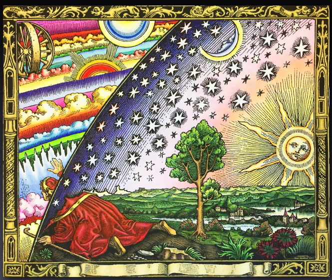
A brief historical overview

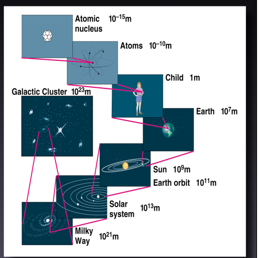


Koupelis - chapters 2 & 3
OpenStax - chapters 2 & 3

1

Summary of lecture I

- Simple observations
  - stars & constellations,
  - Sun, Moon, planets, comets
  - Ecplises, Milky Way
- A first exploration
  - planets → clusters of galaxies
  - emptiness and expanse of space
  - space-time



2

Impressed by celestial events…

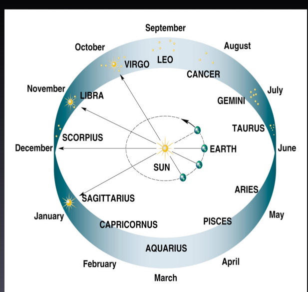
- Stonehenge
- Pyramids
- Sun and Moon temples
- Rites and rituals
- Gods
- Cosmic messages
  (comets, star of Bethlehem)

⇒ ASTROLOGY

3

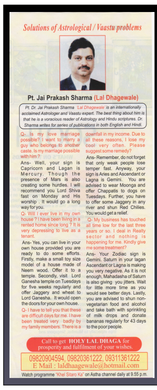
ASTROLOGY:

"gelul in de ruimte"
(Levi Weemoedt)



4

Modern Astrology



Q- I have to tell you that these are difficult days for me. I have been treated very badly by my family members. There is a downfall in my income. Due to all these reasons, I lose my cool very often. Please suggest some remedy?

Ans- Remember, do not forget that only weak people lose temper fast. Anyway, your sign is Aries and Ascendant or Lagna is Gemini. You are advised to wear Moonga and offer Chappatis to dogs on Tuesdays. Further, you have to offer some Jaggery in any river and shun Red Chilies. You would get a relief.

Q- My business has touched all time low for the last three years or so. I deal in Realty sector and nothing is happening for me. Kindly give me some treatment?

Ans- Your Zodiac sign is Gemini. Saturn in your lagan Ascendant or Lagna is making you very negative. As it is not enough, Mahadasha of Saturn is also giving you jitters. Wait for little more time as you would see better days. Lastly, you are advised to shun non-vegetarian food and alcohol and take bath with sprinkling of milk drops and donate bananas regularly for 43 days to the poor people.

(source: Jet Airways in-flight magazine, Oct 2017)

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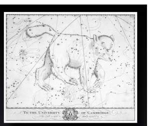
Shifting world views



- Archaeo-astronomy
  - driven by existential questions and practical applications
  - Lascaux, Nabta, Stonehenge, Newgrange, Goseck & Nebra disc, Egypt, Babylonia & Mesopotamia, Maya culture
- Antiquity
  - brilliant ideas, the beginning of 'scientific thought'
  - from a geocentric to a heliocentric world view
- The scientific revolution of the 16th -17th century
  - from Copernicus to Newton
  - the laws of Kepler and Newton

6

Stonehenge - England

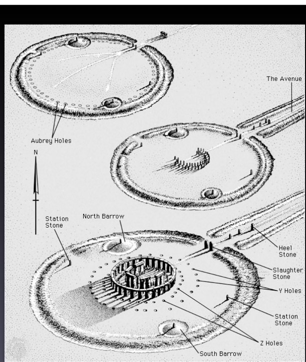
7

Stonehenge

A very complex structure

built in 3 phases
during a long period

5.000 - 3.000 years old



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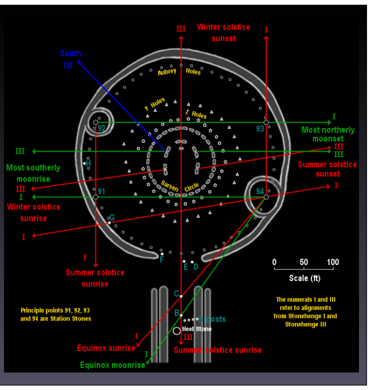
Stonehenge

An old observatory?



