From Earth to the Universe

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Recorded at Primetime Studio, Hamburg, 2015

The night sky … both beautiful and mysterious.

The subject of camp-fire stories, ancient myths and awe for as long as there have been people.

Living beneath the open dark sky the earliest humans were aware of nightly changes as planets marched across the sky, the Moon waxed and waned, and occasional meteors flared across the horizon.

Slowly the simple early observations revealed patterns that could be depended upon, leading to the first calendars.

With the yearly cycle mapped out, settlements and agriculture could develop and early civilisations thrived.

At the same time, the first maps of the sky grouped the brightest stars into familiar constellations, helping to develop navigational skills, expanding trade and aiding exploration.

But the first astronomers had no real concept of the order behind the patterns of the sky.

These early scientists and philosophers were still bound by a view of the cosmos that was tightly interwoven with mythology.

The ancient Greeks, with their rigorous intellectual approach, took the first steps towards separating the young science of astronomy from the ancient sky myths.

The greatest minds of the age, such as *Pythagoras*. *Eratosthenes*. *Apollonius.* And *Ptolemy* helped in developing a more complete scientific system capable of predicting astronomical phenomena.

By observing the apparent motion of the celestial objects around our planet, the ancient Greek astronomers placed Earth at the centre of the cosmos, creating the geocentric system.

Aristarchos of Samos was the first Greek astronomer to propose the heliocentric model, placing the Sun rather, than the Earth, at the centre of the known Universe, but he was largely ignored for many centuries.

It wasn't until the 16th century that astronomers such as *Copernicus* and *Kepler* revived *Aristarchos'* view. By studying the astronomical observations of the Danish astronomer *Tycho Brahe*, supported by solid maths, the heliocentric system gained new relevance. According to this all planets, including Earth, revolve around the Sun.

However, the true revolution in astronomy took place in 1609, when *Galileo* became the first astronomer to turn a telescope towards the sky. In doing so, he broadened the horizons of the known Universe and abolished once and for all the geocentric views of the ancient world.

Today, scientists have huge telescopes, supported by state-of-the-art instrumentation and sophisticated software, to study the Universe and discover its secrets.

ESO's Very Large Telescope has four 8-metre mirrors and they can detect objects as they were just a few hundred million years after the Universe began in the Big Bang!

For the best results, these giant telescopes are most often located in remote mountain regions above much of the atmosphere and away from widespread urban light pollution.

With their help we can see deep into space and through the fog of time to reveal a Universe inconceivable to the people of the ancient world. A Universe which is vibrantly active and violent, and where the game of life and death is played out on a scale that humbles all who observe it.

In the last fifty years, we have reached out into space, leaving the bonds of gravity behind and opened a new era of exploration.

Thanks to the space programme we have seen our planet from an outsider's perspective, as a fragile, pale blue world orbiting the Sun, frighteningly vulnerable in the cold and hostile environment of space.

Space technology has altered our way of life, and changed our perception of the world, from a place defined by maps and borders, to that of a small and insignificant body in space.

The benefits derived from the space programme have a value many times higher than the cost and effort involved.

With space exploration came the technology that has placed telescopes above the atmosphere of our planet. Space telescopes that can record a fresh view of the Universe, observing in wavelengths that cannot penetrate the atmosphere.

Each new generation of telescopes, from Galileo's first simple instruments that showed us the moons of Jupiter, to the Hubble Space Telescope, has opened new windows on the Universe, and challenged our understanding.

Step by step we have been displaced from the centre of the world and placed as exiles on the edge of a vast and inhospitable Universe.

Today, we know that the Sun is an average dwarf star with a diameter of just under one and a half million kilometres, and that it lies one hundred and fifty million kilometres from Earth.

The Sun is a sphere of gas, with a core where temperatures and pressures are so high that nuclear fusion is triggered, converting hydrogen into helium, all the while pumping out energy into space.

Energy that warms and sustains the Earth, supporting life in all its oceans, and across continents.

Periodically, on the surface of the Sun, a localised strong magnetic field forms, creating a sunspot. Here energy can accumulate, which is then often released into space in the form of huge explosions, known as flares.

Solar flares can be accompanied by a burst of high energy particles flung out into space, sometimes reaching Earth and disrupting communications, as well as generating spectacular northern and southern lights.

