WELCOME TO Ancient Astronomy Lecture III

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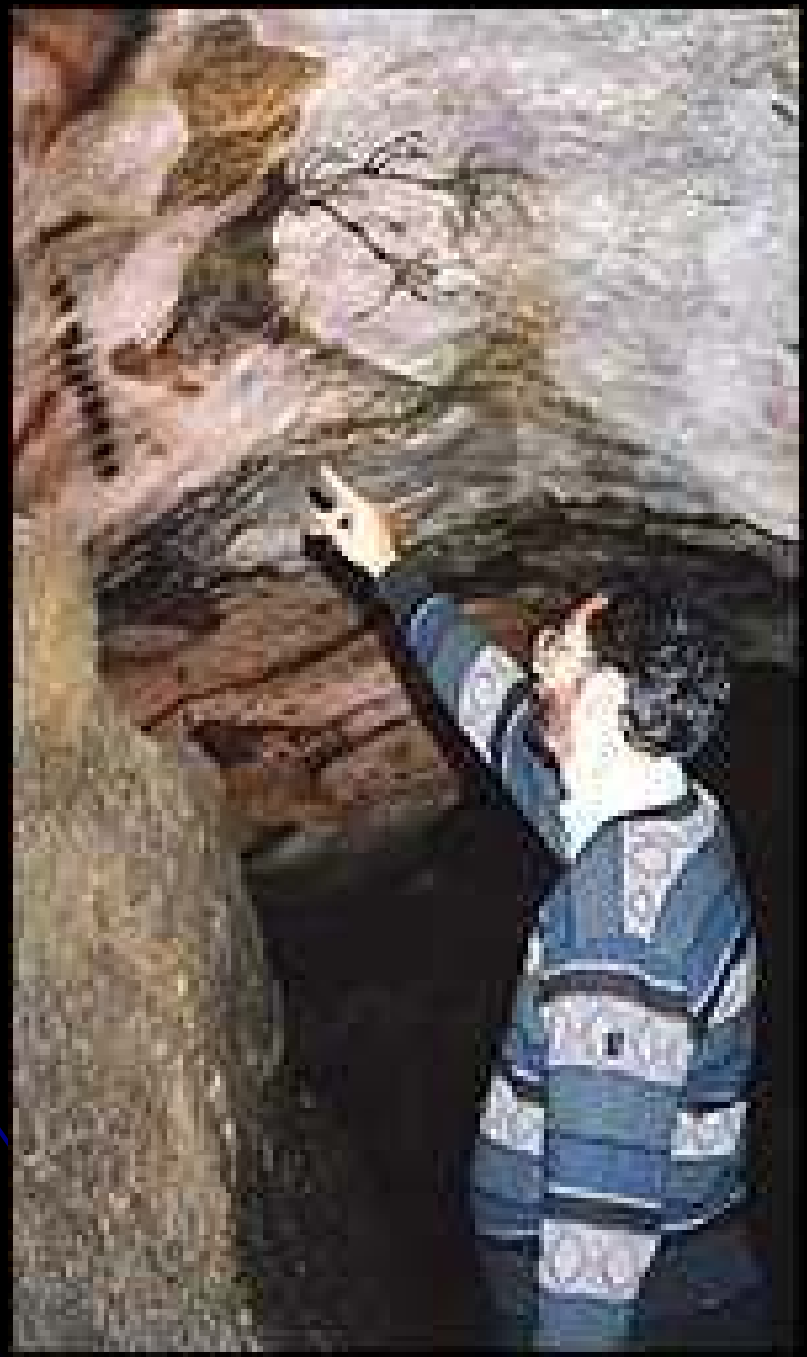
Lectures on the Web

- http://voyager.deanza.edu/~howardp
- Available on-line

Tonight's Lecture

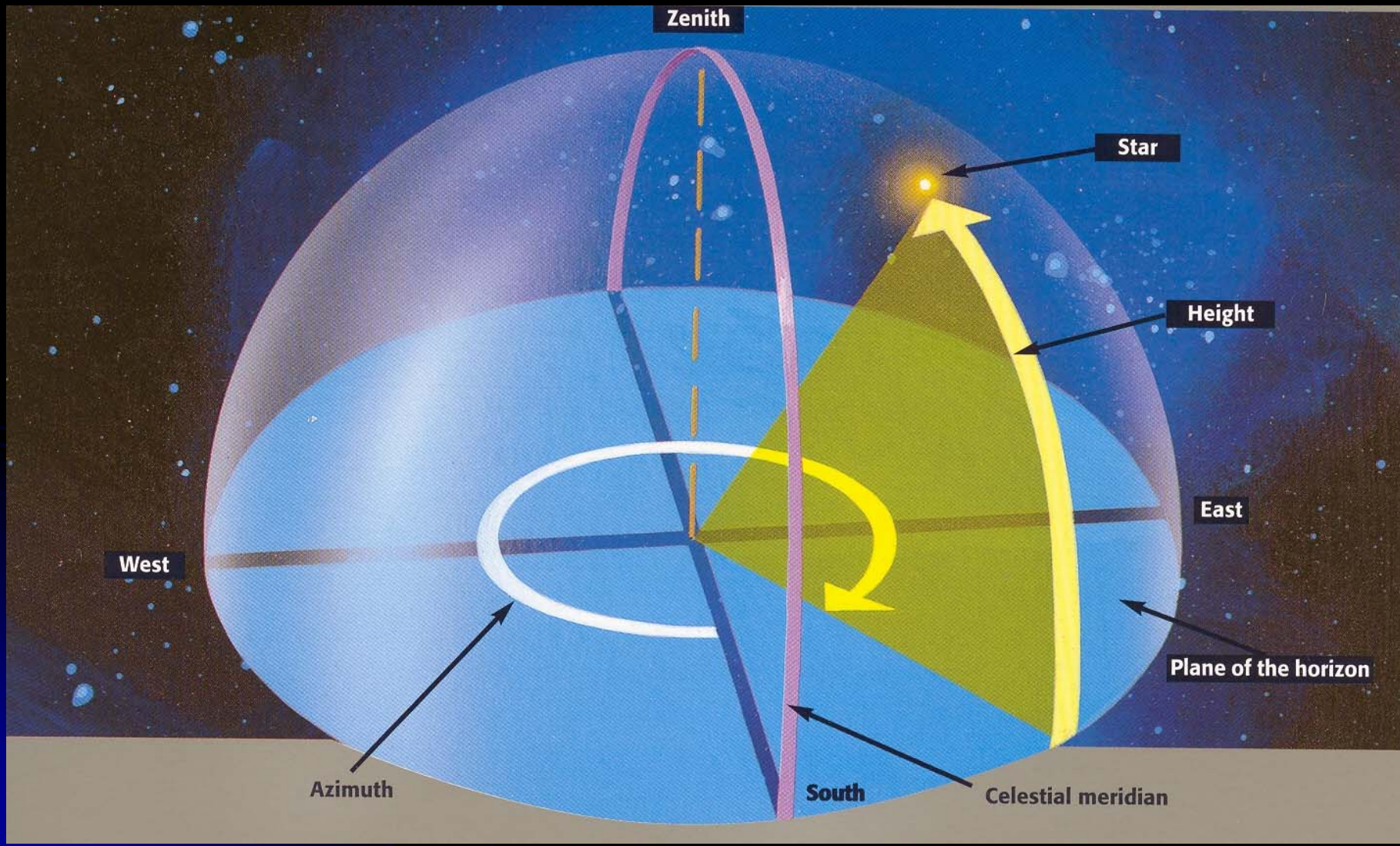
- Mesopotamian astronomy and cosmology
- Origins of the calendar
- Mayan astronomy and cosmology
- Polynesian wayfarers and ancient celestial navigation
- Hellenistic and Roman Period astronomy
  - Ptolemy



Celestial Sphere

Ecliptic Astronomical System
Celestial Coordinates
Absolute System

Relative Coordinates



Celestial Coordinates

- Problem is that altitude and azimuth are relative to the position of the observer
  - Zenith is directly above the head of the observer
  - Nadir is directly under the observer's feet

Celestial Coordinates Cont.

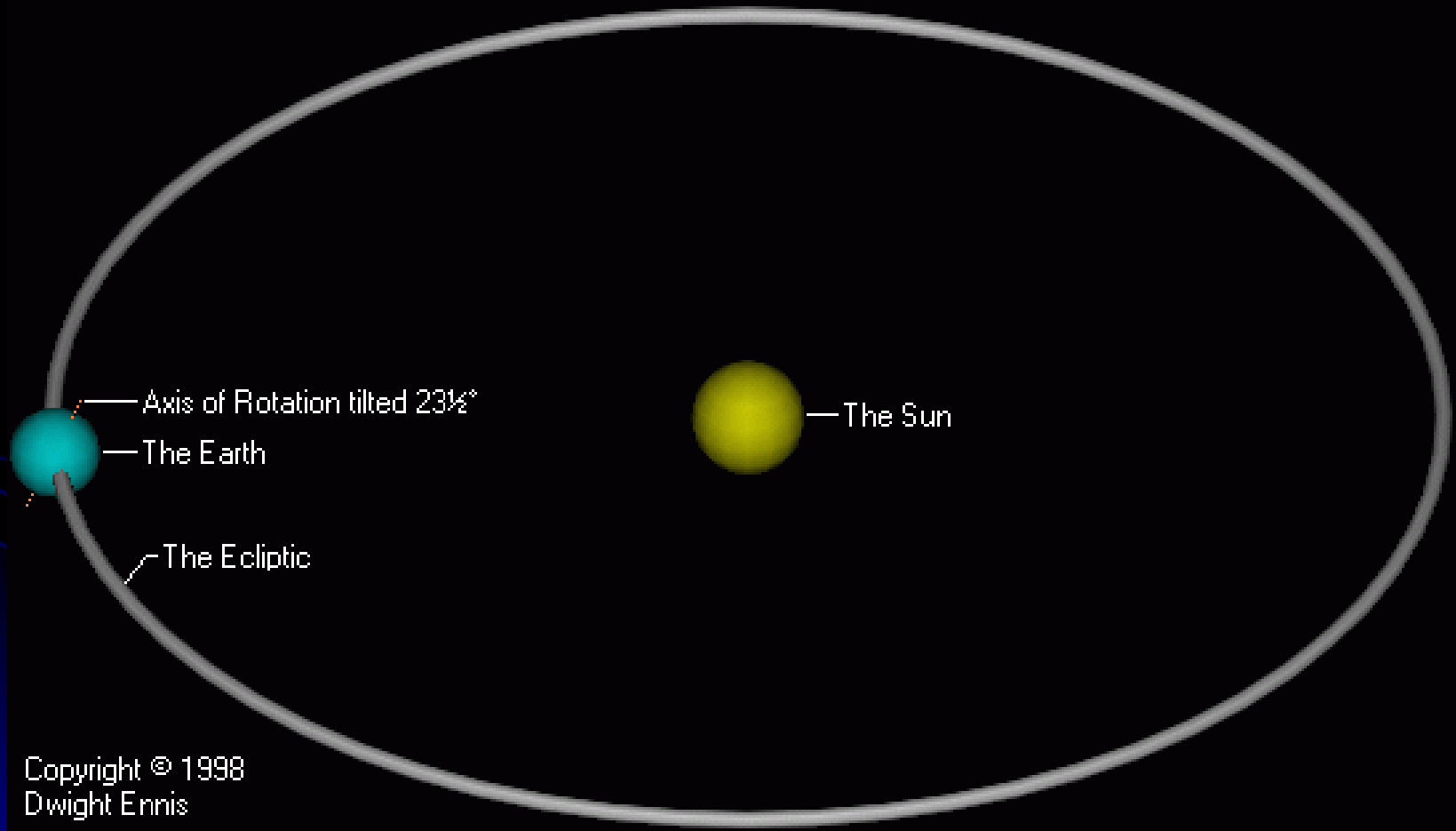
- Earth rotates west to east
- Celestial sphere appears to rotate east to west
  - TRANSIT
    - When an object crosses the meridian to the south
    - CULMINATE
      - Reaches its highest altitude
- Sun, Moon, stars, and planets all “rise” in the east and set in the west

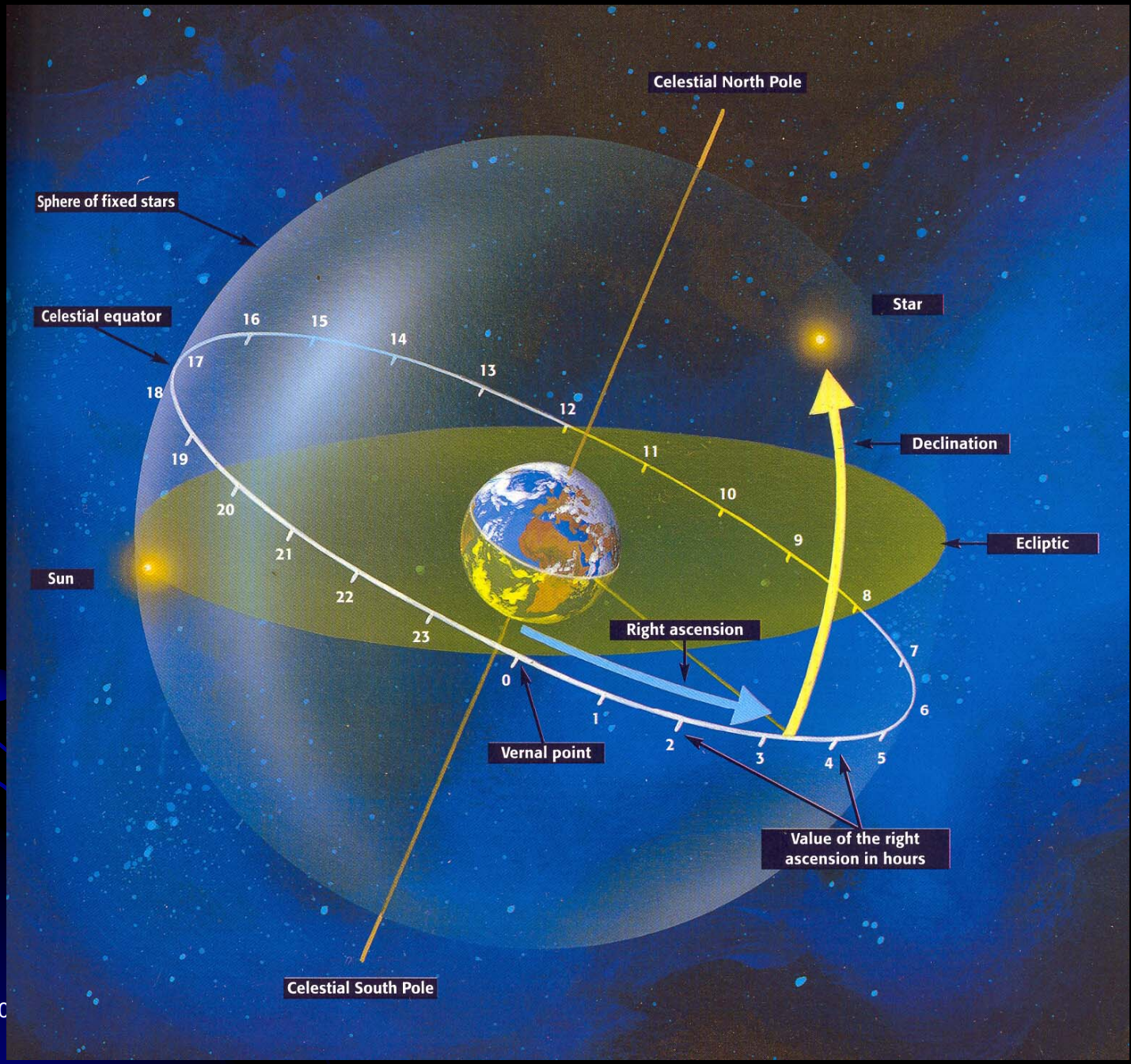
Star Tracks

Star Magnitudes

- Human eye can discern up to ~ 6^{th} magnitude
- Hazy sky or bright lights, bright moon can reduce visibility down to 4^{th}, 5^{th} or 3^{rd} magnitude

Earth's Orbit
The Ecliptic




Celestial North Pole
Sphere of fixed stars
Celestial equator
Star
Declination
Ecliptic
Sun
Right ascension
Vernal point
Value of the right ascension in hours
Celestial South Pole
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Declination

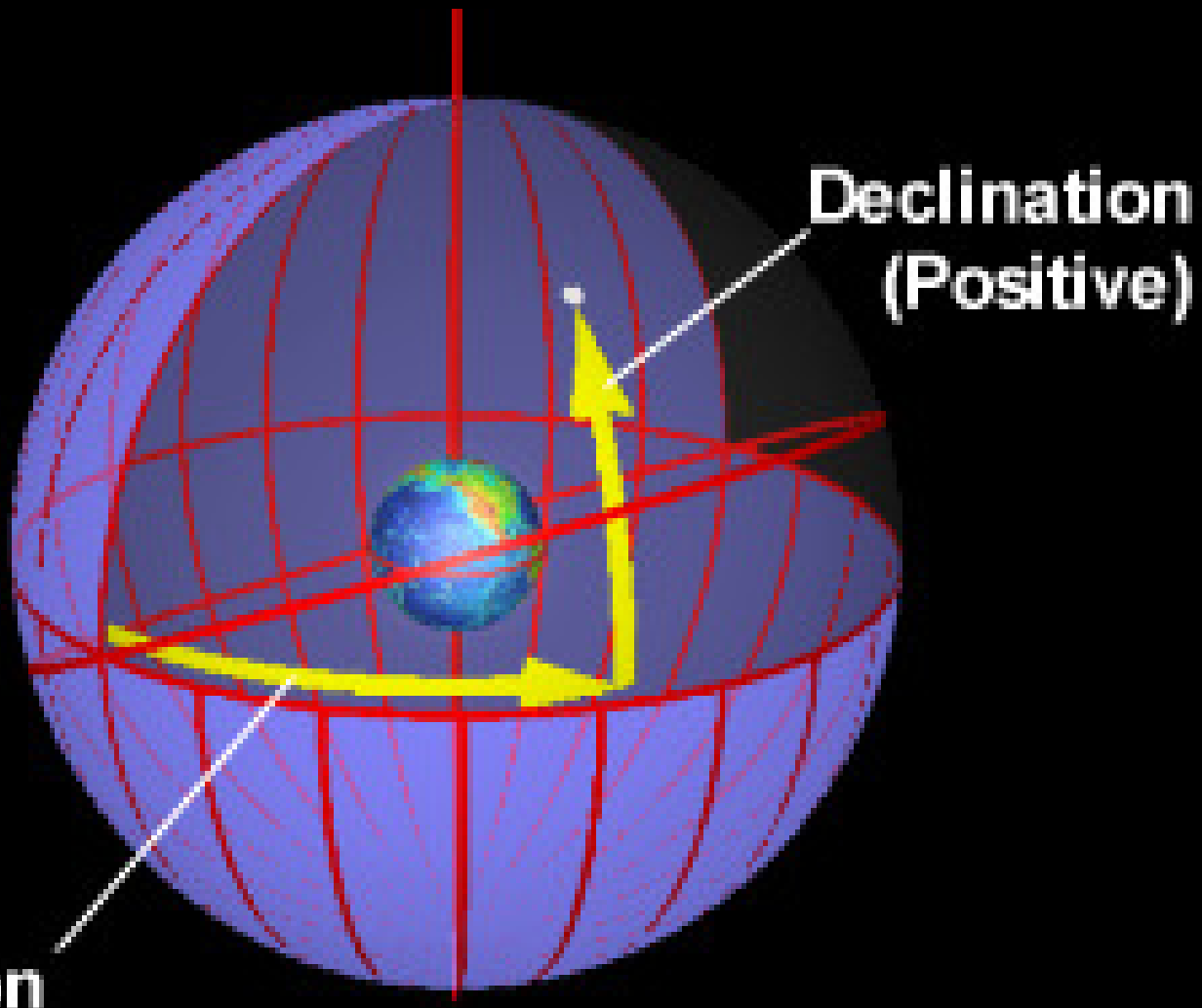
- DECLINATION is measured in degrees north or south of the celestial equator
  - ***Positive*** declinations are ***north*** of the celestial equator
    - North Celestial Pole declination = 90°
  - ***Negative*** declinations are ***south*** of the equator
    - South Celestial Pole declination = -90°
- CELESTIAL EQUATOR
  - On the same plane as the Earth's equator
  - Declination is 0°
- Celestial sphere the movie

Right Ascension

- The equivalent of longitude on earth
- Measured in hours, minutes and seconds to time from the zero line
  - One hour of RA corresponds to 15° (15 degrees)
- Zero Line
  - Ecliptic
- 0^h to 24^h (^{h} = hour)
- Zero Point
  - Point at which the Sun, traveling along the ecliptic, crosses the Celestial Equator from south to north
  - Vernal Equinox (Spring)
  - First Point of Ares
  - Like 0° longitude (Greenwich meridian)

