat darker stars of the star cluster also have proper names, namely *Celaeno* (5.5^m) and *Asterope* (6.0^m). All other visible stars are significantly darker. The total apparent magnitude of the star cluster is around 1.5^m.

Visibility

Seen from Malta, the Pleiades are today both on May 20th (in conjunction with the sun they are invisible) and on November 18th (in opposition to the sun and at midnight with a height of 78 degrees very high above the southern horizon) in the meridian. The meridian is the imaginary great circle that runs through the two celestial poles as well as through the zenith and the nadir. In winter and spring, the Pleiades can be observed in the evening sky in a westerly direction and in summer and autumn in the morning sky in an easterly direction.

The following table shows the times of the first and last rising and setting of the Pleiades; Heliacal here means "belonging to the sun", i.e. close to the rising sun. However, this must be below the horizon, and the distance to the sun (i.e. the elongation) must be more than 18 degrees so that the sunlight scattered in the atmosphere does not outshine the Pleiades. The acronychical rises (evening first) as well as the heliacal sets (morning last) are not important for the fixed stars (and thus also for the Pleiades), as they are in contrast to the moon, the planets and Comets can always be seen in the nights between the first of the morning and the last of the evening:

The position of the Pleiades in the starry sky

Event	Astronomical name	Time	Direction
Last evening	Acronychical set	April 30	West, on the horizon
Proximity to the sun	Conjunction with the sun	Mai 20	At noon in the south, close to the zenith
First morning	Heliacal rise	June 10	East, on the horizon
Distant from the sun	Opposition to the sun	November 18	At midnight in the south, close to the zenith

The time of the heliacal rise of the Pleiades in relation to the twelve months determined by the moon phases made them a calendar star in the Babylonian lunisolar calendar. If the rise had shifted to the third calendar month (Simanu), a thirteenth leap month was inserted, with which the calendar months could be synchronized again with the beginning of spring of the solar year.

The New Zealand Māori also used the heliacal rising of the Pleiades as a basis to set the New Year's date and to begin sowing.

Seen from Malta today, the Pleiades rise approximately 7 arc degrees north of the ecliptic and set 31 arc degrees north of the ecliptic. The Pleiades therefore rise in Malta at an azimuth of 59 arc degrees in the east and set at an azimuth of 301 arc degrees in the west.

Seen from Alsatian **Bel**chen today the Pleiades rise for example always above Little **Bel**chen, where the sun at the summer solstice rises. On May 1, i.e. on the day on which the Pleiades are gone in our time in the Maltese dusk, the sun rises above the highest mountain in the Vosges Mountains, the Great **Bel**chen. This was probably dedicated to the Celtic god of light **Bel**enus, whose feast day **Bel**tane falls on May 1st. The Black Forest Belchen is located exactly in an easterly direction, i.e. on the same latitude as the Alsatian Belchen (47.82° north latitude). On the two days of the equinox at the beginning of spring and autumn, celestial objects that are located near the spring or autumn point of the sun (including the Pleiades, which were there4500 years ago) move from Alsatian Belchen as seen exactly in the east above the Black Forest Belchen on or as seen from the Black Forest Belchen exactly in the west above the Alsatian Belchen below.[16]

Representations in antiquity

The Pleiades are probably depicted as seven golden discs on the Nebra Sky Disc from the early Bronze Age (around 2000 BC). In Mesopotamia they are recorded on the cuneiform tablets of the Astrolabe B calendar. But the Celtic iron sword from the third century BC, found in Allach near Munich in 1891,is also executed with gold inlays showing the Pleiades.[17]

It is also discussed whether the Pleiades within the constellation Taurus (Taurus) are already depicted in the Stone Age drawings in the Lascaux cave.[18][19]

Also on the Bronze Age disc of Phaistos from the island of Crete, a symbol with seven points appears several times, which was associated with the Pleiades.[20]

Similar assumptions exist for an arrangement of seven holes on the calendar stone from Leodagger in Lower Austria.[21]

Tradition

The Pleiades thus had a special meaning in many cultures and often appear in pictorial representations. They are a calendar star, after the rise and fall of which agricultural and seafaring activities were organized in antiquity, as was the case with the Greek poets Hesiod around 700 BC or Aratos von Soloi (* approx. 310 BC; † 245 BC) is occupied. The name Pleiades goes back to the seven daughters of the Titan *Atlas* and his wife, the Oceanid *Pleione* from Greek mythology. They are called: *Alcyone*, *Electra*, *Asterope* (or *Sterope*), *Celaeno*, *Maia*, *Merope* und *Taygete*.

The Pleiades are also called *Siebengestirn* in German, which makes the direct reference to the magical, mystical and divine number seven.[22]

There are countless German synonyms for the Pleiades:[23][24][25][26]

> *Regensterne*, *Schiffersterne*, *Buschelsterni*, *Staubkörner*, *Sieb*, *Glucke*, *Henne*, *Tauben*, *Weintraube*, *Frühlingsjungfern*, *Sieben Schwestern*, *Töchter des Atlas* (also *Atlantiden*, *Atlantiaden*), ...

In many languages they had and still have a proper name:

> Old High German *thaz sibunstirri* (das Siebenstirn), Polish *baby* (crones), Russian *baba* (crone), Japanese *Subaru* (assembly), Turkish *Ülker*, Aztecan *Tianquiztli* (market place), Sumerian *Mul-Mul* (stars), Akkadian *Zappu* (heap), Latin *Vergiliae* (meshwork), Greek *heptasteros* (sevenstar), Arabian *Al-Thurayya* (candelabrum)[27], Hebrew *Kimah* (little heap), Maori *Matariki*, Hawaiian *Makaliʻi*, Aragonesian *As Crabetas*, Welsh *Twr Tewdws*, Finnish *Seulaset* (little sieve or seven brow), ...

The star cluster is mentioned three times in the Old Testament: The 9th chapter “God's power and the powerlessness of man” of the Book of Job mentions the four most striking star constellations in the 9th verse: “He makes the constellation of the bear, Orion, the seven stars, the chambers of the south.” In the 31st verse of the 38th chapter it says: “Do you tie the ties of the seven stars, or do you loosen Orion's chains?” In the book of the prophet Amos in chapter 5, verse 8, it says about the two neighbouring constellations: “He created the seven stars and Orion; it transforms the darkness into the bright morning, it darkens the day into night.“

The term quarantine (from French "quarantaine de jours" = "forty days") is related to the Pleiades, as they are in the subtropical latitudes (today) from May 1st to June 9th, i.e. forty days, from the sun are outshone and then even the brightest star of this constellation, Alcyone (η Tauri), cannot be seen with the naked eye until shortly after sunset and then shortly before sunrise. The Babylonians, who know the stars, are said to have burned forty reeds when the Pleiades returned in the morning sky for their joy.

After the invisibility of the Pleiades, in ancient Egypt the waters of the Nile began to rise for forty days and to fall again for just as long.[28]

Noah opened the window of his ark after forty days [29], and Moses spent forty days on the mountain of God, Sinai.[30] Against this background, it is not surprising that in the New Testament Jesus fasted forty days in the desert[31][32][33], which is why there are forty days of fasting in the lent today.

The Inuit tell the legend that a large bear threatened humanity and was chased into the sky by dogs. As the Pleiades, the pack of dogs would continue to pursue this bear today.[25]

The Australian aborigines of the Loritja say that while the Pleiades are invisible, seven girls come to earth and perform a fire dance.[34]

In connection with the fact that the cuckoo stops singing in early summer and that the Pleiades cannot be seen in the latitudes of the climatically temperate zones for much longer, there is a German legend about a hard-hearted baker who worked for 72 days until the summer solstice calls in vain for his wife and daughters. In this saga it says:

> *The origin of the Pleiades is told as follows: Christ walked past a bakery where fresh bread smelled and sent his disciples to ask for bread. The baker refused it, but the baker's wife was standing in the distance with her six daughters and was giving the bread secretly. For this they are moved to the sky as seven stars, but the baker has become a cuckoo and as long as he calls in spring, from Tiburtii (note: Tiburtii name day of Rome is April 14th) to Midsummer (note: John the Baptist's name day is June 24th (St. John's Day)), the seven stars are [not] visible in the sky.*[23]

In North German and East Prussian sagas there are variants of this story in which the cuckoo cannot recall the family members who have fled or fears their revenge.[24]

Astronomical reference systems

When observing the orbits of the fixed stars directly, there are two natural reference systems, namely the horizontal and the equatorial. For the observation of the seven moving celestial objects in relation to the starry sky, it makes sense to introduce another plane in addition to the horizon plane and the equatorial plane, namely the ecliptic plane.

A historical armillary sphere in the Historical Museum of Basel (Switzerland) with three movable rings that describe the three astronomical planes of the horizon, the celestial equator and the ecliptic. Even the ancient Babylonians observed events in the night sky with simple designs of such armillary spheres.

The horizon

The horizontal coordinate system corresponds to the daily experience of the environment, since the two eyes of humans are usually aligned horizontally next to each other. In the horizon system a stone always falls vertically from top to bottom towards the centre of the earth. It is the most frequently used coordinate system for orientation in everyday life. The ideal horizon is a circular horizontal line with the observer in the centre. The plumb line is perpendicular to the corresponding circle, and therefore, every point on the earth's surface has a different horizon system and shows a different part of the sky above it at a certain point in time.

The cardinal points north, east, south and west are used to indicate directions. In relation to the north direction or alternatively in relation to the south direction, the azimuth can also be used as a clockwise angle where the north direction corresponds to 0 arc degrees, the east direction to 90 arc degrees, the south direction to 180 arc degrees and the west direction to 270 arc degrees.

The height above the horizon is called the elevation angle h from 0 to 90 degrees of arc, with 0 degrees of arc on the horizon and 90 degrees of arc perpendicular above the observer at the zenith. Negative angles are below the horizon, and the nadir is exactly below the observer at an elevation angle of -90 degrees. The meridian is the great circle that passes the north and south points as well as the zenith and nadir.

Due to the rotation of the earth, the horizon system changes permanently in relation to the starry sky.

The celestial poles

When observing the stars at night, it is noticeable that within a sidereal day (from the Latin sideris = the star, i.e. related to the starry sky) of almost 24 hours, they are moving always in the same circle from east to west around the celestial poles and then stand again in the same place in relation to the horizon system. A sidereal day is about four minutes shorter than a sunny day, because the sun seems to move a little to the left in relation to the fixed star sky - due to the rotation of the earth around the sun. After a year, this difference adds up to a whole day, so that any star rises and sets at the same time of day after a solar year and is at the same point in the horizon system and in the corresponding cardinal direction at the same time of day. This can be easily understood with the following rough calculations:

$$4\,\frac{\text{minutes}}{\text{day}} \cdot 360\,\frac{\text{days}}{\text{year}} = 1440\,\frac{\text{minutes}}{\text{year}}$$

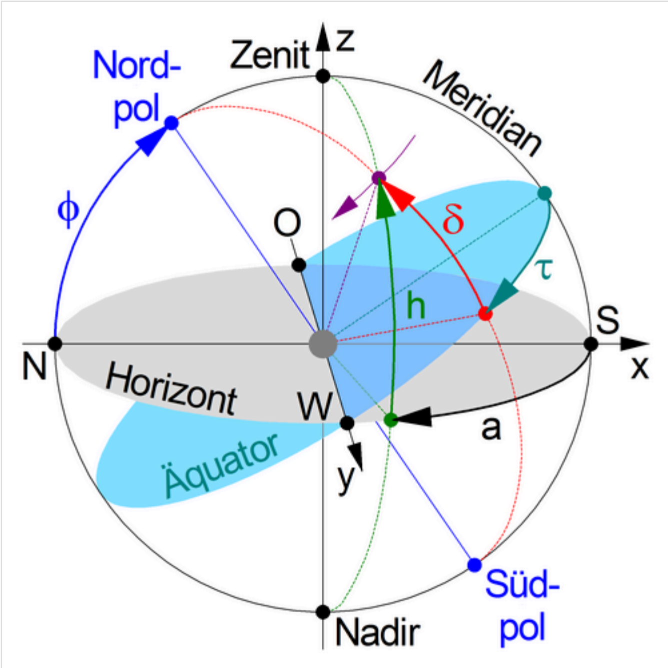
$$\frac{1440\,\frac{\text{minutes}}{\text{year}}}{60\,\frac{\text{minutes}}{\text{hour}}} = 24\,\frac{\text{hours}}{\text{year}}$$

$$\frac{24\,\frac{\text{hours}}{\text{year}}}{24\,\frac{\text{hours}}{\text{day}}} = 1\,\frac{\text{day}}{\text{year}}$$

The northern celestial pole is easily found today through Polaris in the constellation Ursa minor, which lies all night (and all day) in the same location pretty much exactly north of the horizontal reference system. All other stars are constantly changing their position in the horizontal reference system.