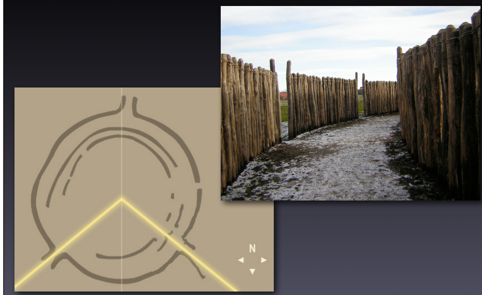
9

Goseck - Germany

- discovered on aerial photographs in '90
- 75 m. in diameter, Stonehenge-like construction
- a settlement since 5.000 B.C.
- solar observatory, marking solar solstices
- reconstructed in 2005

10

Goseck - Germany



11

Goseck - The Nebra disc

Bronze disc:

3.650 years old
oldest known star map
European Bronze Age

Discovered in 1999 on the Mittelberg (252m), 25km from Goseck

30cm in diameter, golden inlays

Symbols:
- Sun / Moon
- 32 stars (incl Pleiades?)
- 2 arches:
  angle between solar solstices
- extra arch: Sun boat, Milky Way, Rainbow?

12

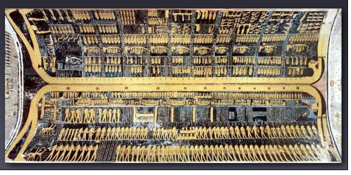
astronomy in Egypt

There's a lot of discussion about the significance of astronomy in Egypt

Importance of astronomy:

- practical use : Heliacal rising of Sirius - flooding of the Nile
  circumpolar stars - alignment of the pyramids
- religion : Sun - Ra

Egyptian world view:
Nut & Ra



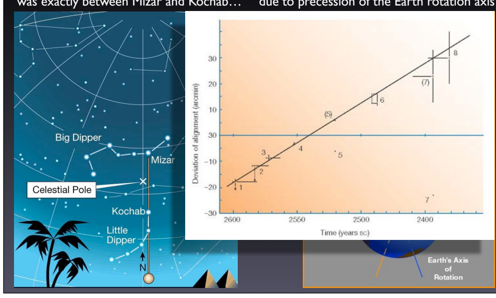
13

Sirius and the Nile

14

aligning the pyramids

In 2462 BC, the North Celestial Pole was exactly between Mizar and Kochab… …but the NCP drifts on the sky due to precession of the Earth rotation axis



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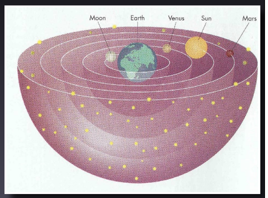
Shifting world views

from a geocentric to a heliocentric world view

Simple observations with the naked-eye were consistent with a geocentric world view.



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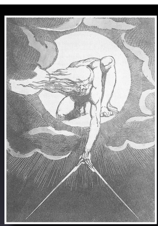
Antiquity

Brilliant thoughts and ideas !

- Pythagoras (530 BC)
  mathematical description, Earth is spherical
- Pythagorian School (450 BC)
  Universe is spherical with central fire
- Aristotle (384-322 BC)
  places the Earth back in the center
- Aristarchus (280 BC)
  places the Sun in the center again
- Eratosthenes (276-195 BC)
  measures the circumsphere of the Earth
- Ptolemy - Almagest (150 AD)
  introduces epicycles,
  and reintroduces a geocentric universe

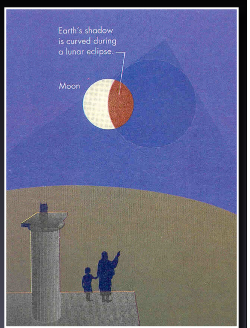


A proper understanding of the relative distances and sizes of the Earth - Sun - Moon

17

From Lunar eclipses, they inferred that:

