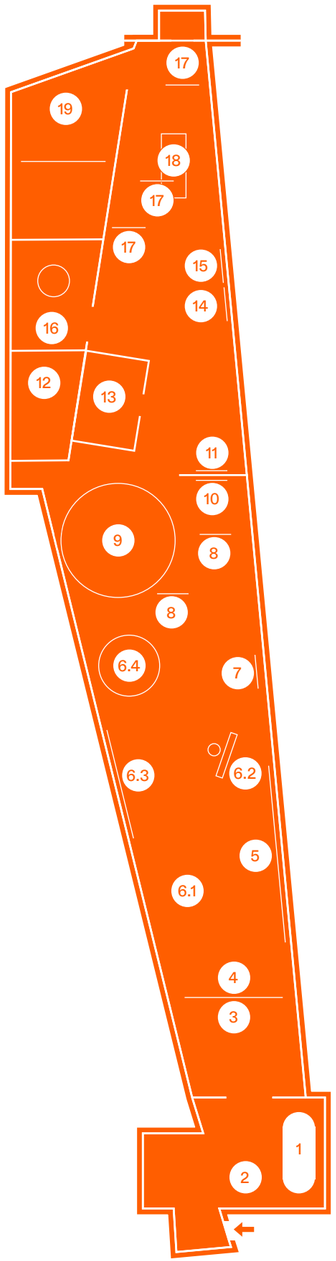

Cosmos
Archaeology
Explorations
in Time
and Space
EPFL
Pavilions
Amplifier for Art,
Science and Society
English
Guide



Plan

1 *Star Mapping Sculpture*
2 *Army of Robots*
3 *Dark Cloud of Debris*
4 *analog_artefacts*
5 *Space Heroes*
6 *The Secret World of Space Junk*
6.1 *Machine 9*
6.2 *Earthly Debris Cabinet*
6.3 *The Secret World of Space Junk*
6.4 *Debris-o-Gram*
7 *Space Cleaner AR*
8 *Virtual Orbital Visit*
9 *Cosmic Collisions*
10 *Space Time Elastic*
11 *SKA Simulator*
12 *OrbitsTriptychon*
13 *The Dynamic Universe*
14 *The Silent Pulsar of the Universe*
15 *The Lost Astronaut*
16 *Sounds of Space*
17 *Venusian Rover*
18 *Aphrodite Terra, Venera 00307 - 00310*
19 *Archaeology of Light*

Installations

1 *Star Mapping Sculpture*
2 *Army of Robots*
3 *Dark Cloud of Debris*
4 *analog_artefacts*
5 *Space Heroes*
6 *The Secret World of Space Junk*
6.1 *Machine 9*
6.2 *Earthly Debris Cabinet*
6.3 *The Secret World of Space Junk*
6.4 *Debris-o-Gram*
7 *Space Cleaner AR*
8 *Virtual Orbital Visit*
9 *Cosmic Collisions*
10 *Space Time Elastic*
11 *SKA Simulator*
12 *OrbitsTriptychon*
13 *The Dynamic Universe*
14 *The Silent Pulsar of the Universe*
15 *The Lost Astronaut*
16 *Sounds of Space*
17 *Venusian Rover*
18 *Aphrodite Terra, Venera 00307-00310*
19 *Archaeology of Light*

Cosmos Archaeology: Explorations in Time and Space

Since the dawn of time, humans have gazed at the stars and attempted to comprehend the cosmos. As recorded from Palaeolithic times to the present, our concept of the Universe has completely transformed. The expansion of our perception has occurred in tandem with the tools and technologies we have invented to map, view, and chronicle the formation and origins of the cosmos, from crude astrological charts carved into bone to the new Square Kilometre Array Observatory (SKAO), the largest radio astronomy facility in the world.

