



Interactive exhibition on the cargo ship

**MS** 

**WISSENSCHAFT**

Science Year 2023 - Our Universe

exhibit texts in English

An Initiative of the Federal Ministry  
of Education and Research

Science Year

2023

our  
**UNIVERSE**

## **1 Black holes and their shadows**

### **Telescopes reveal the big secret**

Nothing gets out of a black hole. Its gravitational pull is so strong that even light cannot escape; hence the name. Black holes continuously draw in nearby matter, making them ever heavier. M87\* is a supermassive black hole surrounded by a rotating disc of matter and dust. The speed of rotation makes the disc extremely hot, causing it to emit energy in the form of radiation. Astronomers use radio telescopes to detect the radiation and create images. Here you see the bright ring around a dark interior, visible as a shadow of the black hole.

#### **Who's behind it?**

Scientists across the world are participating in the Event Horizon Telescope Collaboration. Seven radio dishes in Europe, the Americas and the polar regions are coordinated to function as a single very large telescope with very high resolution. That also allows them to study the comparatively small black hole at the heart of our galaxy, the Milky Way.

## **2 Space travel**

### **How far to the nearest Earth-like planet?**

The nearest planet in any way similar to Earth and which might conceivably be inhabitable is Proxima Centauri b. It is located in Alpha Centauri, the closest solar system to our own. Alpha Centauri is about four light years away. That does not sound terribly far. But a passenger jet flying at 1,000 km/h would take about 4.5 million years to get there. The fastest spaceship ever launched (the Voyager probe) travels at 60,000 km/h and would still take 75,000 years to arrive. We, on the other hand, can transport you to the nearest Earth-like planet in just four minutes. The trip will take you past planets, moons, asteroids and space telescopes to the edge of our solar system and out into interstellar space – finally arriving in the next solar system on the planet Proxima Centauri b.

#### **Who's behind it?**

The ORIGINS excellence cluster is a research partnership based in Munich. ORIGINS is investigating the development of the universe from the big bang to the emergence of life. The participating research institutions are the Ludwig Maximilian University and the Technical University Munich, five Max Planck Institutes, the European Southern Observatory and the Leibniz Supercomputing Centre.

### **3 Light of the universe**

#### **Revealing the unseeable**

In terms of the physics, all the different colours of light are electromagnetic radiation, which we might imagine as waves. The colour depends on the wavelength. Blue light has a shorter wavelength and carries more energy than red light. Radio waves and X-rays also represent parts of the electromagnetic spectrum, but they are invisible to the human eye. Researchers use giant radio telescopes and X-ray telescopes on satellites to capture this “invisible light” from the depths of the universe. Studying the different types of radiation emitted by astronomical objects like galaxies, gas clouds and supernovas allows researchers to unlock and understand their secrets.

#### **Who's behind it?**

The Leibniz Institute for Astrophysics Potsdam (AIP) researches the origins, development and structure of cosmic objects – from our own sun and the Milky Way to faraway galaxies and the universe as a whole. AIP collaborates internationally to develop modern instruments for major observatories, as well as space telescopes for observing different wavelengths.

### **4 Matter**

#### **Compass to the heart of our galaxy**

“Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves. . . . To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we’ve ever known.”

— Carl Sagan, *Pale Blue Dot*, 1994 —

Our planet exists in a void whose vastness is almost impossible for us even to imagine. Yet the parts of the universe are all connected to one another. The compass needle points towards the black hole that holds our Milky Way together.

#### **Who's behind it?**

Elias Naphausen is an artist and musician currently working on a PhD in design at Augsburg University of Applied Sciences. His transdisciplinary research considers how robots might sound in the future, while his artistic approach uses technology to play with contexts and perspectives. This piece was supported by Augsburg University of Applied Sciences.

