

THE DEPTH OF THE HEAVENS – BELIEF AND KNOWLEDGE DURING 2500 YEARS

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Abstract. For Dante Alighieri (1265–1321) the spiritual cosmos contained the Heavens, Earth and Hell, and it was compatible with the physical cosmos known from Aristotle (384–322 B.C.). Dante’s many references in his Divine Comedy to physical and astronomical subjects show that he wanted to treat these issues absolutely correctly. Tycho Brahe proves three hundred years later by his observations of the Stella Nova in 1572 and of comets that the spheres of heavens did not really exist. It has ever since become more and more difficult to reconcile the ancient ideas of a unified cosmos with the increasing knowledge about the physical universe. Ptolemaios derived a radius of 20 000 Earth radii for the sphere of fixed stars. This radius of the visible cosmos at that time happens to be nearly equal to the true distance of the Sun, or 14 micro-light-years. Today the radius of the visible universe is a million billion (10^{15}) times larger than Tycho Brahe believed. The lecture gave an overview of astronomical distances and their dramatic change during two and a half millennia, the following text is an extract hereof.

Key words: history and philosophy of astronomy – astrometry – cosmology: distance scale

1. THE DEPTH OF THE HEAVENS

We see the Sun, Moon and stars on the sky as if placed on the inside of a sphere. But very early man had ideas about the distances to these heavenly objects. The Greek philosopher Anaxagoras living in Athens 2500 years ago claimed that the Sun is a fiery rock larger than the whole peninsula Peloponnes. This implies a distance to the Sun larger than 20 000 km. Anaxagoras, however, was accused of blasphemy and had to leave Athens for that reason, because every-

body at his time believed that Apollon drove his fiery wagon with the Sun across the sky in the day and returned in night sleeping on his ship.

Nonetheless, the Greeks were the first to develop an understanding of nature based on rational explanations rather than on a belief in various gods with human emotions. One of them was Ptolemaios living in Alexandria about AD 150. Ptolemaios is far from being the first to give distances to the planets and stars, but his distances gained the status of highest authority during the following 1500 years. He had his values for the Earth radius and distances to the Moon and Sun from Greek astronomers working between 300 and 100 B.C. His value for the distance to the sphere of fixed stars was 20 000 Earth radii or 14 micro-light-years, 1 light-year being equal to 1.49 billion Earth radii.

Table 1. Historical and contemporary distances – the visible universe is a million billion times larger than Tycho Brahe believed.

Distance to	Ptolemaios AD 150 Dante and Tycho	True distance
Center of Earth	1 Earth radius \simeq 6000 km	1 Earth radius=6370 km
Moon	33 – 64 Earth radii	60 Earth radii
Sun	1210 Earth radii	25 000 Earth radii
Stars	20 000 Earth radii = 0.000 014 light-years	Over 10 light-years since 1838
Most distant stars in the Milky Way	–	30 000 light-years in year 1900
Most distant galaxies observable by 1960	–	2 billion light-years in year 1960
Extreme of the visible universe	Stars: 20 000 Earth radii =0.000 014 light-years	13.7 billion light-years in year 2003
God and the angels	–	–

The Middle Ages, as for instance Dante Alighieri (1265–1321) in his *Divine Comedy*, placed God and the angels beyond Ptolemaios' sphere of fixed stars. This naive and very popular view of the cosmos was not shared by theologians who meant that God is omnipresent at all times.

The Greek value for the Sun's distance was 20 times too small, and not even Tycho Brahe knew better. After his time doubt came up, first for Johannes Kepler in 1617. But it took 150 years before the distance to the Sun was safely known from new observations, namely from Venus transits of the solar disk.

The table shows the distances in the visible universe as given by Ptolemaios and the true values at various times in the development of astronomy. F. W. Bessell measured the first reliable distance to a fixed star in 1838, to 61 Cygni at 11.2 light-years which is a million times larger than Ptolemaios' distance to the stars.

The distance to the edge of the known universe has grown most quickly during the recent 100 years. The distance increased by a factor of one million from 30 000 light-years for Kapteyn's Milky Way cosmos of about 1900 to 13.7 billion light-years for the horizon of the visible universe, according to recent satellite measurement of the age of the universe (WMAP 2003). By 1960 the Palomar 5 meter telescope had already recorded faint galaxies as far away as 2 billion light-years.

The immediate question is: can this rapid growth continue? The answer is NO, because we now have great confidence that the age of the universe is close to 14 billion years, and this defines the cosmic horizon. Finally, outside the cosmic horizon is the invisible part of the universe which is very much larger than the visible universe, but probably of finite extent. And the whole universe is forever expanding with the Hubble flow.

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