The Depth of Heavens
Belief and Knowledge during 2500 Years

Erik Høg

Niels Bohr Institute, Copenhagen

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, Nikolaev, Athens, Catania, Madrid at ESAC, Paris
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.
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 …. 
**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 ➔ Energy + Heavy elements

Some stars live
only 10 mio. years!

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

Sun + Earth

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
The whole universe is about 14 billion years old. It began with the Big Bang. Hubble Space Telescope: The faintest galaxies are seen 13 billion years back.
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
Dante’s Universe

<table>
<thead>
<tr>
<th>Ptolemy</th>
<th>True value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stars</td>
<td>20,000</td>
</tr>
<tr>
<td>Sun</td>
<td>1210</td>
</tr>
<tr>
<td>Moon</td>
<td>33-64</td>
</tr>
<tr>
<td>Earth radius</td>
<td>6400 km</td>
</tr>
</tbody>
</table>

Earth radius = 6400 km

Empyreum
Stars
Sun
Moon
Earth rad.
=6400 km
Jerusalem
Dante’s Hell

The forest
Jerusalem

Kokytos
Lucifer

The most evil
Lucifer

Murderers
Lucifer
Dante and Vergil with Lucifer

Sandro Botticelli ~1500: Divina Commedia
Dante and Beatrice towards the Moon
Dante with Beatrice and lunar spirits
Dante and Beatrice with the stars
What is in the Heavens?

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- Moon, Sun, planets, stars

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1600 B.C.
early bronze age.

Sun, Moon, and stars

First known image of the cosmos.
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 Peloponnisos
- 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!
School of Athens painted by Raphael 1510

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

Aristotle

Newton 1687
Laws of nature for motion
Ptolemy measuring ~150 AD

From G. Reisch, 1512
Ptolemy: Circles, epicycles

All the heavens rotate in 24 hours around the fixed and non-rotating Earth.
The Arabs:
Translation of Greek texts and Science

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

Harun al’Rashid
766 - 809
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
Ptolemy: Circles, epicycles and a non-rotating Earth
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 Sun and two planets
Heliocentric system

the Earth rotates in 24 hours
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
Erik Høg
Tycho Brahe
on Hven
1576-97
A barrel of gold
Sextant 1580
Kepler found ~70 laws for the motion of planets
But we usually mention only 3 of these...
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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Planet sizes

Huygens 1698

Telescope:
Galilei 1610

Ptolemy 150 AD

Star of 1st mag

Sun
Saturn etc.

Mars
Earth

naked eye
telescopic
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<tr>
<td>Stars</td>
<td>20,000</td>
<td>&gt; 10,000 million</td>
</tr>
<tr>
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<td>33-64</td>
<td>60 Earth rad.</td>
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Earth radius = 6400 km
## The Visible Universe

<table>
<thead>
<tr>
<th>Year</th>
<th>Radius – light years</th>
<th>What / Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>150-1600</td>
<td>0.000,014</td>
<td>Sphere of stars</td>
</tr>
<tr>
<td>1900</td>
<td>30,000</td>
<td>Milky Way</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ptolemy</td>
</tr>
<tr>
<td>1960</td>
<td>2,000,000,000</td>
<td>Most distant galaxies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kapteyn</td>
</tr>
<tr>
<td>2006</td>
<td>14,000,000,000</td>
<td>Visible universe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WMAP a.o.</td>
</tr>
</tbody>
</table>
The Visible Universe
is $10^{15}$ times larger
than Tycho Brahe believed
$10^{15} = 1,000,000,000,000,000 = 1$ million billion times

Tycho Brahe
ca. 1590

Ptolemy
ca. 150 A.D.

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The whole universe is about 14 billion years old.

**Hubble Space Telescope:**
The faintest galaxies are seen 13 billion years back.
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The faintest galaxies are seen 13 billion years back.

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*