The stars close enough to the visible celestial pole are always above the horizon for an observation point and are called circumpolar stars. The circumpolar stars of the opposite, invisible celestial pole can never be seen. At the North Pole and at the South Pole of the Earth, all stars in the respective hemisphere are circumpolar, but none is for an observer on the Earth's equator.

All visible stars that are not circumpolar rise at some point in the course of a twenty-four-hour day on the eastern horizon and set on the western horizon. The stars exactly in the middle between the two celestial poles lie on the celestial equator, and they describe the largest circle (a great circle) in the sky. The largest elevation angle is always reached in a southerly direction on the meridian, the smallest, possibly negative elevation angle in a northerly direction on the meridian.



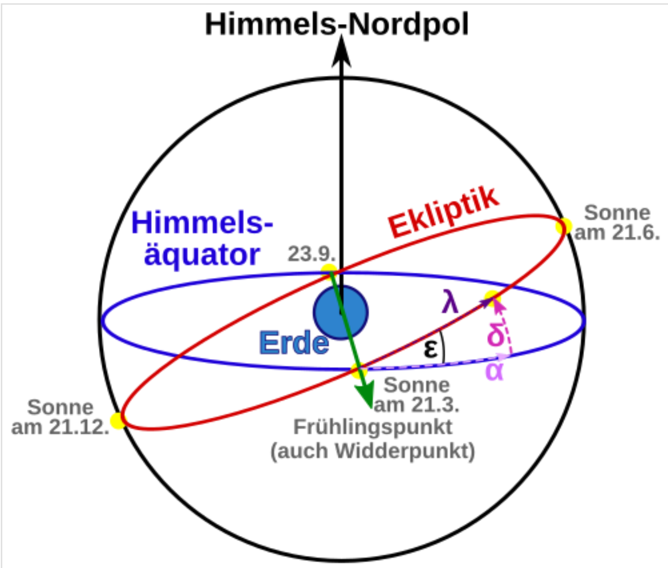
Relationship between horizontal and equatorial coordinate system.

The two angles in the equatorial coordinate system that define the position of any celestial body are the hour angle τ or the right ascension α along the celestial equator and the declination δ perpendicular to it in the direction of the celestial poles, positive to the north and negative to the south. The hour angle of a celestial object corresponds to the time that has passed since its last passage of the celestial object through the meridian, and the hour angle and right ascension are therefore usually given in hours. The right ascension, however, is related to the vernal equinox, which is in the centre of the sun at the beginning of spring. The right ascension and the declination of all fixed stars are constant apart from their slight proper movement and the displacement of the vernal equinox due to the very slow precession of the earth's axis and are therefore given in star catalogues which are related to a particular standard epoch.

The pole height ϕ is the smallest angle between the horizon and a celestial pole along the meridian, which corresponds exactly to the geographical latitude of the corresponding observer on the globe. The angle between zenith and celestial pole complements the pole height to a right angle with 90 degrees of arc and at the same time it corresponds to the inclination between the horizontal plane and the equatorial plane. Both reference systems share both the east point and the west point. At the north pole the pole height is +90 arc degrees, at the south pole the pole height is -90 arc degrees, and on the equator, it is 0 arc degrees.

The vernal equinox

The vernal equinox had and still has an outstanding meaning in celestial science. When the sun is at the vernal equinox, all over the world it rises at 6 a.m. local time in the morning and sets exactly in the west at 6 p.m. local time in the evening. Since the full moon is always opposite the sun as seen from the earth, a full moon that occurs at the beginning of spring stands opposite the vernal equinox at the autumn equinox and rises around 6 p.m. in the east and sets around 6 a.m. in the west.



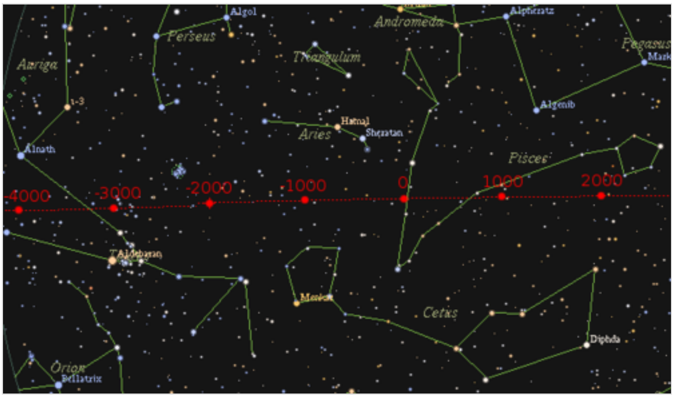
The position of the circular arc-shaped ecliptic with the inclination angle ϵ in relation to the celestial equator with its equatorial coordinates α (right ascension) and δ (declination), here for the ecliptical longitude λ.

Conversely, the sun is at the autumn equinox at the beginning of autumn and rises there in the morning at 6 a.m. local time in the east and sets exactly in the west at 6 p.m. local time in the evening. A full moon occurring at the same time is then near the vernal equinox and rises in the morning at 6 a.m. local time in the east and sets in the evening at 6 p.m. local time in the west.

Due to the precession of the earth's axis, not only the position of the celestial poles along a circular path change in a cycle of 25800 years, but also the vernal equinox. During this time, it traverses the entire ecliptic with its 360 degrees of arc exactly once in a westerly direction. In each of the twelve constellations along this zodiac with an angle of 30 arc degrees per constellation, therefore, it is for 2150 years within a certain constellation. In other words: the vernal equinox shifts by 1.4 arc degrees in one hundred years, by 8.4 arc minutes in ten years or by 50 arc seconds per year to the west.

From 4500 years ago until today, the vernal equinox has moved a good 60 degrees to the west from the constellation Taurus, so that this constellation no longer sets at the same time as the sun at the beginning of spring, but only a good four hours later than the sun sets, and therefore, in the west and in the evening the constellation is clearly visible because the sun is already well below the horizon before the setting of the Hyades and Pleiades. Around 3000 years ago, the vernal equinox was already in the constellation Aries and today it is in the constellation Pisces.

This migration behaviour was already known in antiquity and was represented by the Chaldean scholar Kidinnu (* probably around 400 BC; † probably 330 BC). Nikolaus Kopernikus recognized and named the precession of the earth's axis as the cause of the migration of the vernal equinox 500 years ago, and only Friedrich Wilhelm Bessel was able to determine the precession constant with high accuracy, which was honoured by the Prussian Academy of Sciences in 1813 with the award of a prize.



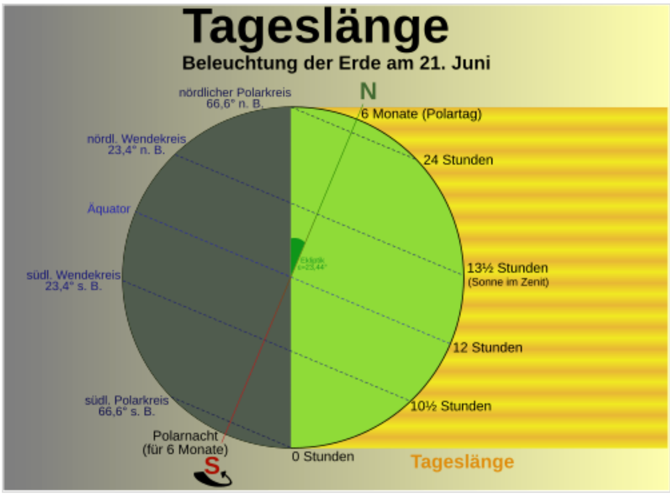
The migration of the equinox along the ecliptic.

The spring equinox represents an anchor in the solar calendars. The Jewish Passover as well as the Christian Easter feast have always taken place after the equinox in spring. For example, Easter Sunday is the first Sunday after the first full moon that follows this equinox. The cultivation of arable land and the sowing of plant seeds were and are carried out in many cultures with reference to the date of the astronomical beginning of spring in order to obtain good harvest yields.

The ecliptic

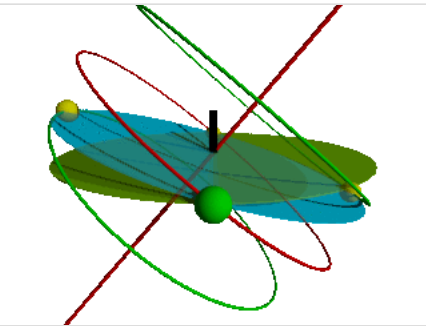
The ecliptic is the imaginary plane in which the earth's orbit moves around the sun during a year. In relation to the celestial equator it is inclined by an angle of a good 23 degrees of arc, which is also called the obliquity of the ecliptic. This matter of fact is the reason for four virtual circles of latitude on the earth's surface:

- The northern tropic circle, on which the sun is at its zenith at midday on the summer solstice.
- The southern tropic circle, on which the sun is at its zenith at midday on the winter solstice.
- The northern polar circle, where the sun doesn't set at the summer solstice or where the sun just doesn't rise at the winter solstice.
- The southern polar circle, where the sun doesn't set at the winter solstice or where the sun just doesn't rise at the summer solstice.



The four polar and tropic circles during the summer solstice in the northern hemisphere. In this illustration, the ecliptic lies exactly horizontally between the centre of the earth and the sun.

The apparent daily movement of the sun

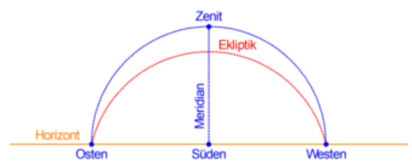
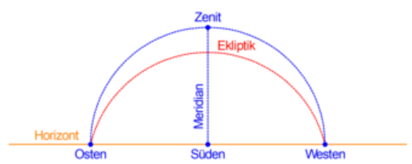


Animation of the apparent daily movement of the sun at the beginning of the four seasons with the three levels of the horizon (green), the equator (red) and the ecliptic (blue). The viewing direction runs from the front in the east (sunrise) to the rear in the west (sunset).

The apparent paths of the sun run in the day arcs above and in the night arcs below the stationary green horizontal plane, which are shown for a geographical latitude of 50 arc degrees. In the south, the day arcs reach their upper vertices at noon, and in the north the night arcs reach their lower vertices at midnight. The black pointer standing vertically on the horizontal plane is aligned with the zenith.
The earth's brown axis of rotation runs from the bottom left (south celestial pole) to the top right (north celestial pole). The sun in the vernal equinox is coloured green, and opposite it is the sun in the autumn equinox when there is the same day and night. At these two times, the sun is on the celestial equator shown as a red circle.
The plane of the ecliptic is shown as a rotating blue disk. The upper sun represents the situation at the summer solstice, and the lower one at the winter solstice. During the summer solstice, the ecliptic is most steeply inclined at noon and least inclined to the horizontal plane at midnight, and the other way around during the winter solstice.