- the Earth is spherical
- the Earth is several times larger than the Moon



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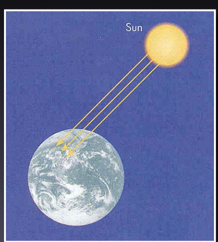
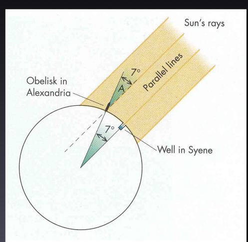
The determination of the circumsphere of the Earth by Eratosthenes is phenomenal:

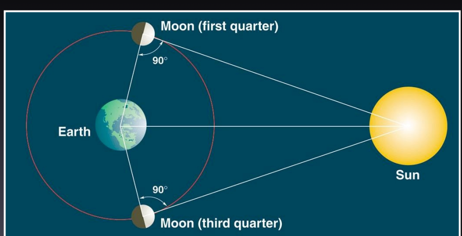




He measured the correct value with an accuracy of a few percent!

19

Aristarchus estimated the scale of the Earth-Sun-Moon system.

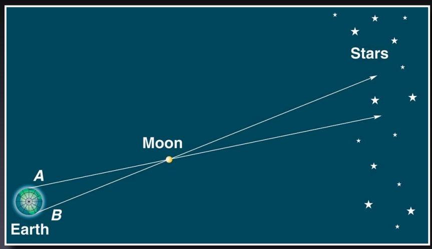


Although he reached the wrong conclusion, the method was phenomenal!

20

21

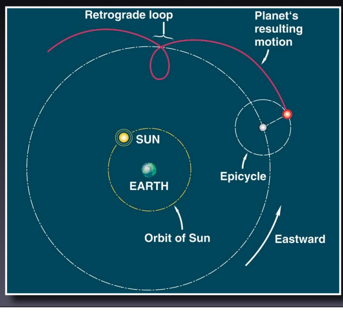
Estimating the distance to the Moon, using the parallax method, failed:



22

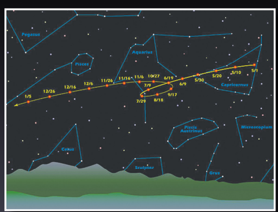
Ptolemy's geocentric model :

uniform motions on *perfect circles* require epicycles
to explain the 'retrograde motion' of Mars, Jupiter and Saturn



23

The retrograde motions of Mars, Jupiter and Saturn

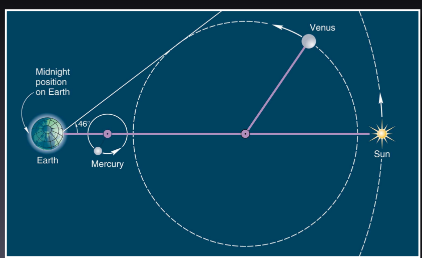


When a planet is opposite of the Sun on the sky, and thus visible at midnight:
- its motion along the ecliptic reverses and
- its apparent brightness increases temporarily.

24

Ptolemy's geocentric model :

Epicycles of Mercury and Venus between the Earth and the Sun
to explain the 'maximum elongation' of these planets from the Sun



Venus is only visible in the evening and morning sky.

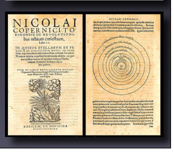
25

The Ptolemaic geocentric model endured until the Renaissance due to dogmatic Christian thinking and reliance on authority.

Nicolaus Copernicus (1473-1543)
discovered shortcomings in Ptolemy's ***geo***centric model :

- inaccurate long-term predictions for a planet's position
- brightness variations of Mars are too large for epicycles
- 'light of life' from a central Sun was deemed more aesthetic

Copernicus developed a ***helio***centric model but still assumed uniform motions on perfect circles with smaller 'epicycles'.