## **5 The sound of the cosmos**

### **Chasing gravity waves**

As Albert Einstein predicted, gravitational waves ripple through space-time. They stretch and compress space, minutely altering the distances between objects. Only recently has it become possible to measure such tiny changes. Gravitational-wave astronomy differs from the methods based on electromagnetic radiation, such as light, infrared and X-ray. While conventional telescopes and satellites look out into space, gravitational-wave detection is more akin to “listening to the cosmos”. Climate researchers apply the same principle to monitor the Earth’s ice caps, glaciers and groundwater (see the exhibit on “Measuring climate change from space”).

#### **Who’s behind it?**

Researchers at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), located in Potsdam and Hannover, and Leibniz University Hannover are leading partners in international gravitational-wave research. They have made crucial contributions to measuring these extremely weak waves: analysing the data, visualising the results and developing new measuring instruments.

## **6 Signals from the depths of the universe**

### **The Effelsberg Radio Telescope**

The huge white dish at Effelsberg in the Eifel mountains is a 100-metre radio telescope. Researchers across the globe use it to investigate young and old stars, cosmic molecules, far-distant radio galaxies and the centre of our own galaxy, the Milky Way. They do not even need clear skies, as the radio waves penetrate through the clouds. Effelsberg is one of the world’s largest radio telescopes, but sometimes even a diameter of 100 metres is not enough. For certain purposes the telescope is connected up to others around the globe to form a “giant eye”. The dish of the model here is 30 centimetres in diameter, so the actual radio telescope at Effelsberg is 333 times the size.

#### **Who’s behind it?**

The Max Planck Institute for Radio Astronomy in Bonn operates the Effelsberg Radio Telescope and APEX, the Atacama Pathfinder Experiment. APEX is located in the Atacama Desert in Chile at an altitude of more than 5,000 metres. Effelsberg also has a LOFAR (Low Frequency Array) station. The Institute studies a wide range of astronomical topics and has a staff of more than 300.



## **7 Waves in space**

### **The Kelvin-Helmholtz instability**

Wave-like structures often appear at the boundaries between gases or liquids. One common example is clouds in the sky. But we also find this phenomenon elsewhere in the universe: in the cloud layers on Jupiter and Saturn, and in interstellar gas clouds and nebulae. One of its main causes is so-called Kelvin-Helmholtz instability, named after Lord Kelvin (1842–1907) and Hermann von Helmholtz (1821–1894). It occurs when two liquids of different density flow past one another at different speeds. Instability at the boundary generates eddies, giving rise to waves. Kelvin-Helmholtz instability is an example of a physical phenomenon that we understand through theory and can test in the laboratory. This also permits us to understand the dynamics of gas clouds in space.

#### **Who's behind it?**

This project was developed by scientists in the collaborative research project SFB1491 "Cosmic Interacting Matters – From Source to Signal". In SFB1491 researchers from the universities of Bochum, Dortmund and Wuppertal are collaborating to bring together plasma physics, particle physics and astrophysics to enhance our understanding of the universe.

## **8 Hunting the blue light**

### **How telescopes detect gamma radiation**

The cosmos is full of violent phenomena. Stars explode, pulsars eject jets of gas into space, black holes consume everything that comes near them. Such events release enormous amounts of energy, some of it in the form of light. As well as visible light, the emitted electromagnetic radiation includes gamma rays, which are the form with the highest energy. Gamma radiation is unhealthy, as it can penetrate human tissue. Fortunately the Earth's atmosphere blocks most of the dangerous radiation. But a few gamma rays do get through. If they encounter molecules in the Earth's atmosphere, the interaction creates many fast-moving invisible particles that rain down on Earth. They emit a blue light that our telescopes can detect.

#### **Who's behind it?**

The Max Planck Institute for Physics studies elementary particles, the smallest building blocks of matter, seeking to solve some of the mysteries of the universe. It investigates questions such as: What does dark matter consist of? Why is there no antimatter left? And what physical processes occur in supernovae and black holes?

