

From Earth to the Universe

Free thirty-minute full-dome show in 4k resolution from ESO available as a series of full-dome frames for free download

Directed by: Theofanis Matsopoulos

3D Animations and Graphics: Theofanis Matsopoulos, Luis Calçada & Martin Kornmesser

Producer: Theofanis Matsopoulos & European Southern Observatory (ESO)

Planetarium Production: Theofanis Matsopoulos

Executive Producer: Lars Lindberg Christensen

Script and Scientific Advice: Nicolas Matsopoulos, Lars Lindberg Christensen & Anne Rhodes

Main Title Designer: Luis Calçada

Narration: Sara Mendes Da Costa

Audio Mix: Theofanis Matsopoulos

German Version by Planetarium Hamburg

Translator/Director: Thomas W. Kraupe

Narrator: Regina Lemnitz

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.

These telescopes have mirrors with diameters of 8 to 10 metres across and they can detect objects as they were just a few 100 million years after the Universe we know 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 Earth's 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 the nuclear fusion of hydrogen is triggered, converting lighter elements to heavier elements, 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.

Venus undergoes intense geological activity, with vast lava outflows continuously transforming its surface. Through these processes, Venus's crust is totally renewed every few hundred million years.

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, roughly 4 times smaller than Earth 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 and the closest to Earth, at a distance of about 70 million kilometres away at its 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.

Most of the time they do so 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 by 30 000 light-years in size.

At its 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 bright nucleus and two spiral arms extending outwards from the galaxy's centre.

A quarter of all observed galaxies are spirals.

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

Most 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:

Milky Way

Credit: T. Matsopoulos

Original Image:N. Risinger (skysurvey.org)

Peering Through The Looking Glass

Credit: ESO/B. Tafreshi

Mayan Calendar

Credit: T. Matsopoulos

Chinese Star Map

Credit: T. Matsopoulos

Cosmic Hole
Credit: ESO/B. Tafreshi

Digital Visualization of Ancient Greek Temple
Credit: T. Matsopoulos

Galileo
Credit: T. Matsopoulos

Galileo Videos
Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)
R.S. Newall Telescope N.O.A.

Credit: T. Matsopoulos
National Observatory of Athens

VLT with Milky Way
Credit: Luis Calçada & N. Risinger (skysurvey.org)

UT Interior in Action with MUSE
Credit: ESO/B.Tafreshi (twanight.org)

UHD NTT Time-lapse
Credit: ESO/B. Tafreshi

Paranal Fish-Eye Time-lapse
Credit: ESO/B. Tafreshi (twanight.org)

Carl Zeiss Aristarchos Dome N.O.A.
Credit: T. Matsopoulos
National Observatory of Athens

Unveiling Our Cool Universe in Ultra HD
Credit: ALMA (ESO/NAOJ/NRAO)/B. Tafreshi (twanight.org)

ALMA Fulldome UHD Time-lapse
Credit: ALMA (ESO/NAOJ/NRAO)/B.Tafreshi (twanight.org)

La Silla Fish-eye View
Credit: ESO/B. Tafreshi

STS-135 Atlantis
Credit: George Fleenor (GeoGraphics Imaging)

Space Shuttle Discovery
Credit: T. Matsopoulos
Original Image: NASA
Earth Picture: NASA / The Gateway to Astronaut of Earth

Earth from the JEM Window
Credit: NASA / The Gateway to Astronaut of Earth

Astronauts in Space
Credit: T. Matsopoulos
Original Image: NASA

Earth Time-lapse: NASA / The Gateway to Astronaut of Earth

From Atlantic Ocean to Kazakhstan

Credit: NASA / The Gateway to Astronaut of Earth

International Space Station

Credit: T. Matsopoulos

Original Image: NASA

Earth Time-lapse: NASA / The Gateway to Astronaut of Earth

Artist's impression of Hubble over Earth

Credit: NASA/ESA

FullDome clip of the Sun

Credit: NASA/SDO/M. Kornmesser/L. Calçada

Sun Scenes

Credit: T. Matsopoulos

Time-lapse and Images Credits: NASA / Goddard Flight Center Scientific Visualization Studio

