



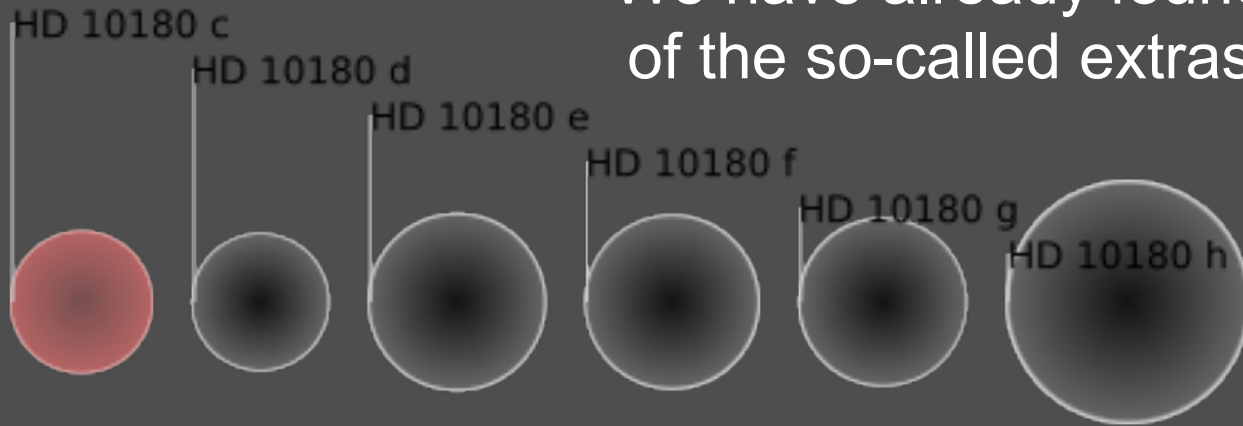
1. Remaining questions about the Universe
2. Timeline of the Universe: Cosmic Year
- L4: Ancient (pre-scientific) astronomy

- Question that we did not address during our journey in L2:
The (observable) Universe is several dozen Gly (giga-light-yr) across. How big is the entire entity, which contains the Universe, but is surely larger?
- One recent research paper estimated from observations the *lower limit* on the so-called radius of curvature of the universe as 46 Gpc, i.e. ~ 150 Gly
- therefore the scale of the larger entity (Cosmos) is larger than ~ 150 Gly
- no upper limit can so far be established (in principle the Cosmos might be infinite)

Another great question: What is the number of planets in the universe?

We have already found thousands of the so-called extrasolar planets

e.g.



What is the number of planets in the universe?

- Remember that each of the billions of galaxies contains billions of stars.
- The # of stars in the (observable) universe is thus of order $(\sim 10^{11}) \times (\sim 10^{11}) = \sim 10^{22}$ stars = 10,000,000,000,000,000,000,000
- And that's only in *the observable* universe! The unnamed bigger entity (like the Ancients, though in reference to something else, we may call it Cosmos) has much more things in it, perhaps similar to what around us.

10% to 100% of those stars have families of planets like our solar system, and on some of *those thousands billions of billions of planets* liquid-water oceans and protective atmospheres may shelter the spark of life. We don't know on how many. We feel it's unlikely for the number to be = 1.

How do we find extrasolar planetary systems? Wait for lecture 20±1 to find out, or watch a romantic movie Clara (on netflix) to get a head start 😊

And a wider set of questions

- It is possible that some other planets are inhabited by intelligent creatures who share your curiosity, wonder at the scale of the cosmos, and are looking back at you when you gaze into the heavens.
- Are there extraterrestrial life forms?
- Are there extraterrestrial civilizations?
- We don't have any scientifically proven facts yet*



* – In 2020 a research group from Harvard laboratory claimed a discovery of first extraterrestrial protein (named *hemolithin*) in meteorite Allende, whose radionuclide age is 30 million years older than the accepted origin of Earth. We'll return to these questions in the last lecture of this course.

This discovery has not been published and independently confirmed yet.

Scales of Time

- We have already looked at the scale of things in the universe, and even glanced a little beyond...

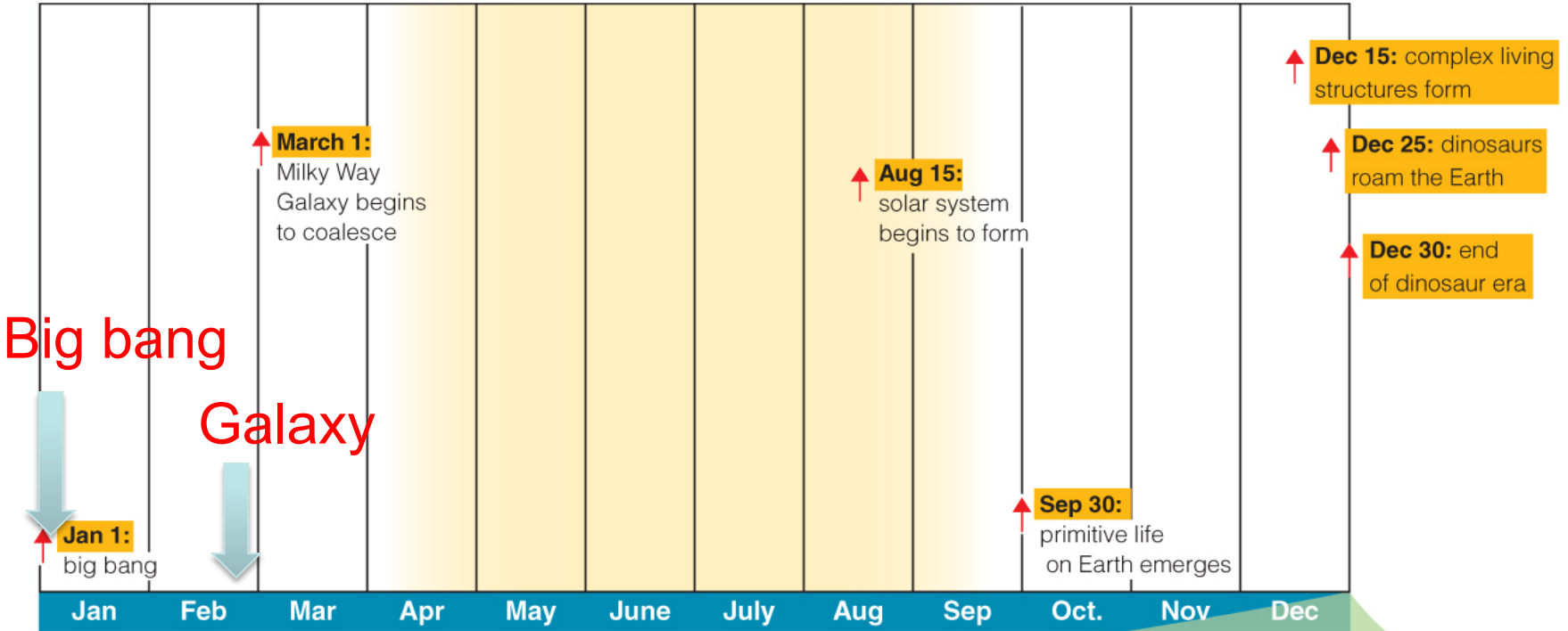
Equally important is that you gain an appreciation for the concept of time

The Cosmic Calendar: Concepts of Time

- Our current understanding of the formation of the universe and its age leads us to believe that it has been about 13.8 billion years (13.8 Gy, 13.8 Gyr) since the *big bang*, the instant our universe commenced expansion and, for all practical purposes, the beginning of time itself. In astrophysics we do not talk about time before the big bang, since it is not known if there was any time continuity leading from something before.
- Let's imagine that the time our universe has existed is spread over a one-year calendar where each month is a little in excess of one billion years – we have, then, a cosmic calendar.
- This concept was devised by Carl Sagan, a well-known planetary astronomer at the end of the 20th century.

The Cosmic Calendar: Concepts of Time

Figure 1.17



December 31

- 11 seconds ago: pyramids were built
- 1 second ago: Copernicus theorized that Earth orbits the Sun
- 0.14 second ago: Elizabeth II became Queen of England
- 0.04 second ago: you were born (if you are 18)
- 0.023 second ago: Canada won the Olympic Gold Medal in women's and men's hockey in 2002
- 2 millionths of a second ago: you started reading this chapter
- Right now: midnight, New Year's Eve.

The Cosmic Calendar: Concepts of Time

Figure 1.17

- Our solar system starts being built around mid-August, and by the end of September primitive life exists on Earth.



December 31

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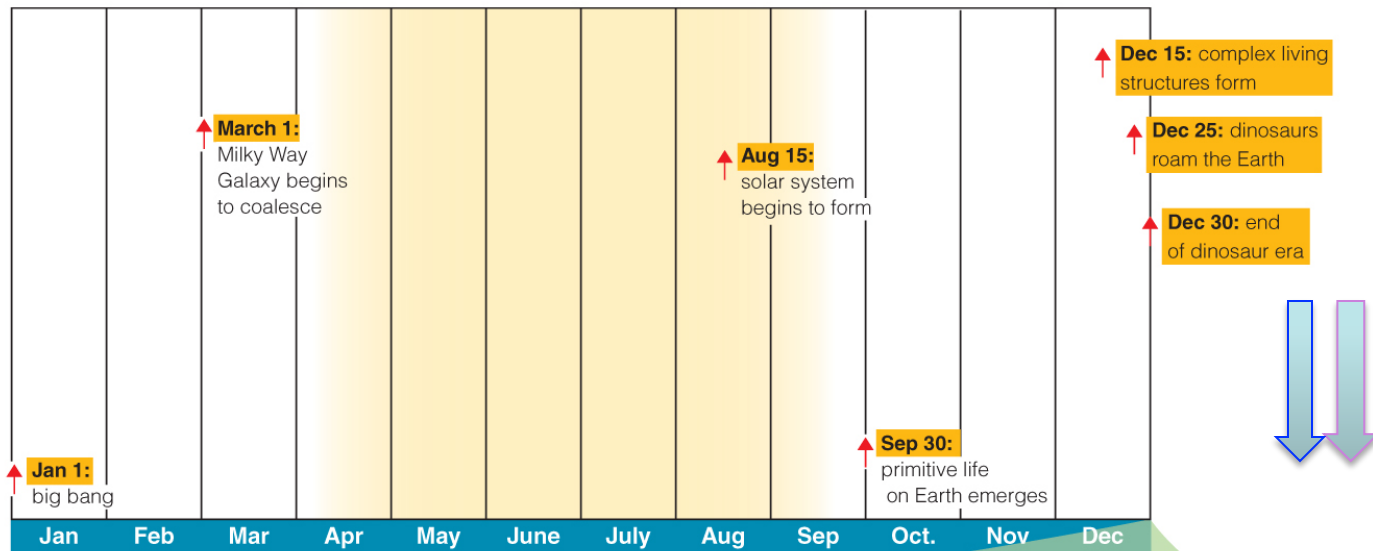
Right now: midnight, New Year's Eve.

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The Cosmic Calendar: Concepts of Time

- However, it is not until mid-December that complex living structures such as invertebrate life formed, and not until December 25 when dinosaurs roamed the Earth.