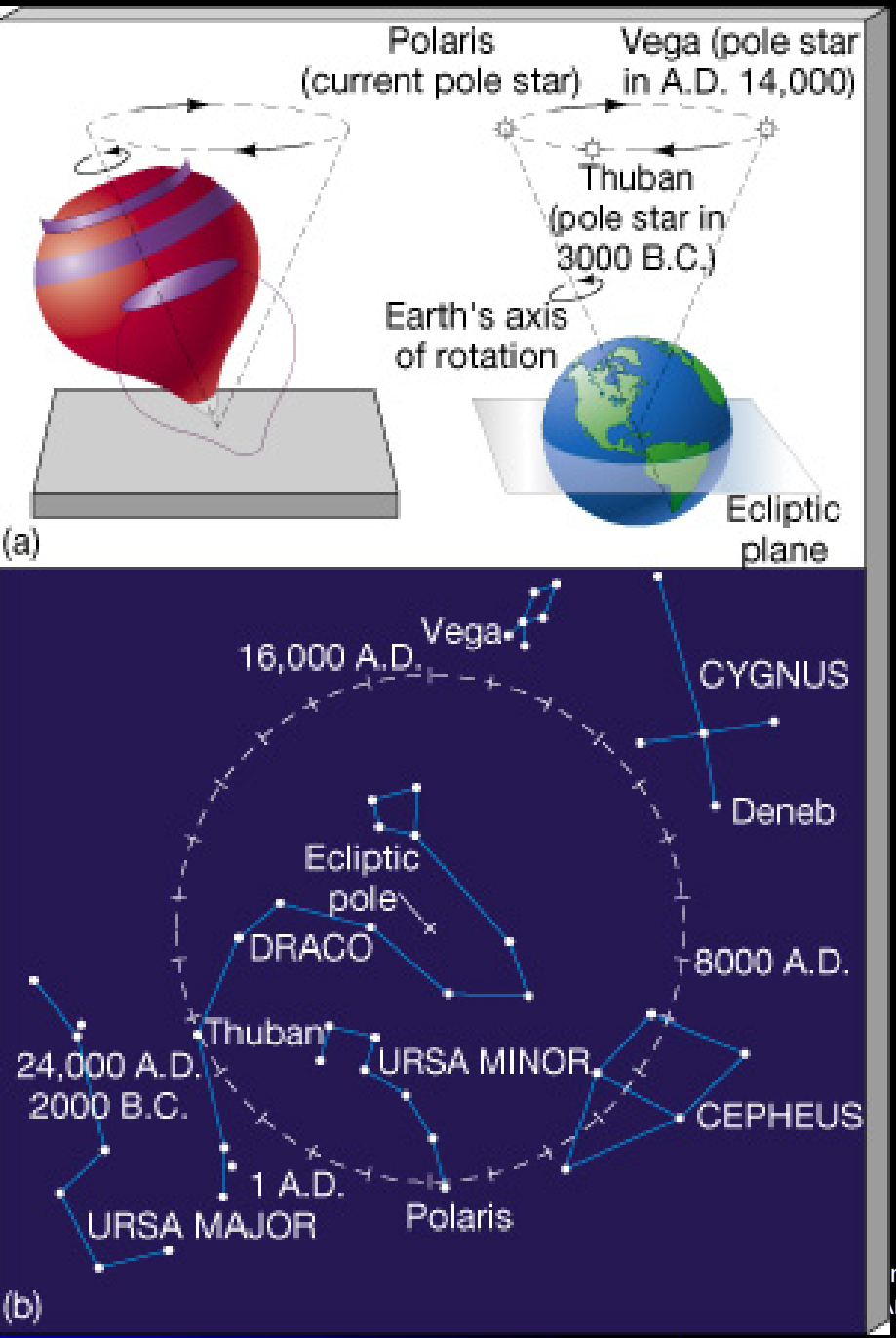
Right Ascension The Movie

Declination
Right Ascension



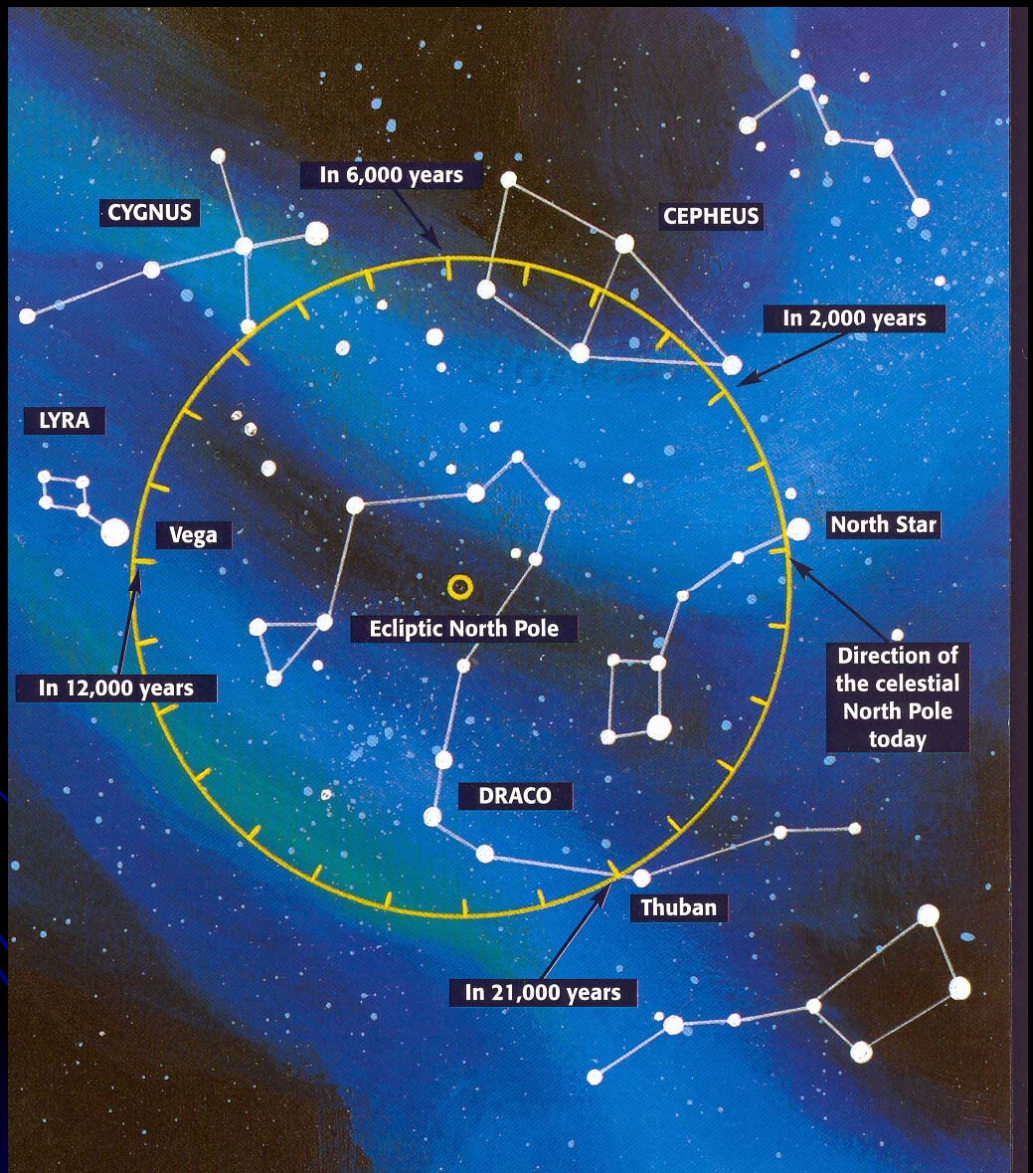
Precession

Precession

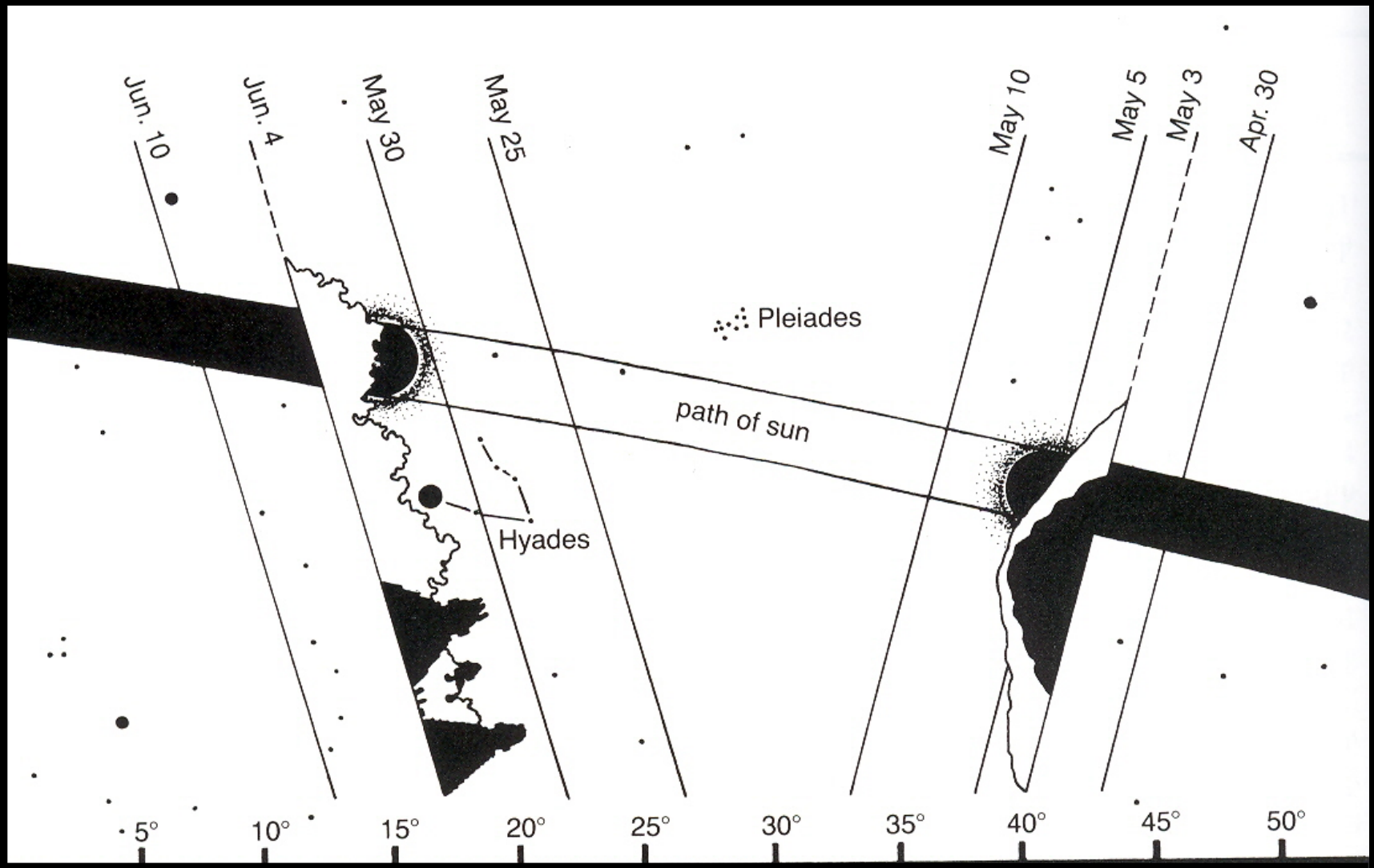


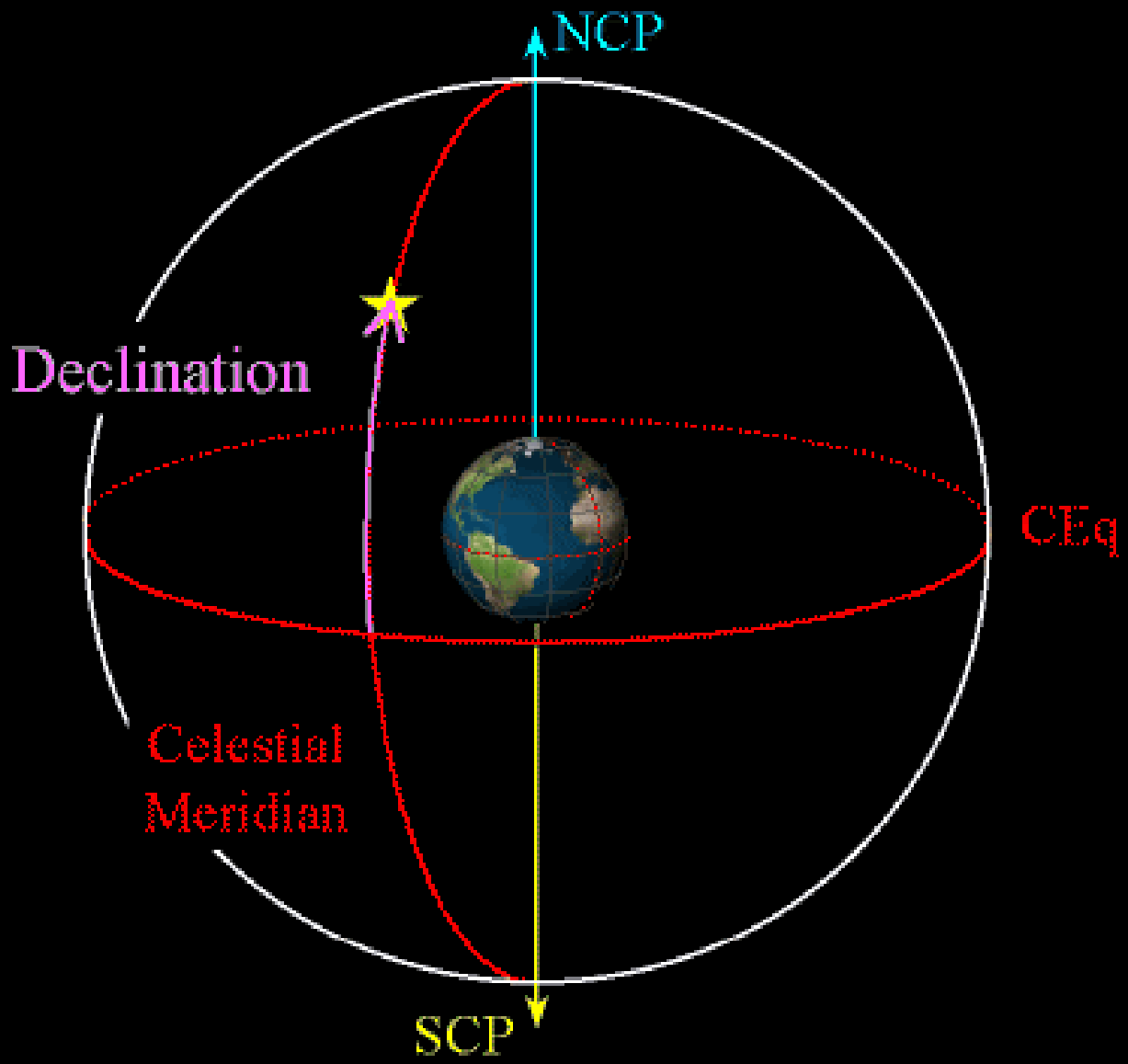
- In 12,000 years Vega will be our “North Star”
- 5,000 years ago Thuban was our “North Star”
- Today Polaris is the “North Star”

Precession


In 6,000 years
CYGNUS
CEPHEUS
In 2,000 years
LYRA
Vega
North Star
Ecliptic North Pole
In 12,000 years
Direction of the celestial North Pole today
DRACO
Thuban
In 21,000 years

Pleiades
Heliacal Rising and Setting




NCP
Declination
CEq
Celestial
Meridian
SCP

Stonehenge Astronomy

Celestial Object Visibility

- Latitude 51° 2’
- Celestial object visibility declinations
  - -39° to +39°
  - Rise and set daily
- Object with high declinations will never set
- Objects with lower declinations
  - Never visible above the horizon

Declinations
4000 – 1500 BCE

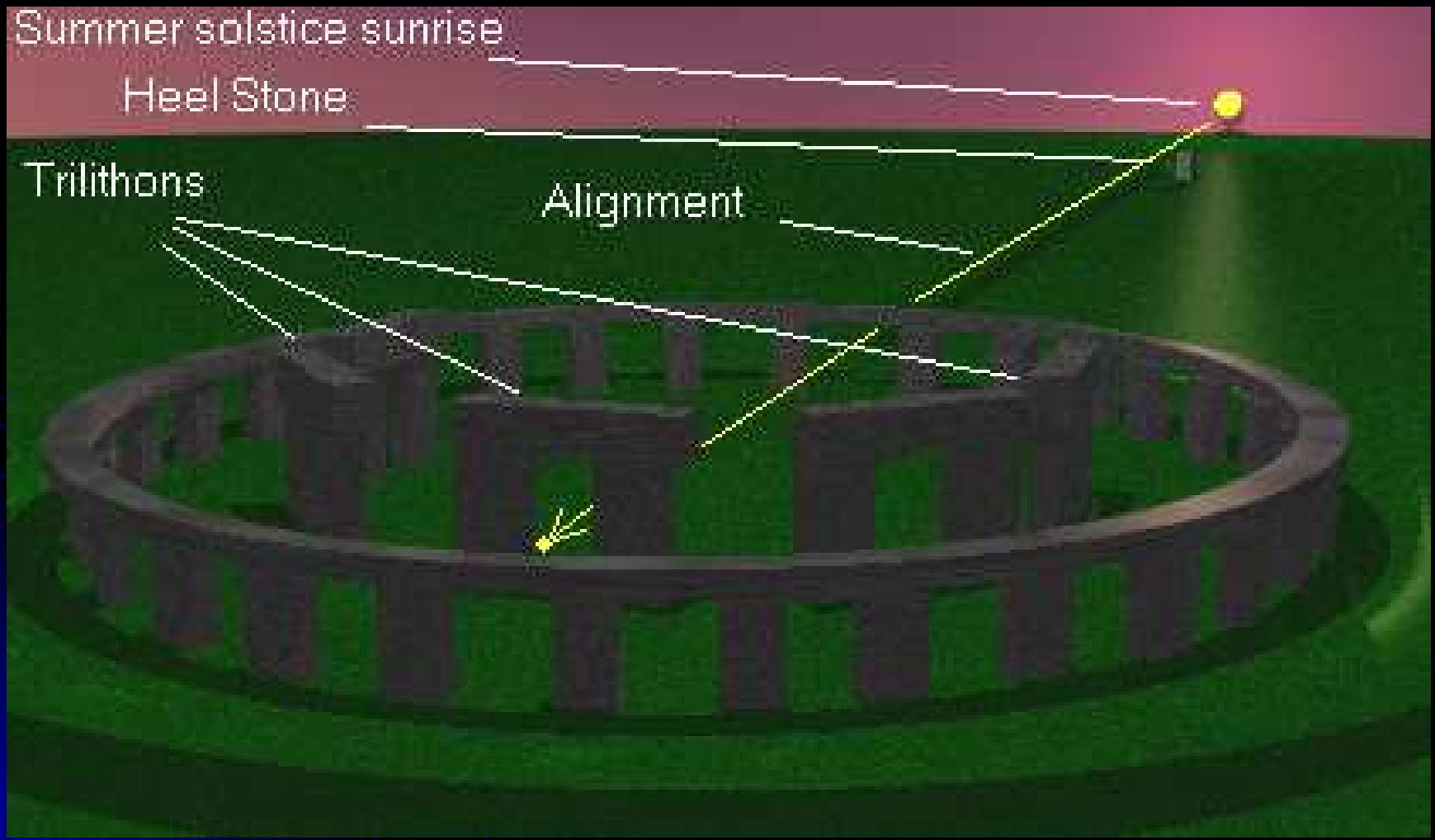
Event	Declination
Moon – northern limit	+28°
Sun : June solstice	+24°
Moon – northern minor limit	+18°
Moon – southern minor limit	-20°
Sun – December solstice	-24°
Moon – southern major limit	-30°

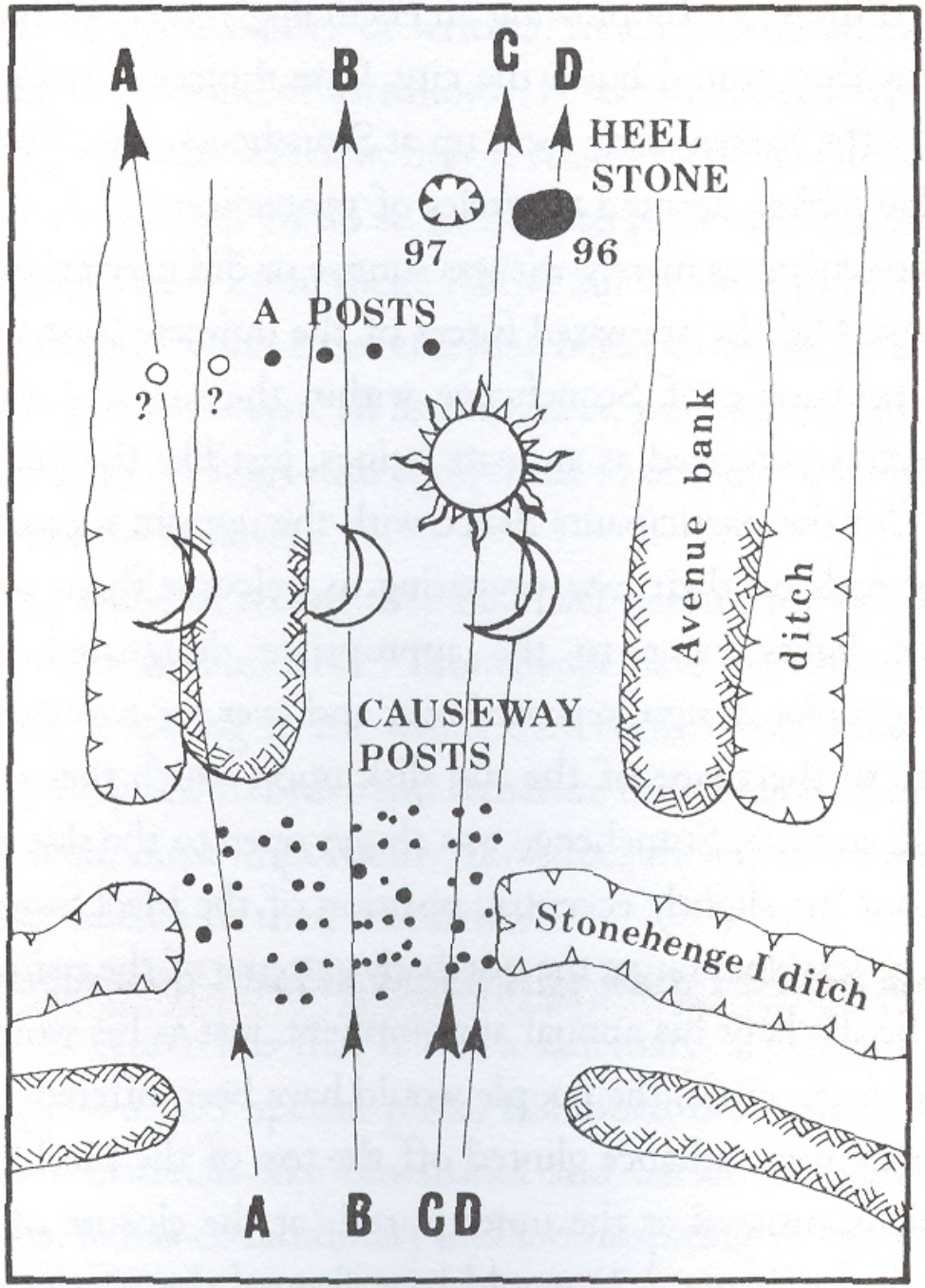
June Solstice

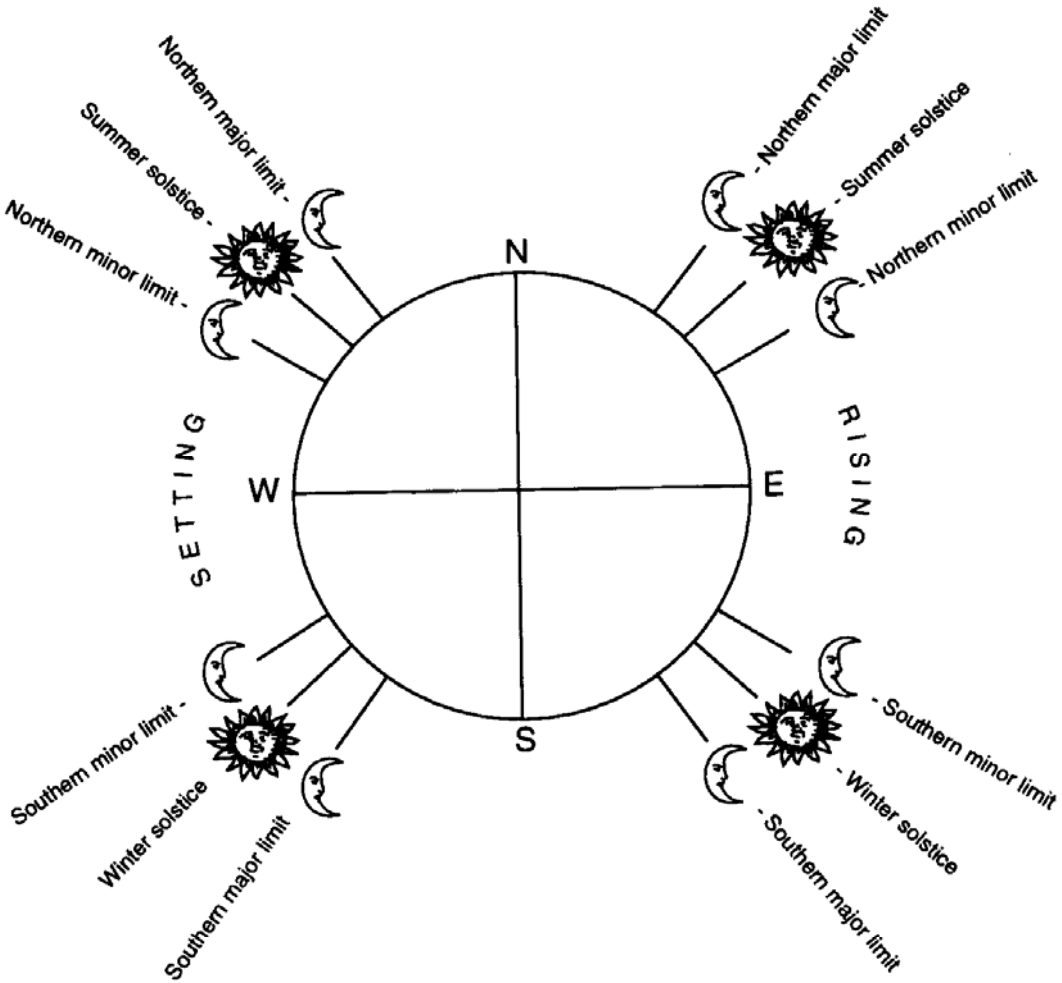
- The sun does NOT rise directly over the Heel Stone