At any time of the day and year the ecliptic has a varying position and a different arc length above the horizon compared to the horizon, but the highest apex is always approximately in a southerly direction. In Malta, the full moon at the summer solstice at midnight only reaches a horizon height of around 30 arc degrees, but at noon the sun is almost in the zenith with a horizon height of over 77 arc degrees (horizon height = 90 arc degrees), and thus there is the longest day of the year. At the winter solstice it is the other way around, and the result is the lowest position of the sun and thus the shortest day of the year. At the equinox at the beginning of autumn, the ecliptic reaches its maximum height at sunrise and the maximum arc length visible above the horizon and the respective minimum at sunset. In the case of the equinox at the beginning of spring, it is the other way around.

The position of the arc of the ecliptic above the horizon at different times

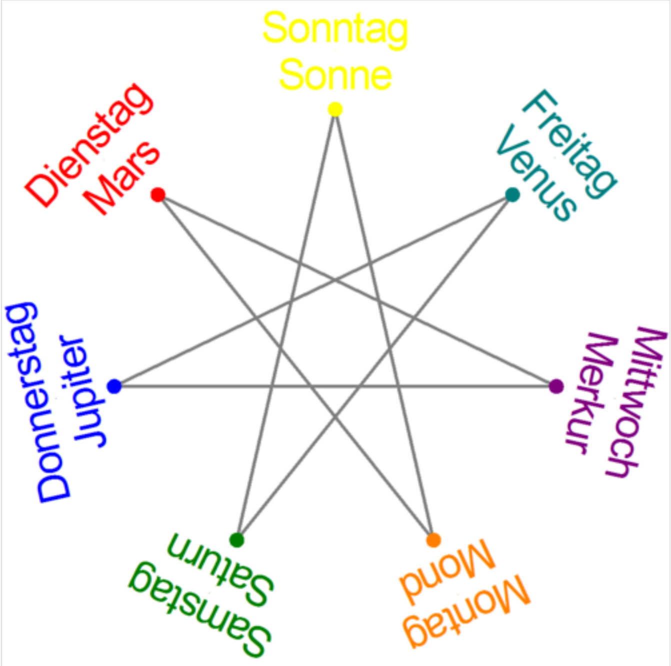
Season	Morning	Noon	Evening
Equinox spring			
Summer solstice			
Equinox autumn			
Winter solstice			

The ecliptical length λ is usually given from the spring equinox as an angle between -180 and +180 degrees of arc in the plane of the ecliptic, so at the beginning of spring the sun is at zero ecliptical longitude. The ecliptical latitude β is determined perpendicular to this as an angle between -90 and +90 degrees of arc in the direction of the poles of the ecliptic. The ecliptical latitude of the sun β_{Sonne} is zero by definition. The declination δ of a point on the ecliptic always lies between $-\epsilon$ and $+\epsilon$. At the point of spring and autumn the declination of the sun is zero, at the beginning of summer it is $+\epsilon$ and at the beginning of winter $-\epsilon$.

All planetary orbits also run near this plane with slight deviations of a few degrees. Due to its slightly inclined orbit around the earth, the earth's moon also has a deviation from the ecliptic, which results in significantly faster apparent fluctuations around this reference plane due to its closer proximity to the earth than the other planets. The moon needs a month to complete one orbit around the earth. Only if the distance to the ecliptic (the height above or below the ecliptic respectively the ecliptic latitude as coordinate) is sufficiently small, it can come to lunar eclipses at the time of full moon or to solar eclipses at the same time of new moon. The two inner planets are orbited by the earth and can therefore only be observed in a relatively small angular segment symmetrical to the sun and with small elongations; in the evening in the west after sunset or in the morning in the east before sunrise. The elongation of the sun is zero. The outer planets orbit the earth's orbit and, like the moon, appear over time on the entire circle of the ecliptic. The elongations of the moon and outer planets can therefore reach all values between -180 and +180 arc degrees.

The seven-day week

All seven celestial bodies, which have always been visible to the naked eye and are moving in relation to the starry sky, seem to move along the ecliptic around the axis between the two ecliptic poles when viewed from the earth's surface. These seven celestial objects, which move quickly compared to the starry sky depending on the distance from the earth and the sun, are given in the table below. The fact that they can only be shown in a heptagram ordered by their (sidereal) orbital periods, which gives the known order of the days of the week, is an indication that knowledge of all orbital periods is a prerequisite for this order. The sun placed at the top of the diagram:



The seven celestial bodies that are moving in relation to the starry sky and their assignments to the days of the week in the representation of a heptagram, which is arranged starting with the moon in counter-clockwise direction and ascending according to the sidereal orbital periods. The sun is at the top.

The seven celestial bodies that move within the ecliptic

Celestial body	Sideric period in days	Apparent magnitude	Maximum ecliptical lungitude	Maximum elongation	Latin name of weekday	Divinity	Weekday	Number	Colour
Moon	27,3	-13^{m}	5,1°	180°	dies lunae	Mani	Monday	2	2
Mercury	77	-2^{m}	7,0°	28°	dies Mercuri	Odin / Wotan / Wodan	Wednesday	4	7
Venus	225	-5^{m}	3,4°	48°	dies Veneris	Frija / Frigg / Frigga	Friday	6	5
Sun	365	-27^{m}	0,0°	0°	dies solis	Sol / Sunna	Sunday	1	3
Mars	687	-3^{m}	1,9°	180°	dies Martis	Tiu / Ziu / Tyr	Tuesday	3	1
Jupiter	4333	-3^{m}	1,3°	180°	dies Iovis	Thor / Donar / Thunar	Thursday	5	6
Saturn	10760	$-0{,}5^{m}$	2,5°	180°	dies Saturni	Saturn	Saturday	7	4

The seven-day week and the names of the seven days of the week go back to these seven celestial bodies. The sun is by far the brightest of these celestial objects, and only the moon can be seen simultaneously with it by the naked eye in the daytime sky throughout the whole day.

Observations near the ecliptic

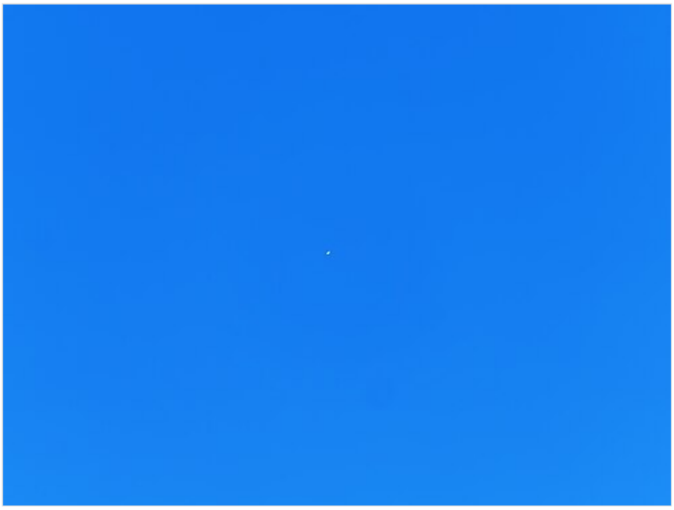
If the sun is close to the horizon and Venus is very elongated, it can also be observed with the naked eye in the daytime sky. After the sun and the moon, Venus is by far the brightest planet and is also known as the “morning star” or “evening star” in poetic literature because of its sheen. Its rising as the “morning star” and its setting as the “evening star” on the ecliptic were calculated as early as the 17th century BC and recorded on the Venus tablets of the Babylonian king Ammi-saduqa. On some of the Celtic bronze disks from Monasterevin (Ireland, first to second century AD[35]) the apparent course of the Venus positions in the evening and morning sky above the horizon in relation to the sun is possibly artistically represented. The other planets (sometimes misleadingly referred to as walking or wandering stars) are only visible between sunset and sunrise.

Of the stars seen in the northern hemisphere, only Sirius in the constellation Canis Major, which is only 8.6 light-years away and was mentioned by the Greek poet Homer as the dog star, is -1.5^{m} brighter than Saturn. The next brighter stars Arktur (α Bootis) in the constellation Bootes, Vega (α Lyrae) in the constellation Lyra, Capella (α Aurigae) in the constellation Auriga and Rigel (β Orionis) in the constellation Orion are with a magnitude of around 0^{m} already one and a half orders of magnitude darker than Sirius and half a magnitude darker than Saturn.

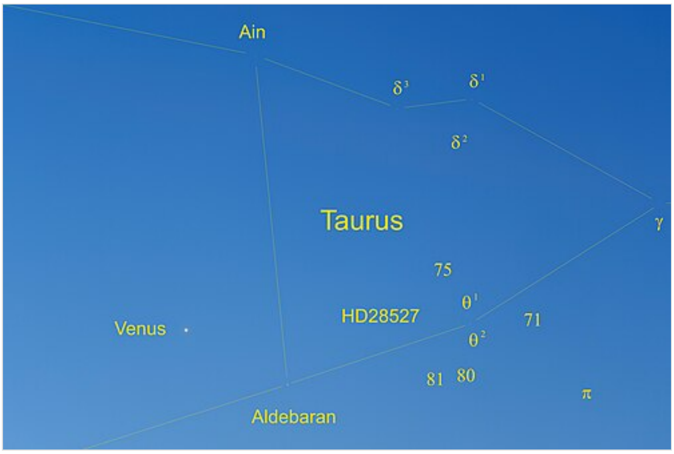
There are only seven bright objects in the fixed star sky near the ecliptic. These can even be seen in the daytime sky during a total solar eclipse[36], as was the case with the English astronomer Edmond Halley (* 1656; † 1742) during the solar eclipse on April 22, 1715 (according to the Julian calendar, according to the Gregorian calendar it was May 3, 1715) in London, when the sun disappeared in the constellation Taurus and its main star Aldebaran (α Tauri) as well as the nearby Jupiter and the star Capella (α Aurigae) in the neighbour constellation Auriga became visible.[37]

The seven brightest objects close to the ecliptic

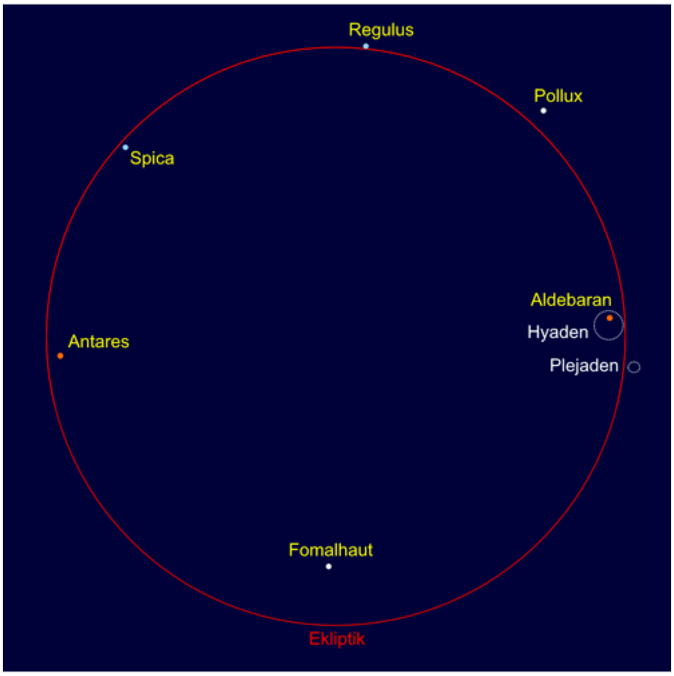
Proper name	Astronomical name	Constellation	Apparent magnitude	Ecliptical longitude	Ecliptical latitude
Antares	α Scorpii	Scorpio	$1,0^{m}$	250,0°	-4,6°
Spica	α Virginis	Virgo	$1,0^{m}$	204,1°	-2,1°
Regulus	α Leonis	Leo	$1,5^{m}$	150,1°	0,5°
Pollux	α Geminorum	Gemini	$1,0^{m}$	113,5°	6,7°
Aldebaran	α Tauri	Taurus	$1,0^{m}$	70,1°	-5,5°
Hyades	Open star cluster	Taurus	$0,5^{m}$	66,1°	-5,8°
Plejades	Open star cluster	Taurus	$1,5^{m}$	60,2°	4,1°



The Venus crescent in great brilliancy at a height of over 30 degrees above the western horizon a quarter of an hour before sunset in the day sky.