## **9 Mapping space with geometry**

### **A satellite to measure cosmic distances**

In order to identify an object in space, we need to know how far away it is. Is it a very bright but distant object? Or is it closer and dimmer? If we know the distance we can calculate the energy an object is emitting or the width of a galaxy. Distances can be determined using a geometrical effect known as parallax. Because the Earth orbits the sun, the position from which we observe the stars changes slightly over the course of the year. The apparent positions of the nearer astronomical objects shift very slightly from our perspective. The greater the shift, the closer the object. Using this technique, the Gaia satellite can measure distances of up to 15,000 light years with great precision.

#### **Who's behind it?**

The exhibit was prepared by the Max Planck Institute for Astronomy and the House of Astronomy, both in Heidelberg. Gaia is a mission of the European Space Agency. The data gathered by Gaia is analysed by 120 mainly European institutions, including the Center for Astronomy of Heidelberg University and the Max Planck Institute for Astronomy.

## **10 Mission in space**

### **Experience the universe**

How was the universe created? What processes occur in our sun? What do far-away planets look like? Astronomers all over the world are working to solve the mysteries of the universe using state-of-the-art telescopes. They tend to be located at remote locations with minimal extraneous light, as these offer the best visibility. Use the virtual reality application to follow researchers to the summit of Cerro Armazones in Chile, where the world's largest telescope is under construction. Experience a journey through the Milky Way, watch a star being born, and land on a distant moon. To learn whether there is life there you will have to collect a rock sample. Good luck!

#### **Who's behind it?**

The VR application is an initiative of the Federal Ministry of Education and Research (BMBF). It was conceived and designed by PT.DESY.

## **11 The invisible universe**

### **Studying the origins of stars and galaxies**

On a clear dark night we can observe the stars and the Milky Way with the naked eye. But the human eye sees only a tiny proportion of the light of the universe. Whole regions of the night sky appear dark because interstellar dust in the Milky Way or other galaxies blocks the light of the stars. In fact half the starlight – including entire galaxies – remains invisible to us. These dust clouds show up in the infrared and submillimetre wavebands, so that telescopes like JWST, ELT and CCAT/FYST can reveal this “invisible universe” to us. And because the light takes so many millions, even billions of years to reach us, it allows us to look back in time. This tells us more about how planets, stars and galaxies have developed since the big bang.

#### **Who's behind it?**

This project was developed by the infrared and submillimetre research groups at the Institute of Astrophysics at Cologne University. These groups investigate the origins of stars and planets and the development of galaxies and the universe. They also build instruments for the Very Large Telescope Interferometer, the Extremely Large Telescope and the CCAT/FYST Telescope.

## **12 Caution, space junk!**

### **Protecting satellites and space stations**

Here you can see what happens when tiny particles of space junk impact satellites and space stations. Researchers are studying how to optimise their exteriors in order to prevent damage to the sensitive equipment inside. The two examples here are replicas of the protective shield of the Columbus module of the International Space Station (ISS). Each is composed of multiple layers. The first layer shatters the particle upon impact, while the others absorb the fragments. Experiments have revealed that the protective effect is improved by using several thinner layers of material rather than a single thick one. This provides adequate protection for the interior of the satellite or space station.

#### **Who's behind it?**

The Fraunhofer Institute for High-Speed Dynamics (Ernst Mach Institute, EMI) investigates the behaviour of materials in high-energy collisions. Because particles in space move at extremely high speeds, even a very small object can cause great damage. To make space travel safer it is therefore very important to study such collisions in laboratory experiments.

## **13 Measuring climate change from space**

### **Studying glacial melting with satellites**

The strength of the Earth's gravity varies from place to place. Regions with greater mass such as mountain ranges exert greater gravitational pull than those with less mass. These very slight differences can be measured very precisely from space. The distance between a pair of satellites orbiting Earth changes as they pass over regions with more or less gravity. The changes in separation can be measured to a precision of a few billionths of a metre. Repeating such measurements allows us to record how the masses change over time – for example as glaciers melt or the groundwater fluctuates. In this way, satellite missions supply important data on climate change.