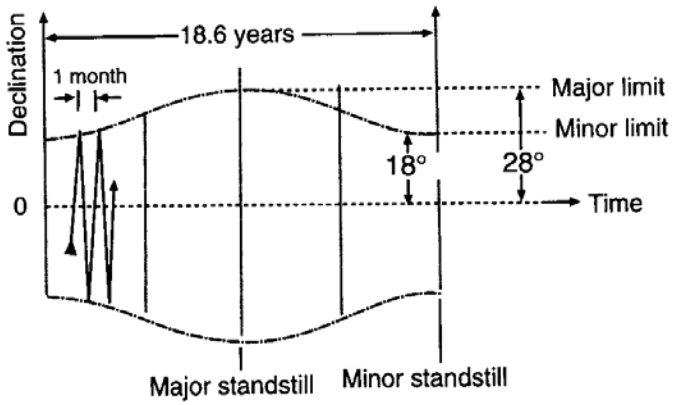
Interactive 360 Panoramic

June Solstice

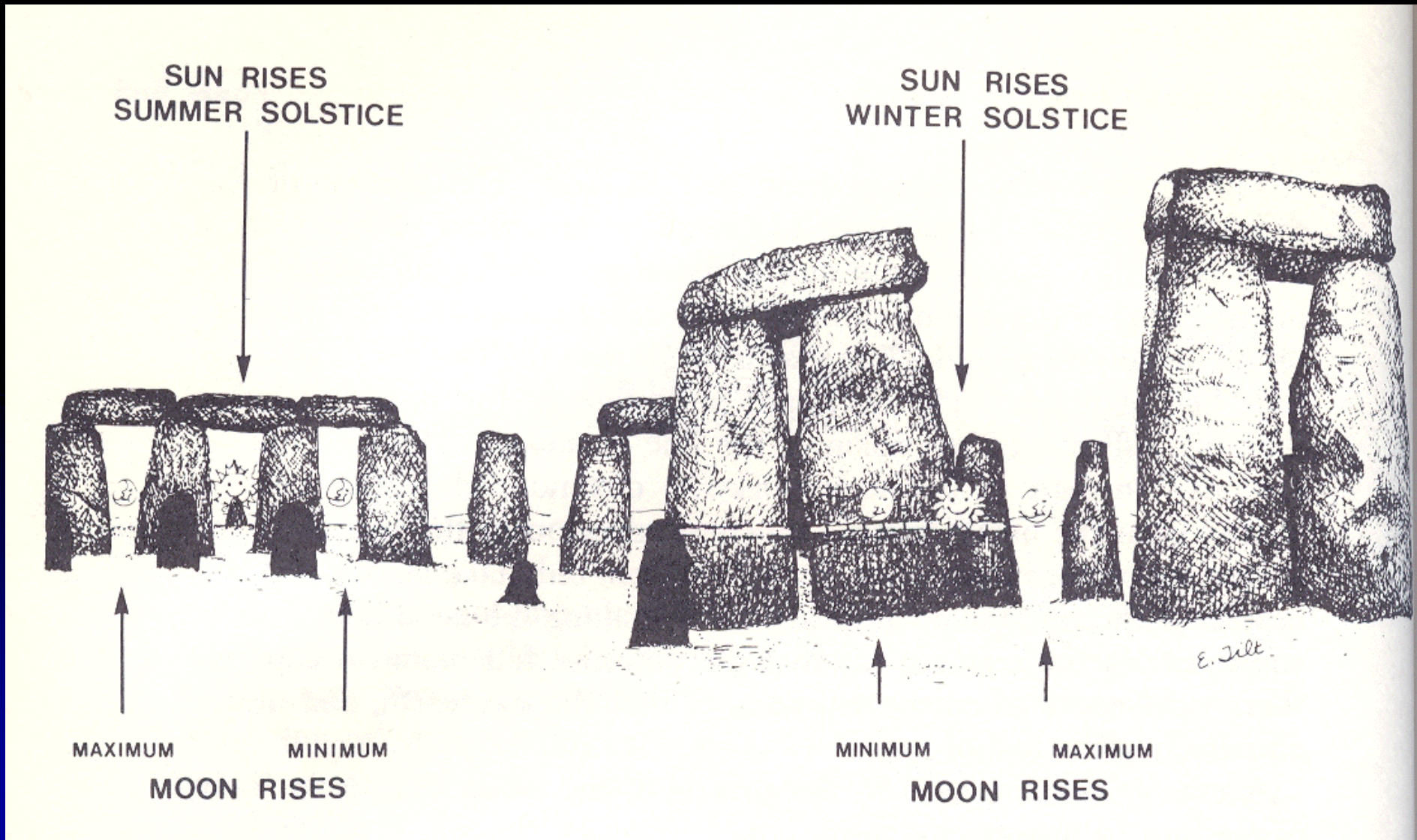



A
B
C
D
HEEL
STONE
97
96
A POSTS
?
?
Avenue bank
ditch
CAUSEWAY
POSTS
Stonehenge I ditch
A
B
CD


Northern major limit
Summer solstice
Northern minor limit
Northern major limit
Summer solstice
Northern minor limit
N
W
E
S
SETTING
RISING
Southern minor limit
Winter solstice
Southern major limit
Southern minor limit
Winter solstice
Southern major limit


18.6 years
1 month
Declination
Major limit
Minor limit
18°
28°
0
Time
Major standstill
Minor standstill

Major Lunar and Solar Events



Conclusions

- Stonehenge 1
  - The only entrance has a declination of +27°
    - Close to lunar northern limit (28°)
  - No known alignments or sightlines
- Stonehenge 2
  - Some lunar alignments have been proposed for the NE entrance posts
    - Unlikely since those posts likely supported structures that would have blocked sightlines
- Lunar alignments in 1 & 2 are unlikely

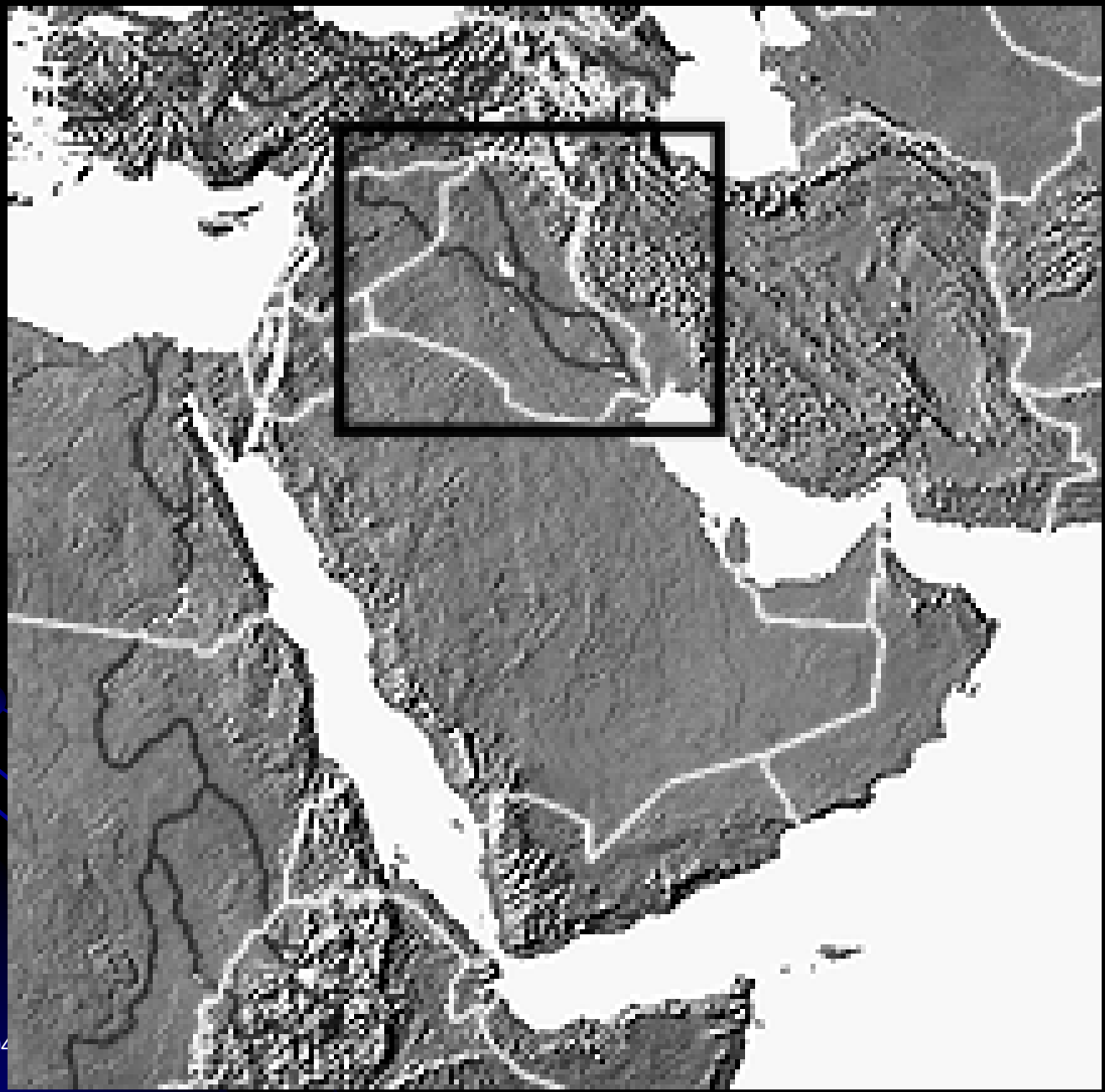
Conclusions Cont.

- Stonehenge 3
  - Clear evidence of solar alignments
  - "Altar Stone"
    - Heel Stone and stone 97 straddle it
    - Bracket the midsummer sunrise
  - "Altar Stone" may be aligned with midwinter sunset

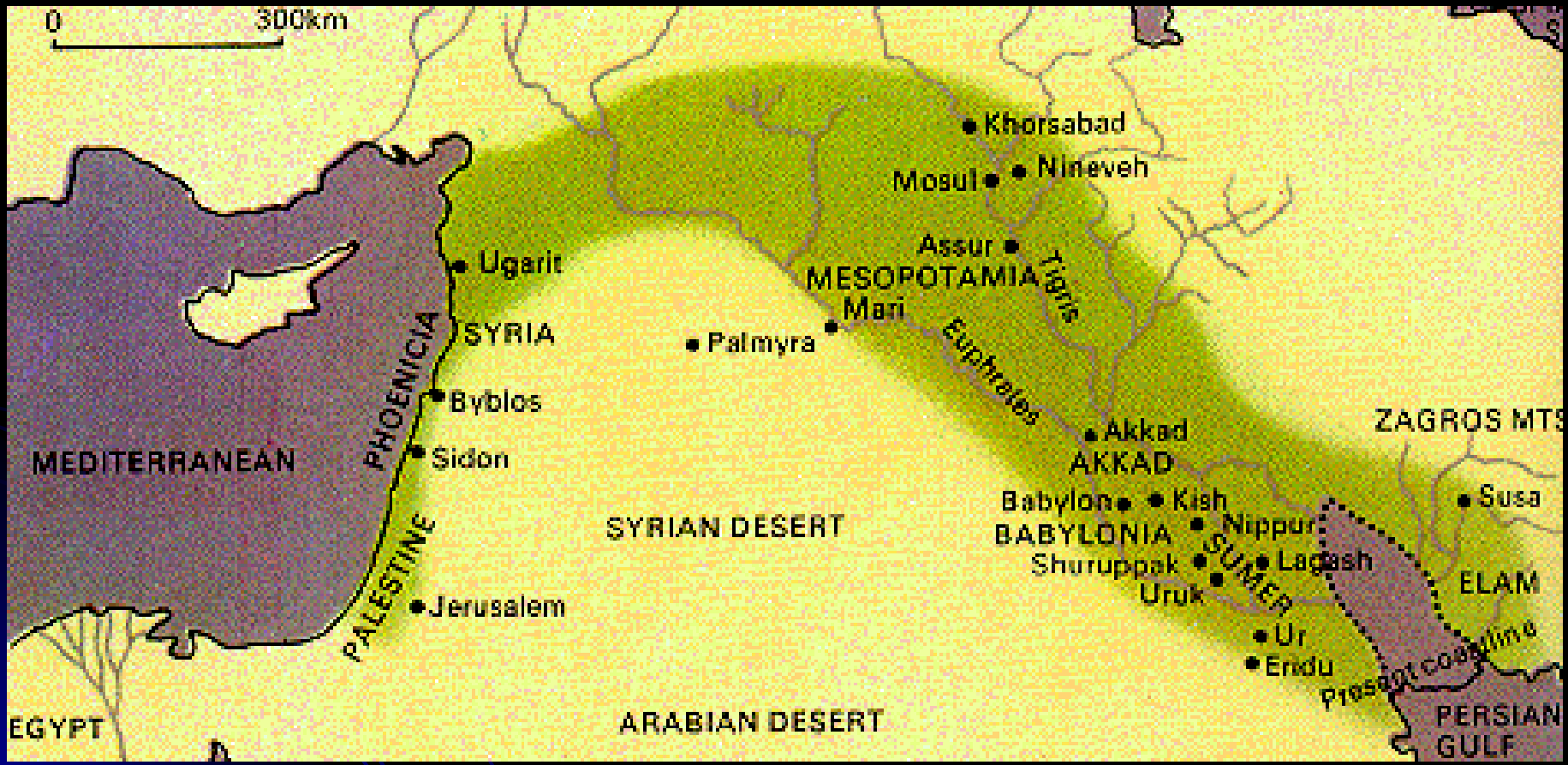
What we Can Say

- Phase three has definite solar alignments
- No known lunar or celestial alignments in Phases 1 & 2
- Proposed Aubrey Hole lunar eclipse computer is very uncertain
- Thom, Hoyle, Hawkins and others
  - Not proven

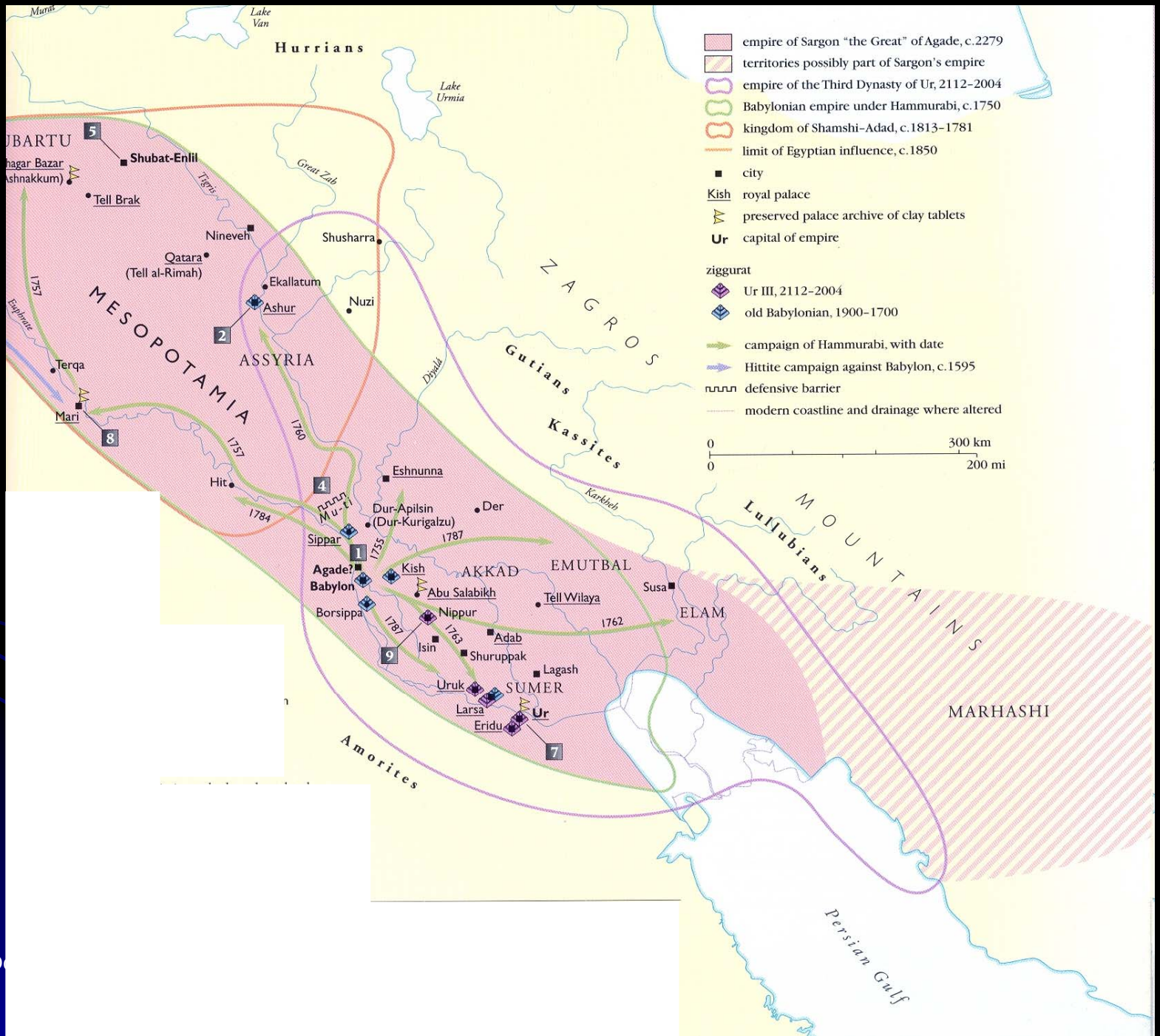
Mesopotamia



The Fertile Crescent




KURBAN HÖYÜK
TELL FAKHARIYAH
Tell Leilan
Halaf
Tell Brak
TELL ES-SWEYHAT
Lake Assad
Khabur River
Upper Zab River
Shanidar
Lake Urmia
Hasanlu
Caspian Sea
Marlik
Nineveh
KHORSABAD
Tell al-Rimah
Nimrud
Hassuna
Lower Zab River
JARMO
Nuzi
MATARRAH
Assur
Ecbatana
Dura -Europus
Palmyra
Mari
Tigris River
Diyala River
ÜÇ TEPE
Samarra
TELL ASMAR
TELL AGRAB
KHAFAJAH
ISHCHALI
SYRIA
Euphrates River
Baghdad
IRAN
SURKH DUM-I-LURI
Uqair
Sippar
Jemdet Nasr
Kish
Babylon
Borsippa
NIPPUR
UMM AL-HAFRIYAT
IRAQ
Susa
CHOGA MISH
BISMAYA
Isin
Fara
Umma
Karkeh River
Uruk
Chogha Zambil
Lagash
Larsa
TELL EL-UBAID
Ur
Eridu
Basra
The Gulf
ORIENTAL INSTITUTE
Other Sites
Modern Cities
0 50 100 200 Mi.
0 50 100 200 Km.