His work was published in *De Revolutionibus Orbium Coelestium*

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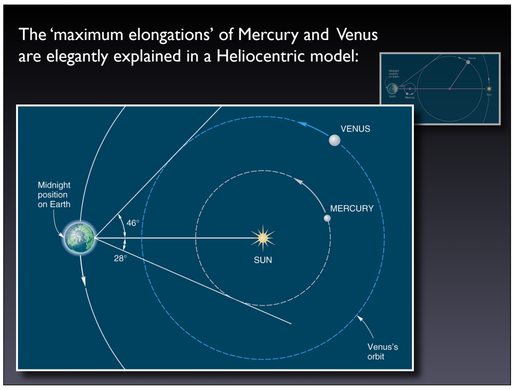
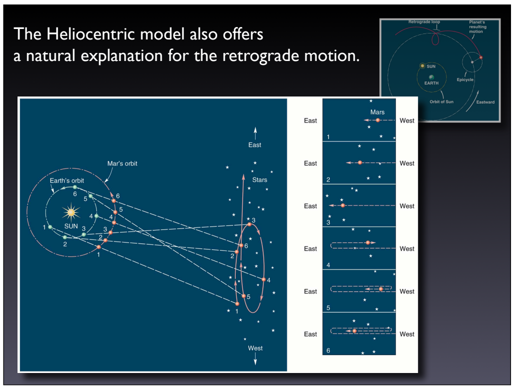
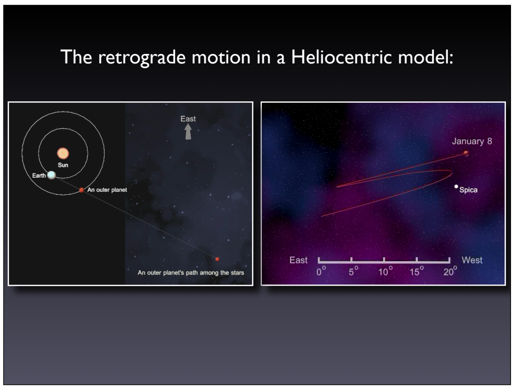

The 'maximum elongations' of Mercury and Venus
are elegantly explained in a Heliocentric model:
VENUS
MERCURY
Midnight position on Earth
46°
28°
SUN
Venus's orbit

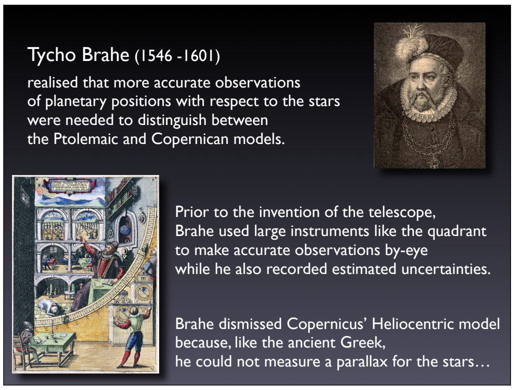
27


The Heliocentric model also offers
a natural explanation for the retrograde motion.
Mar's orbit
Earth's orbit
SUN
Stars
East
West
Mars

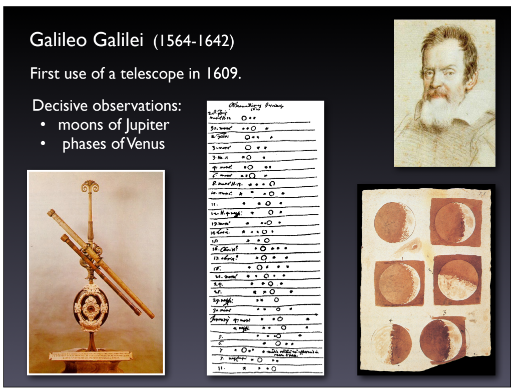
28


The retrograde motion in a Heliocentric model:
East
Sun
Earth
An outer planet
An outer planet's path among the stars
January 8
Spica
East
West
0° 5° 10° 15° 20°

29

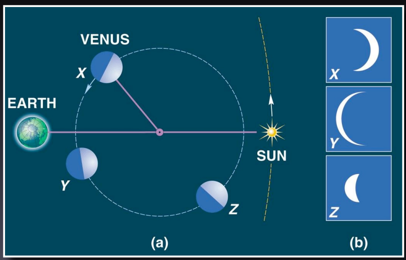

Tycho Brahe (1546 -1601)
realised that more accurate observations
of planetary positions with respect to the stars
were needed to distinguish between
the Ptolemaic and Copernican models.
Prior to the invention of the telescope,
Brahe used large instruments like the quadrant
to make accurate observations by-eye
while he also recorded estimated uncertainties.
Brahe dismissed Copernicus' Heliocentric model
because, like the ancient Greek,
he could not measure a parallax for the stars…

30


Galileo Galilei (1564-1642)
First use of a telescope in 1609.
Decisive observations:
• moons of Jupiter
• phases of Venus

31

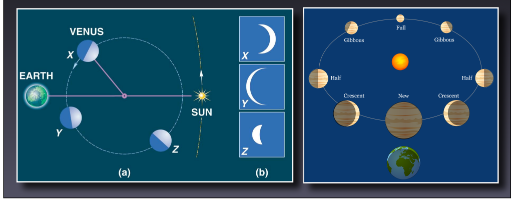
A geocentric model can not explain the apparent phases of Venus.