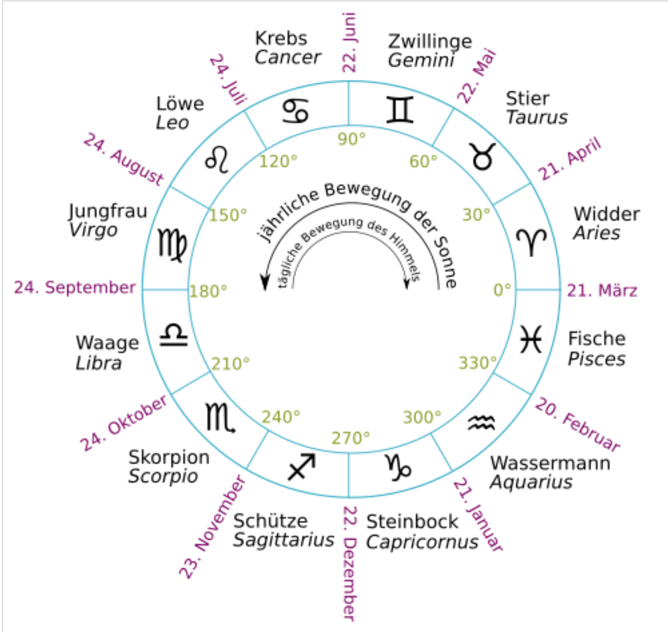


The Hyades with the star Aldebaran and the planet Venus in the head of the bull in the constellation Taurus at dawn over the eastern horizon with all stars with an apparent brightness up to the fifth magnitude.



The seven brightest objects close to the ecliptic.

The Zodiac



The Zodiac.

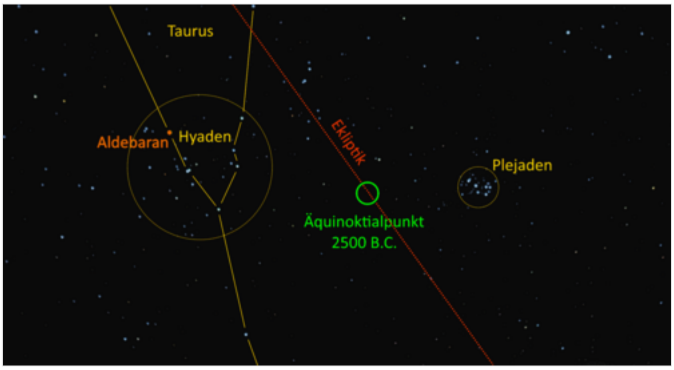
The zodiac describes the twelve constellations along the ecliptic, which appear in the following order:

- Spring
  - Aries
  - Taurus
  - Gemini
- Summer
  - Cancer
  - Leo
  - Virga
- Autumn
  - Libra
  - Scorpio
  - Sagittarius
- Winter
  - Capricornus
  - Aquarius
  - Pisces

Of all the constellations, only these twelve are on the ecliptic. The two open star clusters of the Pleiades and the Hyades belong to the constellation Taurus and are therefore also in the area of the ecliptic. All other constellations, namely Orion and Ursa Major (with the asterism Big Dipper) are off the ecliptic. Most of the constellations visible in the northern hemisphere are on or north of the ecliptic.

All twelve constellations of the zodiac occupy their own 30 arc degree long section of the full circle, with adjacent constellations seamlessly merging into one another. It should be noted that the constellation Libra, which stands between the two constellations Scorpio and Virga, should not be depicted on the celestial table of Tal-Qadi according to the above-mentioned speculation. However, the constellation Libra is quite small and comparatively inconspicuous. In ancient times it was still assigned to the claws of the scorpion. Only the Persians and Babylonians introduced twelve zodiac signs and the regular angular structure on the ecliptic with segments of the same size, each with 30 degrees of arc. It is not known whether and which constellations were in use 4500 years ago.

The Golden Gate of the Ecliptic



The position of the equinox before 4500 years in the Golden Gate of the Ecliptic.

4300 years ago, the vernal equinox was still in the constellation Taurus, 2150 years ago in the constellation Aries (the synonym "First Point of Aries" for the vernal equinox comes from this era) and today in the constellation Pisces. 2500 BC the spring equinox was exactly between the Hyades and the Pleiades in the Golden Gate of the Ecliptic! Around 4500 years ago, a full moon that appeared at the beginning of autumn was at the same time in the equinox and in the golden gate of the ecliptic and set exactly in the west at 6 p.m. local time.

The conspicuous star clusters of the Pleiades and Hyades, which are easily recognizable with the naked eye, form asterisms in the starry sky. Together with the star Aldebaran in the Hyades (it does not belong to the star cluster itself) these objects represent the three brightest objects in the vicinity of the ecliptic in a relatively narrow space, i.e. in an angular range of less than 10 degrees of arc.[38] Together they form the two solid posts of the Golden Gate of the Ecliptic in the constellation Taurus. All seven moving celestial objects move more or less frequently, but regularly very close to the ecliptic, through this gate and thus between the two star clusters, viewed from Earth. Only the Earth's moon, Venus and Mercury can occasionally hit the posts of the Golden Gate or even pass a little outside the Pleiades due to the slightly larger deviation from the ecliptic and their relative proximity to the earth.

The constellation Taurus has always been one of the most important constellations.[39] In addition to the two star clusters, the bright red giant Aldebaran is particularly striking and is often viewed as the shining right eye of the bull. In the 18th century it was also known as the ox eye in Germany.[40] The name Aldebaran is Arabian and means "the follower" (it follows the Pleiades when rising in the eastern morning sky). This main star of the constellation also belongs to the asterism of the winter hexagon, which can be seen in Central Europe from September to April. It is formed by the six main stars of the six neighbouring constellations Taurus, Orion, Canis Major, Canis Minor, Gemini, and Auriga, namely from the bright stars Aldebaran, Rigel, Sirius, Procyon, Pollux and Capella. The winter hexagon surrounds the bright red super giant Betelgeuse in the constellation Orion - i.e. together there are seven very bright stars in this area.

In the western evening sky of Malta, Aldebaran and the Hyades are a little south (left below) and the Pleiades a little north (right above) of the ecliptic at the beginning of spring. The line connecting the star clusters is roughly parallel to the horizon when it sets.

When rising, the Pleiades in the east stand almost vertically above the Hyades, and the ecliptic then does not run upright, but rather flat rising along the horizon to the south.

The ecliptical longitude is measured from the vernal equinox along the ecliptic. For the Golden Gate of the Ecliptic it is around 64 degrees today. It should also be noted that the line connecting the Hyades and the Pleiades at the ecliptical latitude of 0 degrees of arc is cut almost exactly in the middle by the line of the ecliptic. Furthermore, the ecliptic is inclined at an angle of around 45 degrees to this connecting line. In this way, both the position of the ecliptic and its inclination can be easily determined at any point in time, from any point on the earth and directly from the orientation of the Golden Gate of the Ecliptic, without having to observe the orbits or positions of the sun, the moon or any planets.

For the sake of completeness, it should be mentioned that 4500 years ago, every year at the beginning of spring, the setting sun was on the western horizon in the Golden Gate of the Ecliptic, although this could not be seen itself at all because of the bright sunlight. Today this is the case on May 25th, since the vernal equinox has meanwhile shifted by a good two months (one month corresponds to an angle of 30 degrees along the ecliptic).


Venus (bottom centre) one day before its passage of the Golden Gate of the Ecliptic as it approaches the Pleiades.

The moon

The solar year (also the tropical year from ancient Greek τρόπος (tropos) = rotation) describes a complete orbit of the earth around the sun, and it has 365.242 days - that is almost five and a quarter days more than 360, the number that corresponds to a full circle in the degree system of angle measurement. Since it is almost a quarter day longer than 365 days, February 29th is inserted into the calendar almost every four years as a leap day at the former end of the calendar year (September was the seventh month, October the eighth and so on) so that the seasons stay in sync with the course of the sun. This means that the time in the solar calendar when the sun reaches the spring equinox always remains at the beginning of spring.

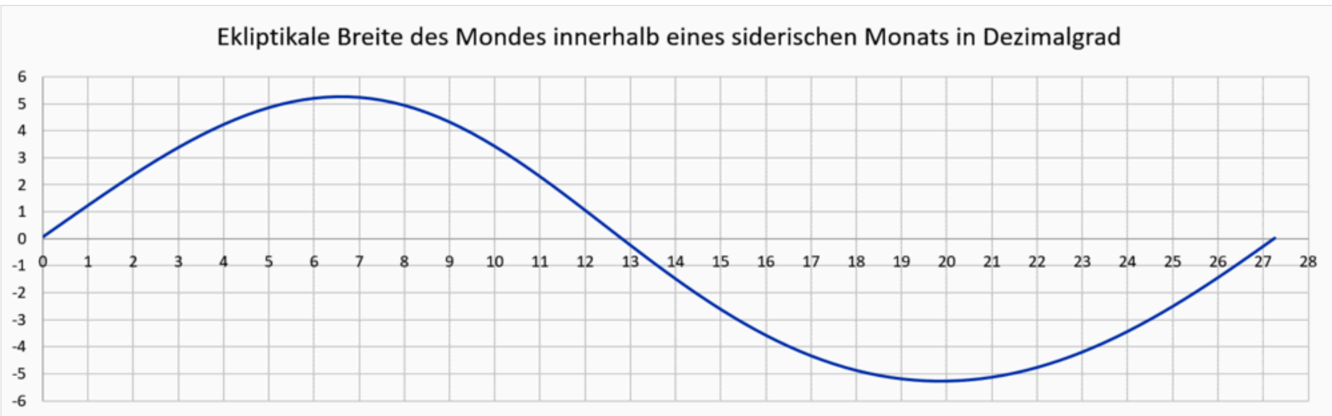
Lunar periods

The moon orbits the earth about twelve times faster than the earth does the sun, and it takes a month to complete one lunar orbit. The simplest perception of the course of the moon is obtained by observing the phases of the moon or its elongations. The synodic month (from ancient Greek σύνοδος (synodos) = meeting) describes the duration between two identical moon phases, i.e. from new moon to new moon or from full moon to full moon. Here, the conjunction of the new moon and the sun is generally regarded as a reference point in time respectively the start of a month. A synodic month lasts about 29.53 days, and twelve synodic months therefore last about 354.37 days - that is a good five and a half days less than 360. This cycle is the basis for a lunar calendar which is around eleven days shorter than a solar year. Therefore, luni-solar calendars have a thirteenth synodic leap month, which is added on average every three years, so that the spring equinox of the sun remains roughly in the same season.

Furthermore, the period can be considered in which the moon appears again in the same place in relation to the fixed star sky. This is usually associated with its appearance at the vernal equinox. This time span is called the sidereal month (from Latin sideris = of the star), and its length is 27.322 days. This is also the duration between two successive appearances of the moon in the Golden Gate of the Ecliptic, since its position is determined by stars in the starry sky.