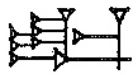

Murat
Lake Van
Hurrians
Lake Urmia
UBARTU
Shubat-Enlil
hagar Bazar
shnakkum)
Tell Brak
Tigris
Great Zab
Nineveh
Shusharra
Qatara
(Tell al-Rimah)
Ekallatum
Ashur
Nuzi
1757
Euphrate
MESOPOTAMIA
ASSYRIA
ZAGROS
Gutians
Kassites
Diyala
Terqa
Mari
1760
1757
Hit
1784
Eshnunna
Mu-ti
Dur-Apilsin
(Dur-Kurigalzu)
Der
Sippar
1755
1787
Agade?
Babylon
Kish
AKKAD
EMUTBAL
Susa
Abu Salabikh
Tell Wilaya
Borsippa
Nippur
ELAM
1787
1763
1762
Adab
Isin
Shuruppak
Lagash
Uruk
SUMER
Larsa
Ur
Eridu
Karkheh
Lullubians
MOUNTAINS
MARHASHI
Amorites
Persian Gulf
empire of Sargon "the Great" of Agade, c.2279
territories possibly part of Sargon's empire
empire of the Third Dynasty of Ur, 2112–2004
Babylonian empire under Hammurabi, c.1750
kingdom of Shamshi-Adad, c.1813–1781
limit of Egyptian influence, c.1850
city
Kish royal palace
preserved palace archive of clay tablets
Ur capital of empire
ziggurat
Ur III, 2112–2004
old Babylonian, 1900–1700
campaign of Hammurabi, with date
Hittite campaign against Babylon, c.1595
defensive barrier
modern coastline and drainage where altered
0
300 km
0
200 mi

Ziggurat of Ur

Ziggurat Reconstruction

Cuneiform

- Wedge-shaped writing system
- Evolved from Sumerian pictograph writing
- Written with a reed that was pressed into wet clay
- Written and read by holding tablet at an angle to the Sun so shadow falls in wedges

Original pictograph	*Pictograph in position of later cuneiform*	*Early Babylonian*	*Assyrian*	*Original or derived meaning*
				bird
				fish
				donkey
				ox
				sun day
				grain
				orchard
				to plow to till
				boomerang to throw to throw down
				to stand to go

Sumerian Pay Stub

Symbols

- Round are units of 10
- Ellipse is an ordinary unit
- 100 would be written as a BIG 10
- Place value system like ours

Cuneiform

- ~3500 BCE
  - Earliest Sumerian pictographs
- ~3350 BCE
  - Earliest bills of lading/account books
    - Clay envelops holding clay tokens
  - Later the table of contents on the envelop was all that was needed
- Eventually used for astronomical texts

Astronomical Tablets

- Old Babylonian Period
  - ~1800 - ~1600 BCE
  - Many mathematical texts
- Earliest astronomy was qualitative
  - Eclipse lists Ptolemy used he said date to reign of Nabonassar (747 BCE)
- Mathematical astronomy begins in about the 4th century BCE (Seleucid Period)
  - Consistent theories about movement of planets, Sun and Moon

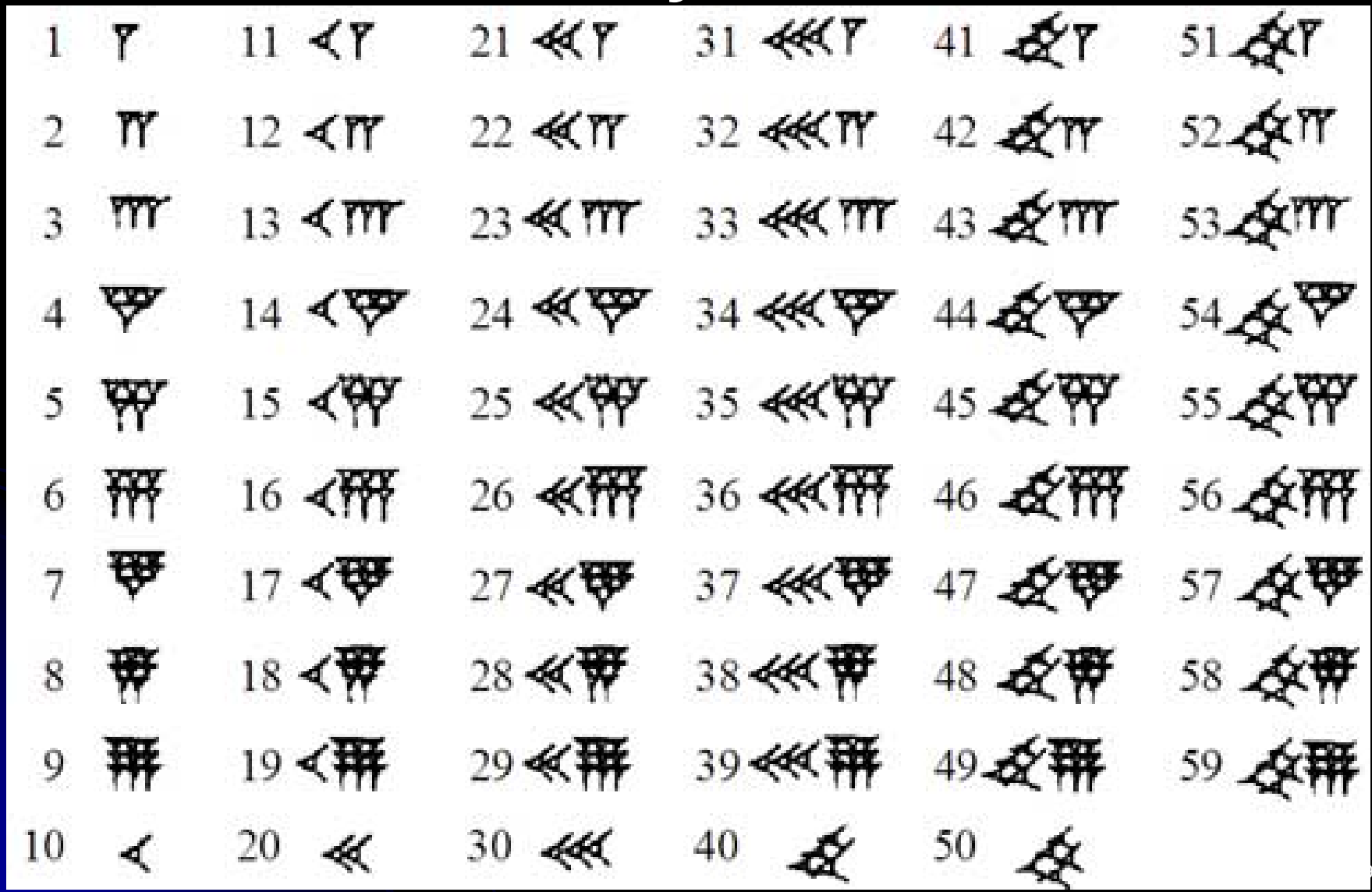
Earliest Observations

- “19 from Moon to the Pleiades”
- “17 from the Pleiades to Orion”
- “How much is one god (star) beyond the other god?”
- 19 and 17 are in units
- The tablet then gives a procedure
  - Like earlier mathematical texts

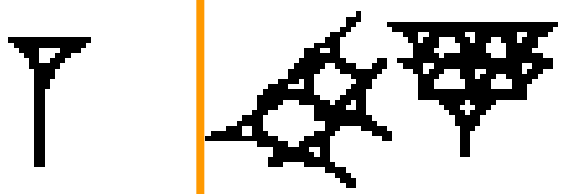
Sexagesimal System

- Base 60
  - Sixty units of one kind are written as one unit of the next higher order
  - We use base 10 in which the number of the next higher order changes at ten units
- Earliest known use is on Sumerian tablets
  - ~3000 BCE
- Used in purely “astronomical” tablets
- Used in pure mathematical tablets
- Base 10 system
  - In parallel use for every day mathematical problems

Number System Cont.



Example

216000	3600	60
		
1,57,46,40 = 424000		

- $1 \times 60^3 + 57 \times 60^2 + 46 \times 60 + 40$
  - 424,000 Decimal/Base 10

Terms

- Ephemeris (des)
  - Table of the sequence of positions of a celestial object by date (and time)
- Synodic Time
  - For a planet – the mean interval of time between successive returns of a planet to the same aspect (position relative to the Sun) as seen from Earth
- Synodic Month
  - The period of time from one new moon to the next new moon

Calendar and Time Keeping

- Problem was to assign a date to a given future phenomena
- Lunar calendar so some months were 29 days and others 30 days
- A tablet for Saturn could cover sixty years
  - Would need Moon ephemerides for decades
- Babylonian solution
  - Divided the mean synodic month into 30 equal parts
  - No name for this unit so given name of tithi from Hindu astronomic term

Time

- Babylonian mean synodic month of 29;31,50,8,20 days
  - 29.530594...days
  - Modern value: 29.5305903...days
- One "tithi" (Hindu) Lunar day unit
  - Could get value of one tithi by dividing 29;31,50,8,20 days by 30
  - Much easier in sexagesimal system
  - Start at the other end, *multiply by 2*, and shift the sexagesimal place
    - 0;59,03,40,16,40 tithi per day

Solution

- Dates expressed as tithis are rarely off by more than ±1 day
- So the sky runs on lunar time
- Example
  - If a helical rising of Venus occurs on a full moon day then five Venus cycles (seasonal years) later it will occur four days prior to the full moon
    - Five Venus years of 583.92 days each = 2920 – 0.40 days
    - 99 full moons (moon phase cycles) = 2920 + 3.53 days

Cosmology

- Ishtar/Inanna
  - Female goddess daughter of Sin
  - Mediated between Sin and Shamash
- Shamash (Sun) ruled the seasons
- Sin (Moon) ruled the sky
  - Moon more powerful than the Sun
  - Control of repeating months may be reason Sin considered the most powerful

Cosmology Cont.

- Universe
  - Heaven
  - Middle Heavens
  - Sky
  - Surface of the Earth
  - Apsu (middle earth)
  - Underworld
- Four Regions
  - Division of the Earth into four regions
    - N, E, S, W

Venus/Inanna

- Largest temple in Uruk dedicated to Inanna
  - Earliest tablets (~3000 BCE) mention Venus
- Sumerian queen of heaven
- Gatekeeper to the underworld
- Enuma Anu Enlil
  - “When the gods of air and sky”
  - Tablet 63 devoted exclusively to Venus

Enuma Anu Enlil

- Series of omen tablets
- "If X happens then Y will follow"
  - "If on the 25th day of month 11, Venus appears in the west, the harvest of the land will be successful."
- Mathematical statements of tablet 63 run for 21 years
- Venus disappear is typically 53 days but is expanded to 90 days (3 lunar months)

Tablet 63 Cont.

"If on the 12th of the month of Kislev Venus disappeared in the east, remaining absent in the sky two months and four days, and on the 16th of the month of Šabat Venus appeared in the west, the harvest of the land will be successful."

"Venus disappeared in the west in the month of Adar 11th; period of absence four days; rose in the east the month of Adar 15th."

Tablet 63

- Important for dating ancient Babylonian history
- We know that it dates from the reign of Ammisaduga
  - He reigned after Hammurabi who reigned somewhere between ~1900 – ~1680 BCE
- Attempts have been made to date the start of the Venus cycle in order to date the tablet
- Currently some scholars support a date of 1581 BCE 1701, 1645, and 1637)

Venus

- Tracking is spatial and linear
- Mathematical not geometrical
- Tablets typically give position in relation to the Zodiac in days
  - Using days as unit to describe a continuous phenomenon
  - Later a “zigzag” function is used

Calendar

- Likely evolved from the Sumerian token system
- Needed by “astronomers/astrologers” to calculate future risings and settings
- Used for omens and devination
- Monthly and day-based calendar no “week” is evident
- Months simply recycled
- No attempt to link months with seasons

Babylonia Month Names

- Adar
- Nisan
- Iyar
- Sivan
- Tammuz
- Ab
- Elul
- Tishreh
- Arahsammu
- Kislev
- Tebet
- Ševat

MUL.APIN

- Observations dated to between 1400 – 900 BCE
  - Likely observed in Assyria rather than Babylon but debatable
- Compilation of astronomical information
- Movement of the Sun and planets

Ancient Maya Astronomy

Mesoamerican Archaeology

Location


UNITED STATES
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
Teotihuacán
Tenochtitlán
Chichén Itzá
Palenque
Bonampak
BELIZE
GUATEMALA
HONDURAS

Location


Gulf Of Mexico
Pánuco
La Quemada
HUASTEC
Cerro de las Mesas
San Luis Potosi
TEOHUACAN
Cholula
Matacapan
Tlaxcala
Mezcala
MIXTEC
Xochipala
Chilpancingo
Tilantongo
ZAPOTEC
Pacific Ocean
Comalcalco
Palenque
Uaxactún
Tikal
Chiapa de Corzo
Chinkultic
Zaculeu
Ecab
Aké
Chichén Itza
Tancah
Acanceh
Tulum
Becan
Chicanná
Xpuhil
Isla Cozumel
Hormiguero
Río Bec
El Mirador
Nakbe
Gulf Of Honduras
Yaxchilán
Quiriguá
Copán
Santa Leticia
Tazumal
Cerén
NICARAO
Maya Region
Trade Route
Archaeological Site
ZAPOTEC Indigenous Group

Chichen Itza

Palenque

Timeline

- Preformative Period
  - ~2500 - ~1800 BCE
  - Contemporary
    - Wessex Culture in Salisbury plain (Stonehenge area)
    - Ur Royal Graves – Mesopotamia
    - Old Kingdom – Egypt
  - Small sedentary villages
  - Earliest pottery

Formative – Pre-Classic

- ~1800 - ~1000 BCE
- Olmec
- Giant stone heads
- Jade figurines
- Major centers
  - Tres Zapotes
  - La Venta
  - San Lorenzo

Middle Formative

- ~1000 - ~300 BCE
- Teotihuacan
  - Largest city in ancient Mexico
  - 30 miles NE of Mexico City
- 365 day year
- 260-day cycle
  - 13 numbers
  - 20 name days

Classic Period

- 200 – 900 CE
- Central Yucatán
- Palenque
  - Stucco work
- Copán
  - High-relief sculpture
- Tikal
  - Monumental architecture

Maya Religion

- Pantheistic
- Possibly impersonal spiritual forces
  - Forces of nature
- Possibly supernatural beings
  - Anthropomorphic

Decline

- Very rapid and total
- Over-population?
- Soil depletion?
- Drought or climate change?
- Mayas were followed by the rise of the Aztec
  - Highlands of Mexico

Maya Astronomy

- A Venus-based calendar
  - Accurate to 1 day in 500 years
- Spanish are a major source of information about the Maya

On Netzahualpilli (king of Texcoco):

"…a great astrologer and prided himself on his knowledge of the motions of the celestial bodies …"

Maya Astronomy Cont.

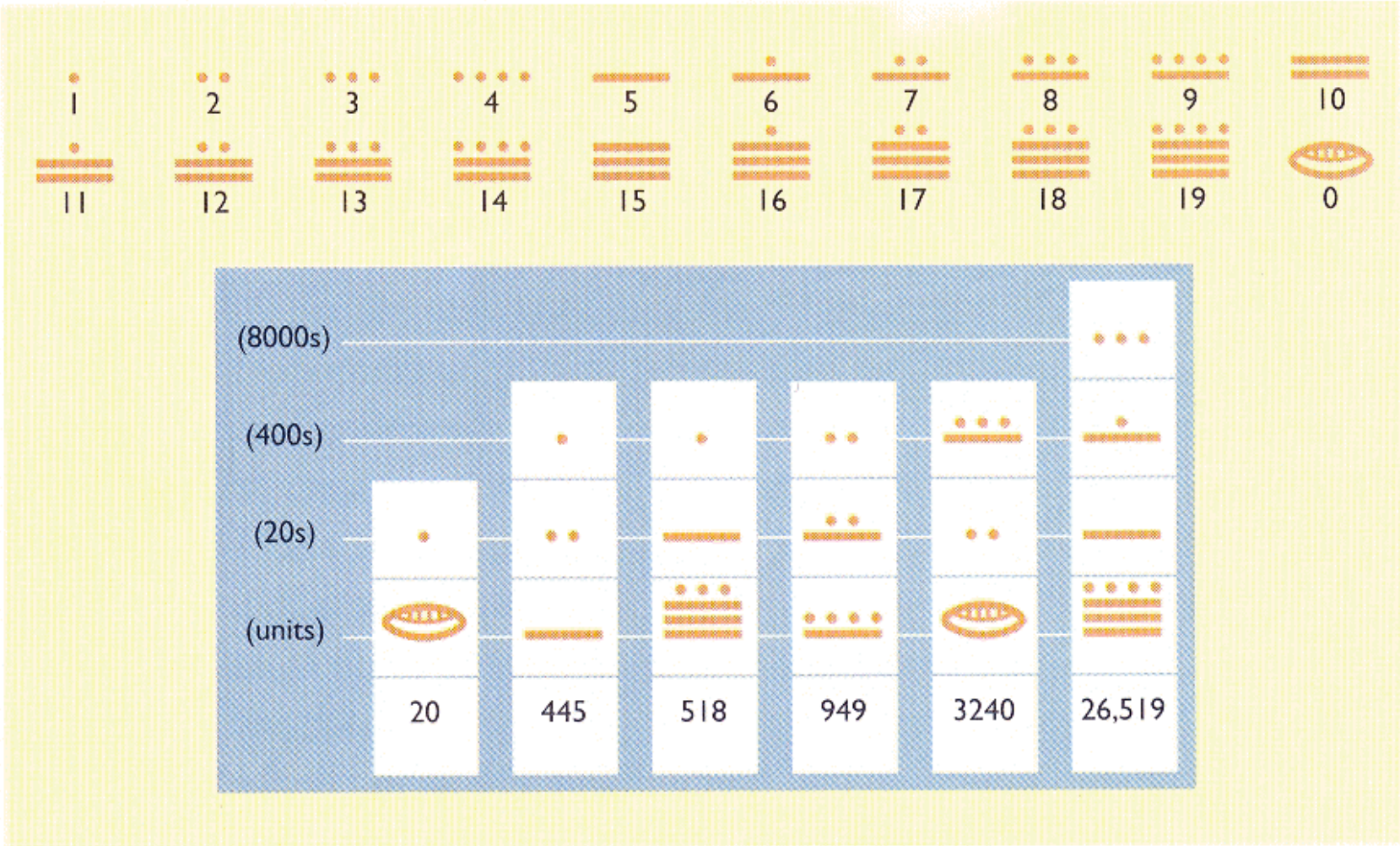
"They have their year as perfect as ours . "

- Used the Pleiades and Gemini to indicate hour of the morning star (Venus).
- Had books that used special notation to track movements
  - "Codices" (codex)

Numerical System

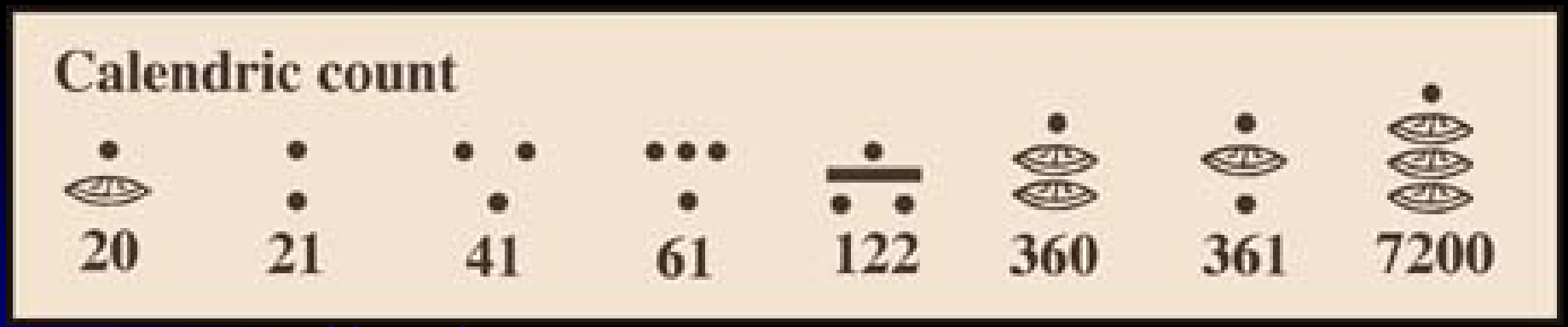
- Base 20
  - Why 20?
    - number of fingers and toes
  - We use the Arabic/Hindu base 10 system
- Numbers written vertically
  - Highest significant numbers on top

Numerical System Cont.



Calendar System Cont.

- Calendar numbers were slightly different
- Instead of 400s you have 360
  - Easier to calculate seasonal years
- Instead of 8,000s you have 7200



Numbers

- Possibly originated as hand gestures
  - Origin of Arabic numerals
- Ones
  - Finger tips
- Five
  - Extended hand with fingers together
- Maya had Zero (0)
  - Wasn't used in Europe until introduced by Moslems on the Middle Ages

Devination

- Modern Maya diviners use a system that is likely the same as their ancestors
- Answers questions about dreams, omens, land disputes, etc
- They carry a bag of seeds and crystals
  - Lays out piles of seeds and crystals
  - The diviner addresses the them asking for light and calrity
  - Counts out the days by name and number
    - 1 Quej
    - 2 K'anil …
    - Analogous to the Maya day names and numbering
  - Stops at one pile of seeds and crystals that contains the answer

Why?