Figure 1.17



December 31

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Burgess Shale in Canadian Rockies near Banff



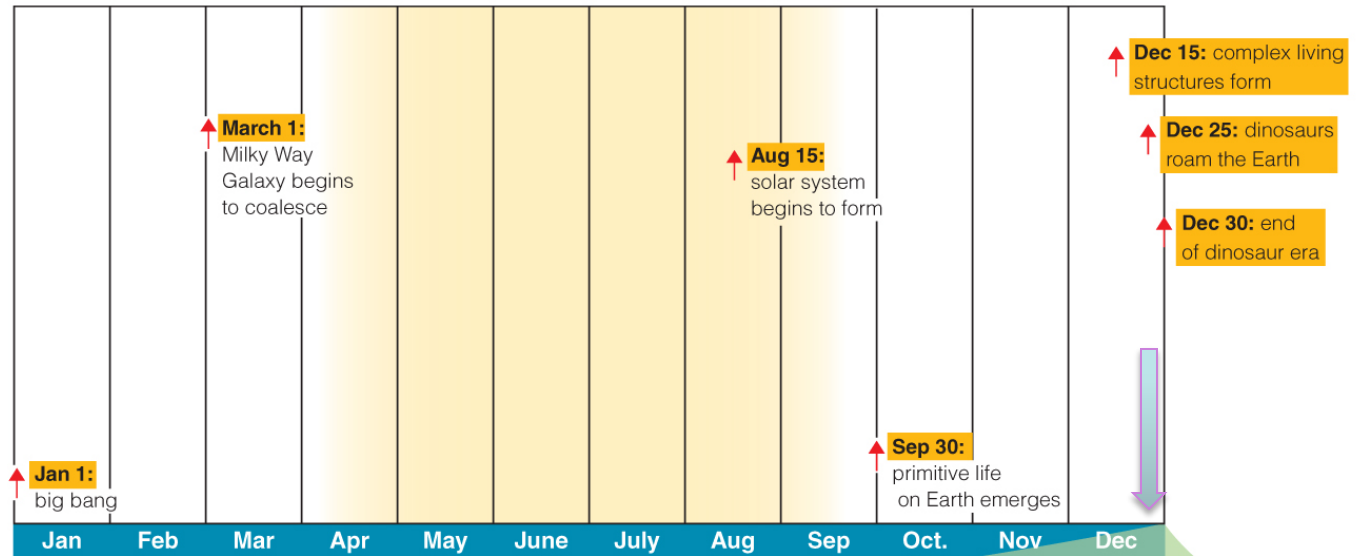
- Fossils from ~500 Myr ago, great variety of life forms present (greater than now) in the Cambrian period



The Cosmic Calendar: Concepts of Time

- The end of the dinosaur era, which took place 65 million years ago, occurred on December 30

Figure 1.17



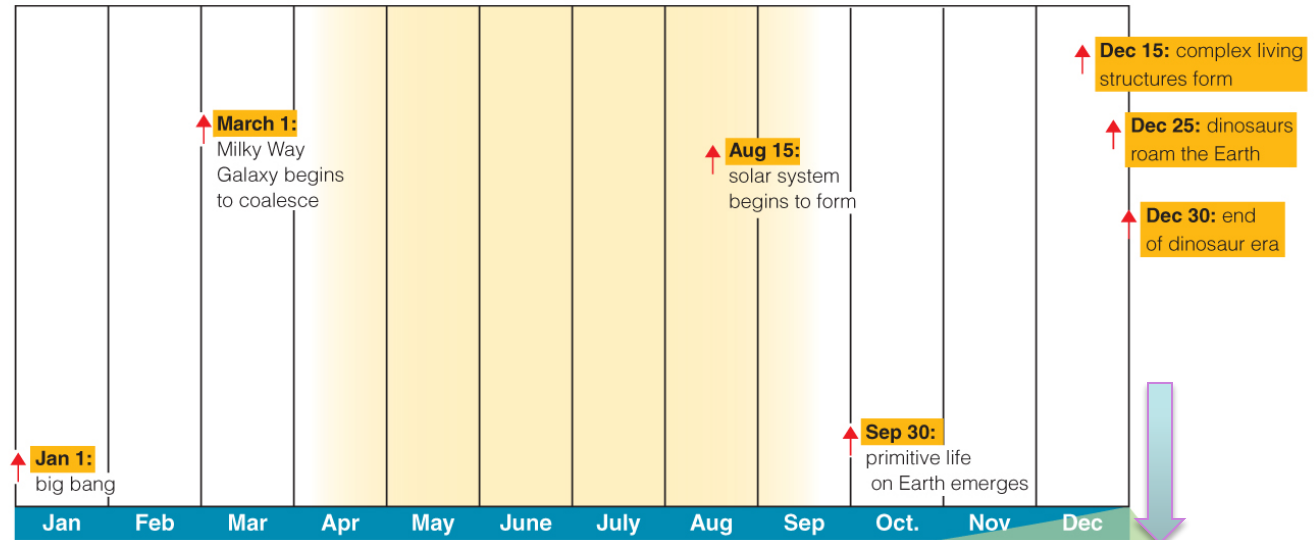
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The Cosmic Calendar: Concepts of Time

- The next day, December 31, is when all of recorded history occurred and even then not until much later in the day – within the last 30 seconds, in fact.

Figure 1.17



December 31

11 seconds ago: pyramids were built
1 second ago: Copernicus theorized that Earth orbits the Sun
0.14 second ago: Elizabeth II became Queen of England
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The Cosmic Calendar: Concepts of Time

- The Egyptian pyramids were built about 11 seconds ago.
- Copernicus convinces humanity that the Earth orbits the Sun ~1 second ago.
- Erwin Schrödinger formulates his wave equation of quantum mechanics and Edwin Hubble observationally proves the expansion of the universe about ~0.14 s ago
- Hubble Space Telescope went into orbit (in 1990), only ~0.05 seconds ago.

The Cosmic Calendar: Concepts of Time

- You were born about 0.04 seconds ago (assuming you are 18).
- I started talking today ~2 microseconds (2 millionths of a second) ago.
- And it is now finally exactly midnight on the last day of the cosmic calendar – Happy New Year!

Lecture 4:

Ancient (pre-scientific) astronomy

- The origins of astronomy (the oldest science) lay in the curiosity of our ancestors, who were excellent at observing and recording the world around them and recognizing patterns in what they observed.
 - These skills were critical for survival in a hostile environment, but although they did not know it, careful observation and pattern recognition were also the prerequisites for what we now call the modern scientific method
 - Realization of periodicities allowed creation of calendar
- *Every culture* on Earth has engaged in and contributed to the development of astronomy, making it a truly global effort. Historical records are far from complete. We will try to follow some of the stories of oldest key developments.

Pseudo-scientific claims about Paleolithic Astronomy

It is possible that observations of the sky occupied early humans (homo sapiens) already 100k yrs ago, but no material signs of this survived.

Yet some modern writes publish dubious or false claims of either the abilities and knowledge of paleolithic societies 40k yrs ago, or outright fantasies about the visits of aliens etc. (von Dänicken and others; Nazca Plateau figures etc.).

Example of the a dubious news/publication:

<https://www.sci.news/astronomy/european-paleolithic-art-complex-astronomy-06658.html>

The authors posit thinly substantiated claims of highly complex knowledge of astronomy, observations of equinox precession spanning *thousands of years*, and supposed records of numerous “comet strikes” in archaic art.

(In fact, even a single comet strike on Earth would reset the biosphere millions of years back).

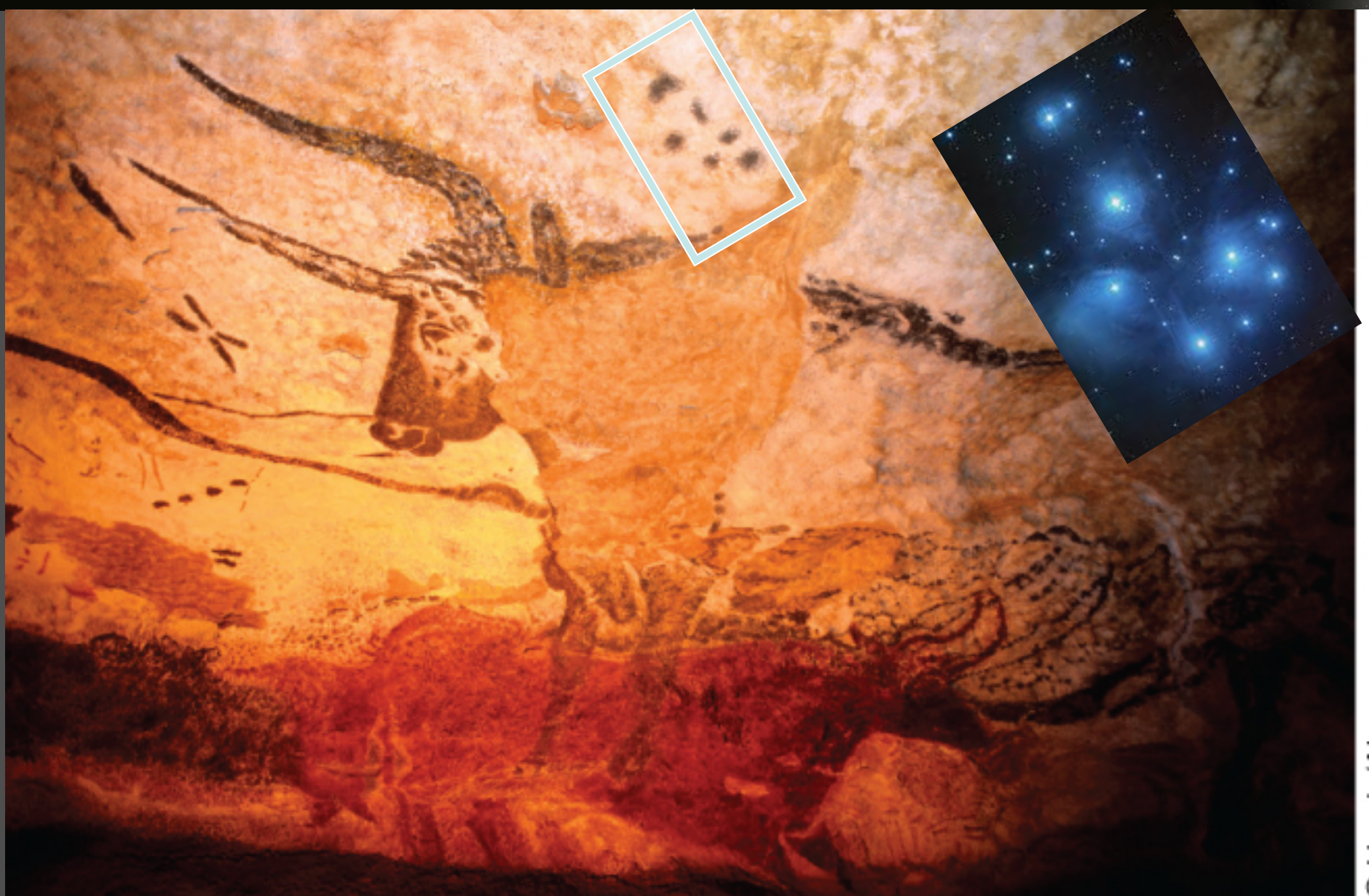
(True) Great Moments of Paleolithic Astronomy

Discovered in 1940, a marvelous (and 1st) example of ancient observations were recorded in Lascaux, southern France .Paleolithic cave paintings date back to 15000 BCE.

More than 900 images of animals show incredible attention to detail and anatomical precision.

- There are also numerous images of geometric figures and astronomical objects

Cave in Lascaux with a likely picture of Orion's Belt, Taurus constellation (incl. Aldebaran = α Tau) and Pleiades star cluster



A Brief History of Ancient Astronomy

- Some recent scientific studies indicate that the paintings may have been a star map or astronomical calendar, but there is no conclusive proof yet.

- Pleiades star cluster lies next to the constellation of Taurus (bull). Orion is at lower left, middle part is called the Orion's belt.



Ancient Astronomy

- Convincing evidence of early astronomical observations was found in Africa, where a carved bone that is 8500 years old shows pictographs of the crescent Moon
- The observed connection between the planting seasons and the position of celestial objects led to the development of religions centered on the Sun, the Moon, and other celestial objects that were personified as deities.

Ancient Astronomy

- Ancient people of central Africa could predict seasons from the orientation of the horns of the crescent Moon each month (once again a result of careful observation and pattern recognition).
 - This allowed them to determine when to plant seeds and grow their crops.
- Other ancient cultures also used astronomical observations of Sun and the Moon for the marking of time, with the Sun used for predicting seasonal events like flooding, seasons, etc.

Abstract designs on *Neolithic* pottery from 6000 B.C.-4000 B.C.

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THE TURN OF THE 7TH TO 6TH MILLENNIUM IN GR

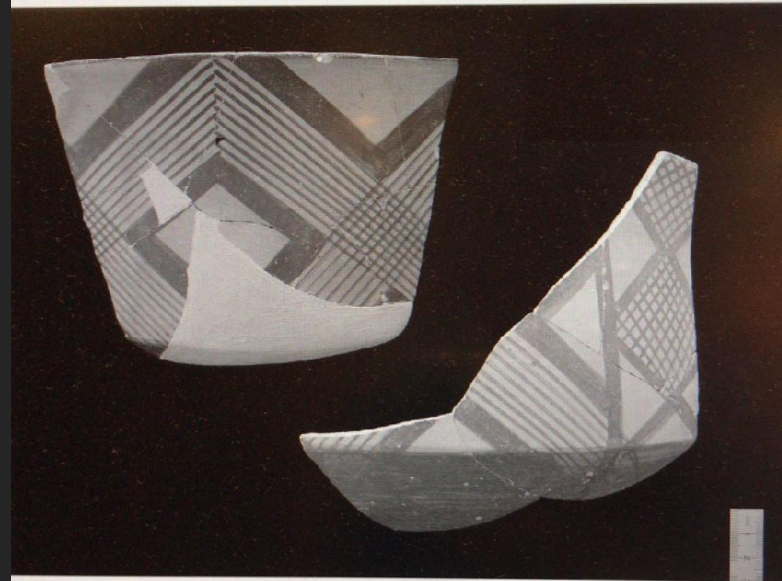


Figure
Neoli
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Franc
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ave required the special skills and regular prac-
tice typical of a few specialized potters within the
group (Kotsakis 1983; Vitelli 1993; Wijnen
1994). Rather than aiming at a standard, utilitar-
ian production, they seem to have aimed at high-
risk vessels, designed for some highly visible
social role and revealing a desire to impress
(Halstead 2011:138). Vitelli (1993:216) thus sug-
gests public ceremonies, likely to have included
feasting and the burning of incense or narcotic
substances, as suggested by localized and exten-

between families or lineages. Halstead has
investigated evidence for feasting in the
Neolithic of Greece, also suggests that feasting
“mediation at and between the contexts of
of the household and local community”
(Halstead 2011:138), large-scale ceremonies
may well have had a competitive aspect.