There is also the draconian month (from ancient Greek δράκων (drakon) or Latin draco = dragon), which has a duration of 27.212 days. This duration describes the times at which the lunar orbit, inclined by a good 5 arc degrees to the ecliptic, crosses the ecliptic; the ecliptical latitude of the moon is then exactly zero. These intersection points are called lunar nodes, and they are reached once a month in the ascending lunar node and once a month in the descending lunar node. If the moon is on the ecliptic, i.e. in the proximity of these lunar nodes, a solar eclipse occurs when it is close to the sun (when the new moon is in conjunction with the sun), and a lunar eclipse occurs when it is far from the sun (when the full moon is in opposition to the sun). These points were formerly known as dragon points, which was derived from the idea that a dragon would devour the moon during a lunar eclipse or the sun during a solar eclipse.

With the following Java program it is possible to compute the ecliptical coordinates of the sun and the moon for any point in time of a Julian date in Julian centuries related to the astronomical standard epoch J2000: → Java programme EkliptikaleKoordinatenMondSonne[41]



The ecliptical latitudes of the moon during a sidereal month with 27-odd days.

Daily changes of the ecliptical latitude of the moon in degrees within a moon quarter

Days after ascending node	Change of ecliptical latitude after one day
1	1,2°
2	1,1°
3	1,0°
4	0,9°
5	0,6°
6	0,3°
7	0,0°

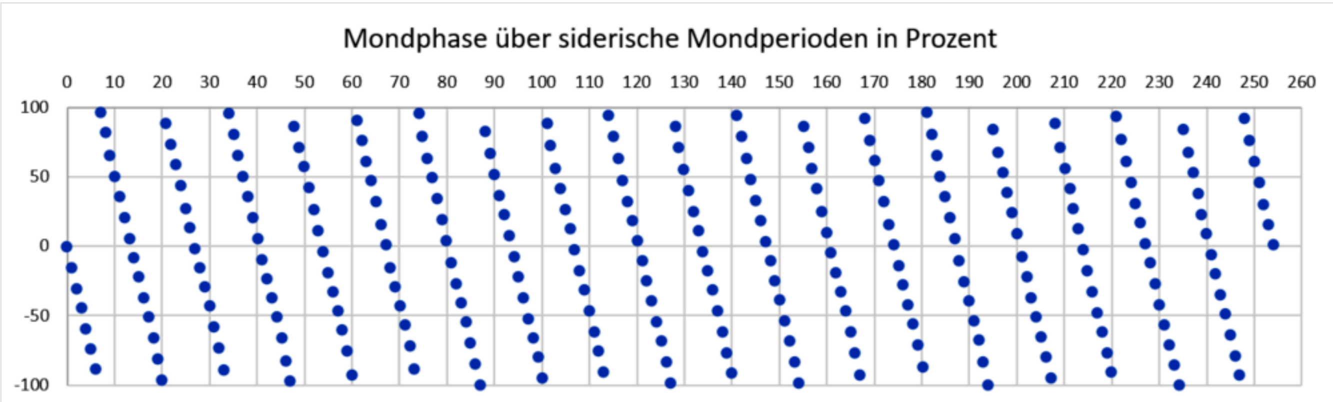
The moon, like the sun, has an apparent angular diameter of approximately 30 minutes of arc or 0.5 degrees of arc. When looking at your own finger with an outstretched arm, this corresponds to about a quarter of the thickness of the finger.

In the course of time, the moon can cover all celestial objects close to the ecliptic (for the seven brightest see above) on its orbit and release them again within an hour, which are located in a band of a good ± 5 arc degrees around the ecliptic.

Sidereal moon periods

The moon appears thirteen or fourteen times in a tropical year at a certain point in the fixed star sky, whereby it always has a different moon age (the number of days since the last new moon) and because of the different period lengths of sidereal months and draconian months always has a different ecliptical latitude.

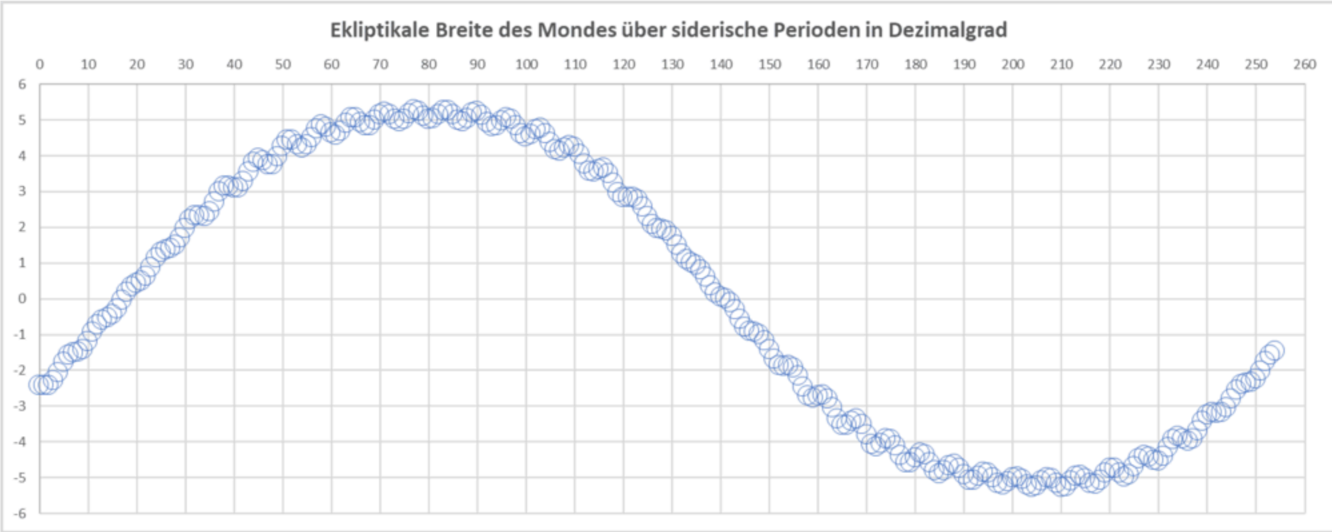
The two following diagrams are intended to illustrate the temporal course of the moon phases and the ecliptical latitudes of the moon when it appeared in the Golden Gate of the Ecliptic during 254 successive sidereal periods of 27.322 days each (a total of 6940 days or 19 years):



The phases of the moon in successive appearances of the moon in the Golden Gate of the Ecliptic within 254 sidereal periods (a total of 19 years). Since the synodic month (from new moon to new moon) is over two days longer than the sidereal month, there are moon phase shifts because the moon has not yet fully reached its maximum moon age after a sidereal month when it has reached the same ecliptical length.

In the upper half of the diagram waxing moons and in the lower half waning moons can be observed. A moon phase of 0 percent stands for a new moon and a moon phase of ±100 percent for a full moon.

The starting point (day 0 in month 0) can be set for example on May 22, 2020, when the new moon and the sun were in the Golden Gate of the Ecliptic.



The ecliptical latitudes of the moon during successive appearances of the moon in the Golden Gate of the Ecliptic within 254 successive sidereal periods (a total of 19 years). Since the draconian month (from one ascending lunar node to the next ascending lunar node) is a good two and a half hours shorter than the sidereal month, there are shifts of the longitude because the moon has already left the ascending node behind at the end of a sidereal month.

At high ecliptical latitudes (above) the Pleiades and at low ecliptical latitudes (below) the Hyades or the star Aldebaran are covered by the lunar disk within the Golden Gate of the Ecliptic.

The starting point (day 0 in month 0) can, for example, be set on May 22, 2020, when the new moon was at an ecliptical latitude of approximately -2.5 arc degrees below the sun, whose ecliptical latitude is always 0 arc degrees, within the Golden Gate of the Ecliptic

After 18.61 years (or 6793.5 days or a good 230 synodic months, in this figure after a good 248.6 sidereal months) the moon reaches the same ecliptical latitude and almost the same lunar phase but is then at a different ecliptical longitude.

The Meton cycle

Not only the determination and prediction of the rising and setting of Venus attracted the attention of ancient astronomers, but also the lunar cycle with the different phases of the moon, as well as the occurrence of lunar eclipses during a full moon and solar eclipses during a new moon. There is a cycle that describes the time after the sun and moon reach the same constellation. After 19 years (or almost 6940 days), not only has the sun reached the same ecliptical length, but also the moon (after 254 sidereal months), and therefore, it also has the same moon phase (after 235 synodic months). In addition, it has approximately the same ecliptical latitude (after 255 draconian months), so that it is almost at the same point of the fixed star sky[42]

The cycle is essentially based on the fact that, although only long-term, but easily observable, that 19 tropical solar years (6939.6 days), 235 synodic months (6939.6 days), 254 sidereal months (6939.8 days) and 255 draconian months (6939.1 days) have almost the same length. The difference between the first two is only around two hours.

This 19-year-old lunar circle or the Meton cycle named after the ancient Greek astronomer Meton (5th century BC) as well as the below mentioned Saros cycle were already known to the Babylonians in ancient times and served as the basis for their lunar calendar. The 19 megaliths of the Bluestone horseshoe from Stonehenge (2270 to 1930 BC) have also been associated with it, for example. Incidentally, the gold hats from the Bronze Age, for example, are also associated with the Meton cycle.[43]

The golden number indicates how many of these 19 years is a certain year, and it still plays an important role in determining the Easter date, for example with the help of the formulas for calculating the Easter date by Carl Friedrich Gauß (* 1777; † 1855). The name golden number possibly comes from the fact that the calendar (parapegma) of Meton on which this cycle is based could be seen in golden letters on the stone walls of his sundial (heliotropion) on the Pnyx Hill in Athens[44][42]

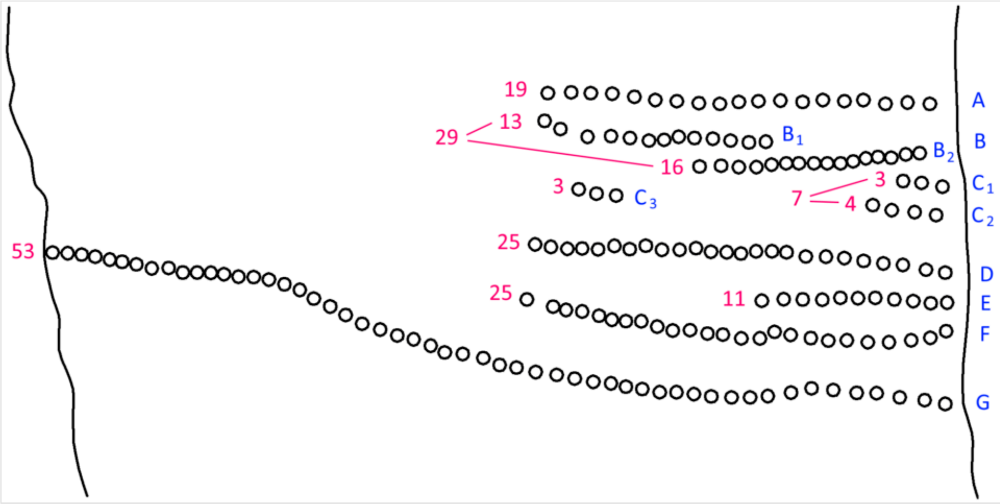
Today in the months around the winter solstice every 19 years the setting full moon can be seen on the western horizon in the Golden Gate of the Ecliptic, as last in December 2018. The lower half of the moon is then covered by the horizon during setting and the visible shining part thus forms a semi-circle, as indicated in the middle segment of the sky table. In this case, the Hyades and Pleiades lie in the west on a line parallel to the horizon and the intermediate full moon, which is still half visible at setting, would correspond to the illustration on the stone tablet of Tal-Qadi. 4500 years ago, this view of the sky arose already around the autumn equinox because of the shift in the spring equinox.