- Used careful scientific-like methods of careful observation and recording
- But their aim was religious, ours' is "truth" and knowledge

Maya Codices

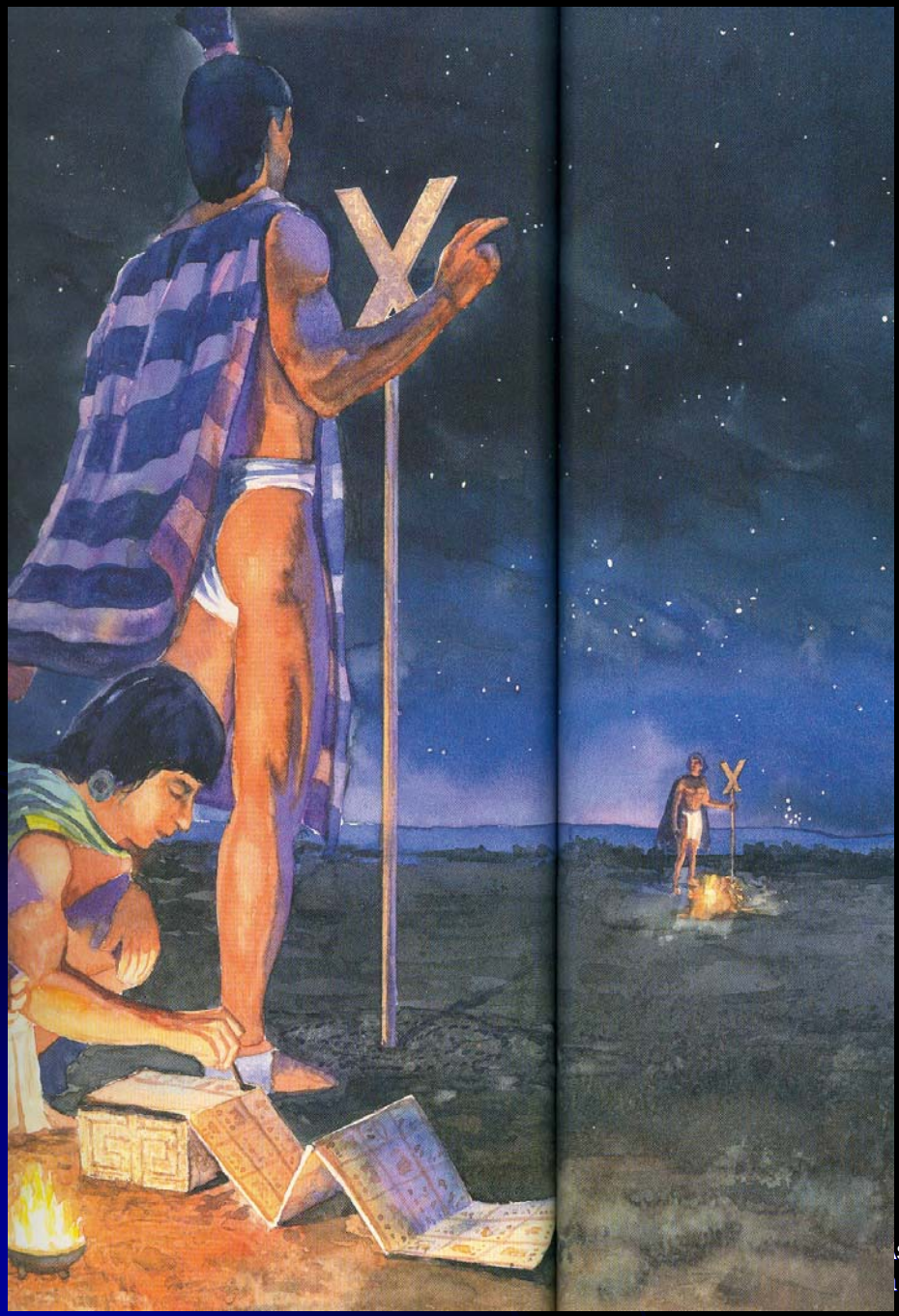
Dresden Codex

Codex

- Written on bark
- Almost all destroyed by Spanish missionary priests
- Only four known to have survived
  - Longest is ~7 meters in length
- “Astronomical”
  - Eclipse predictions (lunar and solar)
  - Celestial body positional information
  - For agricultural purposes etc
- Scientific

Observations

	Modern (days)	As recorded by the Maya	Maya in days	Ptolemy
Lunar (synodic) month	29.53059	405 lunations = 46 tzolk'ins (260 x 46 = 11,960 days)	29.53086	29.53337
Synodic period of Venus	583.93	301 periods = 676 tzolk'ins (260 x 676 = 175,760 days)	583.92027	583.94267
Synodic period of Mars	779.94	1 period = 3 tzolk'ins (3 x 260 = 780 days)	780	779.94
Solar (tropical) year	365.24198	1507 tropical years = 1508 haabs (365 x 1508 days)	365.242	365.24667



Measurements

Time Cycles

- 20 day names with 13 running numerals
  - 260 days
  - Pairs 7 day names with typically 30 numbers
- 13 is known to have been a sacred number
  - Number of layers of heaven
- 20 was the basis of the number system
- 365 – haab
- 52 year cycle
  - Very important festival

260 – tzolkin – ritual cycle

- Fits with a number of natural cycles
- Average period of visibility of Venus - 263 days
- Human gestation is 266 days
- Average length of growing season in most parts of Mexico
- Runs continuously
- Synodic period of Mars is exactly 3 cycles of 260 days
- Or it could be just the number of fingers and toes times the number of layers of heaven

Kin

- Maya word for:
  - Time
  - Sun
  - Day

Time Cont.

- 1 Imix
- 2 Ik
- Match day names with number of the day
- Like we match 1 with Sunday
- 260 day cycle is unique to the Maya of all the known cultures
- Good and bad days
- E.g. certain days were ok to get married on

Dresden Codex

Dresden Codex

- Smuggled out of Mexico in the 16th century
- Found in a Dresden library in the 19th century
- Codices
  - Computation of the months and days of the year
  - Special days and seasons
  - How to read and write
  - Illustrations to help teach the concepts
- Lunar table used to predict eclipses

Dresden Codex

- Lunar table
  - Eclipse prediction
  - Which new moons would eclipse the sun
  - Which full moons would be eclipsed
  - 405 full moons over thirty years
    - Possibly the number had ritual significance
  - Gain understanding of astronomical time

Venus

- 584-day cycle
  - Four parts
- Venus events repeat in five of the 584 day periods
- Five Venus periods coincide with very close to eight seasonal years
  - Same Venus events repeat on the same date of the year

Venus

- Noh ek – great star
- Chac ek – red star
- Sastal ek – bright star
- Xux ek – wasp star
- Male
- Kukulkan/Quetzalcoatl
  - Feather serpent diety

Venus

- Different roles
  - Dawn god
  - Tortoise who weeps for farmers and tears are rain
    - Some Maya farmers still warn all turtles to leave their fields before they burn them

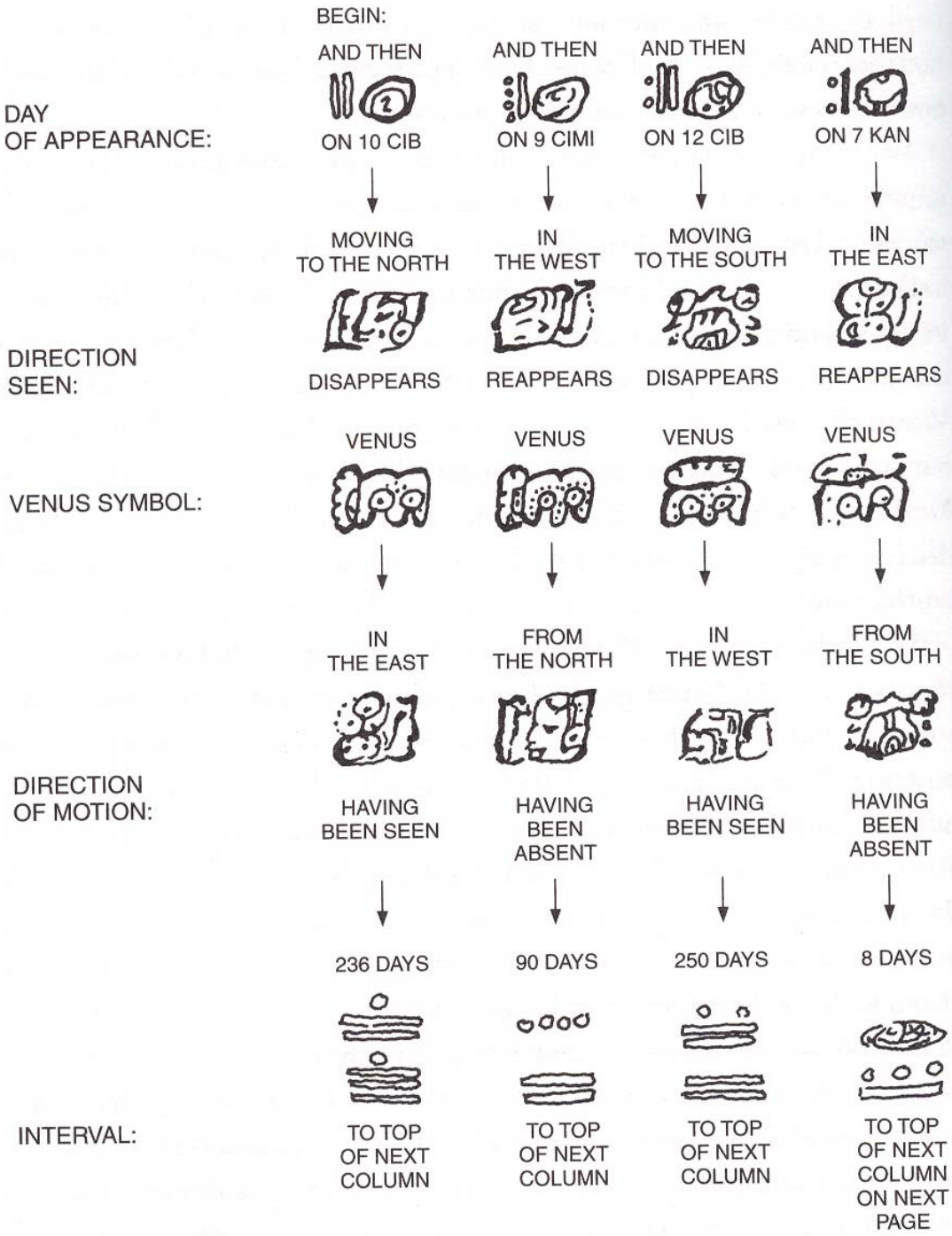
Venus Table

- 13 lines X 5 pages X 584 days per page
  - 37,960 days (~104 years)
  - Great Cycle
  - 584-day Venus, 260-day ritual and 365-day year cycles
- At the end of the Great Cycle you reenter the table and restart the cycle
  - Some complex corrections were required

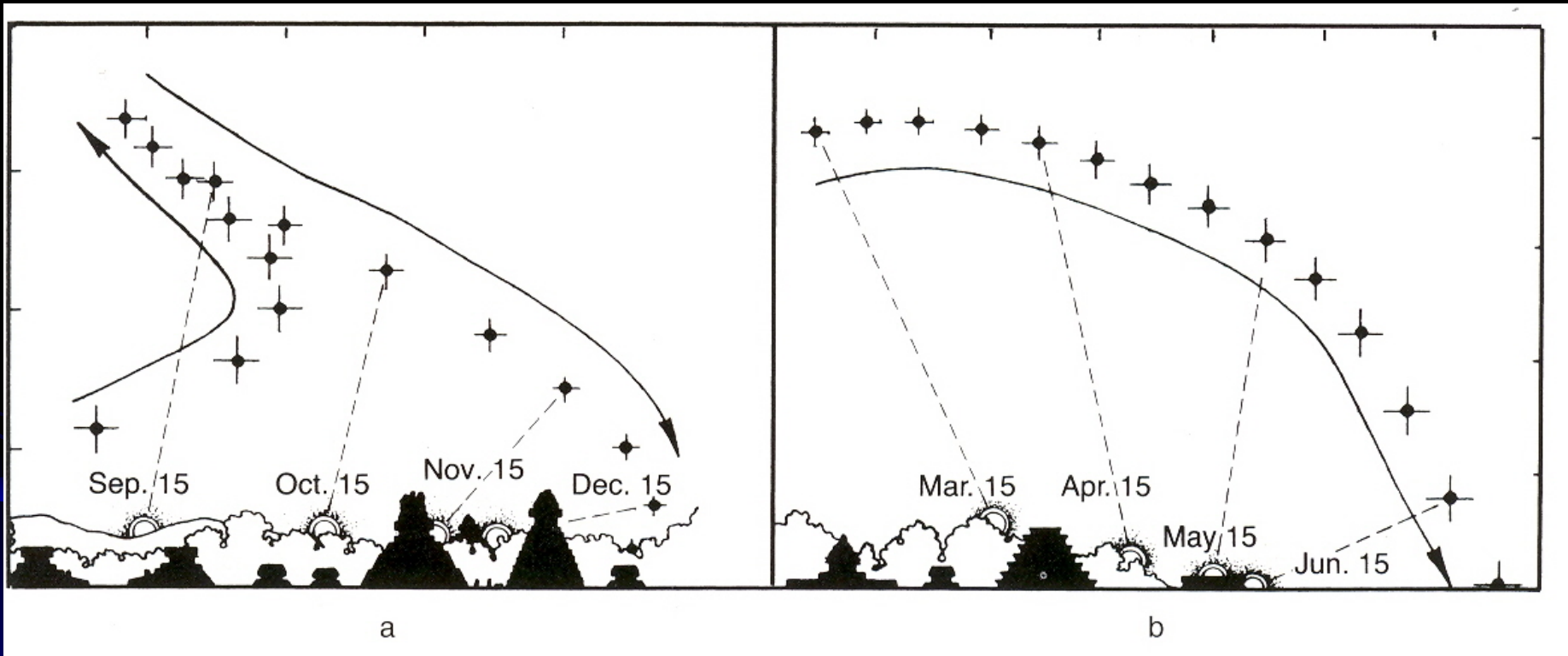
Venus Table Cont.

"And then on the day 10 Cib, moving to the north, … Venus disappears in the east … having been seen for 236 days"

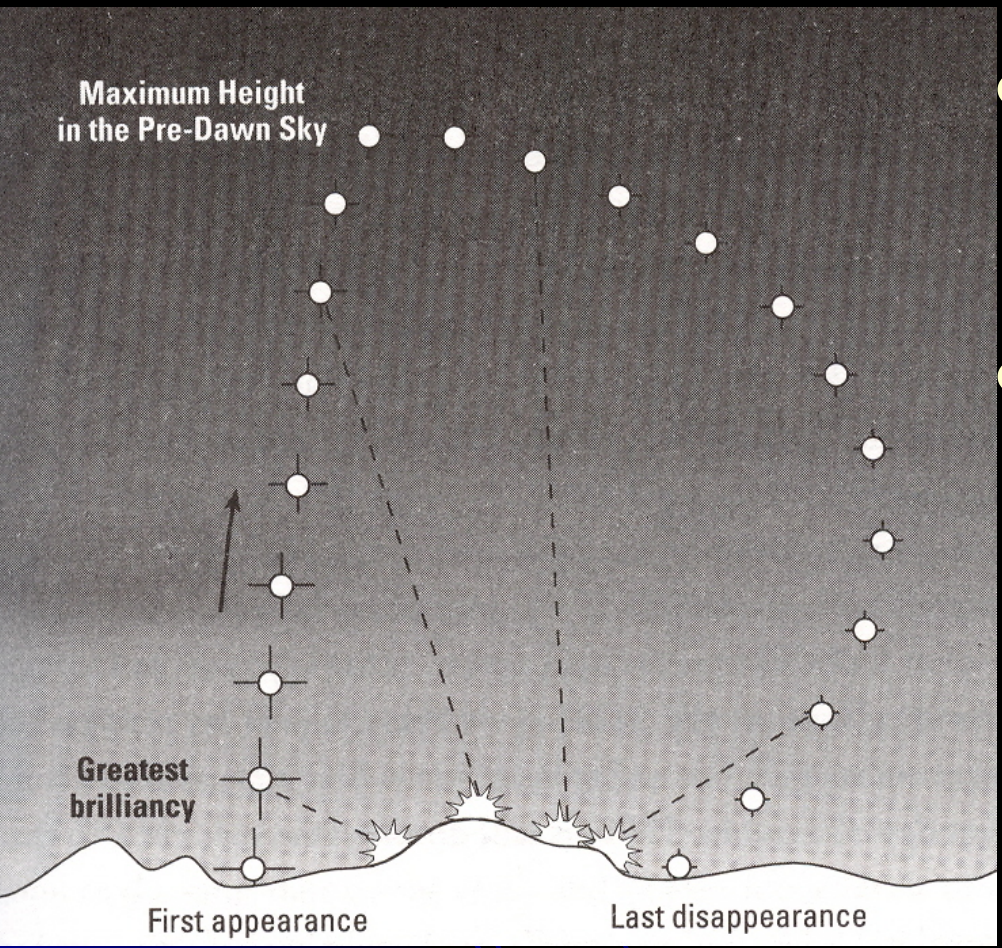
"And then on 9 Cimi in the west, Venus reappears, from the north, having been abset for 90 days."


BEGIN:
AND THEN
AND THEN
AND THEN
AND THEN
DAY OF APPEARANCE:
ON 10 CIB
ON 9 CIMI
ON 12 CIB
ON 7 KAN
MOVING TO THE NORTH
IN THE WEST
MOVING TO THE SOUTH
IN THE EAST
DIRECTION SEEN:
DISAPPEARS
REAPPEARS
DISAPPEARS
REAPPEARS
VENUS
VENUS
VENUS
VENUS
VENUS SYMBOL:
IN THE EAST
FROM THE NORTH
IN THE WEST
FROM THE SOUTH
DIRECTION OF MOTION:
HAVING BEEN SEEN
HAVING BEEN ABSENT
HAVING BEEN SEEN
HAVING BEEN ABSENT
236 DAYS
90 DAYS
250 DAYS
8 DAYS
INTERVAL:
TO TOP OF NEXT COLUMN
TO TOP OF NEXT COLUMN
TO TOP OF NEXT COLUMN
TO TOP OF NEXT COLUMN ON NEXT PAGE

Venus Day to Day



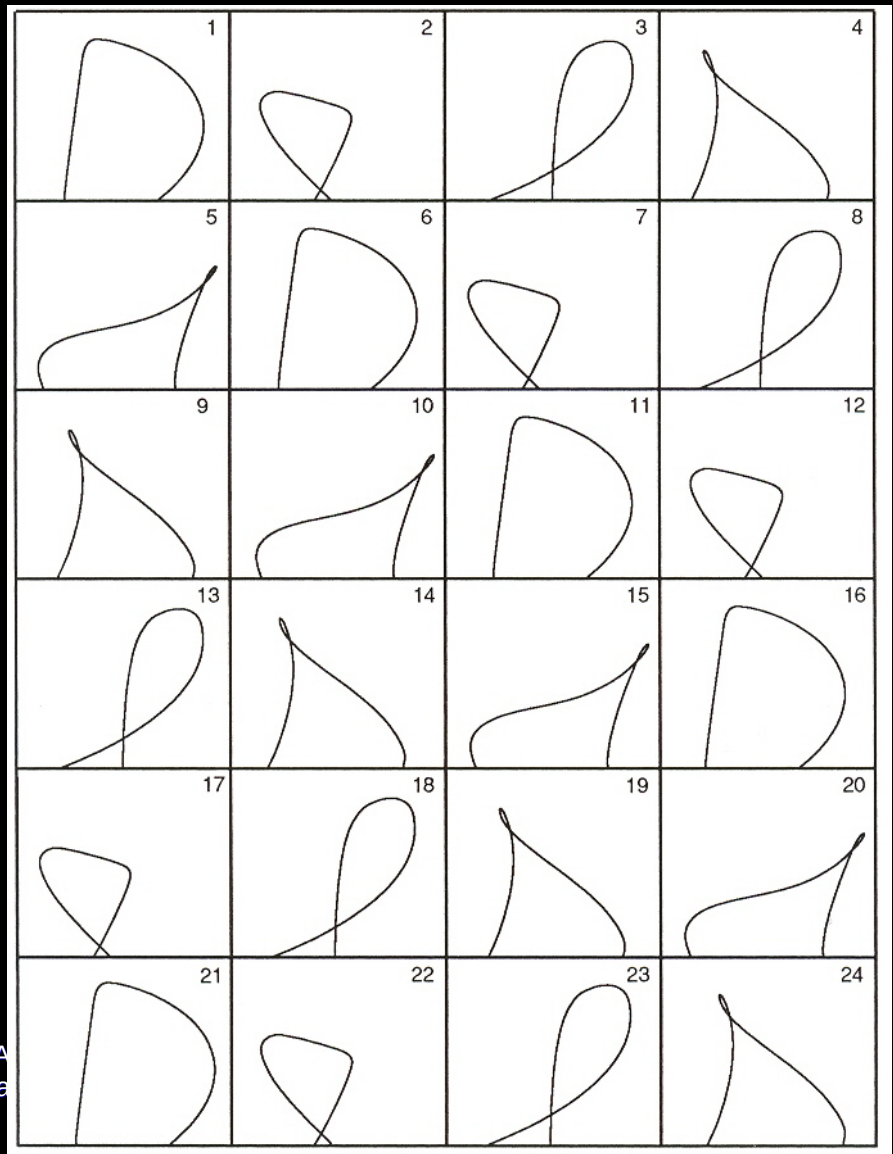
Venus Tracks



- Motion of Venus night to night at the same time of night
- One of five tracks that Venus takes

Venus Cycles

- Requires observation over a full eight-year cycle
  - Morning and evening curves
- Serpentine curve
- Only five shapes
- Repeat of the same pair of curves is 8 years (2,920 days)
- 5 Venus cycles ~584 days each