In parallel, 20th-century advances in our understanding of the laws of physics have revolutionized how we comprehend the nature of the Universe. Once considered infinite, static, and timeless, the cosmos is now understood to have a dynamic and evolving geometry. It also appears to have a beginning: the Big Bang, whose residual light we can now observe from 13.7 billion years ago. *Cosmos Archaeology: Explorations in Time and Space* transports us beyond the frontiers of both art and science as it turns terabytes of abstract astrophysics data into tangible encounters with the Universe.

The exhibition creates new interfaces for scientific visualization of astronomical big data through new media, immersive technologies, and the visual arts. *Cosmos Archaeology* originates in a collaboration between EPFL's Laboratory of Astrophysics (LASTRO) and the Laboratory for Experimental Museology (eM+).

LASTRO works with the largest dataset of the Universe, which is always growing. This data, unlike the visible archives of early astronomy, often consists of bundles of numbers measured from light and its electromagnetic spectrum. During two years of experimentation, the two EPFL laboratories have conceived a variety of new applications to visualize this abstract astrophysical information within 3D real-time interactive environments.

Cosmos Archaeology builds on this interdisciplinary collaboration to represent the Universe based on real data. Previously dispersed datasets have also been united for the first time in a single immersive framework. Presented in a half cave interactive installation, in *The Dynamic Universe* we can travel the entirety of the Universe at every possible scale, from the Earth environment to the far reaches of the cosmos detected by today's instruments. As such, within this exhibition, we too become true archaeologists of the cosmos, excavating its history as well as its depths.

Confined by gravitation to Earth's surface, our exploration of space has involved gradual steps. *The Archaeology of Light*, a film created from The Virtual Reality Universe Project (VIRUP), evokes the history of our reach into the cosmos and its structure and formation. In a 21-minute journey through time and space, this 3D film launches us from Earth to pass through the Solar System and beyond the perimeter of our Galaxy, up to the traceable boundary of the Universe and the origins of the most distant light ever emitted, the relics of the Big Bang.

These virtual technologies invite us to dive into new manifestations of the space-time continuum or to walk in the vicinity of natural and artificial stars. The exhibition's installations thus enable anyone to navigate through the immense Universe and its equally boundless data.

The exhibition features 19 unique projects that encompass the instruments of astrophysics, the visualization and sonification of the data these tools collect, and the people who propel this science. They encompass art and science perspectives through diverse media from interactive experiences based on real-time data, fulldome visualization, 3D film and documentary cinema, to kinetic sculpture, ceramics, and immersive sound installations. Many of these works have been specifically conceived for *Cosmos Archaeology*.

SKA Simulator is an interactive visualization of the South African site of the Square Kilometre Array Observatory, a vast international collaborative scientific project that Switzerland recently joined. The project gives us unique access to visit this remote site and view a new generation of astronomical instruments. Designed to detect radio waves from even before the first stars, the SKAO also promises to fill gaps in our knowledge of the evolution of the Universe, as well as locating potentially habitable exoplanets.

Mars is seemingly closer than ever, as demonstrated in two separate works that take us on distinct journeys to the surface of the red planet. Simone Aubert's *Sounds of Space* is an immersive installation of audio clips relayed from the Mars Perseverance Rover, whereas Florian Voggeneder has created a photographic record of analogue astronauts simulating human expeditions on Mars. Serial space probes have also precisely mapped the terrain of other planets, including Venus. For artist Anna Hoetjes, these datasets provided the basis for a series of

ceramic models of its surface, while Lily Hibberd is using abundant radar imaging to rove over and paint the surface of the planet.

Star Mapping Sculpture mobilizes a collection of aluminium plates pierced with tiny holes used to map stars in the most distant galaxies for the Sloan Digital Sky Survey, measuring the accelerated expansion of the Universe and its future evolution. Stars and galaxies form islands of light in dark space, which is also known to be filled with invisible matter of unknown composition: dark matter. Using Einstein's general theory of relativity to magnify these effects, *Space Time Elastic* applies simulated gravitational lenses in an interactive installation to reproduce the phenomena used to uncover the earliest galaxies and the dark matter of the cosmos.

