

## The Depth of Heavens

Belief and Knowledge during 2500 Years

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**Content:**

- *The universe, as we know: 14 billion years old*
- *Dante's universe, 700 years ago: Divine Comedy*
- *Science, how we came to know: From the Greeks to Tycho Brahe and our time*

Lecture in Copenhagen, Vilnius, Nikolajev, Athens, Catania, and in Madrid at ESAC

## The Disc of Heavens from Germany

### The Nebra disc



1600 B.C.  
early bronze age.

Sun, Moon, and stars

First known image of the cosmos.

2

## What is in the Heavens ?

For man at all times :

- Moon, Sun , planets, stars

For Christians in Antiquity and Middle Ages :

- furthermore *God, the angels, the saints*

**For modern astronomers :**

- Moon, Sun, planets, stars
- + star clusters, galaxies, dust, gas
- + white dwarfs, neutron stars, black holes
- + quasars, invisible Dark Matter ....

3

### Crab Nebula - Dust and gas at distance 3400 light years

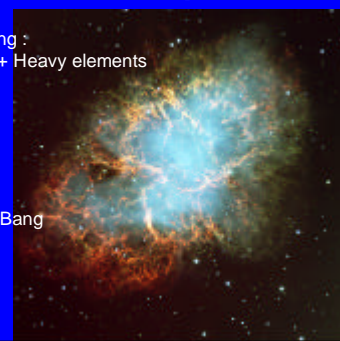
A supernova exploded here in the year 1054 AD  
seen by astronomers in China and Japan

Stars do cosmic recycling :  
Hydrogen  $\Rightarrow$  Energy + Heavy elements

Some stars live  
only 10 mio. years !

Through hundreds of  
generations of stars  
9 billion years after Big Bang

- $\Rightarrow$  Sun + Earth
- $\Rightarrow$  Man



## Andromeda galaxy

with two dwarf galaxies



100 billion stars  
**= 20 stars for every person on Earth**

Distance =  
2.2 million light years

1 light year =  
9,500,000,000,000 km

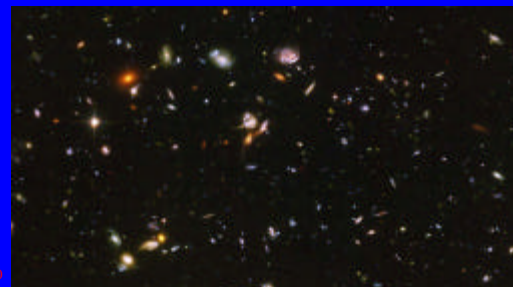
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## The whole universe is about 14 billion years

It began with the Big Bang

Hubble Space Telescope:

The faintest galaxies are seen 13 billion years back



10

10

## Dante Alighieri (1265-1321) The Divine Comedy (1307-1320)

UNIVERSE:

- Empyreum** with God, angels, and saints
- Celestial Spheres** of fixed stars, planets, and Moon
- Spherical Earth** with Purgatory mountain opposite to Jerusalem and **Hell** inside Earth

7

## Dante's Universe

	Ptolemy	True value
Stars	20,000	> 10,000 million
Sun	1210	25,000
Moon	33-64	60 Earth rad.

Earth rad. = 6400 km  
Earth radius = 6400 km

8

## Dante's Hell

The forest Jerusalem

Murderers

The most evil

Kokytos Lucifer

Lucifer

9

## Dante and Virgil with Lucifer

*Sandro Botticelli ~1500:  
Divina Commedia*

10

## Dante and Beatrice towards the Moon

## Dante with Beatrice and lunar spirits



Dante and Beatrice with the stars

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## A historical overview of science

Physics is simple, contrary to e.g. meteorology or biology

Philosophy and science *Babylonians and Greeks*

- 3300 Babylon: 60 -base numerals; mathematics and astronomy
- 570 Thales: Everything is water; natural explanations
- 450 **Anaxagoras:**  
The sun is a glowing rock  
As big as Peloponnison
- 350 Aristotle: Causes; time is cyclic
- 250 Archimedes: Mathematical description of measures  
not causes

## The Greek Cosmos ~ 500 B.C.

The Earth consists of earth, water, air, and fire


Around the Earth are spheres with Moon, planets, Sun and stars

## Plato's distance scale for the planets ~ 400 B.C.

Moon Sun Venus Mercury Mars Jupiter Saturn

## Plato and Aristotle

~ 350 B.C.