“It has been argued here that feasting is
sense of commensality on a social scale
than the basic unit of agricultural production
an important social institution. Neolithic



Mesopotamian Astronomy

- Some of the most careful observers and detailed record-keepers were the Sumerians, Babylonians and Akkadians, living in Mesopotamia
- Sumerian civilization is one of the oldest known, with records reaching 6000 BC
- Babylon is now a city in Iraq, while Mesopotamia is a region between the two rivers: Tigris and Euphrates. The color on the 8th gate tiles is original.



3 stars rising position on a Babylonian disk.

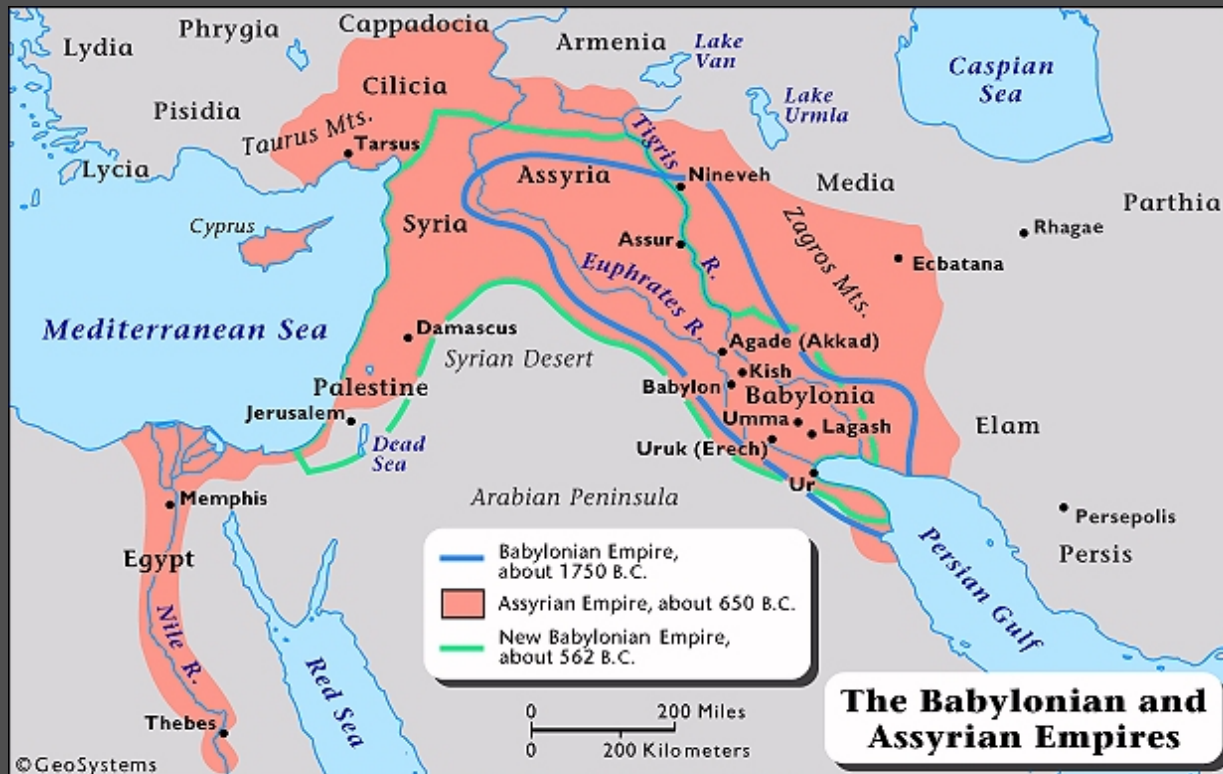
The Mesopotamian priests-astrologers knew the 18-year **Saros**, the sun-moon cycle. Eclipses reoccur with that period.

The first female ‘astronomer’ recorded in history was named in a clay tablet from 2354 BCE: En Hedu’ Anna was Akkadian princess and priestess of the Moon God Nanna (Sin)



A Brief History of Ancient Astronomy

- Babylonian priests, like En Hedu' Anna (daughter of king Sargon) lived in Mesopotamian city Ur (2285-2250 BCE)
- She was expelled and reinstated during the reign of brother Rimush



Venus tablets of Ammisaduqa (Babylon)



Tablet 63 of a Babylonian astrology text

Enuma Anu Enlil

(“at the times of [gods] Anu & Enlil”)

-

The 1st significant astronomical text in history from 1582-1562 BC, life of the 1st dynasty king Ammi-Sad.

In the astral theology of Babylonia and Assyria, triad of gods Anu, Enlil, and Ea became the three zones of the ecliptic, the band in the sky where planets “wander”

Venus tablets of Ammisaduqa (Babylon)



Records rising and setting times of Venus (god of fertility and sex Ishtar ✳𐎶) over the period of 21 years.

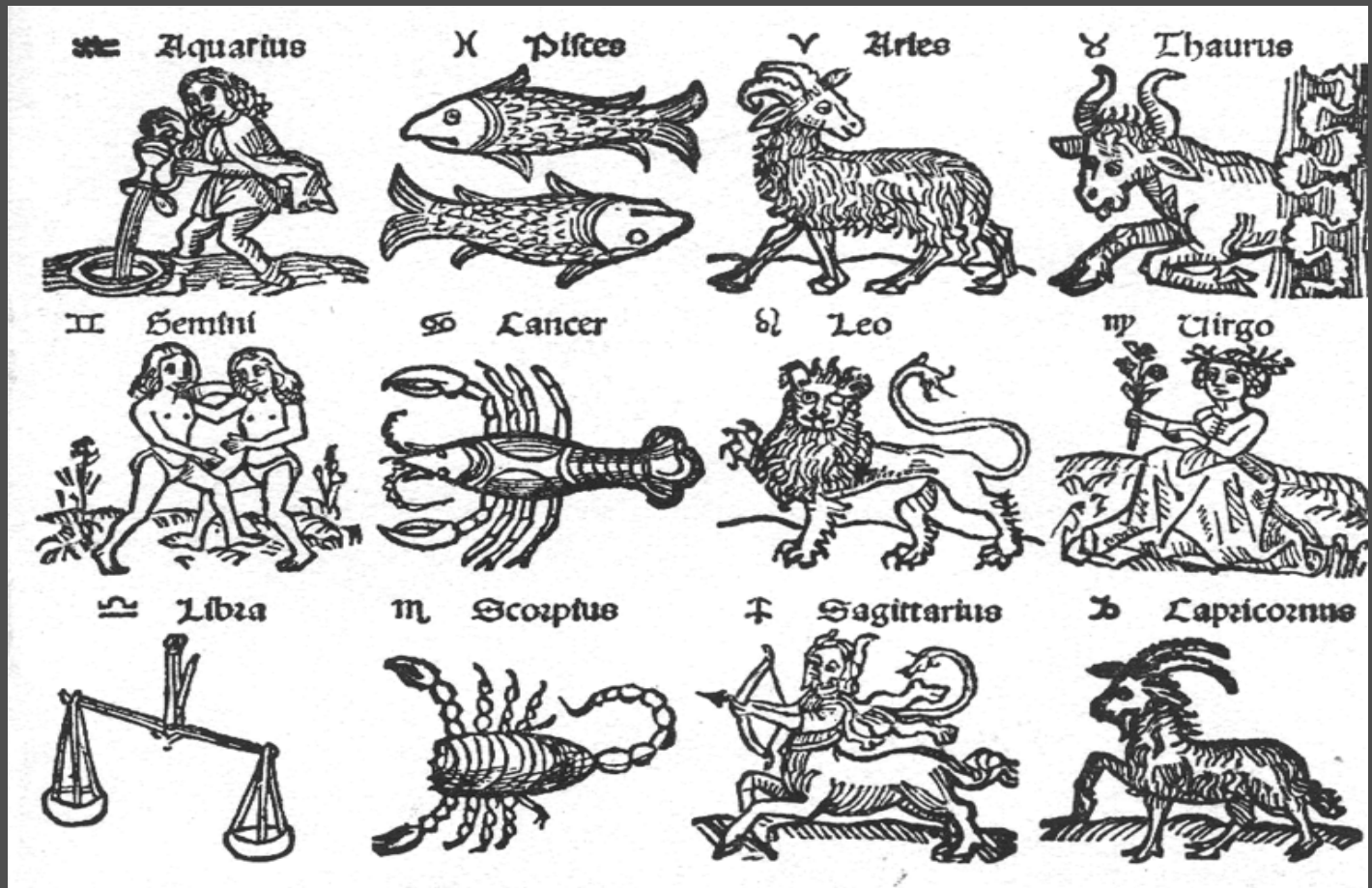


A Brief History of Ancient Astronomy

- Babylonian priests recorded the detailed motions of the visible planets on thousands of tablets more than 4000 years ago.
 - In 763 BCE, a solar eclipse was also observed and recorded by the Babylonians.
 - Our division of circle into $360=6 * 60$ units, and $60'$ in one degree, as well as $60''$ in $1'$, derives from their sexagesimal counting system (base 60).
 - The same hieroglyphic symbol was used for numbers 1, 60 and 3600.

A Brief History of Ancient Astronomy

These ancient astrologers have left their mark on modern astronomy. Our constellations of the zodiac are based on patterns identified by the Babylonians. Some names are Sumerian (pre-Babylonian)



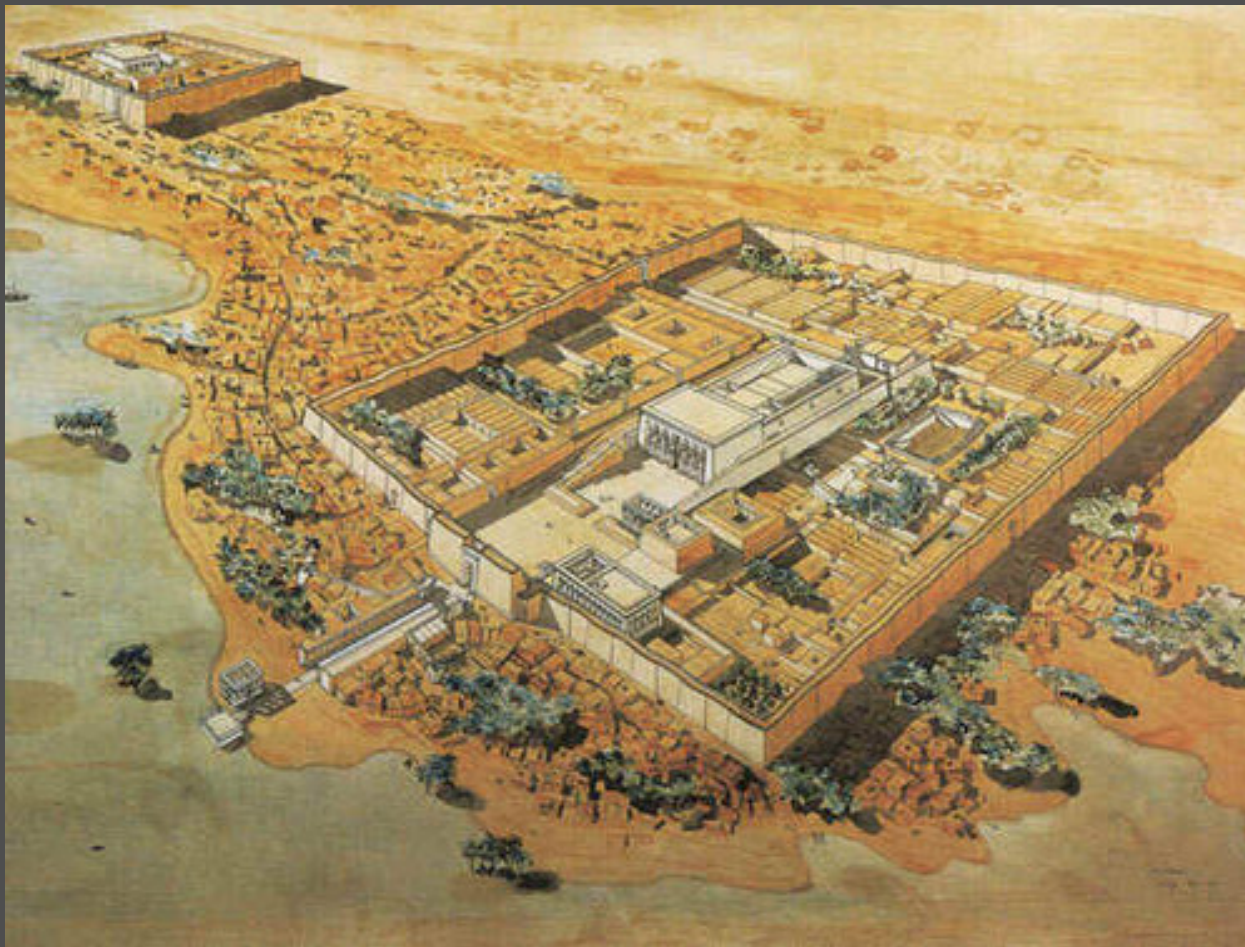
A Brief History of Ancient Astronomy

- Around 4000 BCE, the Egyptians used their observations of the periodic rising of the star known to us as Sirius to mark the first day of a 365-day calendar



Egyptian astronomy: Sirius = Isis, Sun = Ra

- "Her majesty Isis shines into the temple on New Years Day, and she mingles her light with that of her father Ra on the Horizon."