A fundamental characteristic of the human species is the fierce desire to investigate the limits of our territory and expand our habitat. After traversing our planet, the celestial vault hovers above us as the ultimate dimension for exploration. *Cosmic Collisions*, an interactive data browser of 500 of NASA's celestial images, lets us fulfil this desire by surfing through these images while stretched out under a cinematic dome.

Uncoupled from the Earth, astronauts perform an empirical experiment in the environment of space. The impact of this sojourn on Claude Nicollier, Switzerland's first and only astronaut to date, is presented in the navigational browser *Space Heroes*. Other formerly forgotten heroes of astronomy come to light in two documentaries respectively devoted to Jocelyn Bell and Edward Dwight.

Today, space exploration is increasingly questionable as our orbital neighbourhood is populated with a multitude of active satellites and space debris. EPFL is creating solutions for sustainable technologies and methods for more ecological operations. One of the results of this research is the start-up ClearSpace, whose model of the first robot to collect space debris is presented in *Space Cleaner AR*. Two further installations, *Dark Cloud of Debris* and *Orbits-Triptychon*, visualize and sonify the pollution of the near-Earth environment. Lastly, five works by Project Adrift focus on the theme of space junk. These include a sound installation tracking 52,829 of these objects orbiting the planet alongside a cabinet of 17 symbolic pieces of donated terrestrial debris, reminding us of our collective responsibility for what takes place in space.

eM+ is a transdisciplinary laboratory at the intersection of cultural and scientific data, immersive visualisation technologies, and aesthetics.

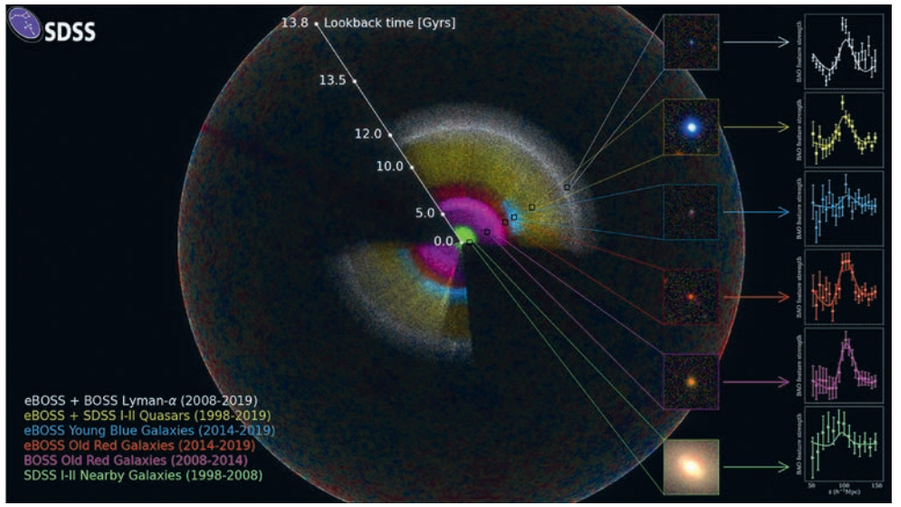
LASTRO covers a wide range of expertise in astrophysics and cosmology, with a focus on advanced research and high-quality education for the next generation of astrophysicists.

1 *Star Mapping Sculpture* 2022

Sculptural installation of aluminium disks, 80 cm diameter each, provided by Sloan Digital Sky Survey, thanks to LASTRO. Concept: Sarah Kenderdine. Artistic and mechanical production: Pascal Bettex. Technical collaborator: Christian Dessarzin. Production: EPFL Pavilions.