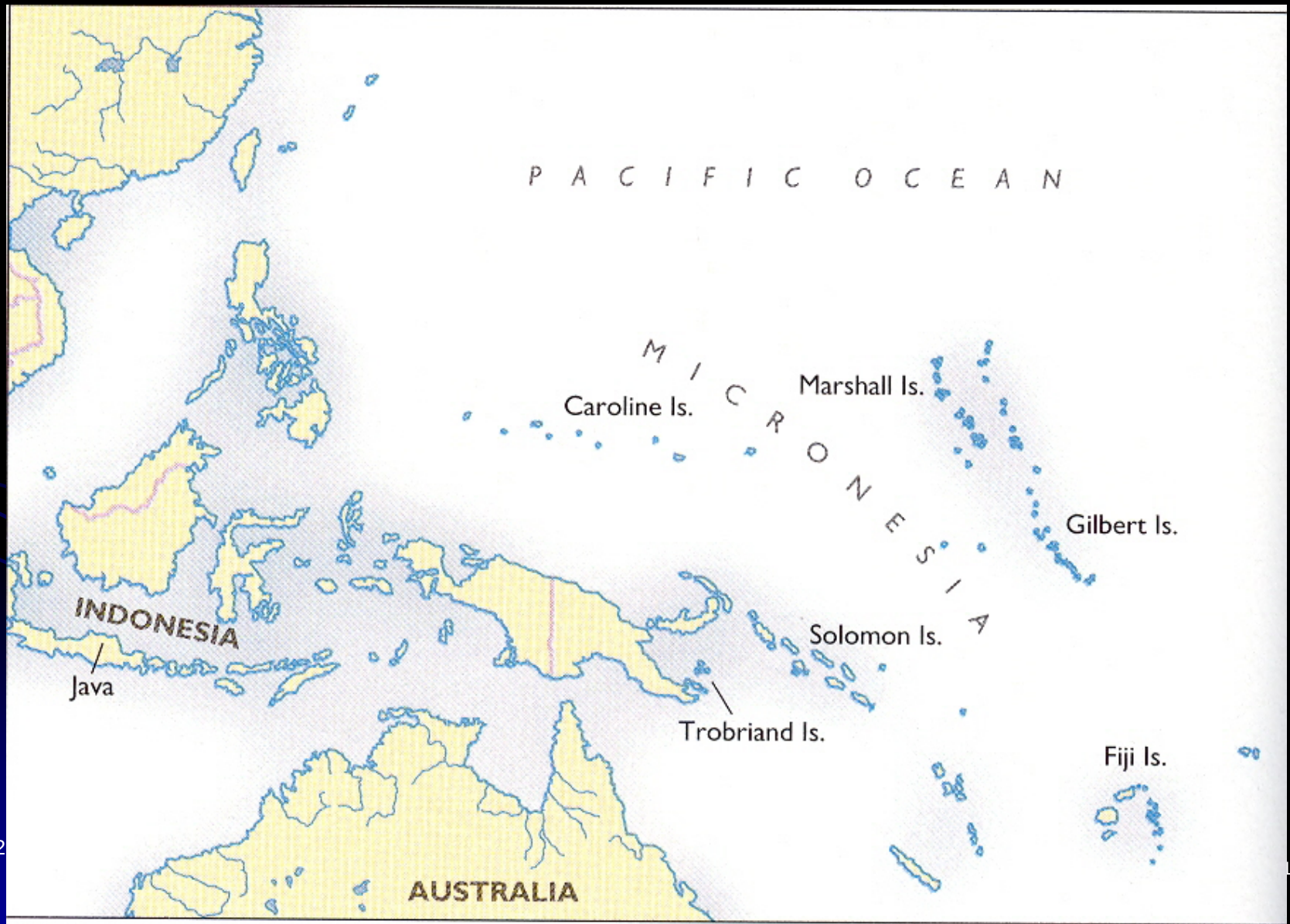


Venus

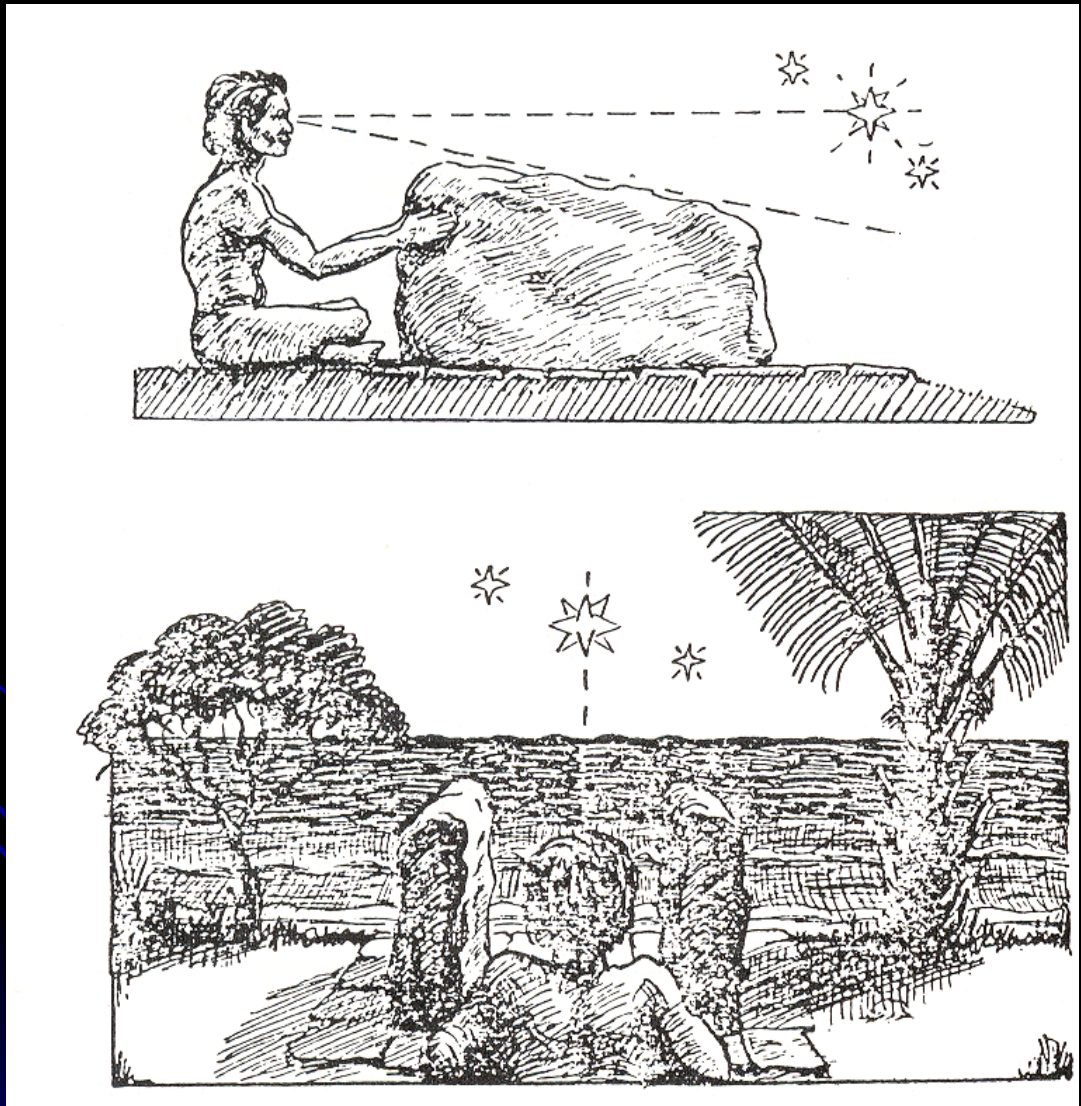
- Rigorous use of mathematics
- Mixed in myth and magic
- Five pages reflect five divisions the Mayas identified
  - Interval of appearance as the morning star
    - 236 days
  - Disappearance
    - 90 days
  - Interval of appearance as the evening star
    - 250 days
  - Second – shorter period of disappearance
    - 8 days

Polynesian Wayfarers

Micronesia


PACIFIC OCEAN
MICRONESIA
Caroline Is.
Marshall Is.
Gilbert Is.
Solomon Is.
Trobriand Is.
Fiji Is.
INDONESIA
Java
AUSTRALIA

Stone Canoes



Stone Canoes

- Used to teach celestial navigation
- Position carefully
- Faces one of the cardinal directions
- Student memorizes the constellation closest to the desired destination

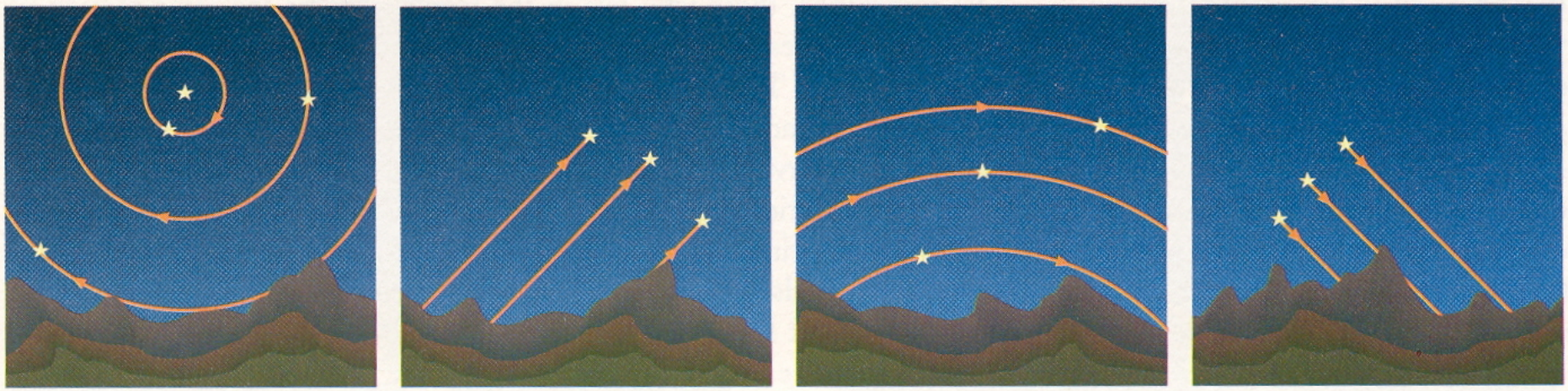
Sky

- Polynesians can use the stars for navigation even though they don't have a "North Star" to fix direction
- Stars rise and set almost vertically from and to the horizon
  - So knowing the direction of a destination you can use a given star or constellation all night as a guide

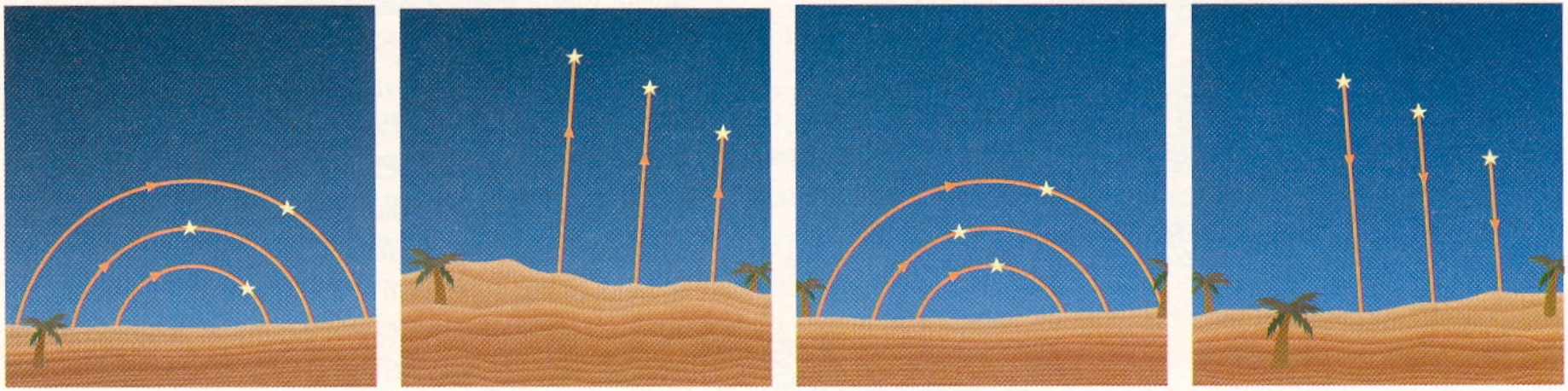
Celestial Navigation Cont.

- Use a series of stars depending on direction
- In a 12 hour night one example uses nine stars on a course of northeast-by-east (54°)
- A course of 80° requires only five stars
- Since it is closer to a cardinal direction (east)

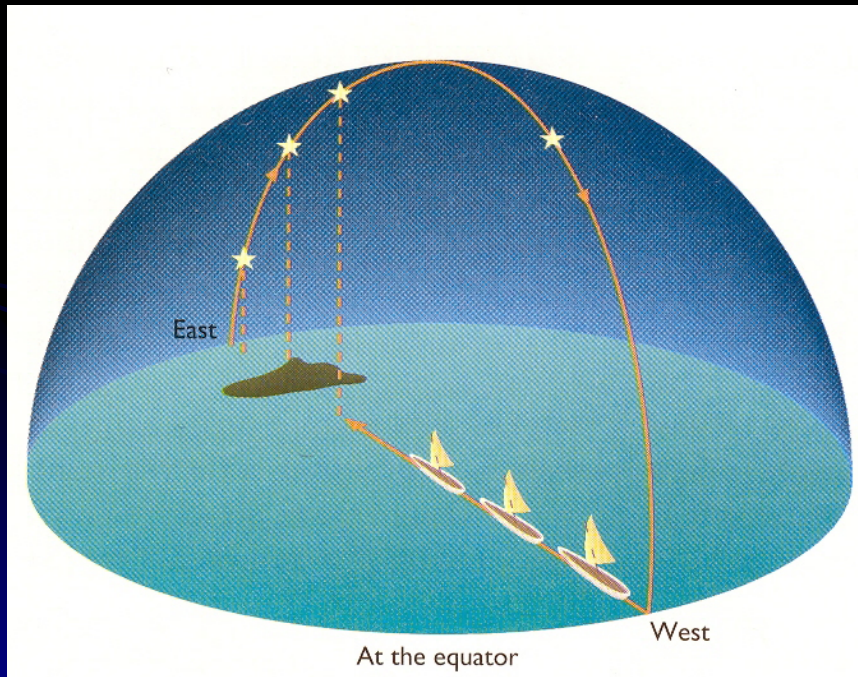
Star Tracks Northern Sky

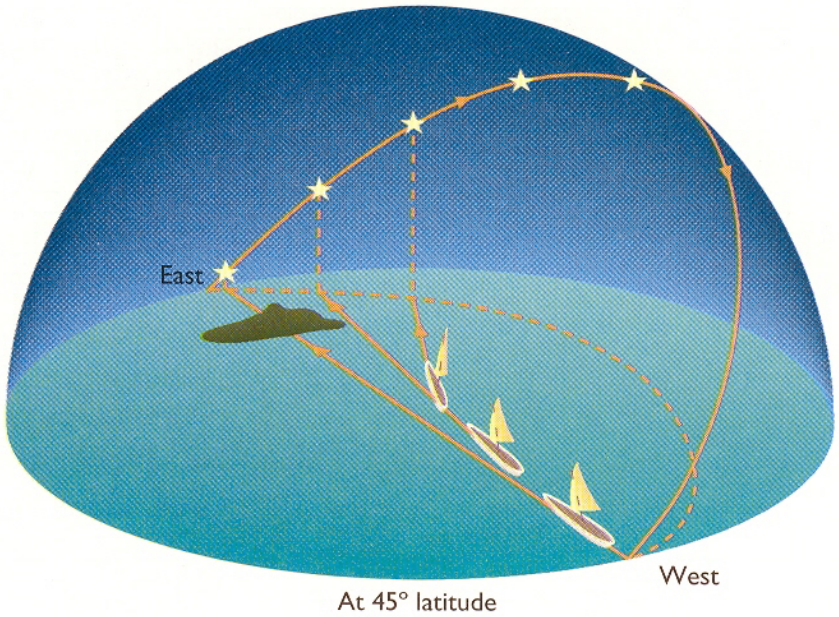


Equatorial Star Tracks

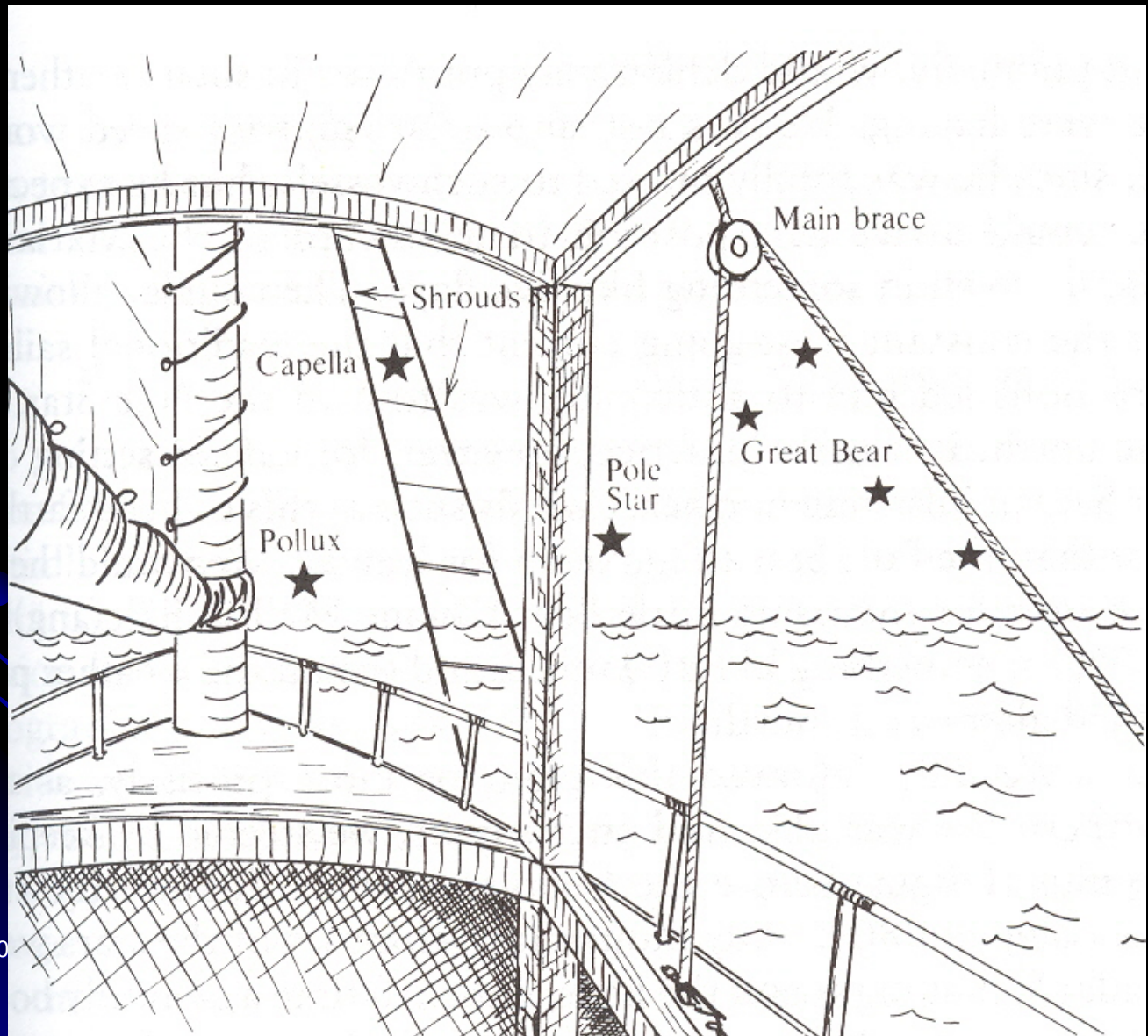


Star Tracks Polynesia

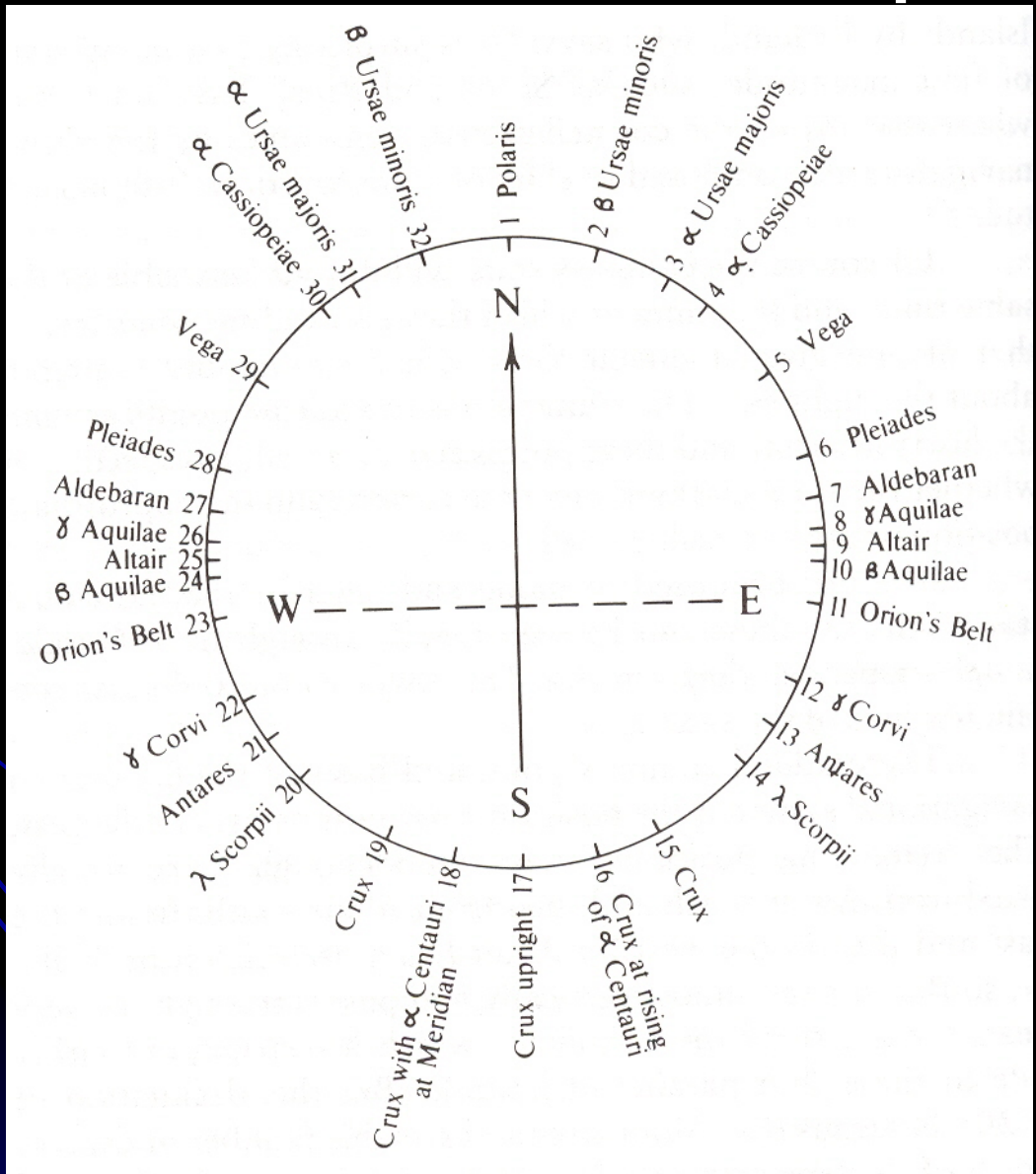




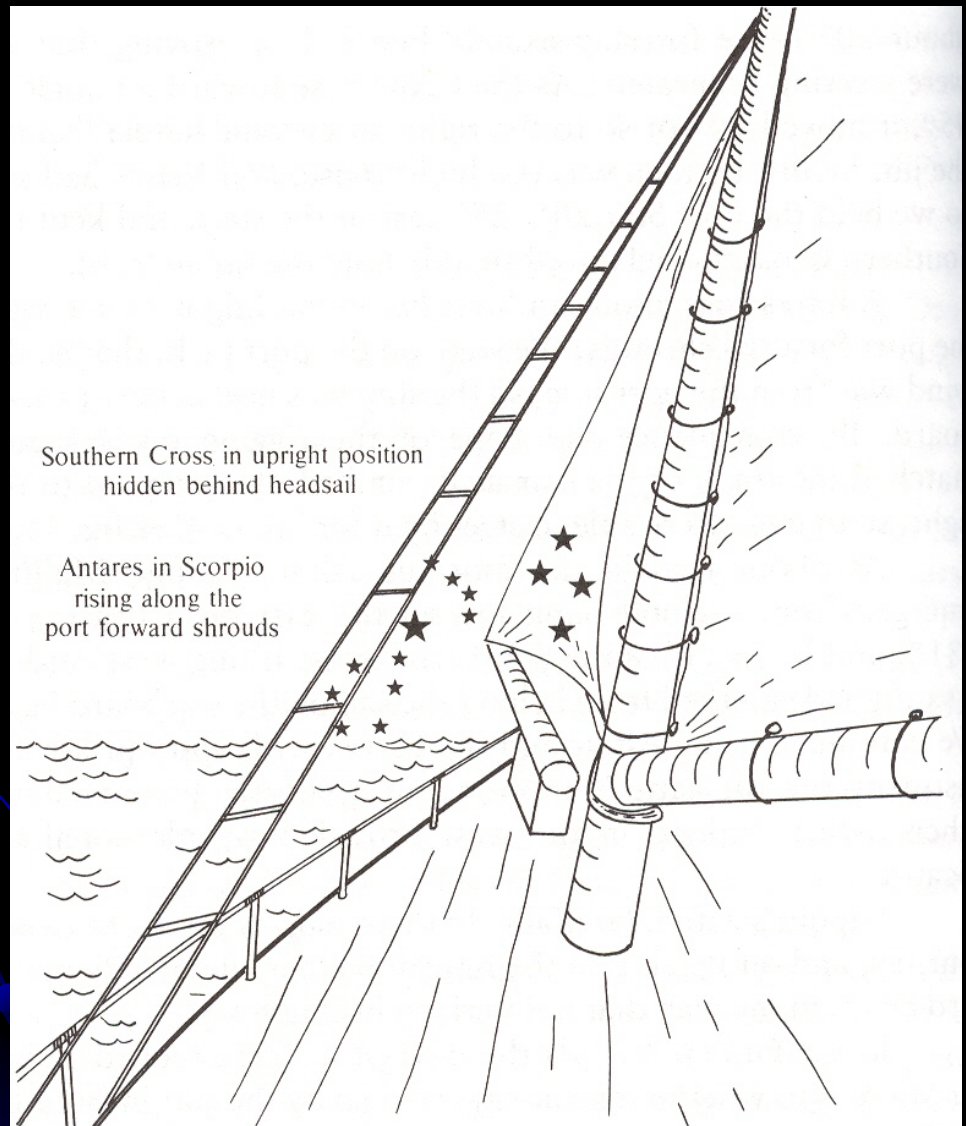
Steering Example
Puluwat to Pikelot to Saipan