Denderah temple

Egyptian Astronomy

- Sirius, the brightest star in our sky, which they identified with the fertility goddess Isis, first appeared in the predawn sky each year just as the Nile began its life-giving floods, on the 35th day of the year.
- (It disappeared on the western sky after sunset 35 days prior to New Year)
 - While the rising of the Nile varied year to year, Sirius appeared with perfect regularity. This helped Egyptians predict planting season and prepare for the floods, or inundations.

Egyptian Astronomy

- The Egyptians were also the first to divide the night and day into 12 hours, using the rising of bright stars (later called decans) during summer nights.
 - Our modern 24-hour clock owes its origins to the ancient Egyptians
 - However, their counting system was typically base-10 (decimal)

A Brief History of Ancient Astronomy

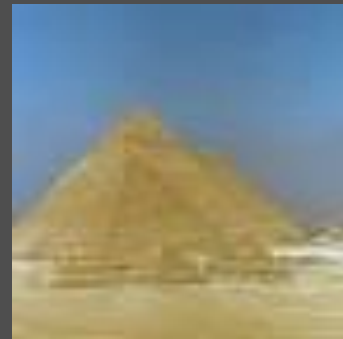
- Pyramids were aligned towards the pole star, which, because of the so-called precession of the equinoxes, was at that time Thuban, a faint star in the constellation of Draco



- Temple of Amun-Re at Karnak, taking into account the changing inclination of the ecliptic, was aligned on the rising of the midwinter sun



Pyramids were sort-of launchers of souls of dead pharaohs into the afterworld through the tunnel at the celestial pole – corridors/shafts where thus oriented toward Thuban (= serpent in Arabic).



Ancient Astronomy in Europe

- Stonehenge, Scotland, begun ca. 2400 BCE

(with sundogs is visible)

- The stone circle begun ca. 2400 BCE
- Marks the rise and set of the Moon during a phenomenon called the lunar standstill, which occurs every 18.6 years due to the precession of the Moon's orbital plane (= Saros cycle)
 - During this time, the most northerly and most southerly rising and setting of the Moon occur every month.



Ancient Astronomy of Mayans and Incas

- The Mayans have built massive ancient structures, such as the Templo Mayor (ca. 1325), Teonochtitlan, to mark seasonal events.



Mayan 'observatories'. El Caracol, Chichen Itza

- Prior to Tonohtitlan, Toltec, Mexican and modern Mayan cultures (in current Mexico and Guatemala) the Mayans have created astronomical temples in Teotihuacan, Chichen Itza, and other cities, precisely aligned with special events such as
 - solar solstices, passing of zenith at noon, and rising times and positions of Venus.
- Maya religious calendar was based on $260 = 13 * 20$ days. This helped reproduce periodicities of Venus and Sun motion



Pyramid of the sun, Teotihuacan, 110m x110m base, one of the largest in the world



Chichen Itza (Yukatan) – Kukulcan temple

- Serpent was a major deity
- E. g. Quetzalcoatl (=Venus) it was a serpent-bird
- here appearing as a shadow during equinoxes



Great Moments of Ancient Astronomy

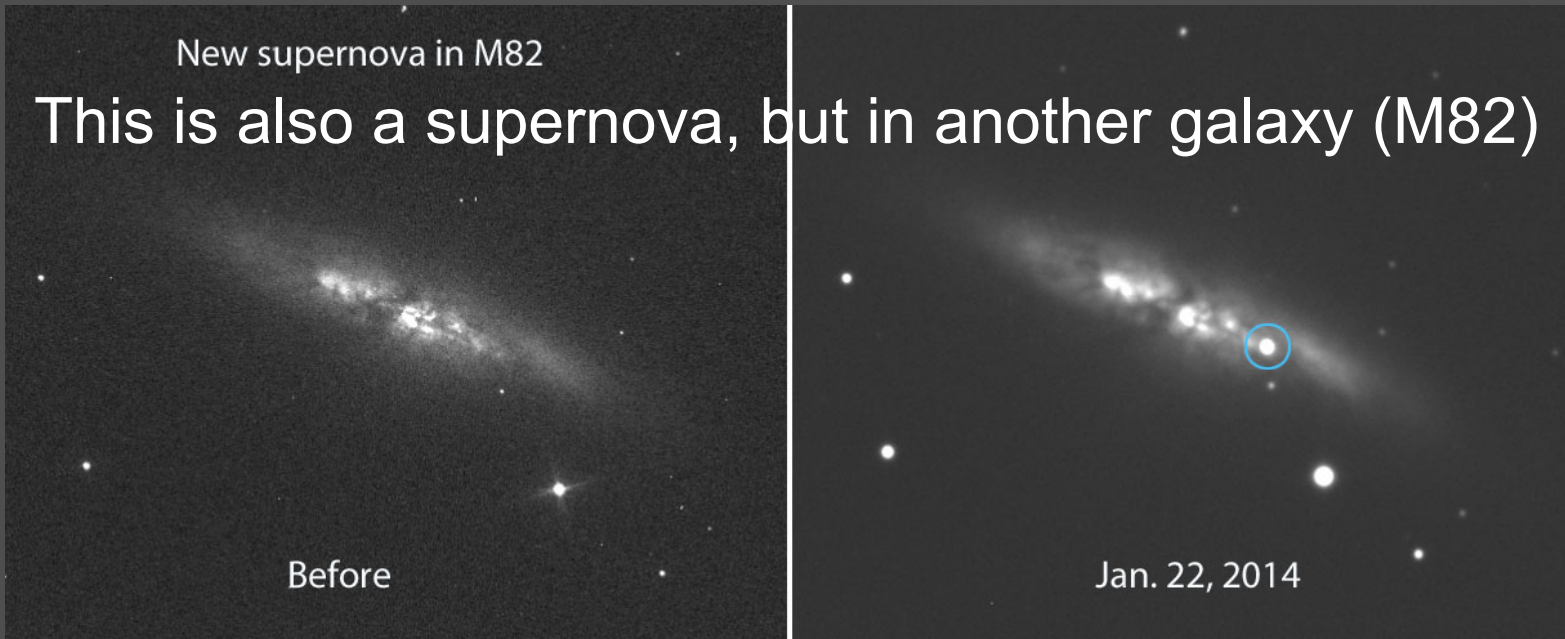
- In 1400 BCE, an exciting event was observed and recorded in China – the sudden brightening and dimming of a “guest star”
 - Although they did not know it at the time, they had made the earliest known record of a supernova explosion!
 - The Chinese also recorded solar and lunar eclipses continuously from the fifth century BCE!

Great Moments of Ancient Astronomy

- In 1054 CE another powerful supernova explosion was recorded by the Chinese.
- It may have also been depicted in an Anasazi rock painting in New Mexico
- The supernova explosion was powerful enough to appear brighter than Venus, visible during the day for 23 days!

New supernova in M82

- This is also a supernova, but in another galaxy (M82)



Before

Jan. 22, 2014

A Brief History of Ancient Astronomy

Today, modern telescopes have been used to capture stunning images of the Crab nebula, which is the expanding gaseous remnant of the supernova explosion of 1054



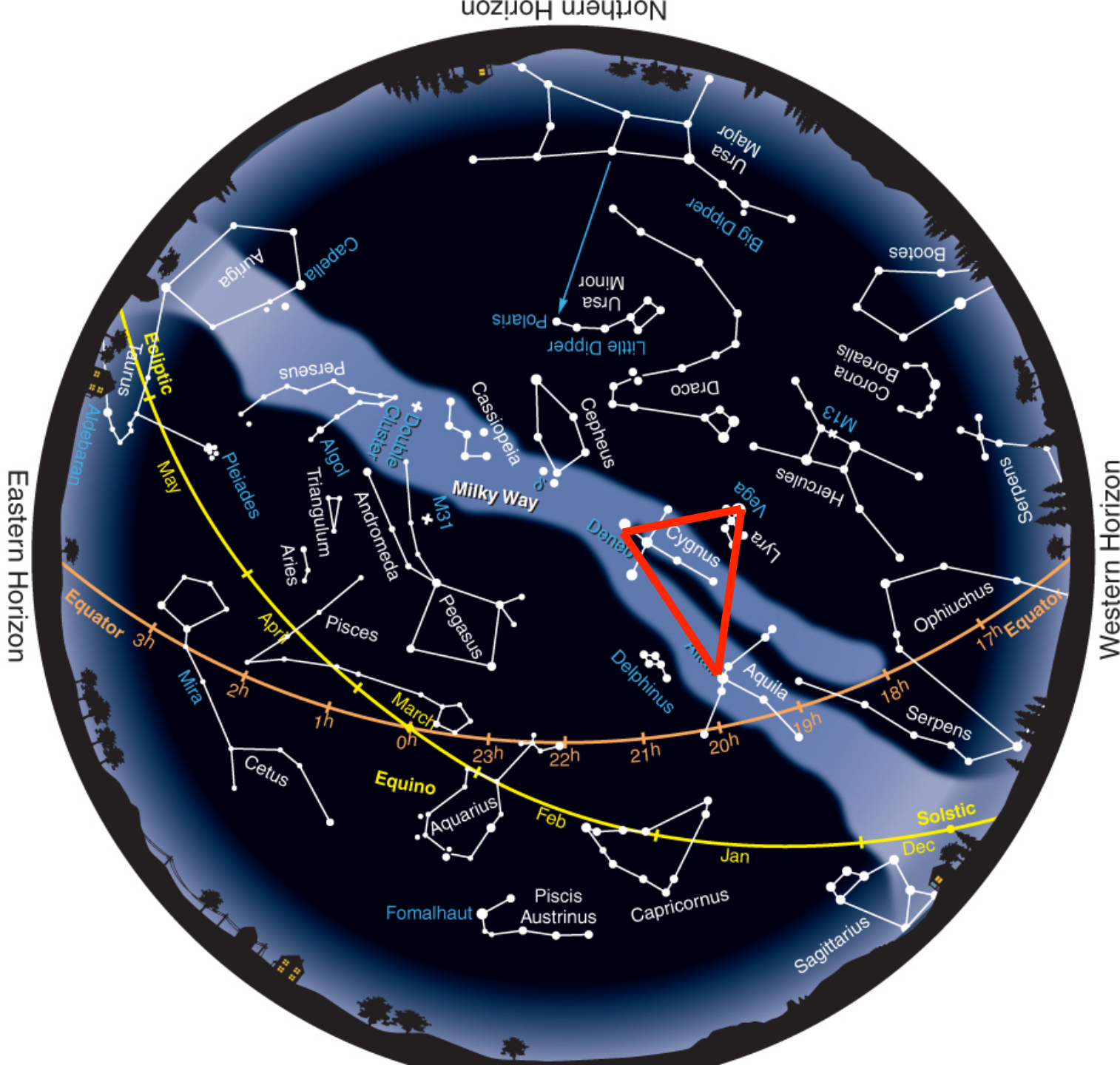
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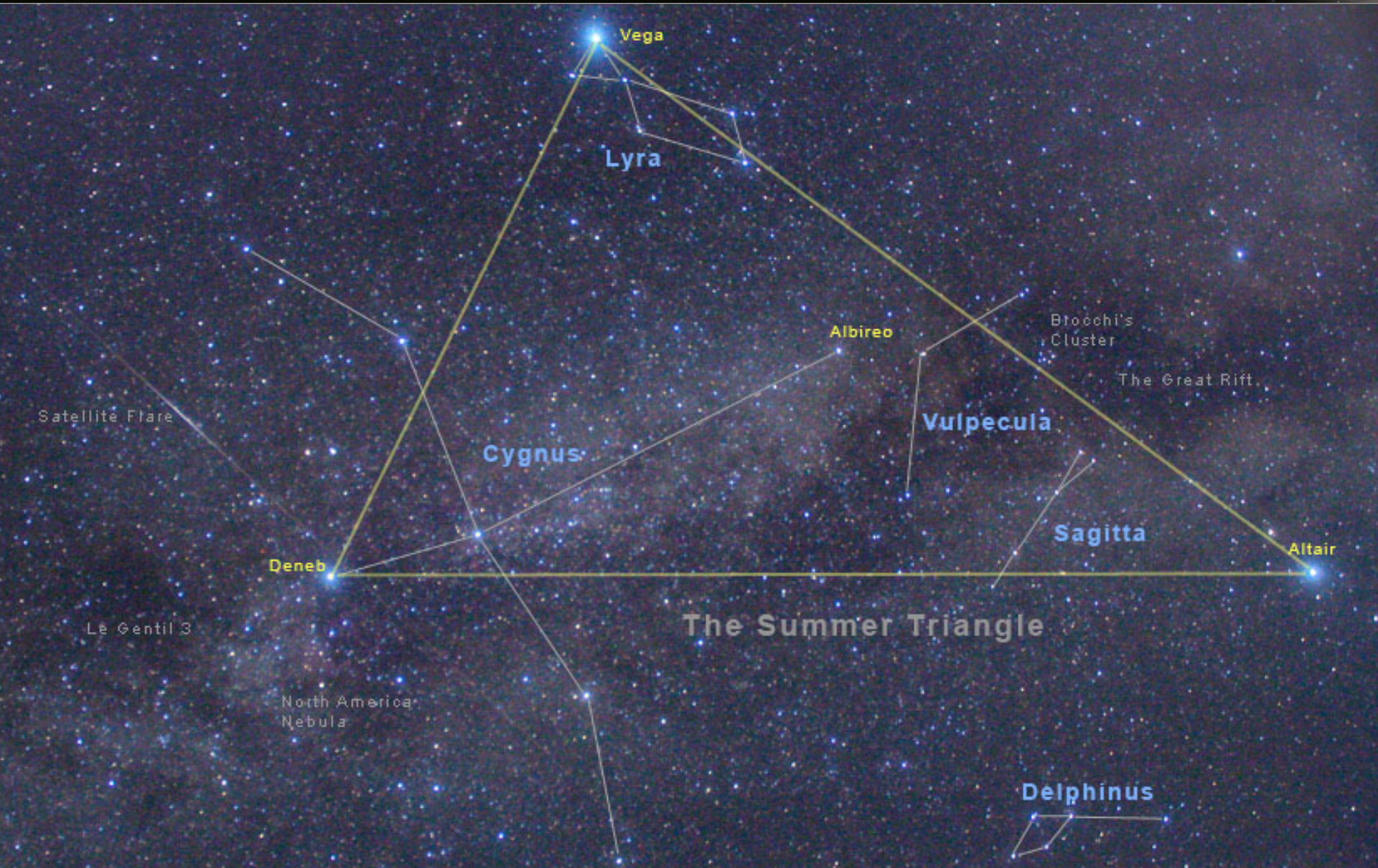
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during the year.