Pascal Bettex

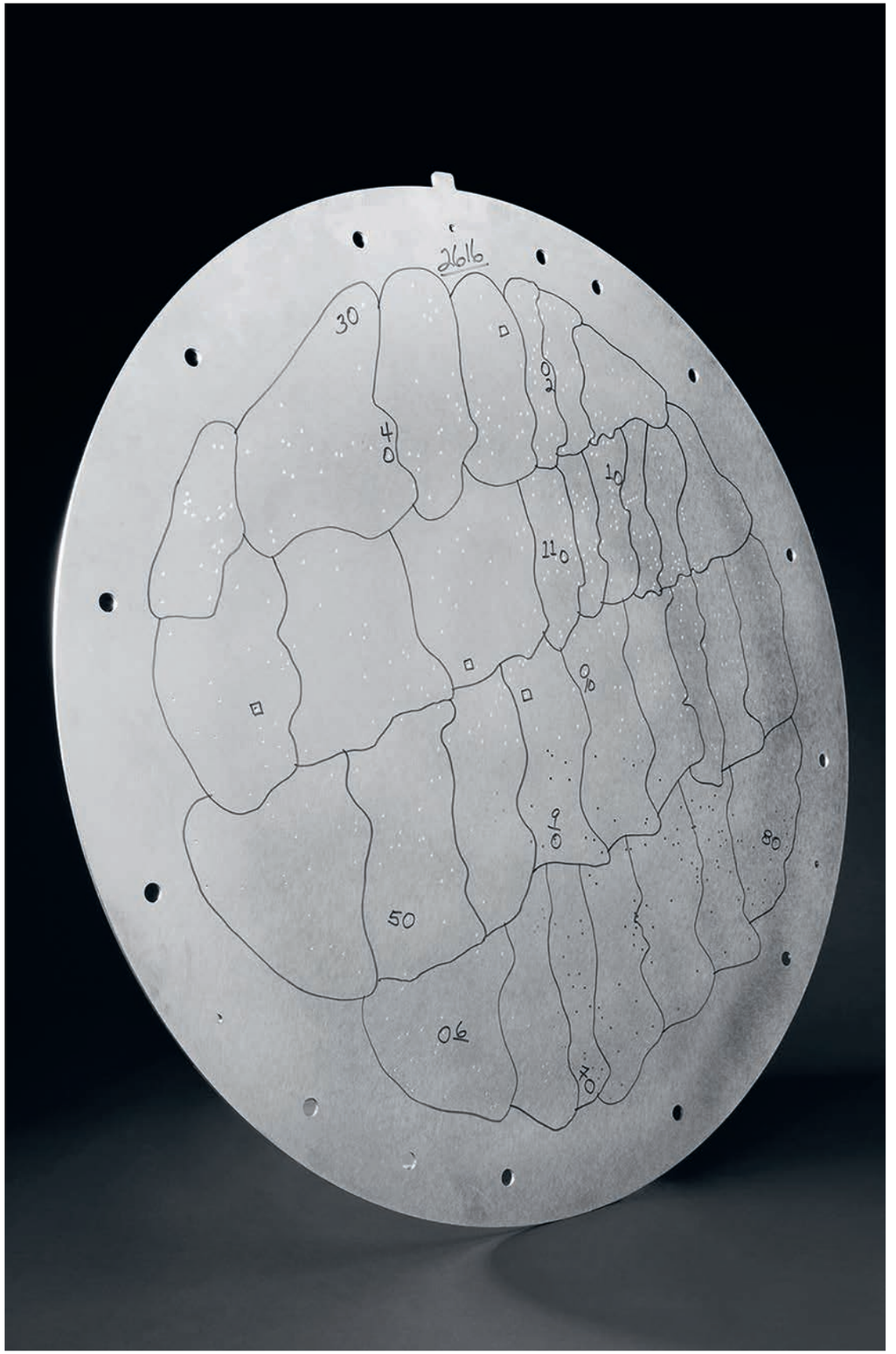
is a kinetic sculptor based in Switzerland.



When light from galaxies and luminous stellar objects traverses the cosmos, its spectrum appears redder as the Universe is expanding, which also leaves traces in the light spectrum. The Sloan Digital Sky Survey (SDSS) is an astronomical observation program that currently uses two telescopes, one located in the United States the other in Chile, to collect the light emitted by nearby and distant objects. As this light is very feeble, the stars are targeted using aluminium plates pierced at the exact points corresponding to their celestial location. Each plate contains 1000 cavities, all connected to optical fibres that transmit the light detected to a spectrograph. This instrument breaks down the signal according to its colour, or wavelength, making it possible to determine the shift toward red or the motion of the object being studied.