In addition to these coincidences, it can also be observed that the moon after 18.03 years (i.e. after 242 draconian months or 6585.3 days) reaches exactly the same ascending or descending node, with the sun and moon also having the same ecliptical length (after 223 synodic months). However, they are then at a different point in the fixed star sky, since this duration does not coincide with the sidereal periods. This cycle is called the Saros cycle.

Furthermore, there is an 18.6-year lunar cycle, which is based on the fact that, due to the precession of the lunar orbit, the ascending and descending lunar nodes have exactly once completely passed through the ecliptic against the direction of rotation of the moon (retrograde) after this time. The lunar nodes move in their ecliptical length at an angle of 19.34 arc degrees per year. This can be observed, for example, on the basis of the deviations in the ecliptical latitudes of the moon and thus the azimuths of the moon rises and sets on the horizon, which repeat themselves after 18.61 years and thereby oscillate around the points of the winter and summer solstices, which by definition lie exactly in the ecliptic at zero ecliptical latitude. The times at which the corresponding points between the northern and southern horizon are closest or farthest apart are called small and large moon turns. In addition, all possible positions of the moon in relation to the ecliptic at the ecliptical longitudes of -180 to +180 arc degrees and the ecliptical latitudes of approximately -6 to +6 arc degrees are reached within this period. Thus, all possible star occultations take place within this period, especially those of the Pleiades, the Hyades and of Aldebaran in the constellation Taurus.

The calendar stone of the Mnajdra temple

It is interesting to note that several rows of holes appear on the calendar stone from the Maltese temple Mnajdra, which also dates from the island's temple period, which could be related to lunar and solar calendars. At the head of the stone there are several hundred holes arranged over a large area, which may represent the individual months or years of long-term observation. Below that, seven horizontal rows appear right aligned:



Sketch of the rows of holes on the calendar stone from Mnajdra after Ventura and Hoskin.[12]

Rows of holes on the calendar stone of the Mnajdra temple on Malta

Row	Number of holes	Possible use
A	19	The Golden Number for the 19 years of the Meton cycle (235 synodic, 255 draconian, 254 sidereal months and 6940 days, respectively). After a tropical year the sun has reached its ecliptical longitude again. After a complete Meton period the moon has the same moon phase and the same ecliptical latitude and the same ecliptical longitude (for example in the Golden Gate of the Ecliptic or in the vernal equinox).
B	B_2 16 (right)	In total 29, for the number of full days in a synodic month (29.5 days). After this time the moon has reached the same moon phase again. From the old light of the moon (last morning) to the full moon there are 16 days and then 13 days until the next old light. After having completed this double row, there will be a carry over to row E, and if row E is completed there will be a carry over to row A for a new tropical year with the next Golden Number.
	B_1 13 (left above)	
C_1	3 (above)	For the 7 full days of a lunar quarter (7.4 days) or a week. If this double row is completed, there will be a carry over to row G for a new week.
C_2	4 (below)	
C_3	3 (left)	For up to 3 completed lunar quarters or weeks in a current synodic month after new moon. At new moon, waxing half-moon, full moon or waning half-moon there will be a carry over to row D, or if this one is also completed a carry over to row F.
D	25	For the 25 moon quarters in the first half of a tropical year.
E	11	For the 11 extra days in a solar year (365.2 days) compared to twelve synodic months (354.4 days).
F	24 + 1 = 25	For the 24 moon quarters in the second half of a tropical year. The 25th hole is separated since it is used for a leap moon quarter at the end of a year that only occurs about every two years.
G	53	For the started 53 seven-day weeks in a solar year (365.2 days) or from one heliacal rise or acronychical set of the Pleiades to the next.

Regarding double row B, it should be noted that in the ancient Egyptian lunar calendar, which was used in the Neolithic, the month did not begin with the invisible new moon, but with the just visible old light of the last morning of the moon, i.e. a good day before new moon.[45] This results in 16 days until the full moon and then another 13 days until the last morning of the moon. The last two holes are set off somewhat to the left, which is consistent with the following fact: two days before the end of a synodic period, i.e. after a good 27 days, a sidereal month is over, after which the moon has reached the same ecliptical length. This means that after this time the moon is again in the Golden Gate of the Ecliptic, for example, before it reaches the sun, which has apparently already moved two days (or 30 degrees) further to the left.

Alternatively, the 50 holes of rows D and F could represent the 50 full seven-day weeks (350 days) within twelve synodic periods lasting 50.6 weeks (354.4 days).

Above the eastern horizon at the last morning the old light of the waning moon was just visible 33 hours before new moon.

About the number seven

So there are seven main stars of the Pleiades, seven regularly observable moving celestial objects and seven fixed bright celestial objects near the ecliptic, which can therefore be covered by the moon or be in conjunction with the planets. It should also be noted at this point that a lunar quarter lasts seven days. In connection with the number seven, also known as divine, mystical or magical, it is worth mentioning that the constellation Orion and the asterism Big Dipper (sometimes referred to as seven stars in the past) in the constellation Ursa Major and the constellation Ursa Minor with the Polaris at its top each consist of seven main stars:

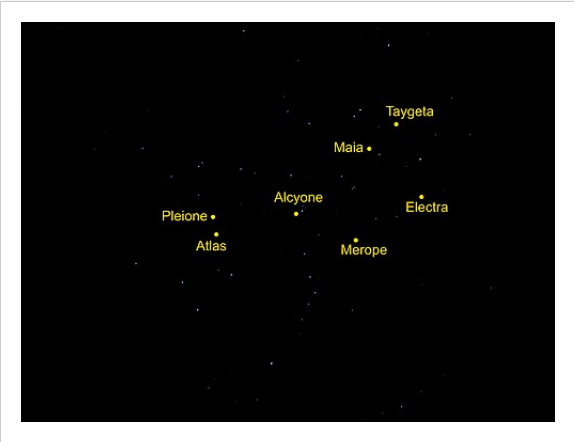
The seven main stars of the asterism Big Dipper

Astronomical name	Proper name	Apparent magnitude
ε Ursae Maioris	Alioth	$1{,}75^m$
α Ursae Maioris	Dubhe	$1{,}8^m$
η Ursae Maioris	Alkaid	$1{,}9^m$
ζ Ursae Maioris	Mizar	$2{,}2^m$
β Ursae Maioris	Merak	$2{,}3^m$
γ Ursae Maioris	Phekda	$2{,}4^m$
δ Ursae Maioris	Megrez	$3{,}3^m$

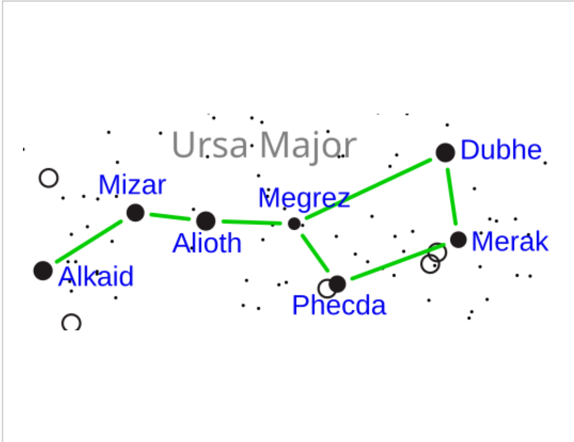
The seven main stars of the constellation Orion

Astronomical name	Proper name	Apparent magnitude
α Orionis	Betelgeuse	0,0 bis 1,5^{m}
β Orionis	Rigel	0,0^{m}
γ Orionis	Bellatrix	1,5^{m}
ε Orionis	Alnilam	1,5^{m}
ζ Orionis	Alnitak	1,5^{m}
κ Orionis	Saiph	2,0^{m}
δ Orionis	Mintaka	2,5^{m}

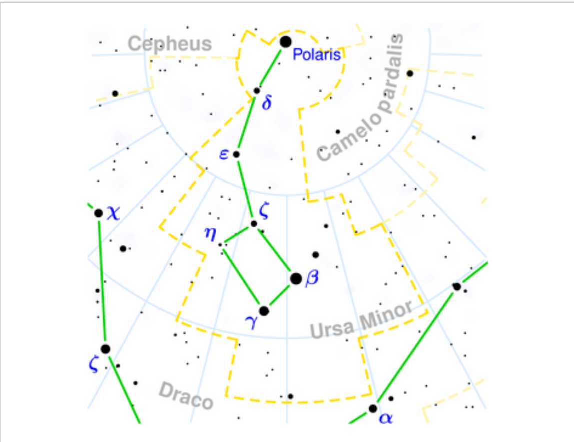
Seven main stars



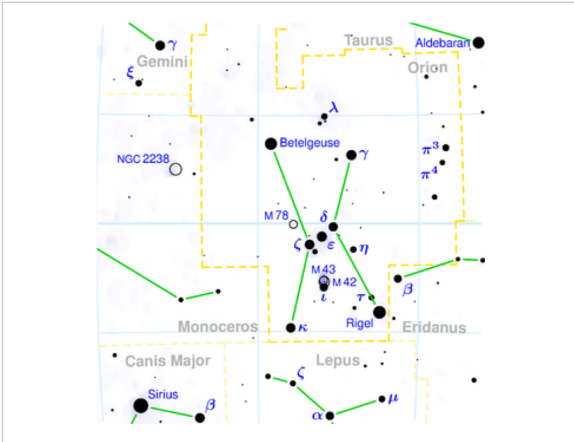
The asterism Pleiades



The asterism Big Dipper



The constellation Ursa Minor



The constellation Orion

It is noticeable that the groups of stars can all be geometrically divided into a group of four and one group of three. This arithmetic is also reflected, for example, in Christian theology, where the divine number seven from the heavenly trinity of God and the earthly four elements (or the four evangelists, the four cardinal points or the four seasons) are added together.

The product of the two summands three and four is twelve. This corresponds to the four seasons of spring, summer, autumn and winter, each lasting three months. The product of the two numbers also corresponds to the number of moons or months in a year as well as the number of constellations on the ecliptic in which the sun stays for one month within a year.

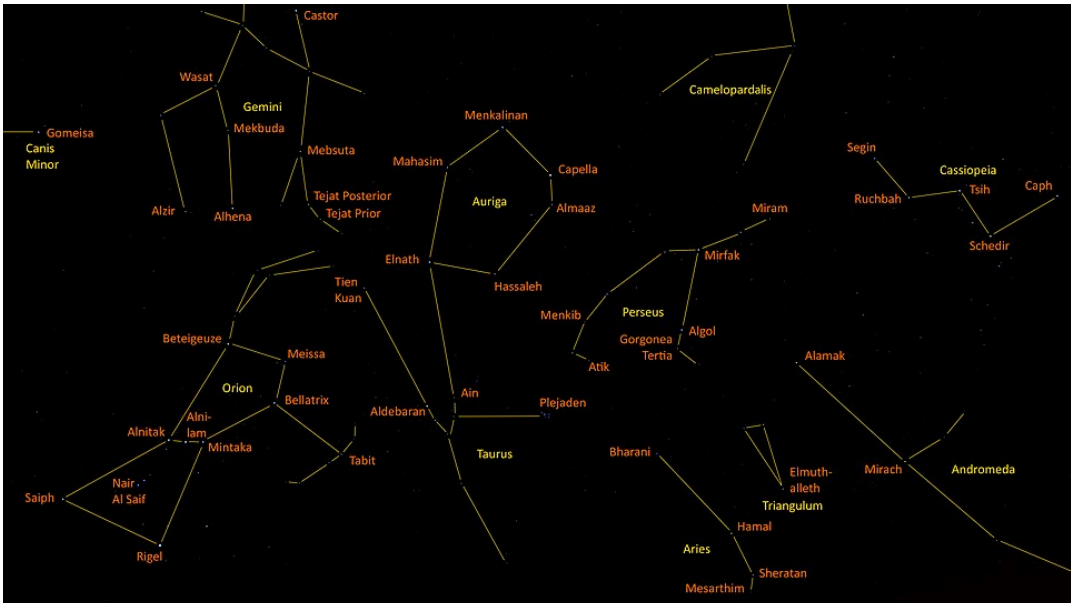
Conclusions

Based on the hypothesis that the two angular segments to the left and right of the centre of the sky table of Tal-Qadi show the asterisms of the Hyades and the Pleiades in the constellation Taurus, which form the Golden Gate of the Ecliptic, the semi-circular symbol in the middle between them could be a segment of the arc of the ecliptic standing above the horizon. All seven moving celestial bodies can be seen moving through the Golden Gate of the Ecliptic. Exactly at this point there was the vernal equinox of the sun.