#### **Who's behind it?**

TerraQ is a collaborative research centre at Leibniz University Hannover where physicists and geodesists collaborate to develop and design new sensors, measuring techniques and analysis methods for current and future satellite missions. They aim to measure processes associated with climate change more precisely than ever before.

## **14 Eyes on the skies**

### **Keeping satellites safe**

Modern life would be very different without satellites, which are crucial for communication, navigation and many other purposes. Protecting them is therefore important. The German Experimental Space Surveillance and Tracking Radar (GESTRA) helps to keep satellites safe in space. It scans for objects such as satellites and space junk and predicts their trajectories. This advance warning of collision allows time for avoidance manoeuvres. GESTRA's phased-array antenna consists of 256 independently controlled modules. This allows it to scan very rapidly in different directions.

#### **Who's behind it?**

Researchers at the Fraunhofer Institute for High Frequency Physics and Radar Techniques developed the system on behalf of the German Space Agency at the German Aerospace Center. A team of 34 invested more than five years of development work to create GESTRA. It is located at Schmidtenhöhe near Koblenz and operated by the German Space Situational Awareness Centre.

## **15 Who cleans up?**

### **Space has laws too**

Humans have been travelling into space for more than 60 years, and a legal framework has emerged. Space law is based on the Outer Space Treaty of 1967, which sets out the rights and obligations of states involved in researching and using space, including the Moon and other celestial bodies. To date it has been signed by 110 states. Space law has expanded over time, for example through the Moon Treaty (1979), but it is still regarded as incomplete. There are many open questions to be discussed and loopholes that need to be closed, such as the question of how to deal with space junk. Here you can test your knowledge on space law and space junk.

#### **Who's behind it?**

This quiz on space law and space junk is an initiative of the Federal Ministry of Education and Research (BMBF). It was conceived and designed by PT.DESY.

## **16 The universe in images**

### **Science and imagination past and present**

Since the earliest times, humans have wondered about what they see in the night sky and how the Earth might have been created. Here we present some of the mythological, religious and scientific ideas about the world, the cosmos and the afterlife. The images originate from Mesopotamia, Europe, Mexico and China and range from the oldest civilisations through to the present day. They reflect diverse interpretations and “controversies” between imagination, observation and tradition. They touch on central categories of human existence (space, time, matter, body, movement, energy, chaos, order, harmony) and form the cultural background to contemporary research and scientific cosmological theories.

#### **Who's behind it?**

The Art Historical Institute in Florence (a Max Planck Institute) sees itself as a laboratory of basic research in art history. It operates in dialogue with other disciplines, adopting transcultural and global perspectives. The Institute seeks to connect historical research with critical discussions of current topics like ecology, migration, digital media, cultural heritage and the future of museums.

## **17 Experiments at the extremes**

### **Looking inside planets**

Conditions inside planets tend to be extreme. Iron behaves differently at the high temperatures, pressures and density found at the Earth's core. Obviously, we cannot go to the centre of the Earth – so how do we study the materials there? At the European XFEL researchers use a diamond anvil cell. A sample is positioned in the cell and subjected to great pressure. While a strong pulsed laser heats the sample, an X-ray image is produced. The data gathered in this way allows researchers to test their theories, for example concerning the origins and characteristics of planets and exoplanets.

#### **Who's behind it?**

The European XFEL (X-Ray Free Electron Laser Facility) outside Hamburg measures 3.4 kilometres, making it the world's longest X-ray laser. In its underground control room scientists from all over the world use extremely intense laser flashes to research the extreme states found inside planets, to map atomic details of viruses and to film chemical reactions. Twelve countries are participating in this international research institution.