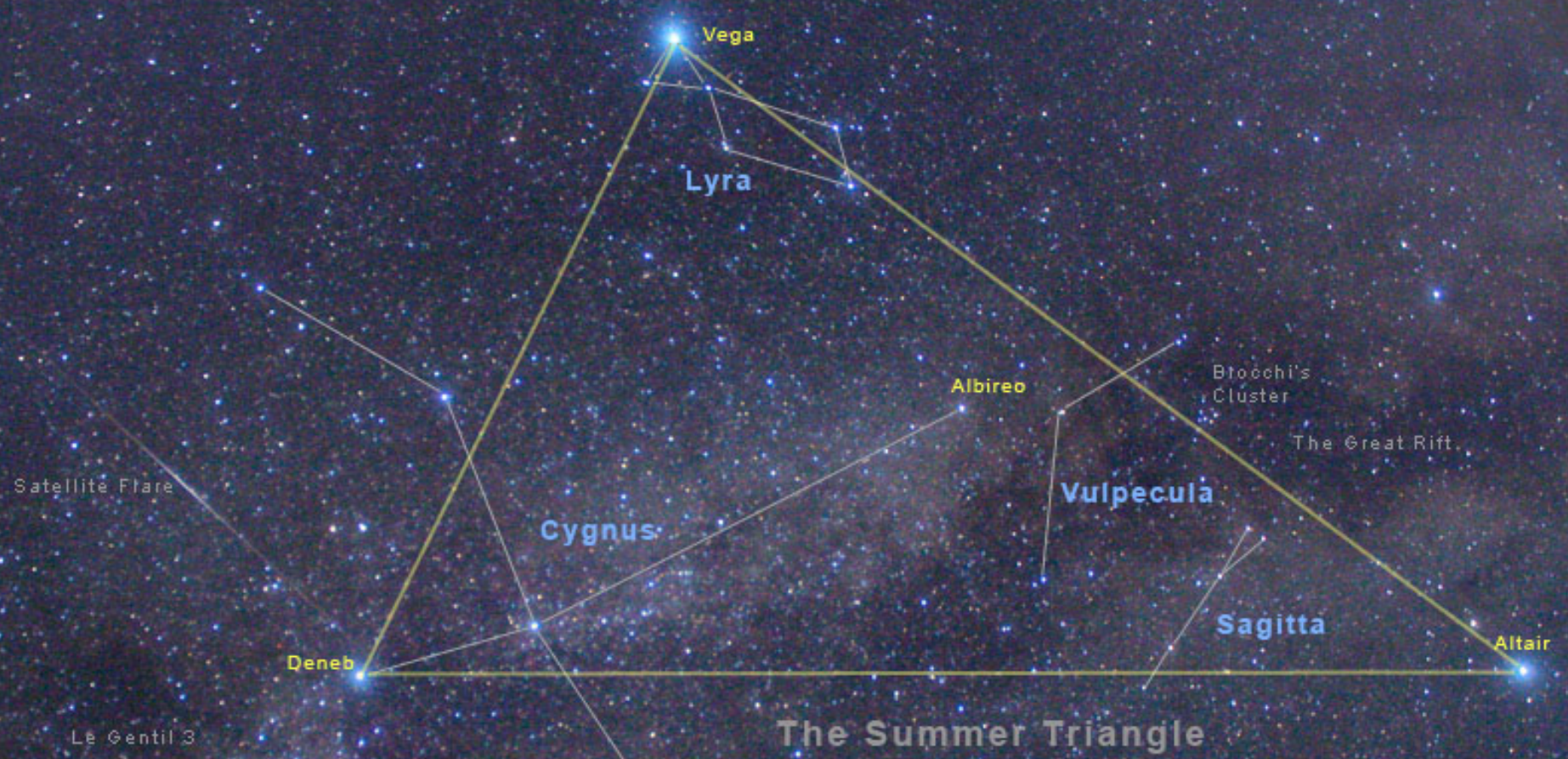
celestial equator
on.



Summer triangle: Vega (α Lyr), Deneb (α Cyg), Altair (α Aql)



Summer triangle: Vega (α Lyr), Deneb (α Cyg), Altair (α Aql)

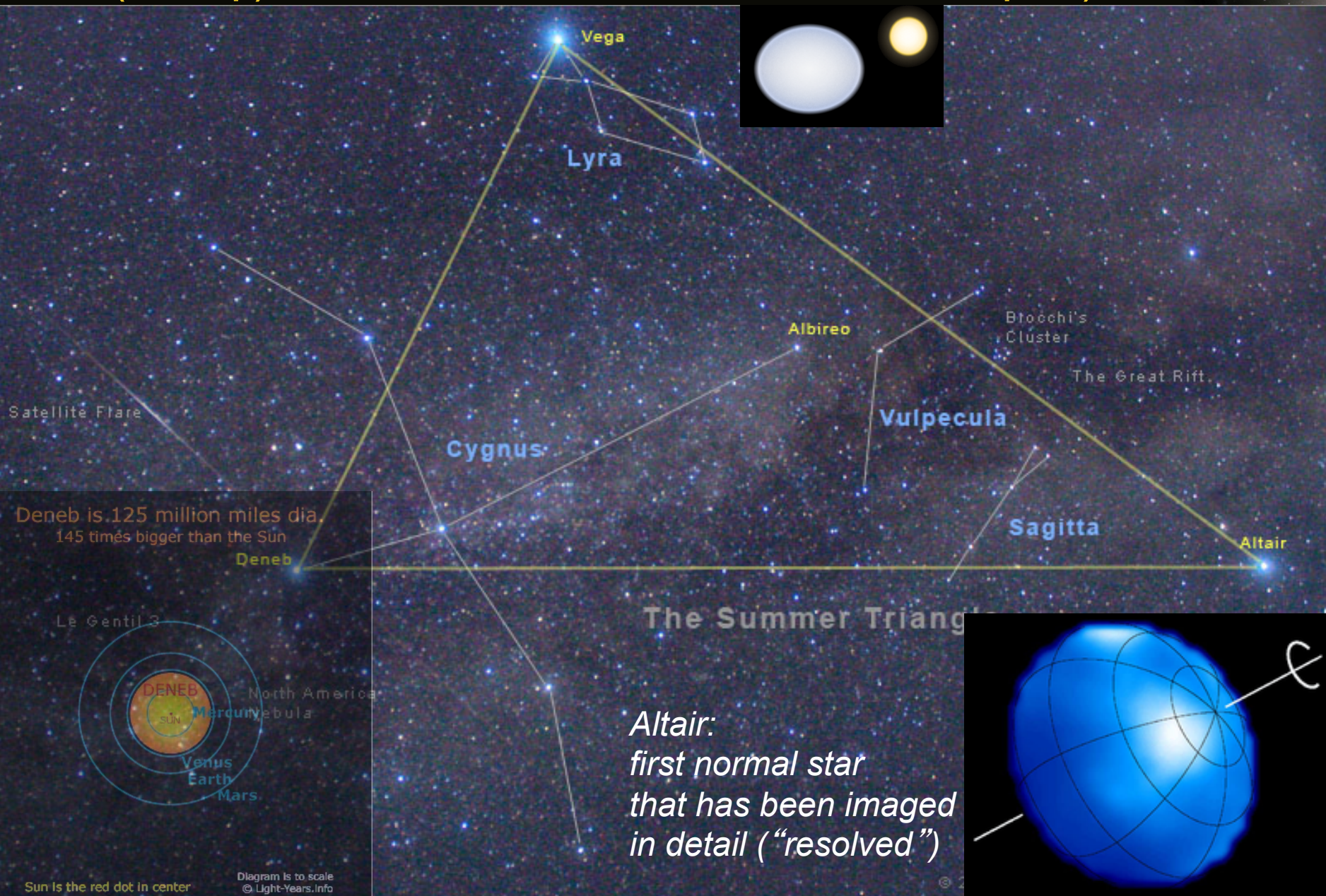


The Summer Triangle

The stars of the Summer Triangle (L = luminosity)

Altair (α Aquilae)	L = 10 L(sun)	d = 16.6 ly
Vega (α Lyrae)	L = 52 L(sun)	d = 25 ly
Deneb (α Cygni)	L = 70000 L(sun)	d = 1550 ly

Summer triangle: Vega (α Lyr), Deneb (α Cyg), Altair (α Aql), modern results on sizes and shapes



The Qixi Festival (Chinese: 七夕節), on 7th day of 7th lunar month of each year (Tanabata in Japan)

Vega
織女 (Zhī Nǚ, English: Weaver Girl)
Lyra Orihime (織姫 Weaving Princess)

γαλαξίας κύκλος (galaxías kýklos)

via lactea,
Satellite Flare

Amanogawa (天の川 Milky Way, lit. "heavenly river")

鹊桥, "the bridge of magpies",

Que Qiao
North America Nebula

Albireo

Brocchi's Cluster

The Great Rift

An-nasr aṭ-ṭā'ir
Flying eagle

Vulpecula

النسر الطائر

Sagitta

Altair

Deneb

The Summer Triangle

牛郎星 (Niú Láng Xīng)

Hikoboshi (彦星)

Cowherder star

Delphinus

Pre-scientific Astronomy & Astrology

- Priests became important members of society thanks to their ability to predict celestial events, which was viewed as a connection to heavenly deities.
 - The association of celestial objects with one or more gods led to the idea that these gods could affect individual human lives.
 - E.g., Jupiter ← DieoPatr = Heavenly Father in PIE language
- This was the birth of *astrology* – the search for influences on human lives based on the positions of planets and stars in the sky.