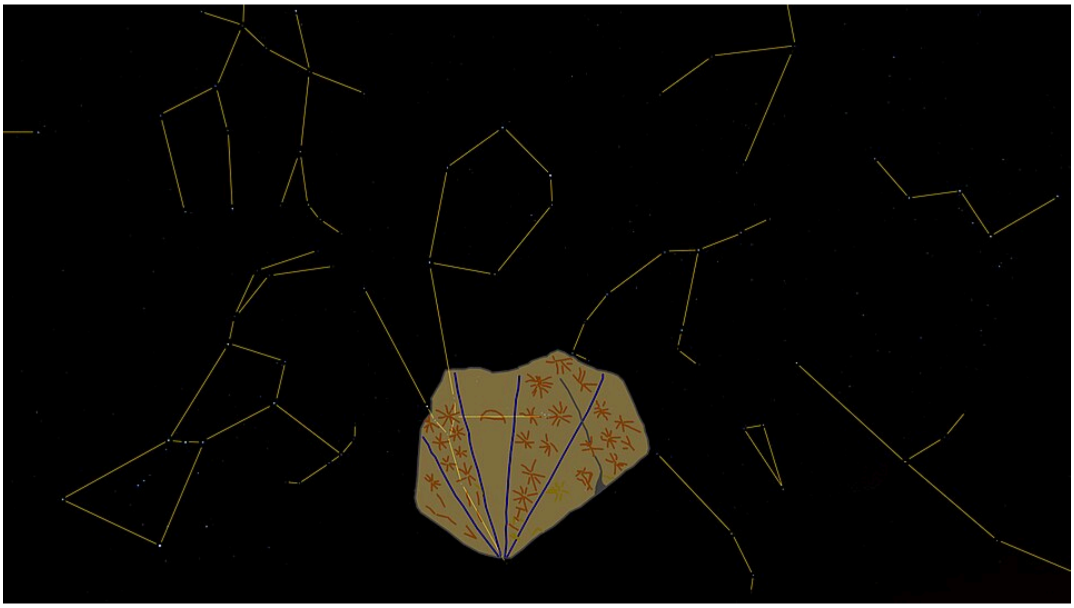
During the astronomical observation of the Hyades and the Pleiades, the position and inclination of the ecliptic can be read directly at any time and at any point in the sky with the help of the appropriately aligned and fitted sky table, without having to observe the course of the moving celestial bodies themselves. With this knowledge, it is then also possible to determine the position of the moving celestial bodies that can be observed at the same time near the ecliptic, i.e. to measure their ecliptical length, for example, from the vernal equinox or from the long right edge of the stone tablet. With the alignment described, this edge is exactly perpendicular to the ecliptic at the strongly indented point and can therefore be used to measure the ecliptical latitude and can thus be used for longer-term observation to determine the draconian period between the passages of the moon through the lunar nodes on the ecliptic. The latitude above the ecliptic is by definition zero for the sun, and for the visible planets and the moon the deviation is only a few degrees. Thus, when aligning the table, the moon enters the Golden Gate of the Ecliptic every 27 1/3 days between the upper right corner of the table and the lower area on the right edge. If it hits the upper right corner of the table, the Pleiades will be covered by the moon twelve hours later. If, on the other hand, the lunar orbit runs on the extreme opposite side of the ecliptic, an occlusion of the star Aldebaran is caused by the moon. Both are extraordinary and special astronomical events.[46][47][48] If the moon is close to the ecliptic during this observation lunar eclipses can occur around full moon, and solar eclipses can occur around new moon.

Astrophotography of the celestial region in the western night sky in November

Photographic image with a horizontal image field angle of 100°.



With illustration and naming of the present-day constellations as well as the associated stars with their proper names



With fitted sky tablet of Tal-Qadi

Animation of the photographic image with superimposition of today's constellations, stars and fitted sky tablet of Tal-Qadi.

Assignment of stars to representation

In this constellation, the single star in the left segment could match to the brightest star in the entire night sky Sirius in the constellation Canis Major, which already had a calendar function in ancient Egypt in the 3rd millennium BC, since its appearance at dawn announced the Nile flood. Between Sirius and the Golden Gate of the Ecliptic, however, lies the striking constellation Orion. The Sumerians saw a sheep in this constellation, the hunter of Greek mythology Orion and the constellation Orion are only documented later. From a geometrical point of view, its striking red shoulder star Betelgeuse is more likely to be displayed on the left side of the panel. The six lines shown between the radial centre of the sky table and Betelgeuse can correspond to the arch of Orion consisting of the six π stars (the central and brightest star π^3 Orionis is also named Tabit after its Arabian name *al-thābit*), the arm to the shoulder star Bellatrix, the shoulder line to the star of the other shoulder Betelgeuse and below it to the belt with the three belt stars Mintaka, Alnilam and Alnitak.

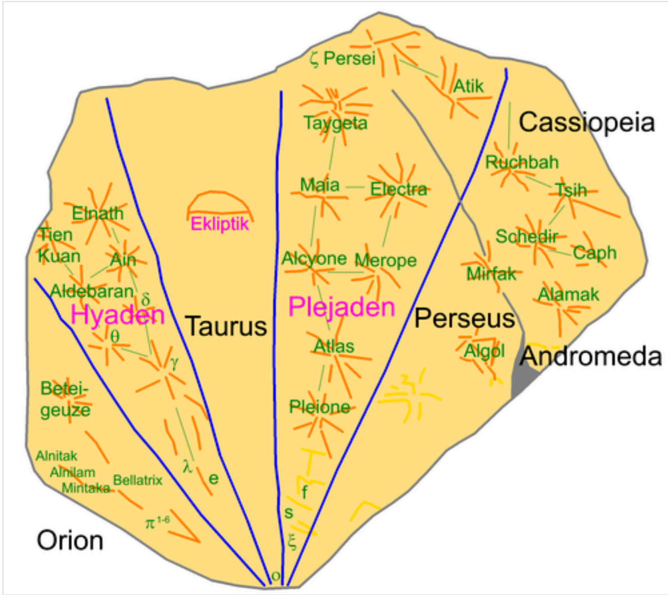
The constellation Taurus today consists of the following bright celestial objects:

- North of the ecliptic:
  - Open star cluster of the Pleiades
  - Elnath (right horn tip, also belongs to the constellation Auriga)
- South of the ecliptic:
  - Open star cluster of the Hyades (head of the bull, including Ain)
  - **Aldebaran** (red, right eye)

- **Tien Kuan** (left horn tip)

However, whether and which constellations were in use 4500 years ago is unknown, and it is therefore worth considering the brightest stars in the firmament. The following table shows the brightest objects in the area of the sky region possibly represented on the sky table of Tal-Qadi:

Proper name	Astronomical name	Apparent magnitude
Sirius	α Canis Majoris	-1,5^{m}
Capella	α Aurigae	0,0^{m}
Rigel	β Orionis	0,0^{m}
Betelgeuse	α Orionis	0,5^{m}
Hyades	Star cluster (Taurus)	0,5^{m}
Aldebaran	α Tauri	1,0^{m}
Pleiades	Star cluster (Taurus)	1,5^{m}
Alnilam	ε Orionis	1,5^{m}
Alnitak	ζ Orionis	1,5^{m}
Bellatrix	γ Orionis	1,5^{m}
Elnath	β Tauri	1,5^{m}
Alamak	γ Andromedae	2,0^{m}
Algol	β Persei	2,0^{m}
Caph	β Cassiopeiae	2,0^{m}
Hamal	α Arietis	2,0^{m}
Menkalinan	β Aurigae	2,0^{m}
Mintaka	δ Orionis	2,0^{m}
Mirfak	α Persei	2,0^{m}
Saiph	κ Orionis	2,0^{m}
Schedir	α Cassiopeiae	2,0^{m}
Tsih	γ Cassiopeiae	2,0^{m}
Ruchbah	δ Cassiopeiae	2,7^{m}



Possible assignment of the brightest celestial objects to the stars shown in the area of the Tal-Qadi sky table.

Ecept for the stars Sirius, Rigel and Saiph, which are clearly remote in relation to the region described on the left, all other bright stars can be assigned to the sky table without problems.

At the point and in the direction where the thick transverse furrow can be seen in the two right-angled segments, the Milky Way, which is only weakly visible in this region, runs roughly in the night sky. Beyond the Milky Way, in the segment to the right of centre, opposite the Pleiades, there are two stars that can be identified with the two main stars Menkalinan (left) and Capella (right) of the constellation Auriga. Alternatively, the two stars Menkib (ζ Persei, 4^{m}) and **Atik** (o Persei, 2,7^{m}) could also have been used to fit the sky table into the sky segment.[49] Today they form the back foot of the constellation Perseus directly north of the Pleiades. The Babylonians referred to this constellation as the Old Man (SU.GI), possibly because of its bowed appearance.

The far-right segment shows a star that matches the very bright star Mirfak in the constellation Perseus, located in the middle of the Milky Way. On this side of the Milky Way there are the three bright stars Algol in the constellation Perseus, Alamak in the constellation Andromeda and at the very bottom possibly also Hamal in the constellation Aries. Behind it lies the very conspicuous constellation Cassiopeia (the celestial W) with its five bright stars, of which Segin (ε Cassiopeiae, 3,3^{m}) is noticeably darker than Ruchbah, Tsih, Shedar and Caph. This constellation of four could be displayed in the right corner of the celestial table.

Finally, it should be noted that under these conditions the radial centre of the sky table lies in the star o Tauri (Omicron Tauri), which with an apparent brightness of 3,5^{m} is not quite as bright as the other stars described in the constellation Taurus, but is still one of the easily recognizable stars in the region and can therefore be used for precise adjustment of the table. The lines between this centre and the Hyades can be traced back to the darker stars in the constellation Taurus (namely λ Tauri (3,5^{m}) and **e Tauri** (5^{m})). There are also several lines from the centre in the direction of the Pleiades, which could indicate the corresponding stars there (namely **ξ Tauri** (3,5^{m}), **s Tauri** (5^{m}) and **f Tauri** (4^{m})).

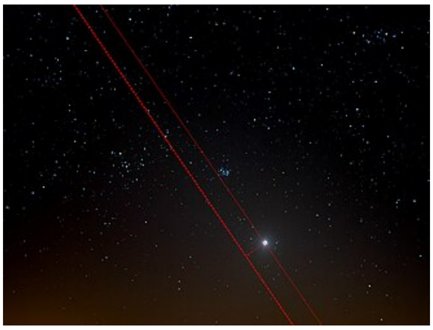
Application

The following pictures show application examples with the fitted sky table from Tal-Qadi:

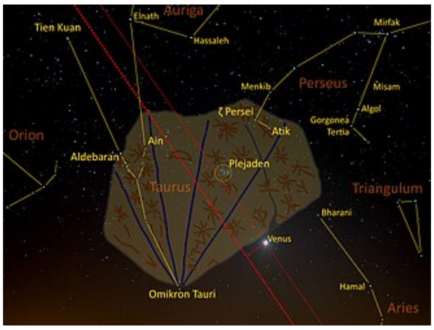
Example of use of the sky table when measuring the ecliptical latitude of Venus

The bright Venus on March 23, 2020 at dusk with the brightest stars (down to 4^m) eleven days before reaching the Golden Gate of the Ecliptic near the Pleiades (centre).

