CHAPTER 1

The Position of the Earth in the Cosmos

Key words: Cosmos / Universe, Galaxies, Stars, Planets, Moons, Asteroids, Meteorites.

Introduction

When we watch all those stars on the sky, watch a meteorite falling or see the sun glowing we often ask ourselves: How far is all of this from planet Earth, and how old are all these objects and how did they all come into existence? Most of the answers below tell us distances and dimensions we can barely imagine – and many are still not precisely known. Nevertheless, we now know quite a lot about what we call the Universe – or the Cosmos – and you will find some very brief answers to these questions.

1.1. The age of Universe

The Universe began with the famous "Big Bang". According to recent studies using the "Hubble Outer Space Telescope", this happened some 13.75 Billion years ago.

1.2. The development of the Universe

With the "Big Bang", the time, space, light and matter of our Universe was born - Einstein's theory of relativity providing a mathematical model for how all these facets are related. The question: "*What was before?",* is simply not relevant, because before the "Big Bang" we have no information at all. The Universe itself has no centre, it expands as everything in it moves away from everything else. At the moment the diameter of the Universe has been calculated as 12 billion light years, each of these light years representing around 9.5 to 10.12 billion kilometres), The Universe, however, might be larger still, and it cannot be proved that it is indeed not infinite.

Another philosophical question is whether the Universe will at some time collapse. However, as gravitational forces may not be strong enough to reverse the continuous expansion of the Universe, it is probably unlikely that this will happen.

1.3. Galaxies

Matter is very unequally distributed across the Universe: There is only 1 atom in every 5 m^3 on average in the Universe, with 1,000,000 atoms per 5 m^3 in galaxies. For comparison, the air we breathe has around 130,000,000,000,000,000,000,000,000 atoms per 5 m^3. We also find concentrations of matter in stars, and these stars are usually organised into larger structures, such as "Star systems" (such as our own "Solar System") and "Galaxies". Galaxies have an age of about 12 billion years. This concentration is due to the gravitation attraction between all matter.

The time between the origins of the Universe and the origins of the first galaxies is around 1 to 2 billion years: This time is called the "Dark-Age" of the Universe, because there were no stars to "illuminate" it. Galaxies have different shapes, most known are "Spiral-Galaxies" and "Elliptical Galaxies", however, there are also "Irregular Galaxies" which have no centre. Galaxies are not equally distributed in Universe; many form clusters, the largest known cluster comprising more than one thousand galaxies. The closest cluster to us is known as the "Virgo-Cluster", and our spiral-galaxy - the "Galaxis" or "Milky-Way" is on the edge of this cluster, as is the "Andromeda-Galaxy", which contains about 100 billions of stars and can sometimes be seen with the naked eye in the night sky. Our star, the Sun, and our solar-system, are part of the "Milky-Way" galaxy, situated towards its outer rim, the Sun being the centre of our planetary system. The distance to the "Andromeda-Galaxy" is about 2,000,000 light years, but the nearest star to us – excepting our own – is around 3 light years away and our sun-system has a diameter of only 0.002 light years. Our solar-system has an age of about 4.6 billion years.

1.4. The "Galaxis" or "Milky-Way"

Galaxis is a greek word which means 'Milky-Way'- the blurred ribbon of light which can be seen on a clear night crossing the sky and which represents a side view of part of our galaxy, made up of millions of distant stars. The Galaxis is a flat disc with a diameter of about 100,000 light years and around 16,000 to 30,000 light years deep. It contains around 100 billion stars, organised within spiral "arms" galaxy linking to its centre. The stars in their spiral arms rotate around the centre of the Galaxis every 100,000 years to 200 million years. At the outer rim of one of the spiral arms of the Galaxis, about 30,000 light years from its centre, is our home with our star the Sun and its orbiting planets. Above and below the disc of the Galaxis there are numerous spheres of star clusters, and our galaxy itself forms part of "Virgo-Galaxies-Cluster".

1.5. Stars, Planets, Moons, Comets, Asteroids (or Planetoids) and Meteorits

A **star** is a ball of gas, composed typically of 99% hydrogen and helium, held together by its own gravity. Stars originate from gas clouds, mainly composed of hydrogen, which collapse under their own gravity, forming "Globuls" - discrete dust and gas clouds. These "Globuls" then contract over around 10 to 15 million years to form stars. The surface temperatures of stars can range between 3,000 to 20,000 degrees centigrade, whilst within larger stars, temperatures can reach millions of degrees. Stars are often organised as double stars or within star clusters and can be classified in "Supergiants", "Bright Giants", "Giants", "Dwarfs" and "White dwarfs". Some

have planets like our Sun. People have long perceived patterns in the stars visible from the Earth, imaginatively linking these patterns to myth and legend, such as the “signs of the zodiac”.