**Aristotle:**

- Causes
- Theory for the universe
- Time is cyclic
- Speculation!**
- An ingenious attempt

**Archimedes:**

- Mathematical description of measures – **not causes**.
- E.g. Theory of equilibrium:
- Eternal law of nature!**


19

## School of Athens

painted by Raphael 1510



**Aristotle**




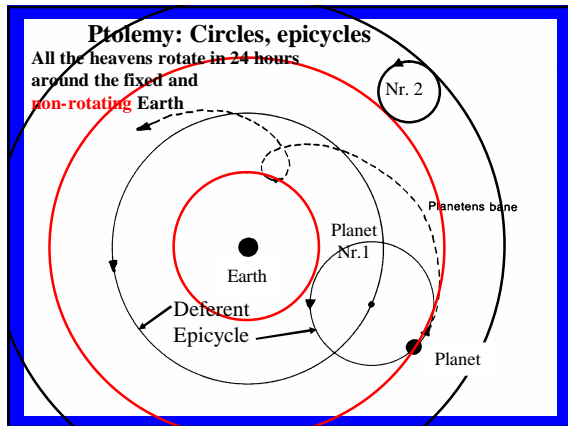
**Archimedes**  
~ 250 B.C.  
Laws of nature for **equilibrium**

**Newton 1687**  
Laws of nature for **motion**

## Ptolemy measuring


~150 AD

From G. Reisch, 1512

## The Arabs:

### Translation of Greek texts and Science



**Harun al-Rashid**  
766 - 809

*Our arabic numerals: from India to Europe:*

- 500 In India: "Position" numerals: e.g. 0, 10, 203
- 820 Al-Khwarizmi: Algorithm; astronomy
- 1021 Alhazen: Book on light and optics
- 1085 Toledo taken by Christians: large Arab library**
- 1120 In Europe:
- Al-Khwarizmi's book on algebra is translated

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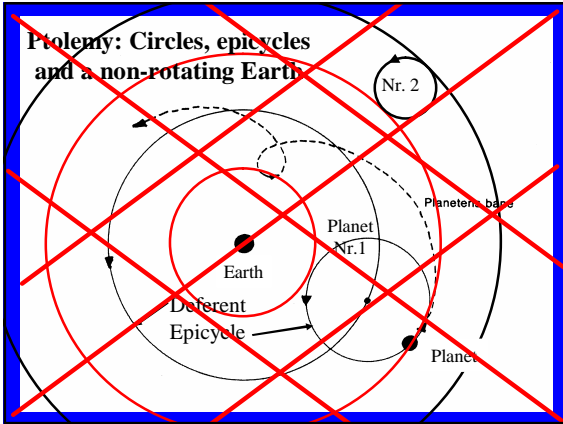


**God as the architect of the world**

*from a Middle Age Bible  
ca. 1250  
Codex Vindobonensis*

**And: Men of church had time to think and to teach**

24 20



**Copernicus 1514 and 1543**  
after Aristarch of Samos ~310-230 B.C.

**New theory of the universe:**

The Sun is at the centre,  
NOT the Earth

The Earth circles the Sun in **a year**

**and** the Earth rotates in **24 hours**

**The Sun and two planets**  
**Heliocentric system**

Copernicus 1473 - 1543

26

**11 Nov. 1572**  
**Nova Stella**

R.A. 0.5 h  
Dec. 63 deg

Cassiopeia

Pole

-8 p.m.

-8 a.m.

Moon's horiz. parallax  
6000 km/380,000 km  
=0.016=0.9 deg

Tycho Brahe measured the nova:  
Larger distance than the Moon

**He concluded in 1572:**  
This is a miracle  
a sign from God

**We say:**  
He tipped the  
antique picture of the world

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SEXTANS ASTRONOMICUS TRIGONICUS  
PRO DISTANTIIS REMANENS.

**Tycho Brahe**  
on Hven  
1576-97  
**A barrel of gold**

Sextant 1580

Hog

**Kepler 1619** *Harmonices Mundi*

Kepler found ~70 laws for the motion of planets  
But we usually mention only **3** of these...

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**Isaac Newton 1687:**  
*Philosophiæ Naturalis Principia Mathematica*

**Mathematics 1665-66:**  
Differential- and integral calculus

**+ Clear concepts 1687:**  
Gravity, force, acceleration,  
absolute time, velocity

**>>> Laws of motion:**  
Kepler's **3** laws;  
motions in the heavens and on Earth....

**>>> The technical revolution**

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**Telescope: Galilei 1610**

**Planet sizes**  
*Huygens 1698*  
 telescopic

*Ptolemy 150 AD*  
 naked eye

**Dante's Universe**

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**The Visible Universe**

Year	Radius – light years	What / Who
150-1600	0.000,014	Sphere of stars <i>Ptolemy</i>
1900	30,000	Milky Way <i>Kapteyn</i>
1960	2,000,000,000	Most distant galaxies <i>Palomar 5 meter</i>
2006	14,000,000,000	Visible universe <i>WMAP sat.</i>

Copenhagen University - Erik Hog - April 2008

**The Visible Universe**  
 is  $10^{15}$  times larger  
 than Tycho Brahe believed  
 $10^{15} = 1,000,000,000,000,000 = 1 \text{ million billion times}$

Tycho Brahe  
ca. 1590

Ptolemy  
ca. 150 A.D.

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Website: [www.astro.ku.dk/~erik](http://www.astro.ku.dk/~erik) Read e.g.:  
*The depth of heavens ... during 2500 years, and:  
 The age of the world from the highest authorities*