Nordic gods found a way into our language

- The days of the week were named in Germanic languages (today: Icelandic, Scandinavian, German, English languages) for the Sun, the Moon, and the five planets visible to the naked eye.
- Mone's dag -> Monday
- Tyr's dag → Tuesday
- Odin's dag → Wednesday
- Thor's dag → Thursday
- Freja's dag → Friday
- Saturn's day → Saturday
- Sun's day → Sunday

ASTROLOGY

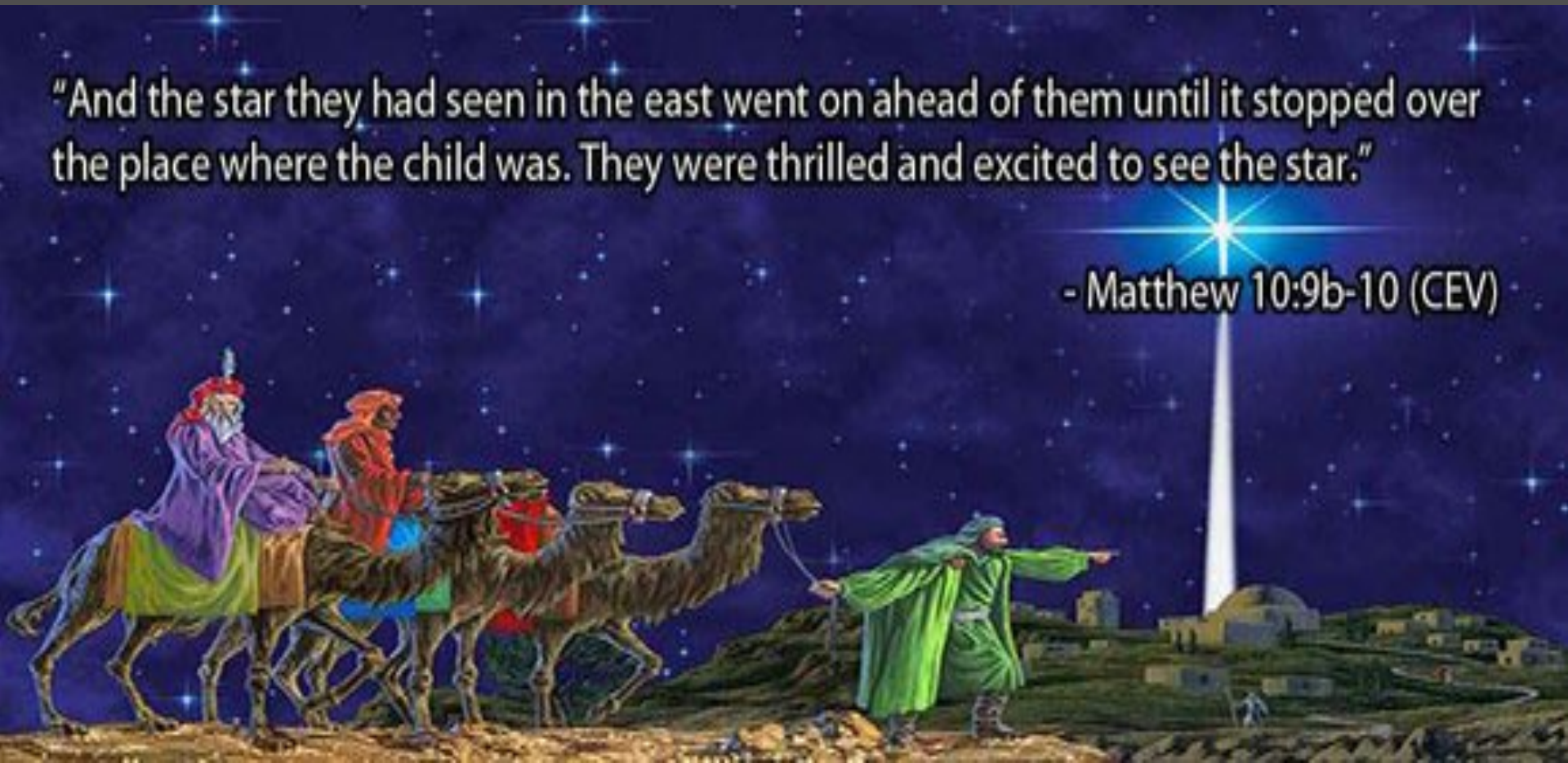
- We will deal in ASTB03 with astronomy not astrology
- Astrology is guessing the best time to do important things (electoral astrology), or a persons character or future (natal astrology), or finding an answer to a question (mundane a.) from the positions and patterns of planets in the sky. It is non-scientific and unproven, but popular, partly because horoscopes and predictions sell well. In the past, it was used in place of today's medicine and meteorology as well.
- *Numerous scientific tests have shown that astrological predictions are no more accurate than we should expect from pure chance.*

Astronomical observation in Christian Scriptures?

- What was the “Star of Bethlehem” in the Nativity of Jesus? A comet?

“And the star they had seen in the east went on ahead of them until it stopped over the place where the child was. They were thrilled and excited to see the star.”

- Matthew 10:9b-10 (CEV)



Probably, a visit from astrologists from the East

- Giotto di Bondone picture Adoration of Magi (1304) shows a comet,
- But no bright comets appeared around that time

Plus, a comet would not be
A good omen !



Likely astronomical (scientific) explanation

Birth of Jesus was miscounted to year 1 of CE by medieval monk. Already Johan Kepler in 1500s confirmed that and thought that it happened in year 6 BC.

* *

Conjunction (close approach on the sky) of Saturn and Jupiter took place in the year 7 B.C.

and

Zodiacal Light (sunlight scattered back to Earth by numerous tiny dust particles in a disk of the solar system; those dust particles come from evaporating comets and colliding asteroids)



A moonless night (new moon) on 14 Nov 7 BCE was like this:

- Jupiter and the cone of Zodiacal Light, Sinai Peninsula,
- in 6 BC & 2011 CE



Two planets close together = conjunction

- Jupiter and Saturn conjunction in the constellation of Pisces (Fish) – symbol of Palestine and Judea
- Might have been enough of a celestial event to cause Babylonian or Persian astrologers (Magi, Wise Men) to undertake a long camel trip to Jerusalem
- There, as known from historical sources and scriptures, advisors to king Herod said the visitors should go to Bethlehem, a nearby village, where someone important might have been born (Jesus Christ)
- If they departed in the afternoon on foot, on a moonless night of 14 Nov 7 B.C, they'd have seen a very strong cone of light shining toward the horizon from the “star of Bethlehem”, in fact Jupiter+Saturn.
- Thus the biblical story might be astronomically correct

A scientific explanation points to November as time of the possible visit of the Wise Men to Jesus Christ

- This is how astronauts saw a bright Venus and Earth in 1966, Zodiacal light also seen



Comets → debris → enhanced Zodiacal Light & meteor showers → meteorites

The dust from comet Tempel-Tuttle enhanced the Zodiac Light on 7 Nov BCE. (Leonids meteor showers coming apparently from constellation Leo every year in mid-November are associated with comet 55P/Tempel-Tuttle)

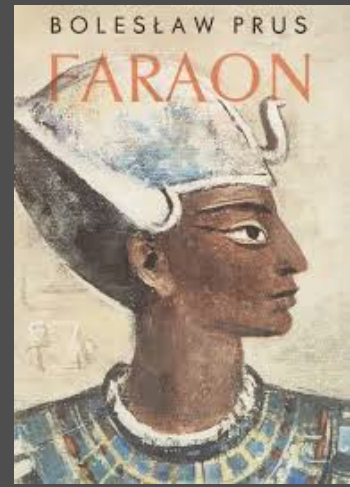


meteor shower



A Brief History of Ancient Astronomy

- Astronomical observations benefited and impacted ancient societies in many ways, including timekeeping, efficient agricultural practices, navigation, and the religious and ceremonial practices
- Egyptian priests might have benefitted politically from ability to predict **solar eclipses**, which were presented as acts of anger of gods. This was used in a work of fiction
- “The Pharaoh” novel about their power struggle with the pharaohs by Bolesław Prus



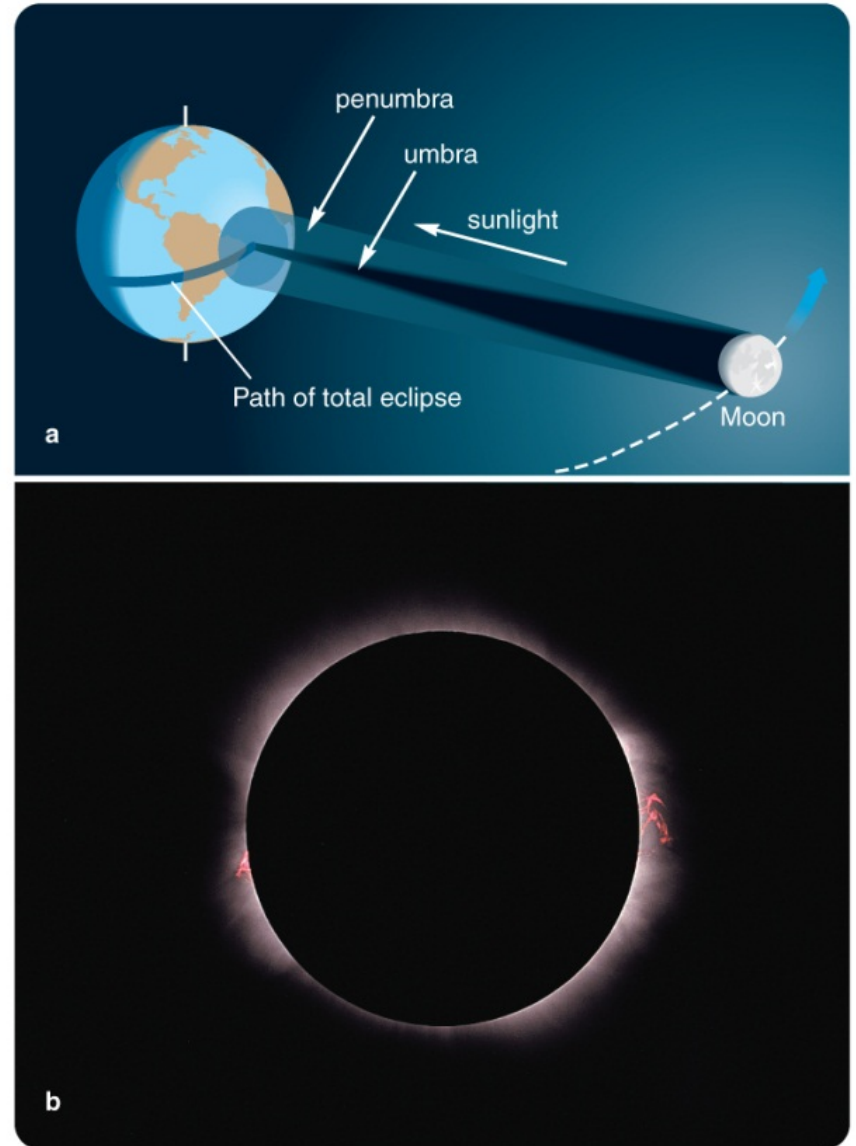
What did the ancient observe:

- **Solar Eclipses**
- Total darkness lasts only a few minutes. The period of totality lasts on average only 2 or 3 minutes and never more than 7.5 minutes.
 - This is because the darkest part of shadow (umbra) is never more than 270 km in diameter on Earth's surface and sweeps across the landscape at over 1600 km/hr.

Solar Eclipses

- During totality you can see subtle features of the Sun's atmosphere.
 - These include red flame-like projections that are visible only during those moments when the brilliant disk of the Sun is completely covered by the Moon.