The Coronal Mass Ejection strikes the Earth

Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio

Visualization Credits: Greg Shirah (NASA/GSFC), Lead Animator

Horace Mitchell (NASA/GSFC), Animator

Tom Bridgman (GST), Animator

Mercury

Mercury 3D Space Scene

Credit: T. Matsopoulos

Messenger 3D Model and Messenger Pictures

Credit: NASA

Milky Way Picture: ESO/S. Brunier

Venus

Venus 3D Space Scene

Credit: T. Matsopoulos

Venus Textures Credit: NASA

Milky Way Image: ESO/S. Brunier

Earth

Earth 3D Space Scene

Credit: T. Matsopoulos

Earth Textures Credit: NASA

Milky Way Image: ESO/S. Brunier

Fly Above Earth

Credit: NASA / The Gateway to Astronaut of Earth

Moon Phases

Credit: NASA/LROC/M.Kornmesser

Moon Landscapes

Credit: NASA, T. Matsopoulos

Mars

Credit: NASA/M.Kornmesser

Water On Mars

Credit: ESO/M. Kornmesser, T. Matsopoulos

Mars Panorama

Credit: T. Matsopoulos, Mahdi Zamani

Mars Landscape Image: NASA

Jupiter

Jupiter 3D Space Scenes

Credit: T. Matsopoulos

Jupiter Textures: NASA

Milky Way Image: ESO/S. Brunier

Saturn

Saturn 3D Space Scene

Credit: ESA/Hubble (M.Kornmesser & L. Calçada),
T. Matsopoulos

Milky Way Image: ESO/S. Brunier

Titan Space Scene

Credit: T. Matsopoulos

Textures: NASA

Milky Way Image: ESO/S. Brunier

Uranus - Neptune

Uranus - Neptune 3D Space Scene

Credit: T. Matsopoulos

Textures: NASA

Milky Way Image: ESO/S. Brunier

Kuiper Belt Planets

Credit: T. Matsopoulos

Textures/Images: NASA

Milky Way Image: ESO/S. Brunier

Asteroids

Asteroids 3D Space Scenes

Credit: T. Matsopoulos

3D Models : NASA

Milky Way Image: ESO/S. Brunier

Comet Hale Bopp

Credit: ESO/E. Slawik

Comet NEAT

Image Credit: National Science Foundation
(Kitt Peak National Observatory)

Milky Way Galaxy

Credit T.Matsopoulos

Image Credit: NASA, JPL

Exoplanet Kepler 22

Credit: T. Matsopoulos

Original Image: ESO, M. Kornmesser/ Nick Risinger

Star field/Supernova Explosion

Credit: T. Matsopoulos

Video Credits: ESA/Hubble (M. Kornmesser) and

ESA/NASA and Felix Mirabel (the French Atomic Energy Commission & the Institute for Astronomy and Space Physics/Conicet of Argentina)

Milky Way Fly Inside

Credit: T. Matsopoulos

Milky Way Image: ESO/S. Brunier

Globular cluster (artist's impression)

Credit: ESO/M.Kornmesser/L. Calçada.

Background image: N. Risinger (skysurvey.org)

NGC 7006 Cluster

Credit: T. Matsopoulos

Original Image: ESA/Hubble, NASA

Pleiades Cluster

Credit: T. Matsopoulos

Original Image: NASA/ESA/AURA/Caltech

Messier 7 Cluster

Credit: T. Matsopoulos

Original Image: ESO

IC 2944

Credit: T. Matsopoulos

Original Image: ESO

NGC 2264 and the Christmas Tree Cluster

Credit: T. Matsopoulos

Original Image: ESO

Eagle Nebula

Credit: T. Matsopoulos

Original Image: NASA, ESA and The Hubble Heritage Team

Mystic Mountain Nebula

Credit: T. Matsopoulos

Original Image: NASA, ESA, M. Livio and the Hubble 20th Anniversary Team

Helix Nebula

Credit: T. Matsopoulos

Original Image: ESO

Dumbbell Nebula

Credit: T. Matsopoulos

Original Image: T.Matsopoulos

Crab Nebula

Credit: T. Matsopoulos

Original Image: ESO

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
Credit: T. Matsopoulos
Original Image: NASA/ESA

NGC 5128 Galaxy
Credit: T. Matsopoulos
Original Image: ESO

NGC 1309
Credit: T. Matsopoulos
Original Image: NASA/ESA
Background Image: ESO/Digitized Sky Survey 2

Messier 33 Galaxy
Credit: T. Matsopoulos
Original Image: ESO

Ring Galaxy
Credit: T. Matsopoulos
Original Image: NASA/ESA and The Hubble Heritage Team STScI/AURA
Background Image: ESO/Digitized Sky Survey 2

NGC 3256 Galaxy
Credit: T. Matsopoulos
Original Image: NASA, ESA, the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
Background Image: ESO/Digitized Sky Survey 2

Abell 1703
Credit: T. Matsopoulos
Original Image: NASA, ESA, and Johan Richard (Caltech, USA)
Acknowledgement: Davide de Martin & James Long (ESA/Hubble)

Interacting Galaxies (Arp 273)
Credit: T. Matsopoulos
Original Image: NASA, ESA and the Hubble Heritage Team (STScI/AURA)

Full-dome 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,

Full-dome view of Earth
Credit: NASA/M.Kornmesser.
Background image: N. Risinger (skysurvey.org)