Observing stars in the Milky Way offers insights into the formation of our own galaxy, while studying extremely distant galaxies allows us to measure the expansion of the Universe. SDSS requires thousands of plates, each corresponding to a specific region of the sky. They are only mounted on the telescope for about an hour, after which they no longer serve any astronomical purpose. Some of the remaining plates are subsequently distributed for educational and artistic projects, with the aim of disseminating astrophysical knowledge and its tools.

Star Mapping Sculpture presents a collection of these plates in a choreographic installation. Adapting the SDSS plates from their original scientific purpose, the artist Pascal Bettex gives them new life to convey his vision of space in motion. His kinetic installation *Star Mapping Sculpture* thus evokes how the operation of the Universe is largely ruled by subtle invisible mechanics.

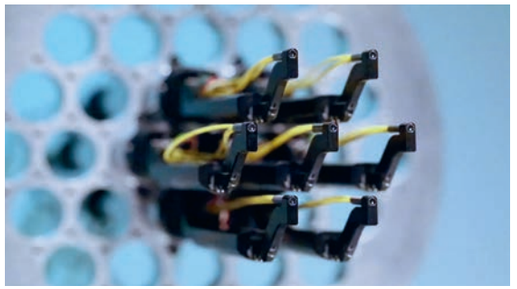


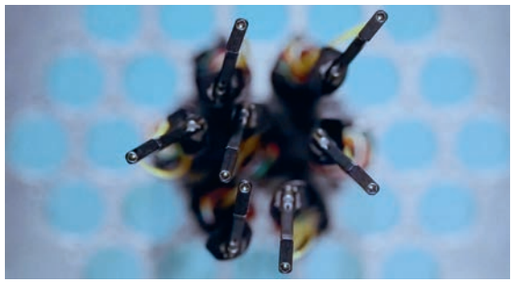
2 *Army of Robots* 2022

Installation of microrobots, optical fibre, motors.
Production: EPFL Pavilions, LASTRO.

LASTRO Astrobots

is an interdisciplinary team of astrophysicists, robotics researchers and engineers.





Images: Courtesy of EPFL Astrobots and SDSS.

One of the key missions of the Sloan Digital Sky Survey (SDSS) is the three-dimensional mapping of the cosmos. In analysing the light spectrum that travels through the Universe, and in combining the data for different galaxies, astrophysicists can define cosmic distances. The study of the distribution of the 3D structures also allows for the understanding of the mechanisms underlying the formation of galaxies on a cosmic scale.

The mapping of the Universe with the SDSS plates has already taken more than 20 years. The process has been slowed because of the ground-based location of the telescopes, whose operation depends on the seasons and weather conditions. The fifth period of the SDSS observation campaign began in 2020 and is expected to observe nearly six million stars over five years. To optimise the acquisition process, the plates that were previously perforated to measure a certain portion of the sky have been replaced by microrobots that adjust the position of fibres to each region of the sky observed. These tiny robots were created by the EPFL Astrobots interdisciplinary team, which includes astrophysicists and robotics researchers as well as engineers.

Army of Robots presents a test plate equipped with an array of these microrobots, whose movements are controlled by a computer. Each robot can be programmed to direct a corresponding optical fibre towards the desired portion of the sky, like dozens of eyes probing the depths of the Universe. As the robots are placed side-by-side on the tiny plate, great care must be taken to avoid blocking their movement. The size of the operation reflects the disparity between the human scale and that of the cosmos, as the extreme focus of the light contrasts with the immensity of the space observed.