Currently the Sun is in a very stable state and will continue to radiate energy at a steady rate for another 5 billion years or so. But eventually the fuel powering the core will run out, and the Sun will slowly cool and expand to become a red giant, engulfing all the inner planets, including the Earth.

Mercury is the closest planet to the Sun, a lifeless world with a very thin atmosphere.

Its surface is littered with craters created by collisions with tens of thousands of asteroids and comets.

In 2004, scientists sent the space probe Messenger to Mercury to study this alien world. Messenger has provided a wealth of scientific data as well as high resolution images of the surface of the planet.

Venus is roughly the same size as Earth but its atmosphere is choked with greenhouse gases and sulphuric acid. As a result, its surface temperature reaches a searing 400 degrees Celsius.

The surface of Venus is known to be geologically active with fresh lava flows.

The third planet from the Sun is the Earth, with its liquid water oceans and oxygen-rich atmosphere.

The Earth is an oasis of evolved life in the Solar System.

The Moon is our natural satellite, with a diameter roughly 4 times smaller than Earth’s and lacking an atmosphere.

The Moon's surface is covered in craters which, as on Mercury, are the result of thousands of collisions during the early stages of the formation of the Solar System.

The Moon is the only celestial object that has been visited by manned space missions.

Mars is the fourth planet from the Sun. Only 70 million kilometres away from Earth at closest approach.

Scientists have been exploring Mars systematically for the last 40 years and we now know many of its secrets.

We have mapped its surface remotely, showing its numerous craters, enormous extinct volcanoes and its deep canyons.

There was almost certainly water on the red planet long ago. Now, only small quantities of underground water remain. It is possible that a simple form of life could persist somewhere below the surface.

Scientists continue to explore Mars with small remote-controlled vehicles, and it will be the target of several future manned missions.

Jupiter is the largest planet in the Solar System, with a diameter of more than 11 times that of the Earth. Its atmosphere is dense and very dynamic and is mainly composed of hydrogen, helium and methane.

One easily identifiable feature of its atmosphere is the great red spot, a huge storm, twice the size of Earth, which has lasted for hundreds of years.

Among Jupiter’s varied collection of satellites are two of particular interest: Europa, which hides a large ocean of water beneath its icy surface, and Io, with its many volcanoes and continuous lava outflows.

Saturn is perhaps the most impressive planet in the entire Solar System thanks to its majestic ring system. Saturn’s rings are made up of pieces of rock and ice, mainly from former satellites that were torn apart by the planet’s gravity.

One of Saturn’s moons, Titan, is an interesting world. Scientists have detected an atmosphere rich in organic matter and a surface with lakes of liquid methane.

The next planet out from the Sun is Uranus, which also has a large, but less dramatic ring system.

The outermost planet in the Solar System, Neptune, looks quite like Uranus yet has a much more active atmosphere.

Beyond Neptune is a region containing dwarf planets such as Pluto, Eris, Makemake and Haumea.

These dwarf planets, as well as probably hundreds more as yet undiscovered, and thousands of smaller objects, are located in a large zone at the edge of the Solar System called the Kuiper Belt.

Further in, between Mars and Jupiter, the asteroid belt contains thousands of asteroids of various shapes and sizes.

Space probes have managed to approach some of them and study them in detail.
One probe even landed on the asteroid Eros and analysed its surface.

Finally, there are a huge number of celestial objects composed of ice and dust that we sometimes see from Earth as comets.

In the past, their presence in the sky was thought to herald destruction and political upheaval.

The Sun and its planets belong to a giant complex of at least two hundred billion stars that make up our galaxy, the Milky Way.

Recently, we have detected planets in orbit around other stars in our galaxy, and the study of these new and sometimes exotic worlds is a burgeoning field of observational astronomy.

Stars come in many different types and sizes, but none of them live forever. Their lifetimes range from a few million to billions of years. But when their fuel is exhausted, they die.

Some die in a violent manner, leaving behind exotic stellar remnants such as white dwarfs, neutron stars and black holes.

Stars usually form in groups called stellar clusters, which fall into two categories: globular or open clusters.

Globular clusters have a high concentration of stars, tightly bound into a ball by gravity, and their age can be deduced from the distribution of the types of stars within each cluster, giving astronomers a key to their history.

They are very common objects within galaxies. Some giant elliptical galaxies can host up to thirty thousand globular clusters.

Open clusters contain a smaller number of stars, all of much the same age.