## **18 Micrometeorites**

### **Stardust everywhere**

As well as the eight planets and their moons, our solar system contains many other objects. These range from dwarf planets, asteroids and passing comets to miniscule particles known as interplanetary dust. When larger pieces of dust enter the Earth's atmosphere the friction causes them to glow (meteors) and fragments reach the Earth (as meteorites). Smaller particles measuring just a few millimetres burn up completely in the atmosphere (shooting stars). But the very smallest particles heat up and cool down again on their way through the atmosphere, showering onto the Earth as micrometeorites. The exhibit shows how you can find micrometeorites – or “stardust” – in your everyday surroundings.

#### **Who's behind it?**

This exhibit was prepared by the micrometeorites working group at the Walter Hohmann Observatory in Essen. We are grateful to Bresser GmbH for the loan of the microscope and to Zech + Waibel Modellbau for the 3-D model.



## **19 The emptiness of space in the laboratory**

### **What happens in a vacuum?**

Most of the gas molecules in space are accounted for by objects of significant mass such as stars and planets. The void in-between is essentially empty, an almost perfect vacuum. The phenomenon of the vacuum has fascinated humanity ever since it was discovered. We speak of a vacuum when the pressure within a closed vessel is less than the normal atmospheric pressure of 1 bar. The extreme pressure differential presents great technical challenges for manned space travel. Material scientists replicate exactly those conditions in their laboratories on Earth. Technologies such as electron microscopy, spectroscopy and vacuum evaporation all require a vacuum to function.

#### **Who's behind it?**

The Leibniz Institute for Solid State and Materials Research studies innovative materials and their physical and chemical properties. Its research operates at the micro, nano and atomic levels. Many of its experiments require extreme conditions similar to those in space.

## **20 Searching for dark matter**

### **How to reveal the invisible?**

We see many things when we look out into space. But we also know from observations that the universe must contain six times more matter than we are able to see. Scientists are currently trying to find out what properties this “dark matter” has. They have already ascertained that when a heavy dark matter particle collides with a lighter xenon atom, a flash of light will be produced and electrons will be released. Observing both the flash of light and the release of electrons together would be the first proof of dark matter. In order to solve this great mystery of the universe, a huge underground tank containing eight tonnes of liquid xenon has been installed at a depth of 1,400 metres in Italy.

#### **Who's behind it?**

The Max Planck Institute for Nuclear Physics in Heidelberg conducts experimental and theoretical basic research in the fields of astroparticle physics and quantum dynamics. Its researchers study the properties of particles from outer space and the dynamic behaviour of atoms and molecules.

## **21 Seeing the Earth from new perspectives**

### **Satellite images for environmental and climate protection**

Today there are thousands of satellites orbiting the Earth. Many of them serve to observe the Earth's surface using cameras, infra-red detectors (thermal imaging cameras), radar and other devices. What can the images be used for? In this exhibit you can explore how different types of satellite image can help us to save water, protect the environment and avoid natural disasters. There are several scenarios to choose from. Try out some of the satellite imaging instruments to see how they can make our lives easier. There are many more examples. Can you think of other applications?

### **Reduce to the max – Observing the Earth with ERNST**

This is the nanosatellite ERNST. The term “nano” derives from the Greek word for “dwarf”. Here you can see ERNST in its original size – just 25 by 25 by 37 centimetres. It weighs about 22 kilograms, about the same as an average seven-year-old. So it is smaller and lighter than many of the satellites currently in orbit, and cheaper as well. ERNST's main purpose is to spot rocket launches on Earth using its infrared detector. But satellites like ERNST can also take on other important tasks such as detecting forest fires or measuring soil moisture. ERNST is powered by three solar panels. It is currently scheduled for launch in April 2024.

#### **Who's behind it?**

ERNST was developed by the Fraunhofer Institute for High-Speed Dynamics (Ernst Mach Institute, EMI). The EMI investigates the behaviour of materials under brief extreme stress, such as occurs in high-velocity collisions. Two other Fraunhofer Institutes – the Institute for Technological Trend Analysis and the Institute of Optronics, System Technologies and Image Exploitation – also contributed to the development of ERNST.