Planets are very closely linked to their stars and originated at the same time. Some have remained primarily as gas-balls, but others collapsed under their own gravity and develop into rocky planets. All planets have a nearly rounded form and orbit around their star in broadly circular – or slightly elliptical - orbits. In our planetary system, the “Solar-System”, we find the “Inner Planets” - the rocky planets Mercury, Venus, Earth and Mars - and the “Outer Planets”, the “Gas-Giants” Jupiter, Saturn, Uranus and Neptune. The inner and outer planets are separated by the asteroid-belt, a band of rocky and icy debris, left over from the formation of the solar-system. Planets may have rocky moons like our own planet’s Moon, or moons made up by frozen water and gases. Planets within our solar system are called “Planets”, whereas outside of our solar system they are called “Exoplanets” or “Exosolar Planets”.

Comets are masses of dust and ice, sometimes with a rocky core, with a diameter of a few kilometres and a characteristic orbit within our solar system. When a comet passes near to the Sun a portion of this frozen material evaporates, forming a glowing head called the coma. Because of the solar wind – particles emitted by the Sun which stream into space - some comets also form a tail pointing away from the Sun, that can extend for millions of kilometres. Within the ice that makes up comets, such as the famous Halley’s Comet, there can be up to 25% organic molecules. Some scientists have speculated that such molecules may have contributed to the origins of life on Earth, but others strongly disagree.

Asteroids (or Planetoids) are rocky left-overs from the origins of our solar system. Ninety-nine percent of them are found in the asteroid-belt, the largest ones, however, are concentrated in the “Kuiper-belt”, which lies outside of the orbit of Neptune. Around 507,271 asteroids have so-far been identified within the asteroid-belt and they orbit the sun like the planets. Some, however, have distinctly exocentric orbits, meaning that they may cross the orbits of planets, such as our own, and sometimes even collide with the planets. The results of these collisions can be quite devastating and it is believed that an asteroid hit the Earth 65 million years ago causing mass extinctions. Asteroids are classified by spectral analysis according to their chemical composition and their surface characteristics.

Meteorites are mainly fragments of asteroids, less than 10 km in diameter. We know today, however, that some very rare meteorites originated from the Moon and from the planet Mars, and were broken off during a collision with another meteorite or asteroid, before being attracted to Earth by our own planet’s gravity. Meteorites and meteoritic material is continuously hitting the Earth. Most of these are “Rocky-Meteroites” (also known as “Chondrites”), and they are as old as our solar system; “Achondrites”, however, also fall and these are largely composed of iron and nickel. Meteorites are captured by the gravity of the Earth, and due to friction with the atmosphere they heat up and glow - usually disintegrating and disappearing in a trail of light. These ‘Shooting-Stars’ are usually all we see of a meteorite, as most vaporise in the Earth’s atmosphere before anything can reach the ground.

1.6. The geological activity away from planet Earth

Geological activity on other bodies in our solar system is recorded on the surface of the rocky planets and moons and even on the surface of some of the frozen ice moons. However, most of these bodies are nowhere near as active as Planet Earth.
For instance Mars, although half of the size of the Earth, probably still has a core of iron and a

mantel of melted rocks and a crust. But it is “cold planet”, apparently with nothing like the Plate Tectonics activity we see on Earth. Mars can divided into two hemispheres, like the Earth. The southern hemisphere is covered with impact craters, the northern is a rolling hill country; the border between the two being the “Janus-Head”, a steep feature around 6 km in height. Impact craters on Mars reach diameters of around 2,300 km and a depth of 7 km. Volcanos, such as the great “Olympus Mons”, can reach a height of 24 km and a diameter of 500 km. Canyons such as the “Valles Marinensis”, can be 4,000 km long, 600 km wide and 7 km deep. We know quite a lot about Mars, as its surface has been photographed in detail by orbiting probes, and even sampled directly by rover-vehicles landed on its surface.

In contrast, although “Europa” - a moon of planet Jupiter - has a core of iron and rock, it is covered by a 100 km thick layer of water, the uppermost 30 km of which is frozen. Around 3 km below the surface there are liquid “salt lakes”, but below the ice layer there are 70 km of liquid water.

Intended learning outcomes:

- Understand the origins and age of the Universe.
- Understand the organisation of galaxies and stars.
- What is the “Milky Way”?
- Read about our solar-system and its planets.
- What are and where do we find asteroids and meteorites?

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