A 'Full Venus' is not possible.

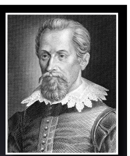
32

A geocentric model can not explain the apparent phases of Venus.



33

Johannes Kepler (1571-1630)
postulated empirical laws for planetary motions
based on accurate measurements of Tycho Brahe.



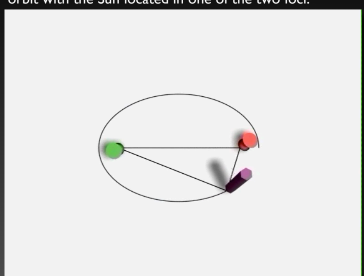
The 3 laws of Kepler for planetary motion:

- Each planet moves around the Sun in an *elliptical* orbit with the Sun located in one of the two foci.
- The straight line between the Sun and a planet sweeps equal areas during equal intervals of time.
- The square of the orbital period of a planet is proportional to the cube of the semi-major axis of the orbit (P^2/A^3 = constant)

34

Kepler's First Law:

Each planet moves around the Sun in an elliptical orbit with the Sun located in one of the two foci.



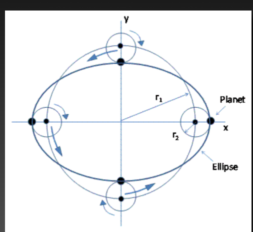
35

Kepler's First Law:

Each planet moves around the Sun in an elliptical orbit with the Sun located in one of the two foci.

By the way:

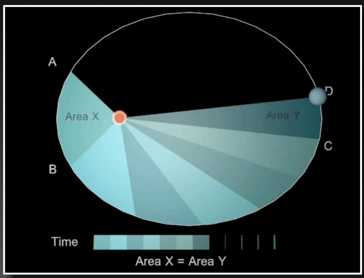
an ellipse is well approximated with circular epicles on a circular orbit.



36

Kepler's Second Law:

The straight line between the Sun and a planet sweeps equal areas during equal intervals of time.



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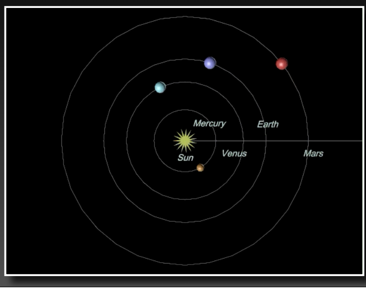
Kepler's Third Law:

The square of the orbital period of a planet is proportional to the cube of the semi-major axis of the orbit (P^2/A^3 = constant)



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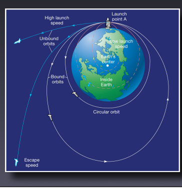
The validity of the empirical laws of Kepler was proven mathematically in 1687 by Isaac Newton's theory of gravity, published in

Philosophiae Naturalis Principia Mathematica

- One of nature's four fundamental forces.
- Gravity keeps the Moon in an orbit around Earth, humans bound to Earth's surface, the Earth & Moon around the Sun.
- It keeps satellites in their orbits : A satellite launched with sufficient speed, will keep 'falling' in a circular orbit.
- Kepler's empirical laws are easily derived from Newton's physical Law of Gravity!



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Newton's three laws of motion:

1. An object will remain in rest or maintain a constant speed in a straight line, unless an outside force acts upon it.
2. A force acting upon an object causes it to accelerate at a rate proportional to the force and inversely proportional to its mass:
   Force = mass x acceleration or $F = ma$
3. When object X exerts a force on object Y, object Y exerts an equal and opposite force back on X:
   Action = − Reaction

Newton's Laws of Universal Gravity:

$$F = G\frac{m_1 m_2}{d^2}$$

F = gravitational force
G = universal constant of gravity
m_1 = mass of object 1
m_2 = mass of object 2
d = distance between the two objects