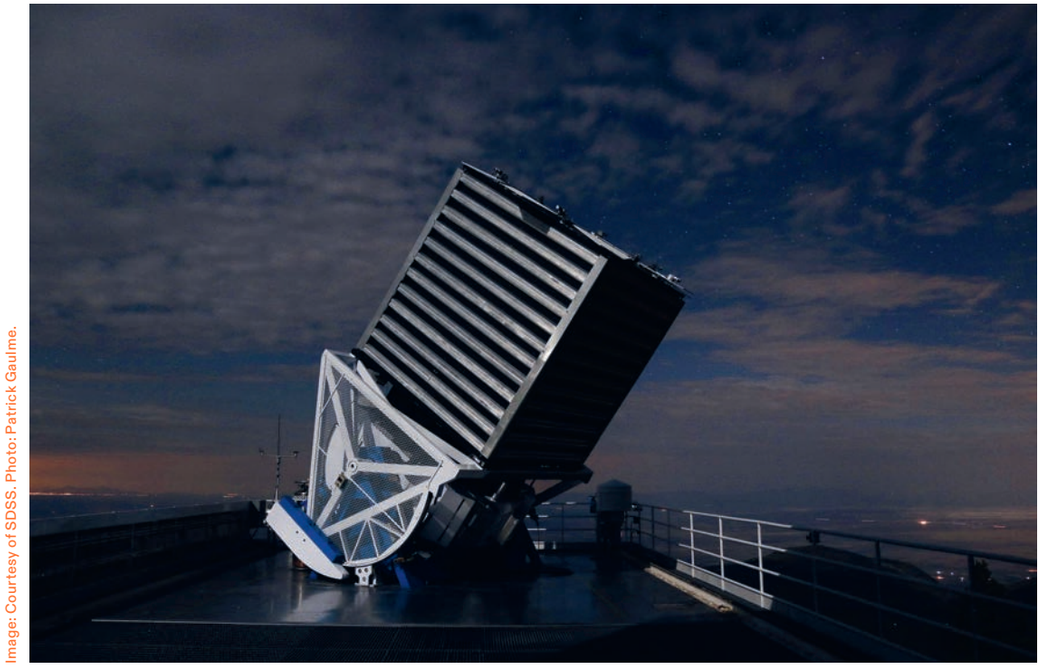


Image: Courtesy of SDSS. Photo: Patrick Gaulme.

Image: Courtesy of EPFL Astrobots and SDSS.