Figure 2.7



Solar eclipse

2012



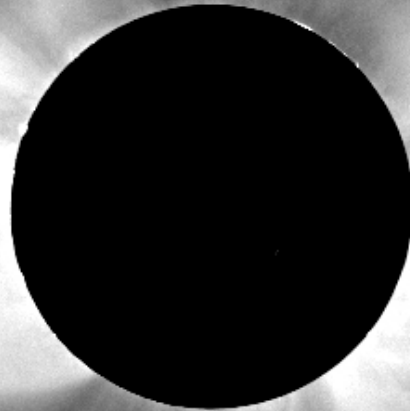
Solar eclipse

2012



Solar eclipse – the active sun

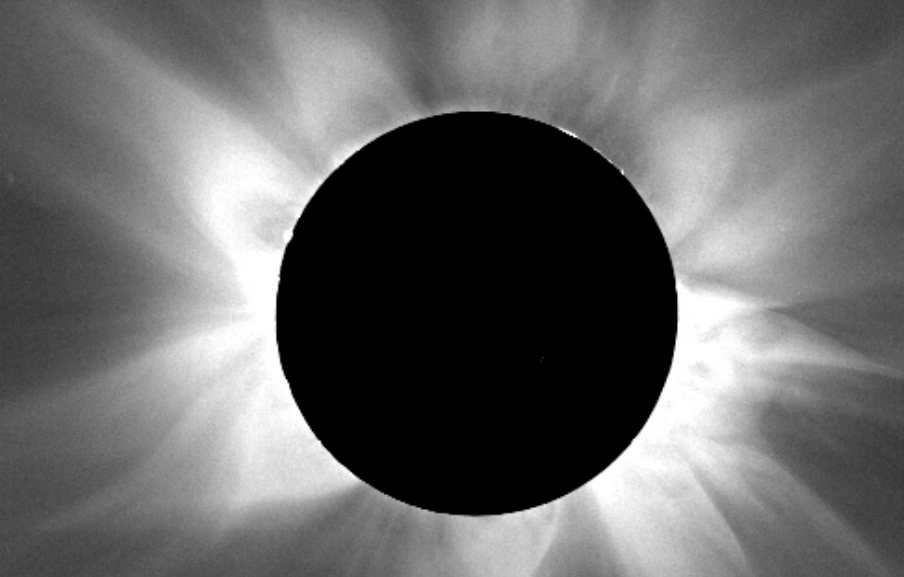
1980



Solar eclipse - the active sun

The white streamers are the upper layers of the solar atmosphere called Corona (that is, crown).

It is a nonuniform, outflowing part of the sun, gradually becoming the rarified **solar wind** that flows past the Earth and planets (mainly, ionized hydrogen and helium, and the free electrons)



Streamers emanate from regions called coronal holes, where the magnetic field lines leave the sun & flow out into space

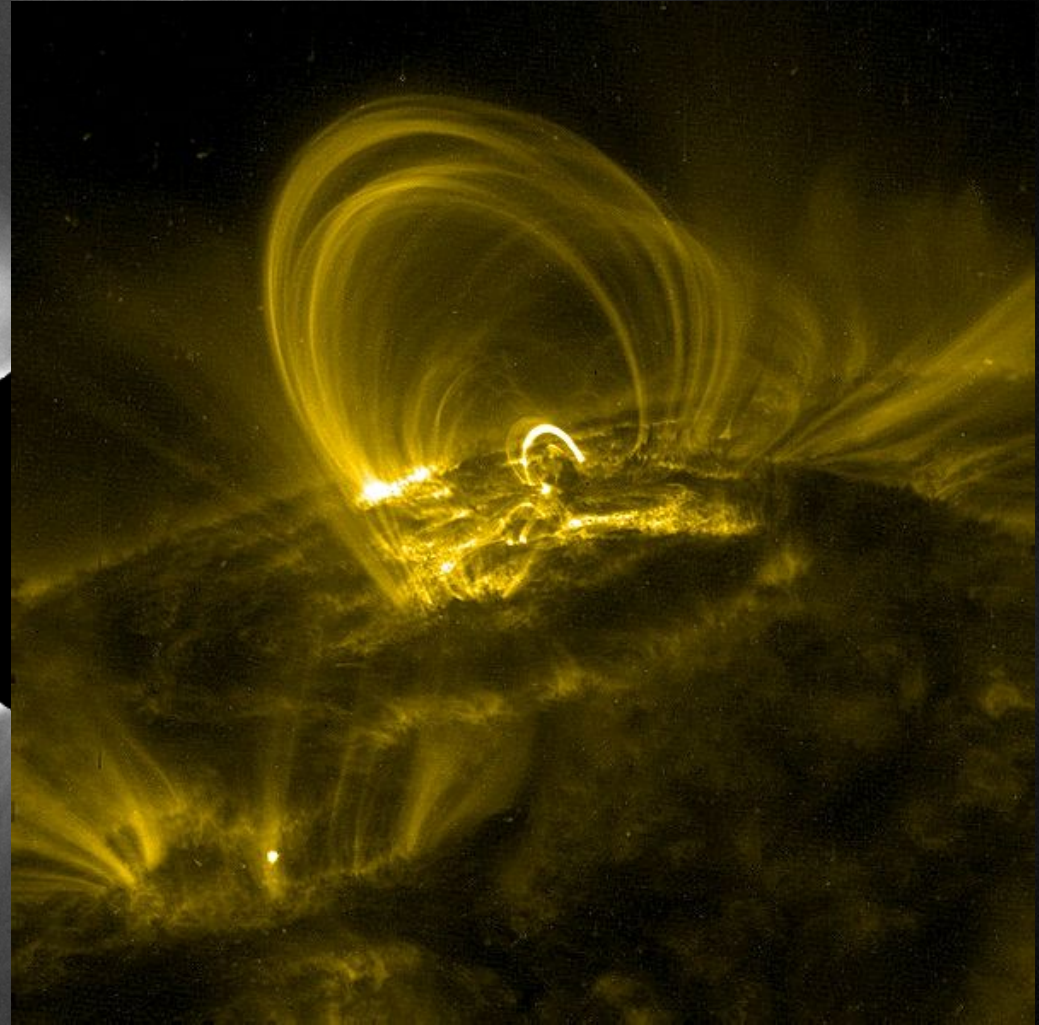
Solar eclipse - the active sun

How does the sun get its corona?

(i) Hot temperature causing the outflow – 1 mln Kelvin

(ii) Magnetic fields, the so-called Reconnection of loops.

Loops are regions where gas flows along magnetic field tubes.



Ultraviolet picture of the coronal loop

The sun is an active star

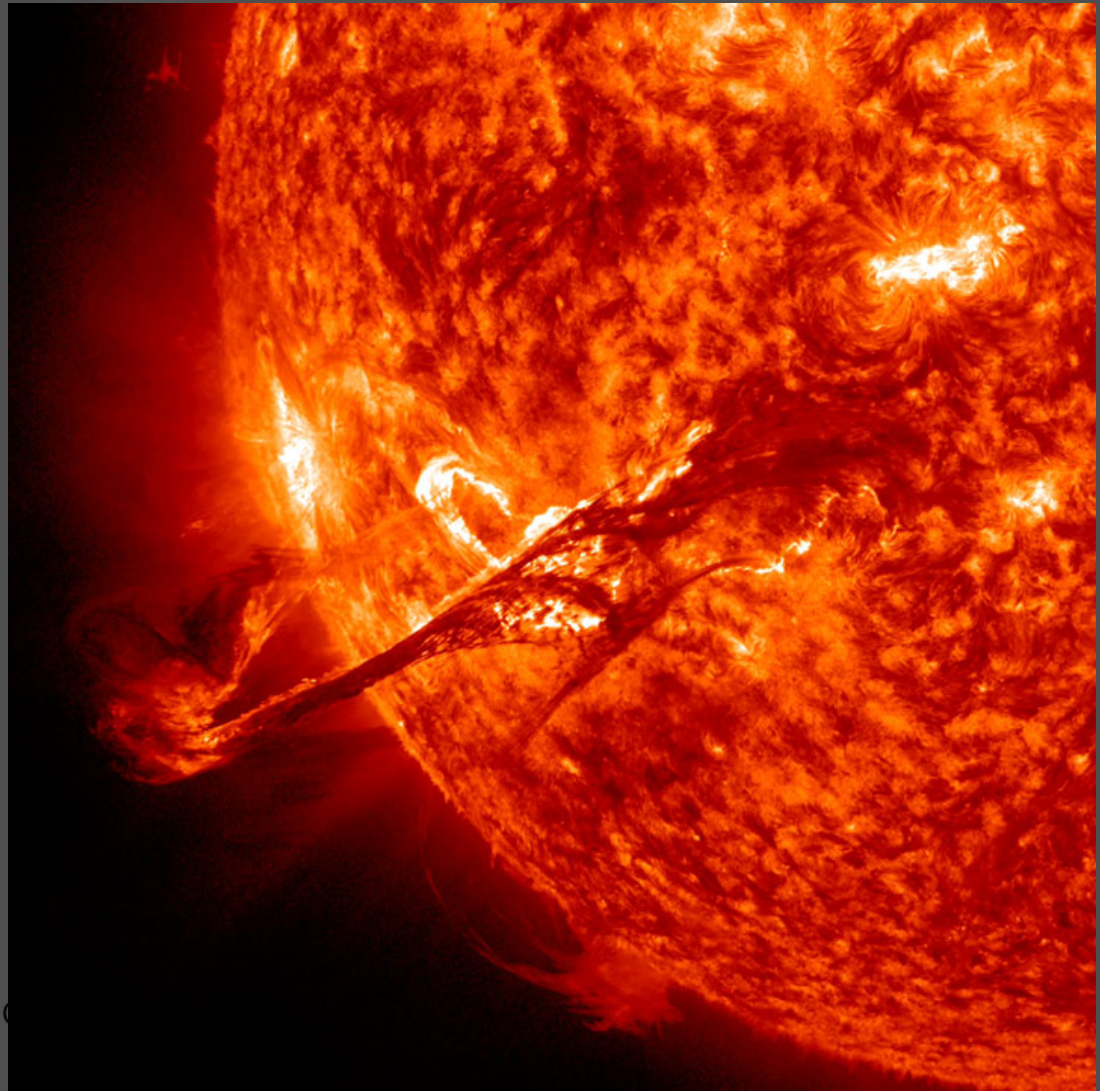
A solar flare



The sun is an active star (here, in extreme UV)

Solar Dynamics Observatory – satellite observatory

<http://www.youtube.com/watch?v=QrmUUcr4HXg>



Solar Eclipses - ANNULAR



- Sometimes, when the Moon crosses in front of the Sun, it is too small to fully cover the Sun.
 - Then, you would witness an annular eclipse.
 - This is a solar eclipse in which an annulus (‘ring’) of the Sun’ s disk is visible around the disk of the Moon.

This type of eclipse never becomes totally dark. Also, there are partial eclipses, which people don’t notice if not warned (they think a cloud covered the sun)

Solar Eclipses

- Annular eclipses occur because the Moon follows a slightly elliptical orbit around Earth.
 - If the Moon is in the farther part of its orbit during totality, its apparent diameter will be less than the apparent diameter of the Sun, and you see an annular eclipse.
- Also, Earth's orbit is slightly elliptical.
 - As a result, both the Earth-to-Sun distance and the apparent diameter of the solar disk vary slightly.
 - These contribute to the effect of the Moon's varying apparent size.

Solar Eclipses

- If you plan to observe a solar eclipse, remember that the **Sun is bright enough to burn your eyes** and cause permanent damage if you look at it through any optical instrument, even small binoculars
 - This is true whether there is an eclipse or not: for safety it's better not to look at the sun directly even w/o the instruments

Recent Solar Eclipses

- **Table 2.1** none in 2014, one in 2015 and two in 2016; also two solar eclipses in 2021.

Date	Total or Annular (T/A)	Time of Mid-eclipse** (GMT)	Maximum Length of Total or Annular Phase (Min:Sec)	Area of Visibility
2012 May 20	A	23 ^h	5:46	Japan, N. Pacific, W. USA
2012 Nov. 13	T	22 ^h	4:02	Australia, S. Pacific
2013 May 10	A	0 ^h	6:04	Australia, Pacific
2013 Nov. 3	AT	13 ^h	1:40	Atlantic, Africa
2015 March 20	T	10 ^h	2:47	N. Atlantic, Arctic
2016 March 9	T	2 ^h	4:10	Borneo, Pacific
2016 Sept. 1	A	9 ^h	3:06	Atlantic, Africa, Indian Ocean
2017 Feb. 26	A	15 ^h	1:22	S. Pacific, S. America, Africa
2017 Aug. 21	T	18 ^h	2:40	Pacific, USA, Atlantic
2019 July 2	T	19 ^h	4:33	Pacific, S. America
2019 Dec. 26	A	5 ^h	3:39	Asia, Australia
2020 June 21	A	7 ^h	0:38	Africa, Asia
2020 Dec. 14	T	16 ^h	2:10	Pacific, S. America

The next major total solar eclipse visible from North America will occur on August 21, 2017, when the path of totality will cross the United States from Oregon to South Carolina.