Stars in open clusters are loosely bound by gravity. Such clusters lose some or even all of their stars to the effects of gravity from other star clusters or gas clouds as they orbit the Milky Way’s centre.

In general, open clusters survive for a few hundred million years.

Between the stars there are huge clouds of interstellar dust and gas.

The gas in these nebulae consists of hydrogen, helium and other ionised gases.

There are reflection nebulae, emission nebulae and dark nebulae.

If conditions are right these clouds can also collapse under their own gravity, until nuclear fusion ignites and new stars are born.
The great act of creation continues to this day.

Planetary nebulae are a type of emission nebula that are created when stars similar to the Sun expand, eject their outer layers and eventually become white dwarfs.

Supernova remnants are a special type of nebula which enrich interstellar space with the heavy chemical elements indispensable to the creation of life. These remnants are the last surviving traces of the spectacular final demise of high-mass stars.

Our galaxy is a spiral galaxy, 150 000 light-years wide.

At it's centre, a colossal black hole with a mass of about four million suns is lurking.

Enormous as it is, the Milky Way is far from the only galaxy in the Universe. There are hundreds of billions of galaxies, and they come in all shapes and sizes.

Elliptical galaxies are typically made up of older stars.

Spirals are usually composed of a nucleus, thought to host a black hole, and two or more spiral arms extending outwards from the galaxy's centre.

More than half of all observed galaxies are spirals.

Galaxies with no specific shape are called irregulars. Their dust and gas content is huge.

Most large irregular galaxies began as spirals or ellipticals but were deformed by the gravitational pull of other galaxies.

Under the influence of gravity, galaxies have a tendency to form groups, clusters and super clusters.

Within groups and clusters of galaxies, interactions and collisions are regular occurrences, which can distort the shape of the interacting galaxies, and even change the course of their evolution.

The Universe of galaxies is one that is in constant motion, a sweeping cosmic dance which, although beautiful, reveals the violence at its heart.

It appears that the Universe was created in a tremendous expansion — the Big Bang — almost 14 billion years ago. Since then, the Universe has been expanding, and today its expansion not only continues, but is accelerating.

But despite all that we have learned, many of the greatest questions about the creation and the eventual demise of the Universe remain unanswered.

We live in a vast and violent Universe that exceeds human measures and imagination, but is governed by firm physical laws that allow the extraordinary complexity we call life to arise.

From our vantage point, on a pale blue planet, orbiting an undistinguished star, far from the centre of our galaxy, we are privileged to be able to look out and seek the answers to these grand questions of existence.

Footage and Images:

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Original Image:N. Risinger (skysurvey.org)

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Cosmic Hole
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Galileo
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From Atlantic Ocean to Kazakhstan
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Mercury
Mercury 3D Space Scene
Credit: T. Matsopoulos
Messenger 3D Model and Messenger Pictures
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Milky Way Picture: ESO/S. Brunier

Venus
Venus 3D Space Scene
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Earth
Earth 3D Space Scene
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Jupiter 3D Space Scenes
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Saturn 3D Space Scene
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Milky Way Fly Inside
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Globular cluster (artist's impression)
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Background image: N. Risinger (skysurvey.org)

NGC 7006 Cluster
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Pleiades Cluster
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Messier 7 Custer
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NGC 2264 and the Christmas Tree Cluster
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Eagle Nebula
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Original Image: NASA, ESA and The Hubble Heritage Team

Mystic Mountain Nebula
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Dumbbell Nebula
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Crab Nebula
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Simulation of Gas Cloud Approaching the Black Hole at the Center of the Milky Way
Credit: ESO/L. Calçada/MPE/M. Schartmann

Hubble Deep Field
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NGC 1132
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Abell 1703
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Interacting Galaxies (Arp 273)
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Fulldome Simulation of Colliding Galaxies
Credit: NASA/STScI
Visualization by Frank Summers, Space Telescope Science Institute
Simulation by Chris Mihos, Case Western Reserve University, and Lars Hernquist, Harvard University

JWST Fulldome Science Simulation: Galaxy Collision
Credit: T. Matsopoulos/NASA Goddard Space Flight Center
Advanced Visualization Laboratory at the National Center for Supercomputing Applications
Simulation by Brant Robertson, UC Santa Cruz, and Lars Hernquist, Harvard University

Fulldome view of Earth
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Cosmic Cruising
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