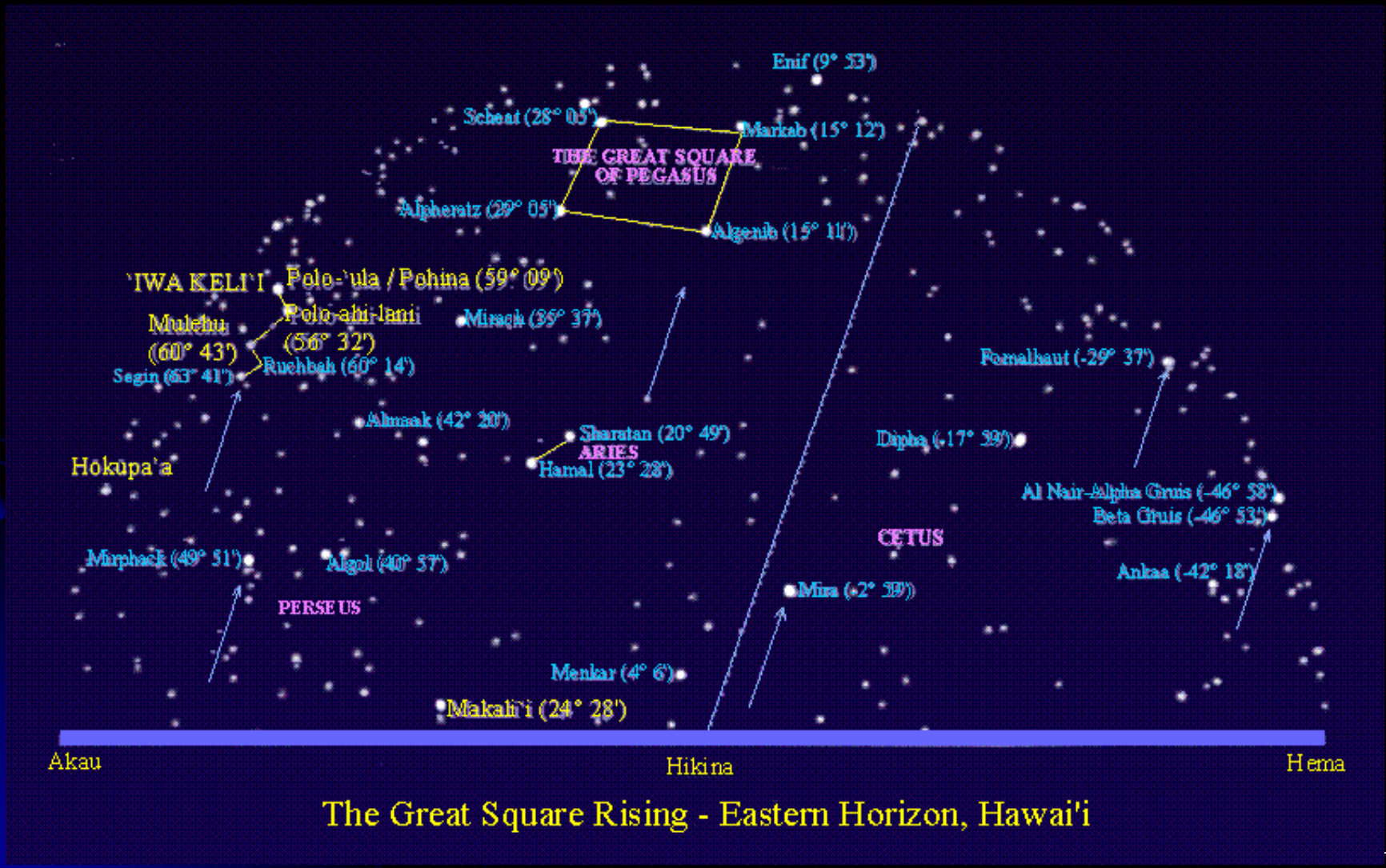
Carolina Star Compass



Steering
Antares and Southern Cross

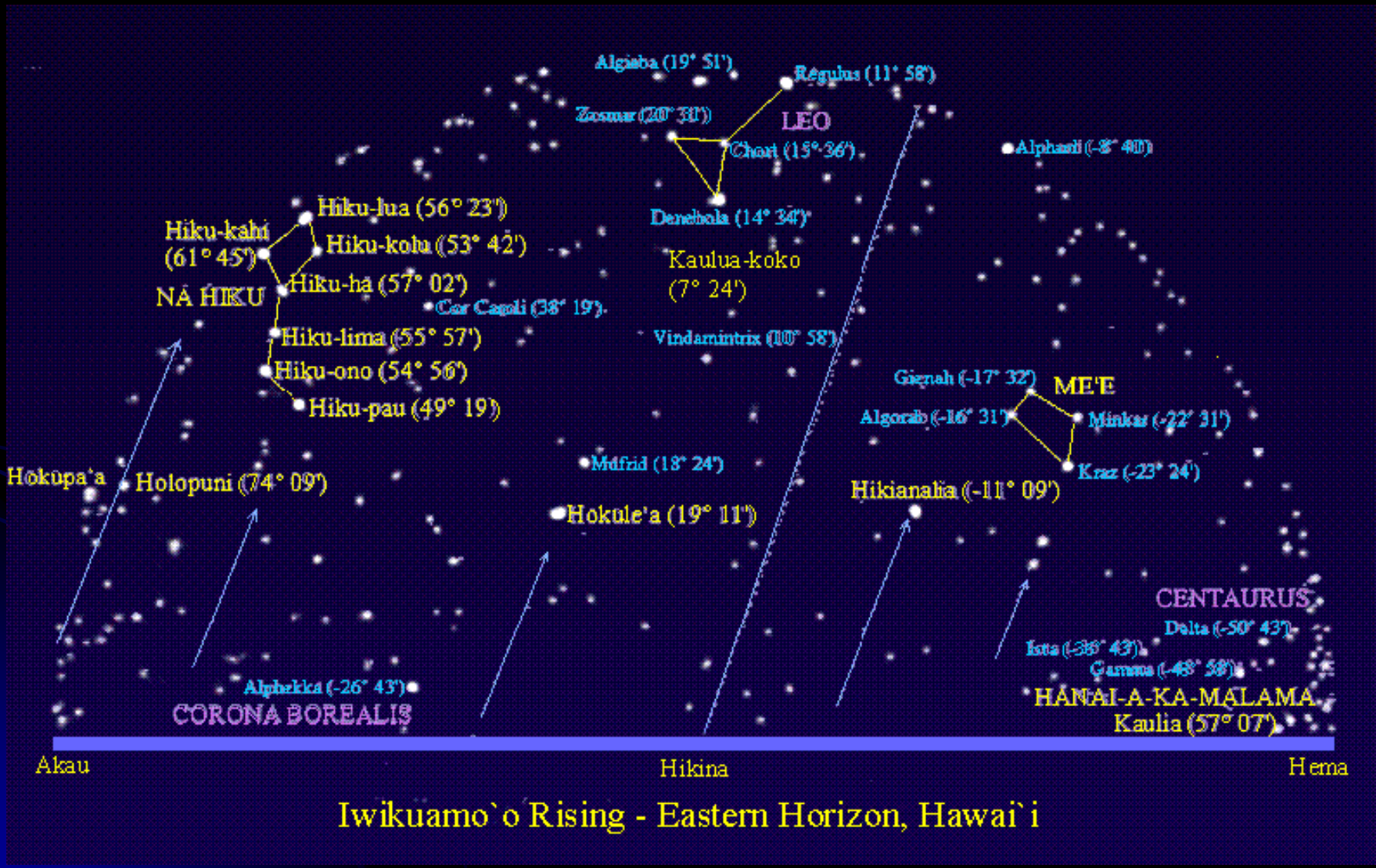


Kite of Kawelo

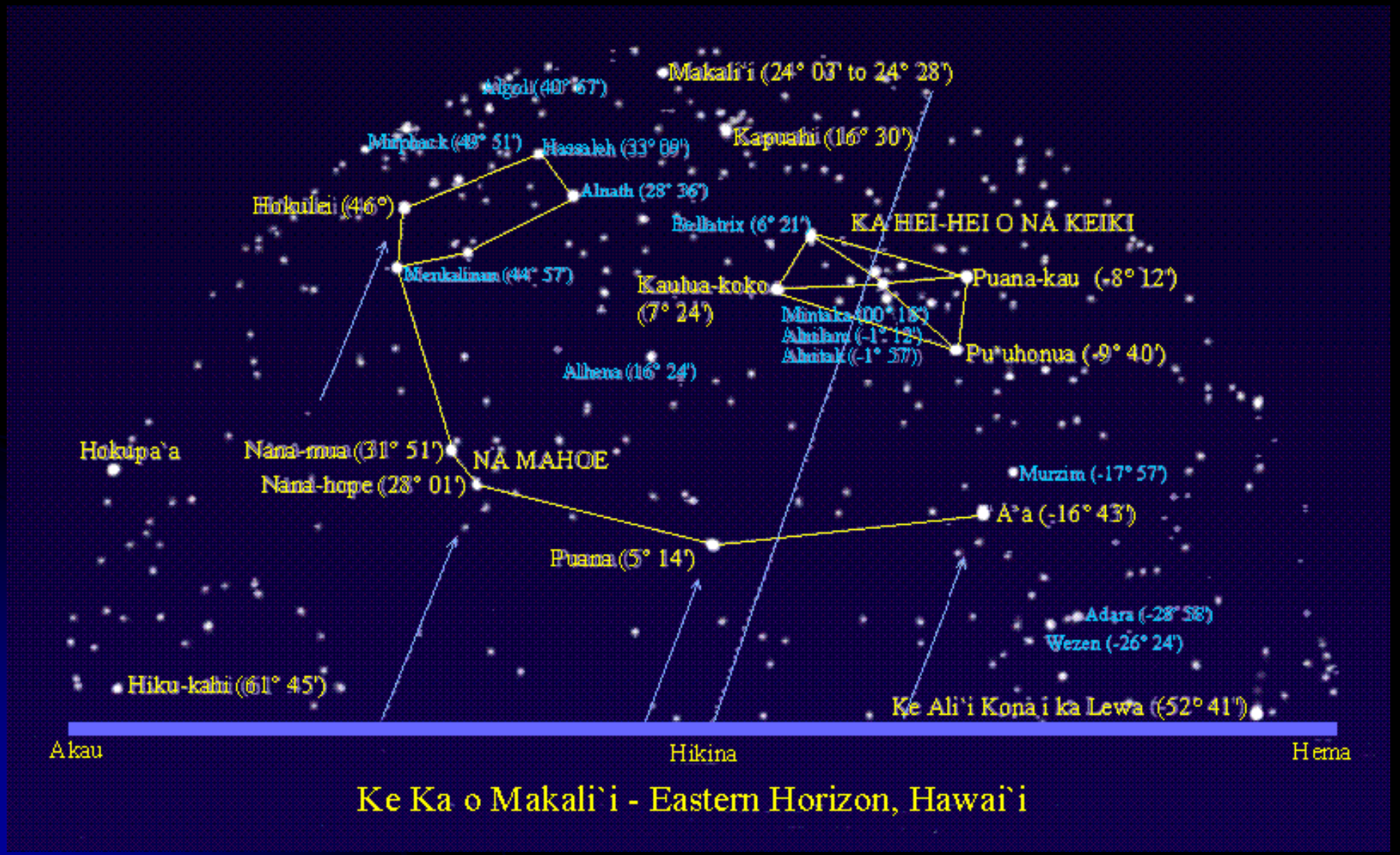


The Great Square Rising - Eastern Horizon, Hawai'i

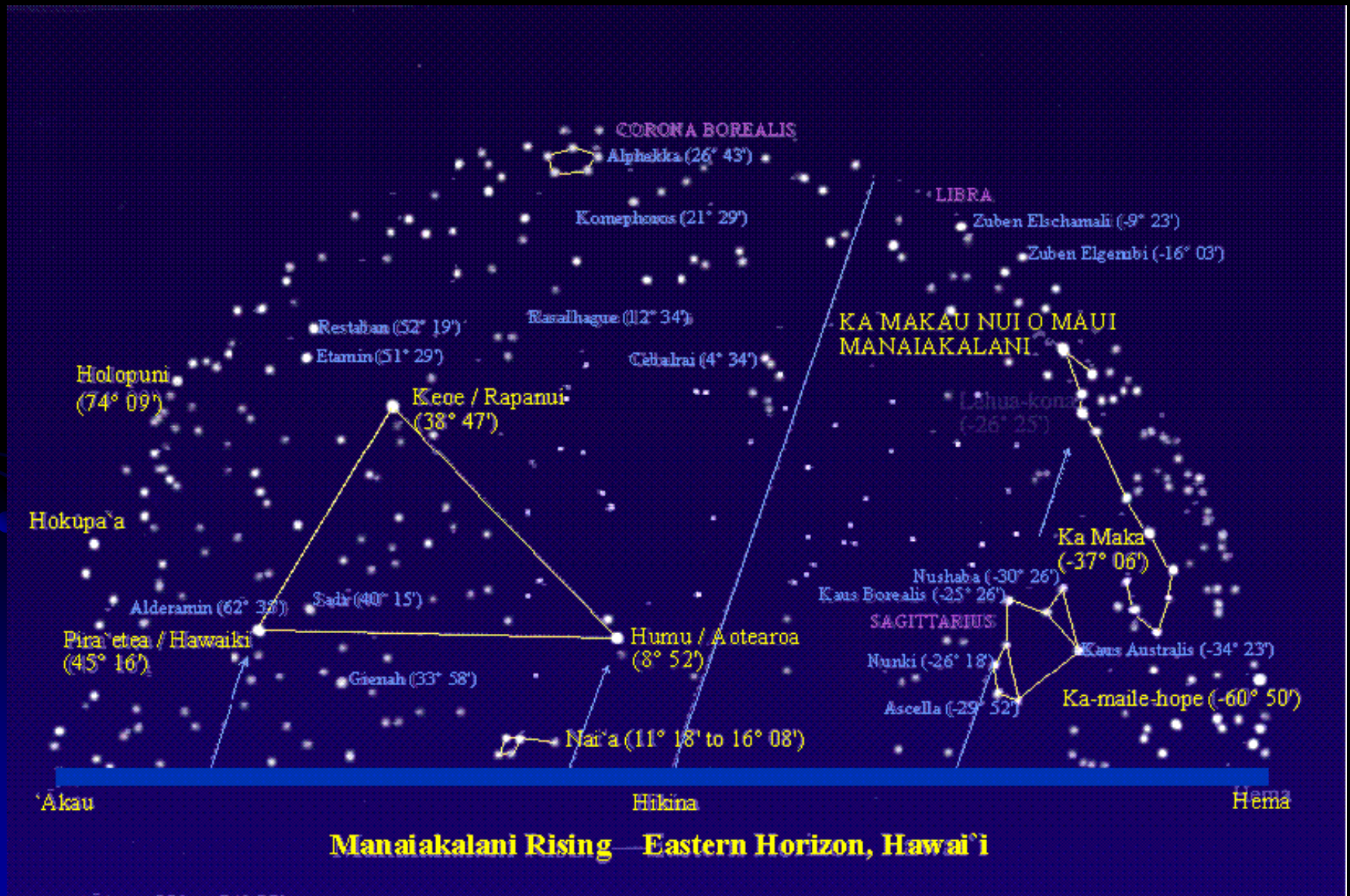
N-S Line


Algieba (19° 51')
Regulus (11° 58')
Zosma (20° 31')
LEO
Chort (15° 36')
Alphard (-8° 40')
Denebola (14° 34')
Hiku-lua (56° 23')
Hiku-kahi (61° 45')
Hiku-kolu (53° 42')
Kaulua-koko (7° 24')
NA HIKU
Hiku-ha (57° 02')
Cor Caroli (38° 19')
Vindamintrix (10° 58')
Hiku-lima (55° 57')
Hiku-ono (54° 56')
Hiku-pau (49° 19')
Gienah (-17° 32')
ME'E
Algorab (-16° 31')
Minkar (-22° 31')
Kraz (-23° 24')
Hokupa'a
Holopuni (74° 09')
Mufrid (18° 24')
Hikianalia (-11° 09')
Hokule'a (19° 11')
CENTAURUS
Delta (-50° 43')
Iota (-36° 43')
Gamma (-48° 58')
Alphekka (-26° 43')
CORONA BOREALIS
HANAI-A-KA-MALAMA
Kaulia (57° 07')
Akau
Hikina
Hema
Iwikuamo`o Rising - Eastern Horizon, Hawai`i

The Bailer


Algol (40° 67')
Makali`i (24° 03' to 24° 28')
Mirphack (49° 51')
Hassaleh (33° 09')
Kapuahi (16° 30')
Alnath (28° 36')
Hokulei (46°)
Bellatrix (6° 21')
KA HEI-HEI O NA KEIKI
Menkalinan (44° 57')
Kauhua-koko
(7° 24')
Puana-kau (-8° 12')
Mintaka (00° 18')
Alnilam (-1° 12')
Alnitak (-1° 57')
Pu'uhonua (-9° 40')
Alhena (16° 24')
Hokupa`a
Nana-mua (31° 51')
NA MAHOE
Nana-hope (28° 01')
Murzim (-17° 57')
A'a (-16° 43')
Puana (5° 14')
Adara (-28° 58')
Wezen (-26° 24')
Hiku-kahi (61° 45')
Ke Ali`i Kona i ka Lewa (52° 41')
Akau
Hikina
Hema
Ke Ka o Makali`i - Eastern Horizon, Hawai`i

Navigator's Triangle



Celestial Navigation

- Polynesians used various methods to navigate between islands
  - Stars
  - Winds
  - Currents
  - Stick maps

Greek Astronomy

Homer

- Homer's Iliad and Odyssey
  - Likely written down end of 8th century
- Homer likely lived somewhere between the 8th and 7th century BCE.

Achilles' Shield

- Iliad – Achilles' shield

"He made … on it all the constellations … the Pleiades and the Hyades and the strength of Orion and the Bear, who men also give the name the wagon who turns in a fixed place and looks at Orion and she alone is never plunged intot the wash of the ocean …"

"… the Ocean River which ran around the uttermost rim …"

Homer Cont.

- Pleiades
- Orion
- Ursa Major (Bear and Wagon)
  - Circumpolar
- Sirius
  - “Dog star”
- Boötes
  - Arcturus brightest star
  - “Guards” the Bear

Homer Cont.

- Odysseus steers by the Bear
  - Keeps it to his left sailing East
- Achilles shield appears to be a depiction of the earth as flat
- Likens the sky to iron and bronze
  - Possibly thought that the sky was solid

Homer Cont.

- He knows that different stars are visible at different times of the year
  - "…that star of the waning summer who beyond all stars rises bathed in the Ocean …"
    - Talking about Sirius
      - Brightest star in the sky
- Sirius
  - In the summer in Greece Sirius makes its heliacal rising in summer
  - Time of year is told by stars

Homer Cont.

- Homer mentions the morning and evening star but does not mention that it is the same “star” Venus
  - Possibly unaware that they are the same celestial object
- No mention in Homer of astrological use of the stars and planets

Hesiod

- Greek poet
- Lived after Homer
- Likely in the 8th century BCE
- Used stars to tell planting and harvesting times

Hesiod - Works and Days

- Poem
- Agricultural calendar
  - What should be done when
- Uses heliacal risings of different stars and planets to tell when something is to be done
  - “When the Pleiades, daughters of Atlas, are rising, begin the harvest, the plowing when they set.”

Pleiades

- Helical rising is in May
  - Just before sunrise
  - Wheat harvest
- Heliacal setting is in late Fall
  - Plowing
  - Planting grain

Hesiod Cont.

- Says that planting cannot be put off until "turning of the Sun"
  - December solstice
- Knows about the Equinox
  - "…days and nights are of equal length …the Earth … bares her various fruits ."

Hesiod Cont.

"…has finished sixty wintry days
After the turning of the Sun, then the star
Arcturus leaves the holy stream of Ocean
And first rises brilliant in the twilight.
After him …the swallow,
Comes into the sight …when spring is beginning."

- This allows us to check when Hesiod lived

Hesiod Cont.