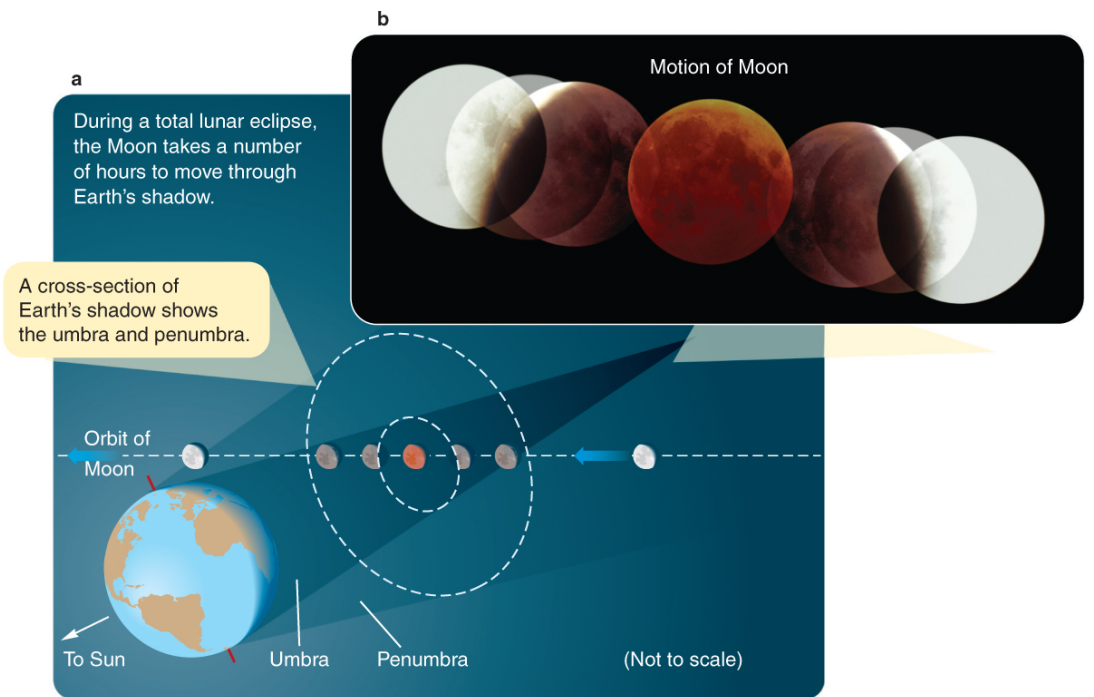
Another type: Lunar Eclipses

If you were on the Moon during totality, you would not see any part of the Sun directly

- It would be entirely hidden in large Earth's shadow
- But you would be able to see Earth's atmosphere lit from behind by the Sun as ring

Thus the moon does not disappear, it becomes dark dark red (blue light is scattered out by Earth's atmosphere - hence the blue sky!)

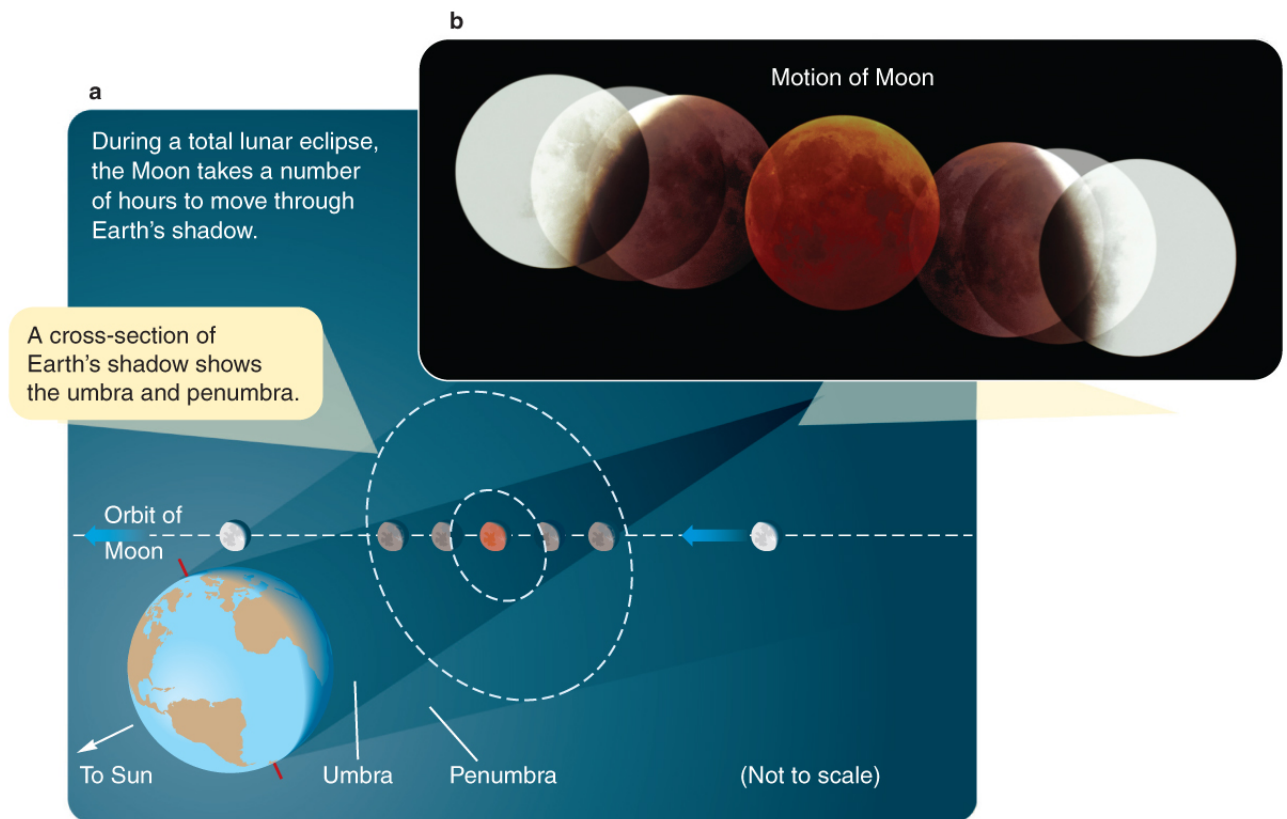
Figure 2.9



Lunar Eclipses – in other words..

The red glow from this ring consisting of all the Earth's simultaneous sunsets and sunrises illuminates the Moon during totality and makes it glow coppery red.

Figure 2.9



Lunar Eclipses – how often?

- Lunar eclipses always occur at full moon but not at every full moon! Here is why:
 - The Moon's orbit is tipped about 5 degrees to the ecliptic. So, most full moons cross the sky north or south of Earth's shadow and there is no lunar eclipse that month.
 - For the same reason, solar eclipses always occur at new moon but not at every new moon.

Figure 2.10



Understanding lunar eclipses

- Although there are usually no more than one or two lunar eclipses each year, it is not difficult to see one.
 - You need only be on the dark side of Earth when the Moon passes through Earth's shadow.
 - That is, the eclipse must occur between sunset and sunrise at your location to be visible
 - The whole hemisphere sees the lunar eclipse
 - In contrast, very few places on Earth see the eclipse of the sun, especially the total eclipse

Lunar Eclipses

recent lunar eclipses

Date	Time** of Mid-eclipse (GMT)	Length of Totality (Hr:Min)	Length of Eclipse† (Hr:Min)
2012 June 4	11:03	Partial	2:08
2013 April 25	20:10	Partial	0:28
2014 April 15	7:48	1:18	3:34
2014 Oct. 8	10:55	0:58	3:18
2015 April 4	12:02	Partial	3:28
2015 Sept. 28	2:48	1:12	3:30
2017 Aug. 7	18:22	Partial	1:54
2018 Jan. 31	13:31	1:16	3:23
2018 July 27	20:23	1:43	3:55
2019 Jan. 21	5:13	1:02	3:17
2019 July 16	21:32	Partial	2:58

*There are no total or partial lunar eclipses during 2016 or 2020.

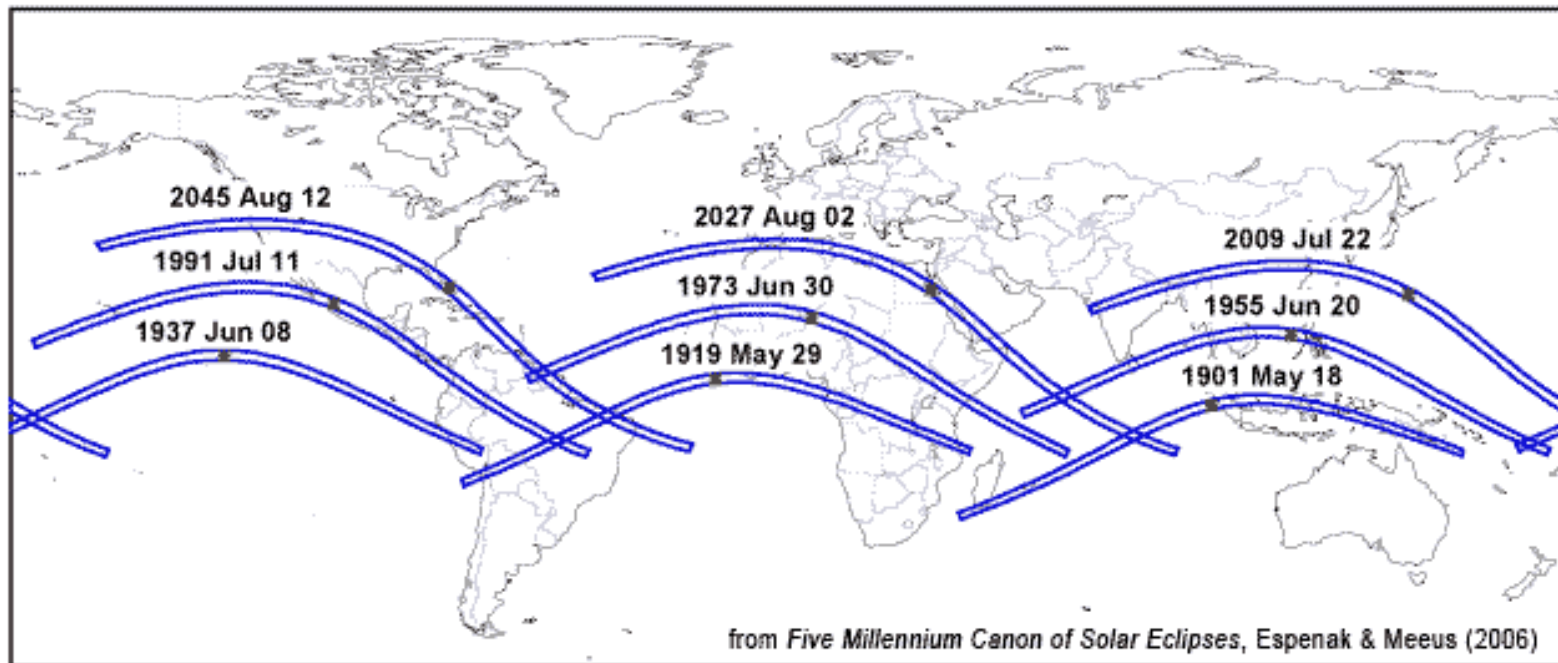
**Times are Greenwich Mean Time. Subtract 5 hours for Eastern Standard Time, 6 hours for Central Standard Time, 7 hours for Mountain Standard Time, and 8 hours for Pacific Standard Time. For Daylight Savings Time, add 1 hour to Standard Time. From your time zone, lunar eclipses that occur between sunset and sunrise will be visible, and those at midnight will be best placed.

†Does not include penumbral phase.

Lunar Eclipses

- The orientation of the Moon's orbit in space varies slowly. As a result, solar and lunar eclipses repeat in a pattern called the Saros cycle, lasting 18 years 11 days 8 hours. Ancient people who understood this **Saros cycle** could predict eclipses without understanding what the Sun and Moon really were.

Figure 1 — Eclipses from Saros 136: 1901 to 2045



Transition to ancient Greek astronomy

- Pre-scientific astronomy had only involved making observations, recognizing patterns, and making rudimentary predictions. A crucial part of the scientific method – **building and testing models and hypotheses** – was apparently missing
- This was about to change in **Classic Ancient Greece**, civilization which did grow and blossomed on the ashes of earlier, very high-tech civilizations of the Mediterranean. These civilizations lived and traded in a world resembling modern, globalist manner: Hittite, Egyptian, Assyrian, Babylonian, Aegean and Minoan, Mitanni, Mycaenian, Cypriot, Ugarit, Amurru, Assuan, Trojan, Canaani. Following a civilizational catastrophe spurred by migrations of warrior nations (Sea People) from the North, Late Bronze Age (LBA) ended abruptly around 1177 BC (at the time of the Trojan war). ALL the cities of LBA ancient civilizations were burned, and the ability to read and write cuneiform tablets in Akkadian (like English today) vanished.