## **22 Quiz: Which technologies originated in space research?**

Certain technologies that we take for granted today were originally developed for space research. Others that might appear space-related are in fact not. See if you can guess which is which – and learn a little more about the background.

## **23 Understanding the universe**

### **Your journey into the world of science**

Your trip through the universe starts here! We will take you from shining stars and dark matter to tiny molecules and gigantic galaxy clusters – and back to planet Earth. The more we learn about the universe, the more we realise how little we know. The work of researchers across the world is driven by that fascination. They use a variety of methods to examine the universe from different perspectives. They study the light from far-off galaxies, research the building blocks of life and observe the interactions between humans and nature here on Earth. So come with us on your own personal intergalactic tour!

#### **Who's behind it?**

This exhibit from the University of Bonn was developed by Transfer Center enaCom, the Transdisciplinary Research Area on “Building Blocks of Matter and Fundamental Interactions”, and the Argelander Institute of Astronomy in collaboration with other partners.

## **24 Cosmos in play – Astronomical phenomena in games**

Games integrate many aspects of life, often emulating and interpreting the natural world. They reference symbols, myths, rituals, prophecies and worldviews. There are often multiple variants of meaning. For example, the four on a dice can represent both the points of the compass and the seasons. Ideas associated with astronomy and time appear in many outdoor and board and card games as well as dances, along with worldviews from the corresponding cultures and periods. Anthropologists and historians have reconstructed the meaning of games by referencing oral traditions and historical texts – and sometimes even archaeological finds.

#### **Who's behind it?**

This is a project of the Society for Archaeoastronomy (GfA), which studies the field of cultural astronomy. The idea was inspired by a study by Dr Michael A. Rappenglück (chair of GfA) in 2021. Gilching Adult Education Centre (VHS) and Gilching Observatory supported this project.

## **25 Would we think differently on Mars?**

### **How our environment affects our brains**

Studies have shown that our perception and some of our abilities are influenced by our environment. Imagine you are an astronaut travelling to Mars with a small team on a long-term mission. Mars has a monotonous landscape of red sandy deserts. In this barren and isolated setting you would use certain areas of your brain a great deal less than on Earth. The regions responsible for navigation, learning and social skills would shrink. Your team would have to train those capabilities.

You can explore the effects of the environment on your own brain. If you choose to spend time in the countryside, or even a park, your brain will normally relax immediately and your mood will improve.

#### **Who's behind it?**

The Lise Meitner Group for Environmental Neuroscience at the Max Planck Institute for Human Development investigates the effects of the environment on the brain. The researchers are particularly interested in settings that are either very barren (such as the Antarctic) or especially varied and stimulating, like big cities.

## **26 Relax in space**

### **Get a new perspective with a virtual trip to the Moon**

Astronauts who have looked down at the Earth from space often report feelings of deep awe and a realisation that everything is connected. Seeing things from a distance also makes everyday problems appear relative and easier to solve. We call this the "overview effect". While spending time on the actual Moon is impossible for most of us, you can induce the relaxing effect by participating in a virtual meditation trip. Fly to the Moon with us, experience a clear view of the Earth, and feel at peace with yourself in a warm and benign atmosphere.

#### **Who's behind it?**

The Lise Meitner Group for Environmental Neuroscience at the Max Planck Institute for Human Development investigates the effects of the environment on the brain. The researchers are interested in extreme settings such as the ISS space station and even the Moon. Scan the QR code to learn more about the group's projects.

## **27 Quiz – Science or fiction?**

Our world is changing so rapidly that yesterday's visions quickly become today's reality. On the other hand, certain technological innovations from space research sound so utopian that they might be out of a science fiction story. Test your knowledge of space technology with this mix of true scientific findings and ideas derived from novels, films and TV series. Do you know which are science and which are fiction?