- Possibly used folklore
  - Heliacal rising and setting of stars
    - Fixed star phases
- Earliest parapegma known from 5th century BCE

Epicycles

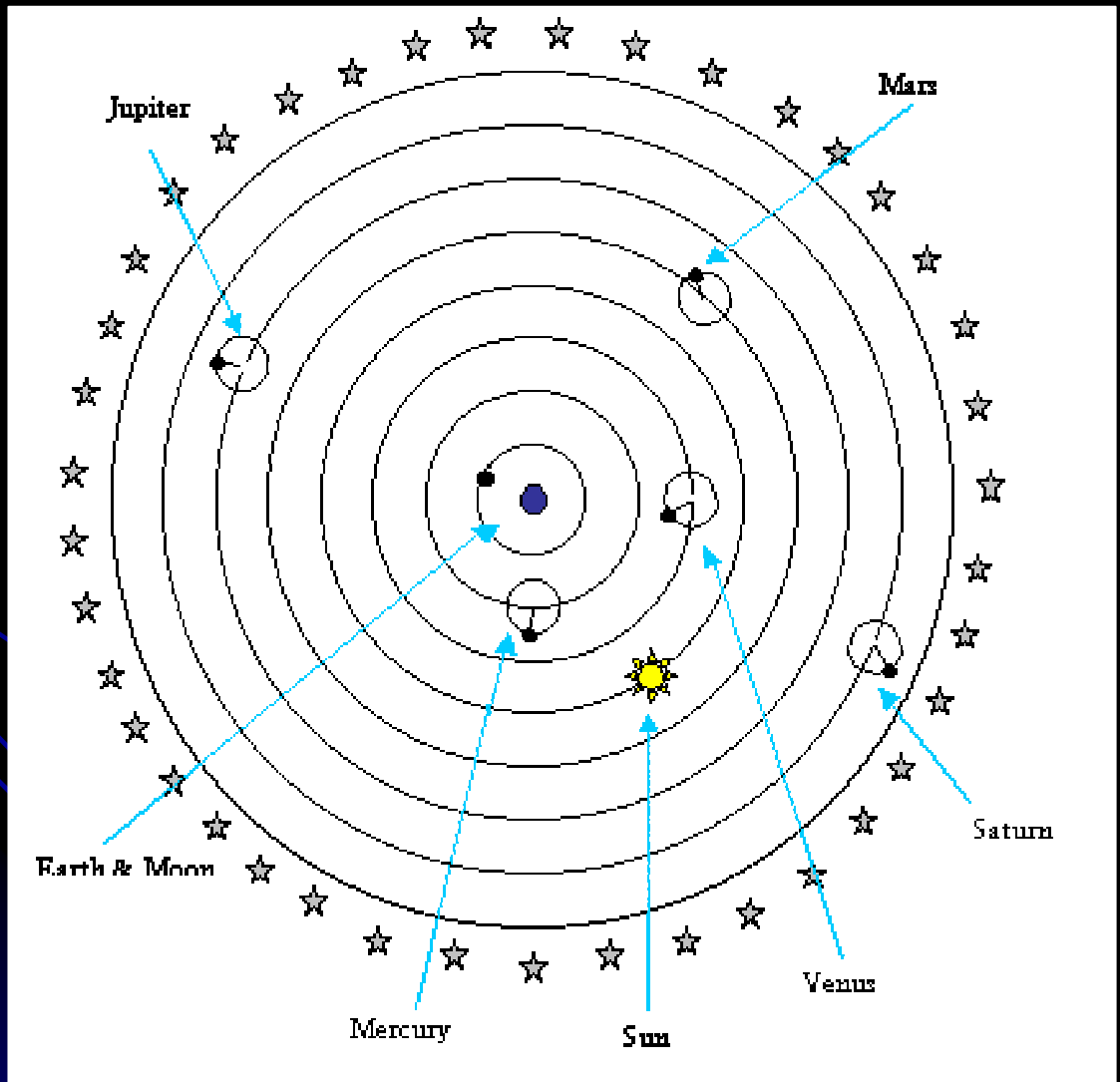
- Hipparchus
  - 2nd century BCE
  - Bridge between Greek and Mesopotamian astronomy
- Ptolemy
  - ~100 CE
  - Used epicycles to reconcile observed tracks of the planets and geocentric cosmology

Claudius Ptolemy

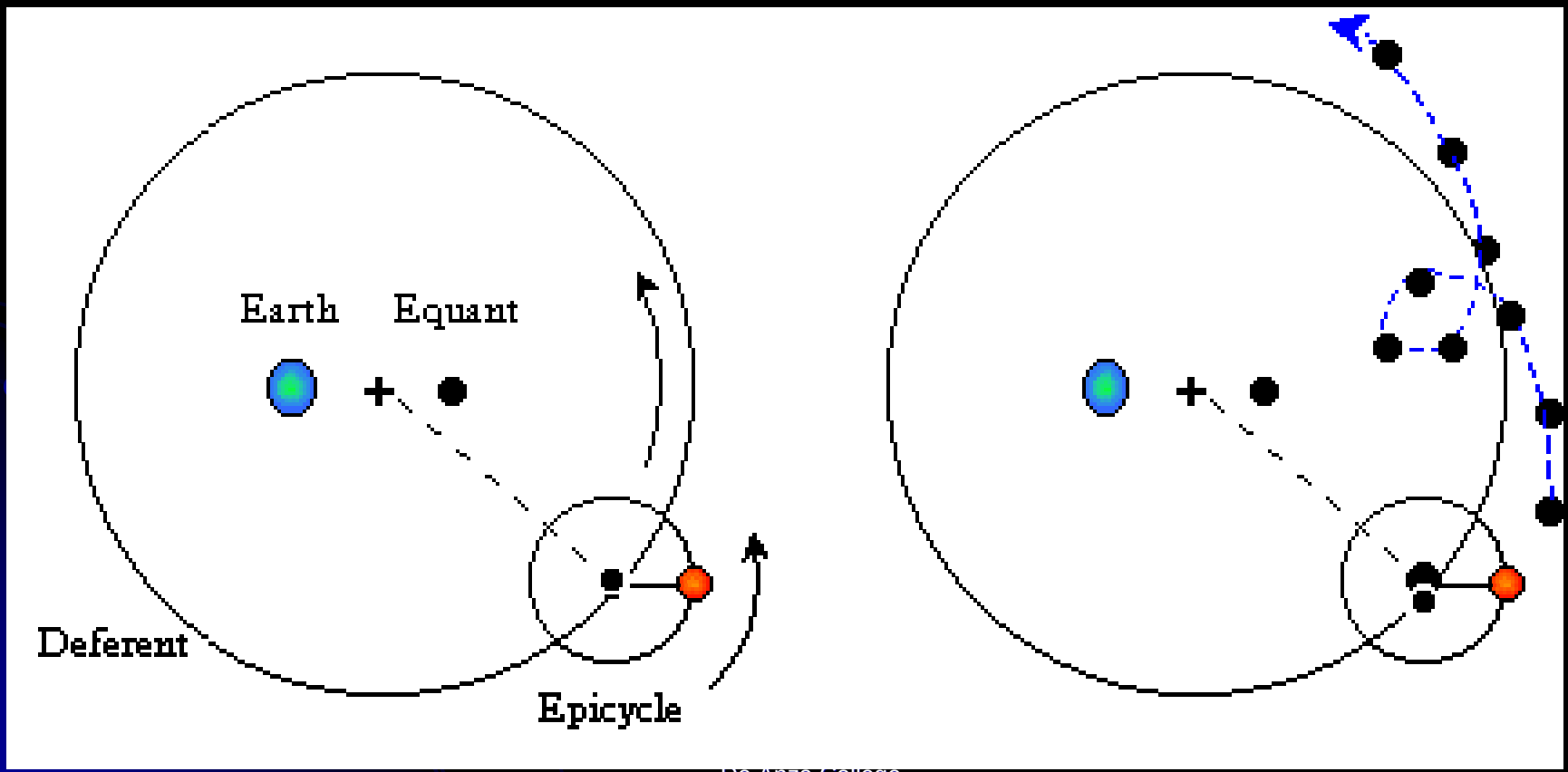
Life

- Very little known
- Born ~85CE
- Died ~165 CE
- Spent life in Alexandria in Egypt
  - Center for learning in the Hellenistic and Roman world
- Syntaxis
  - Arabic name Almagest (pronounced …jest)
- Geocentric model after Aristotle
- Epicycles
- Equants

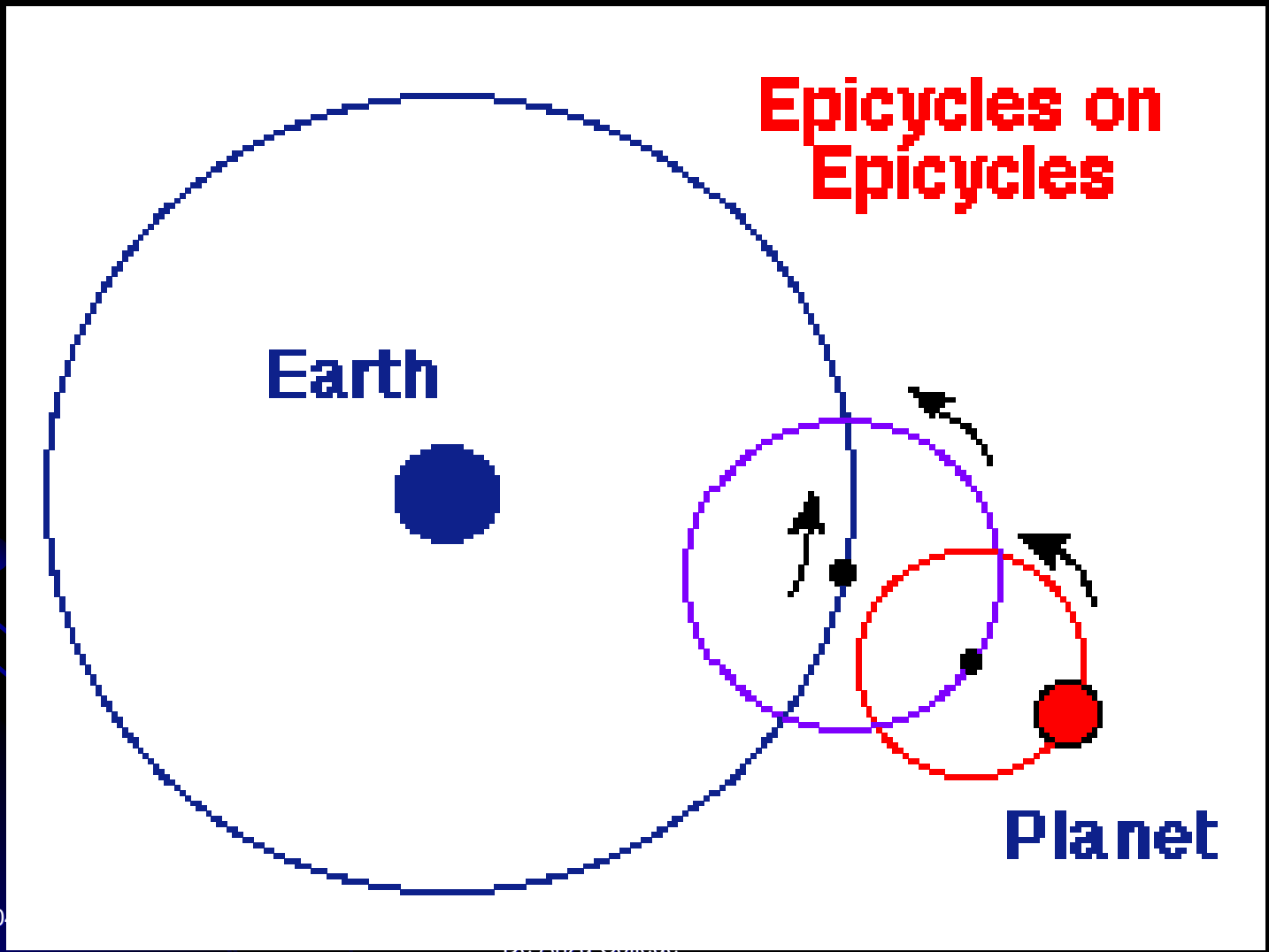
Geocentric Model



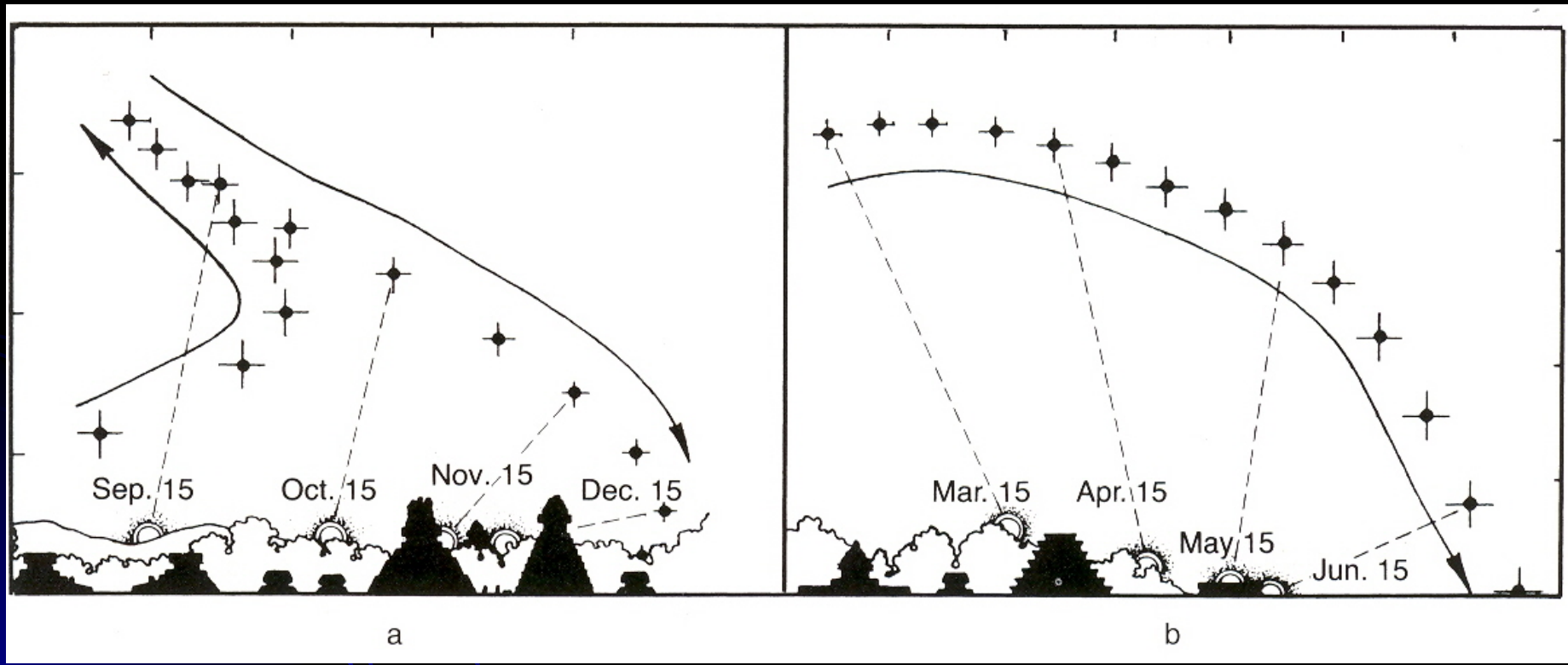
Epicycle



Epicycles on Epicycles



Venus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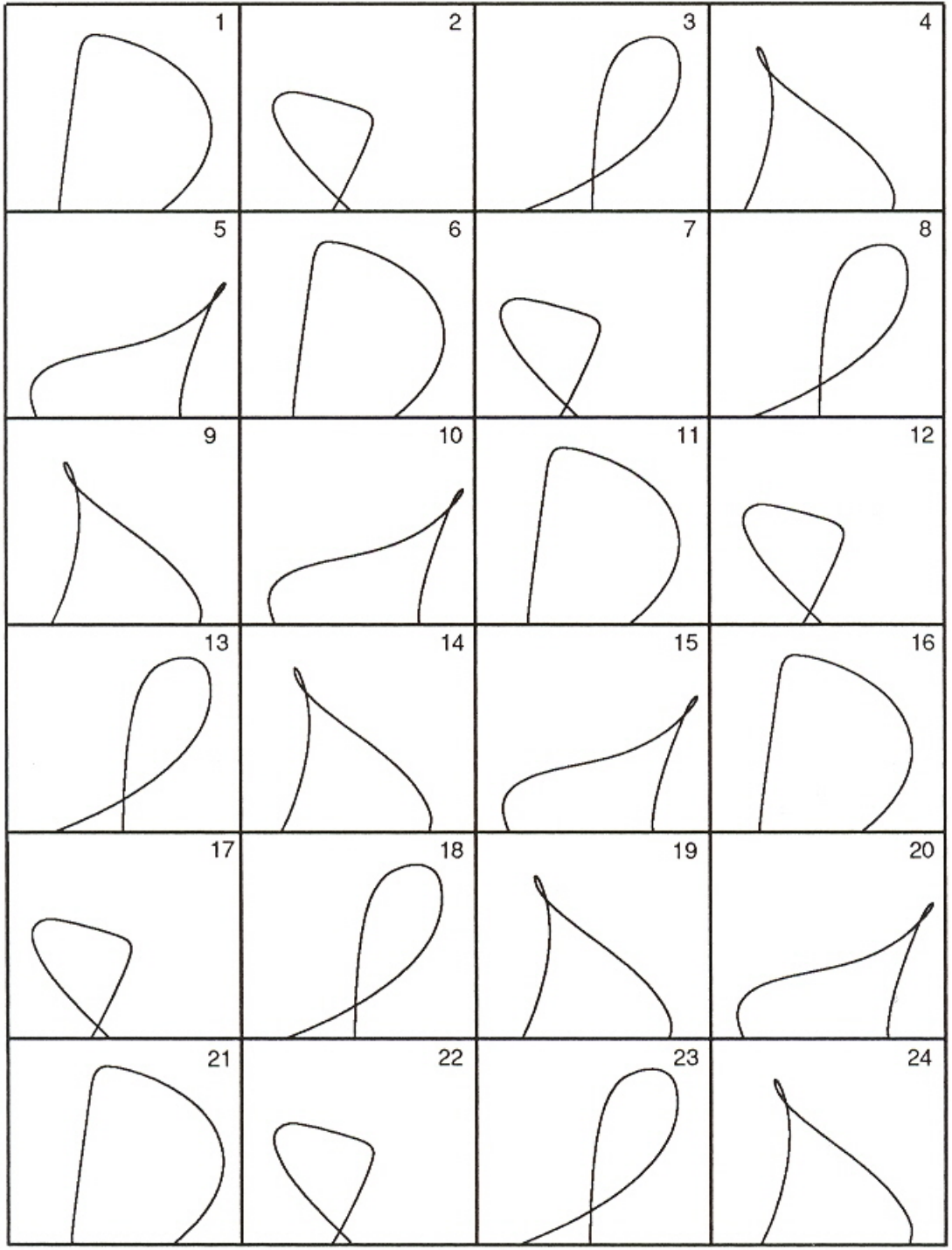
Oct. 15
Nov. 15
Dec. 15
Mar. 15
Apr. 15
May 15
Jun. 15
a
b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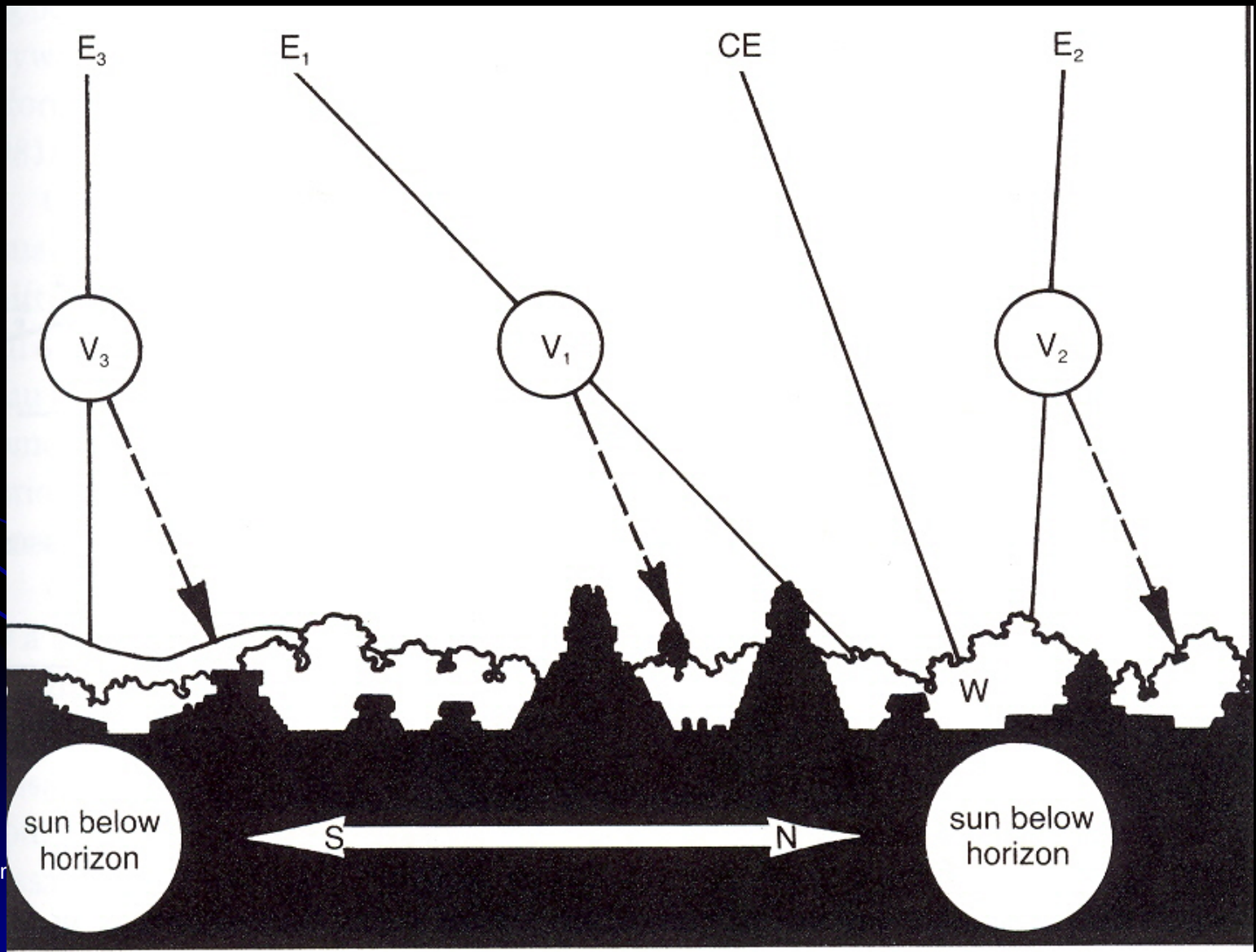
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E1
CE
E2
V3
V1
V2
W
sun below horizon
S
N
sun below horizon

Thank You