Venus in complete darkness in the cone of the zodiacal light 8 degrees above the western horizon with all stars down to the 8th magnitude (bis 8^m).



The ecliptical latitude of Venus (thin red dashed lines), i.e. its distance from the ecliptic (thick red dashed line), was 3 degrees.

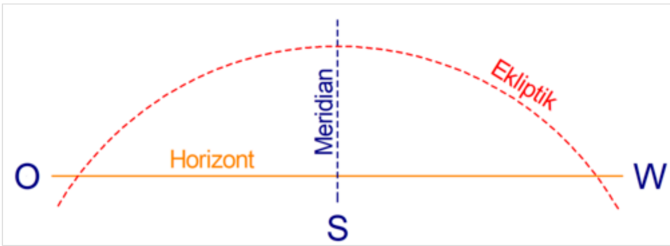


Location of the celestial table fitted into the starry sky (bottom right) from the notched point with the ecliptic lines and today's constellations, which is only 0.6 metres away from the observer. It is possible to measure the ecliptical latitude of Venus along the long straight edge of the celestial table (+3° north of the ecliptic line).

The lower tip of the board fitted in this way stands exactly on the western horizon during the difficult last, only short-term opportunity to observe the Pleiades in the evening sky, at the acronychical setting or last evening (today on May 1st) and before it is not visible anymore to the naked eye in the northern subtropical latitudes for forty days. If the Pleiades are higher on this evening, they will be outshone by daylight; if they are lower, their light will be obscured on the long way through the atmosphere by strong scattered light and increased extinction.

The arc

The arch with the straight line in between in the middle segment of the sky tablet of Tal-Qadi should not be a symbol for a gate. Gates with semi-circular arches were not even widespread at that time. In this context, however, it must be noted that the ecliptic, viewed from the earth, represents an arc of a circle that intersects the horizon at two points and continues below it. Because of the great similarity, it is not unreasonable to assume that the symbol shown in the middle segment of the stone tablet, which lies exactly in the Golden Gate of the Ecliptic, represents the arc of the ecliptic above the horizon and also a little below the horizon.



The ecliptic above the horizon looking south at sunset at the beginning of spring.

In addition to the simple interpretation of the circular arc in the middle angular segment of the sky table as the arc of the ecliptic above the horizon, there is another possibility for an explanation: today, at the winter solstice, the full moon can be observed every 19 years in the Golden Gate of the Ecliptic as it sets can then be seen directly above the horizon or on the upper edge of the sky table as an upwardly curved semi-circle.

Apart from that, with regular and long-term observation based on the ecliptical latitudes and moon phases occurring in the Golden Gate of the Ecliptic, the 19-year Meton cycle could always be traced. For example, the full moon appears on November 30, 2020 after midnight in the Golden Gate of the Ecliptic - even then it would be half-hidden behind the aligned sky table as a semi-circle. On this very day, due to the sufficiently small ecliptical latitude of -1.8 degrees in the morning, there is a partial penumbral moon eclipse, which is only visible on the night side of the earth then outside of Europe.[50]

Final consideration

Every astronomer knows how difficult it is to operate equipment and read or write documents in the dark of night. A table that is easy to touch and, if necessary, illuminated by twilight or red glow in a moderate way that is acceptable for simultaneous observation of the sky, is certainly a useful tool in this context.

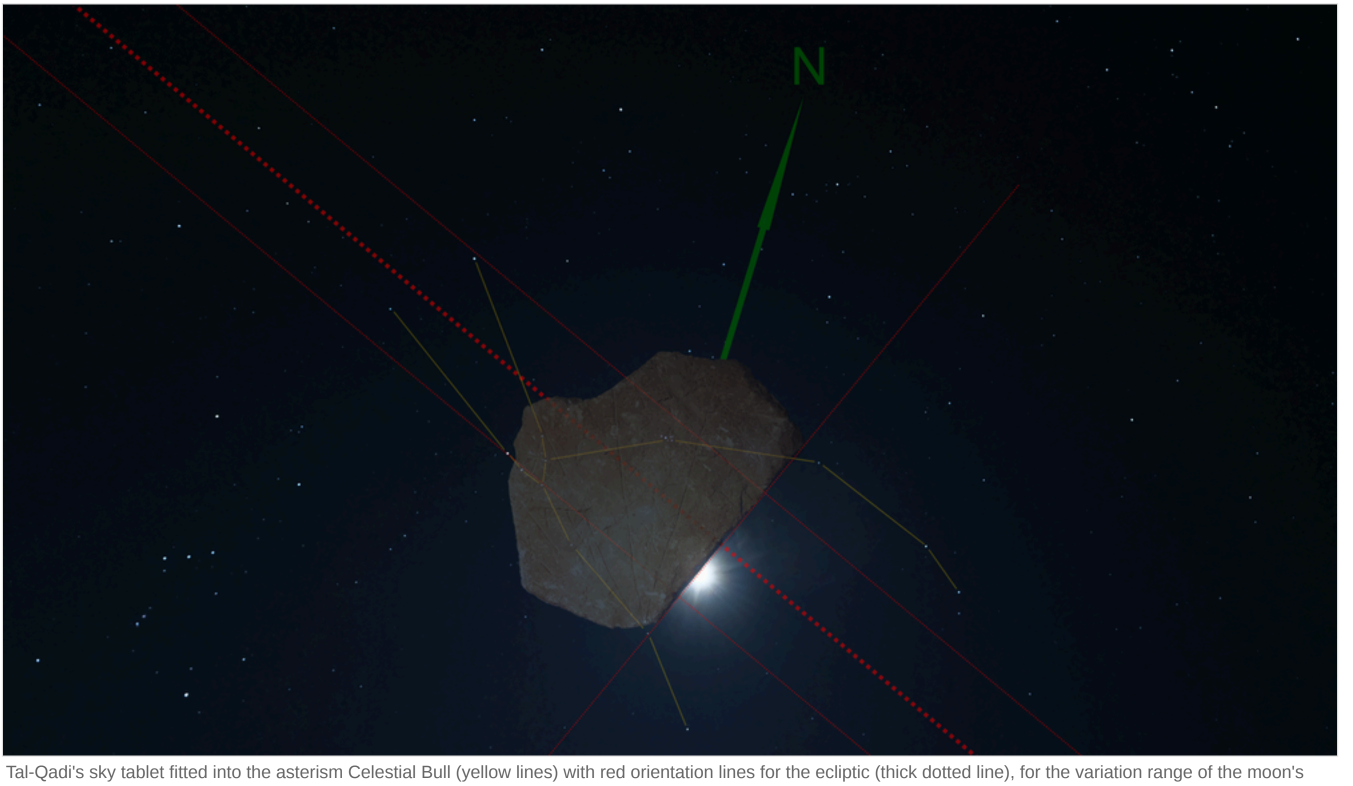
With the assumptions presented here and which are obvious, the Tal-Qadi sky table would not only display a historically significant image of the Maltese sky around 4500 years ago, but could also have been used to determine calendar dates at that time. This would be evidence of the early and by no means trivial astronomical knowledge of the inhabitants of the island at that time.

Moonset on the horizon of the western morning sky.

Dedication

This compilation is dedicated to the German scientist Friedrich Wilhelm Bessel (* 1784; † 1846), who completely unjustifiably stands unnoticed in the shadow of the prominent personalities of his time and his environment.

The main author particularly thanks his university professor Fritz Hinderer (* 1912; † 1991). With his always friendly, interested and affectionate manner, as well as his profound knowledge, he not only taught him astrophysics, but also introduced him to the numerous facets of astronomical observation with his very extensive set of astronomical tools.



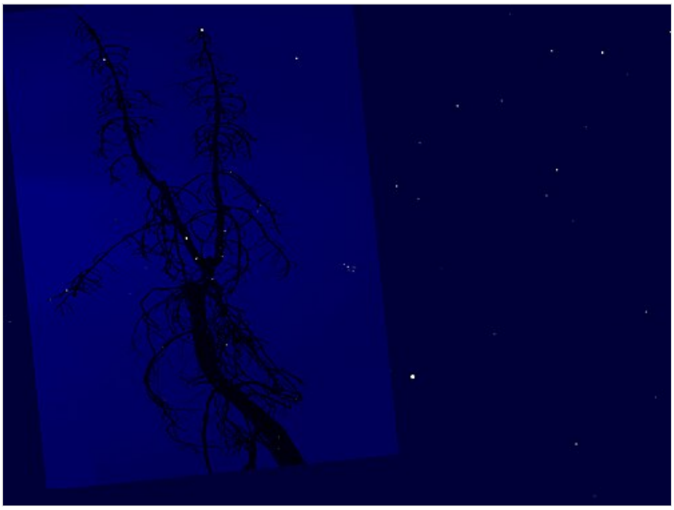
Tal-Qadi's sky tablet fitted into the asterism Celestial Bull (yellow lines) with red orientation lines for the ecliptic (thick dotted line), for the variation range of the moon's ecliptic latitude (thin dotted lines 5.5° south and north of the ecliptic line) and for the north direction (green).
In the centre, the Celestial Bull, which includes the constellation Taurus (Taurus) at the bottom centre, as well as the bright star Menkar (α Ceti) in the constellation Cetus (whale) and the constellation Aries (ram, to the right of the full moon).
The bright red giant Aldebaran is at the left notch of the sky tablet, the rear foot of Perseus (ς Persei and Atik) at the upper small arc of the celestial table, ο Tauri at the bottom corner of the celestial table and Bharani (41 Arietis or also Nair de Butein) at the right corner of the celestial table.
The ecliptic intersects the centre of the long edge of the sky chart perpendicularly, the semicircular symbol in the centre of the sky chart and the top of the sky chart (top left of the image). The Pleiades are in the centre of the fourth angular segment of the sky chart from the left. The poles of the ecliptical coordinate system are in extension of the long edge of the sky table (thin red dotted line). The celestial poles of the equatorial coordinate system are offset by 24° in the direction of the line between the two right angular segments of the sky tablet. The ecliptic latitude can be read from the long edge of the celestial chart (thin red dotted line) perpendicular to the ecliptic line. The full moon was south of the ecliptic during the exposure (ecliptic latitude = -3°).
On the lower left the constellation Orion, on the upper right the constellation Perseus, on the upper left the constellation Auriga, on the upper right the constellation Cassiopeia, on the upper left the constellation Gemini, on the right the small constellation Triangulum and on the outer right the constellation Andromeda.

0:00 / 0:00

Air de Cour "Je suis ravi de mon Uranie" (1625) of the French composer Étienne Moulinié. Urania was the patron goddess of astronomy in ancient Greece.

Lyrics:
Je suis ravi de mon Uranie,
Toute beauté pres d'elle est ternie;
Jamais l'amour dedans ces bois
N'en a fait voir, n'y régner de pareille.
C'est une merveille,
Sa seule voix
Peut dompter, et sousmettre les plus grands Roys.

Translation:
I am delighted with my Urania,
All beauty near her has faded;
Never has love in these woods
Neither displayed such a thing, nor spread such a thing.
This is a wonder,
Her voice alone
can conquer and subdue the mightiest kings.



The Golden Gate of the Ecliptic as a photomontage with the contour of a dead spruce, which happens to represent the shape of the bull's head in the constellation Taurus. In the lower centre there is the bright Venus, in the centre the Pleiades and in the upper right the constellation Perseus.

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