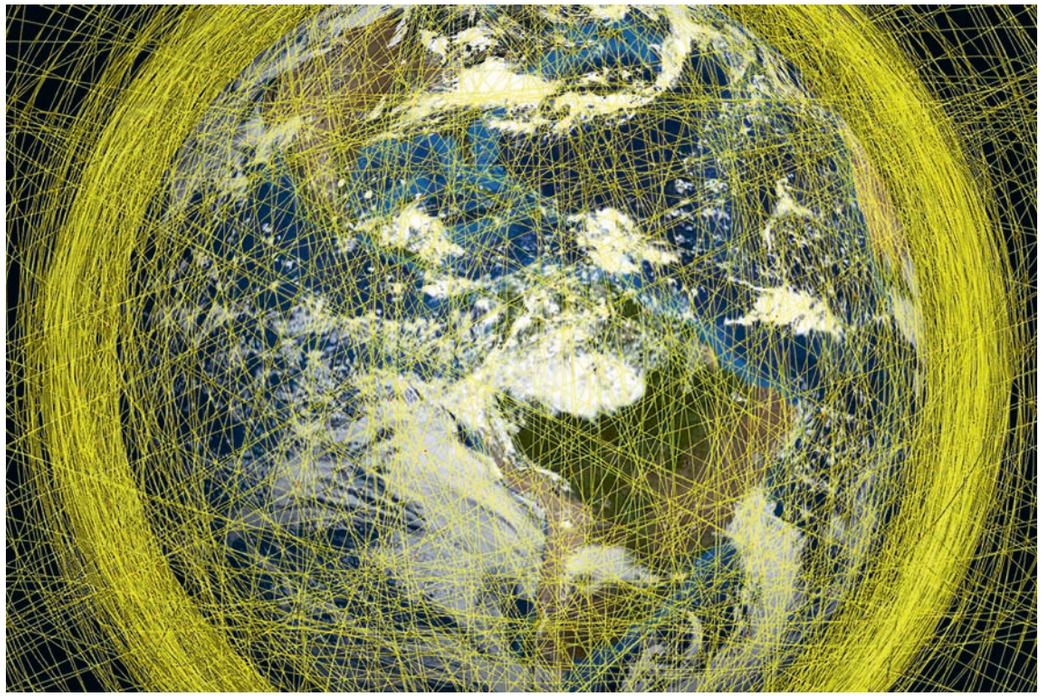
3 *Dark Cloud of Debris*

2022

Interactive data visualization.
Production: eM+.

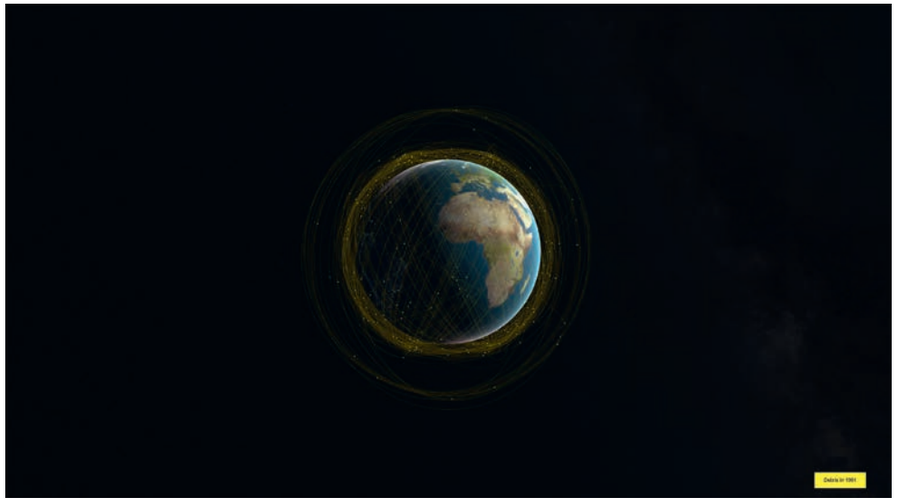
Theodore Kruczek

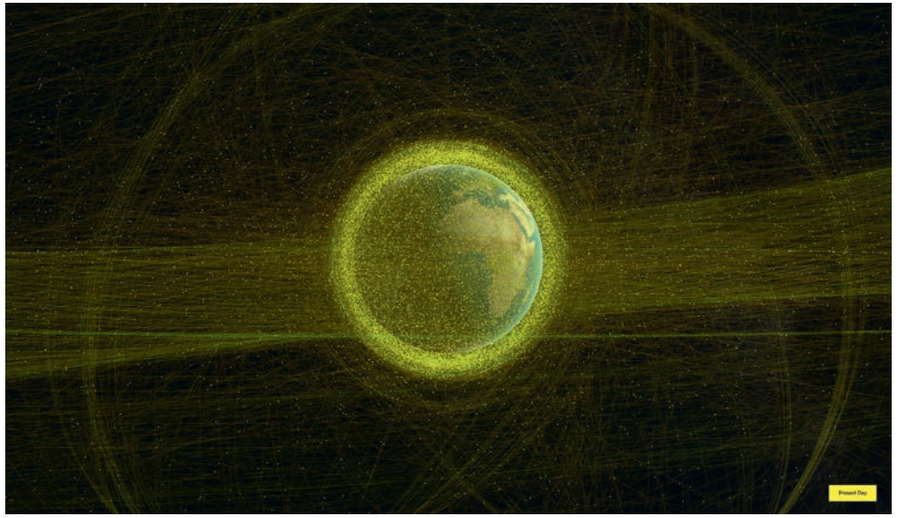
is creator of KeepTrack.space and is based in the United States.

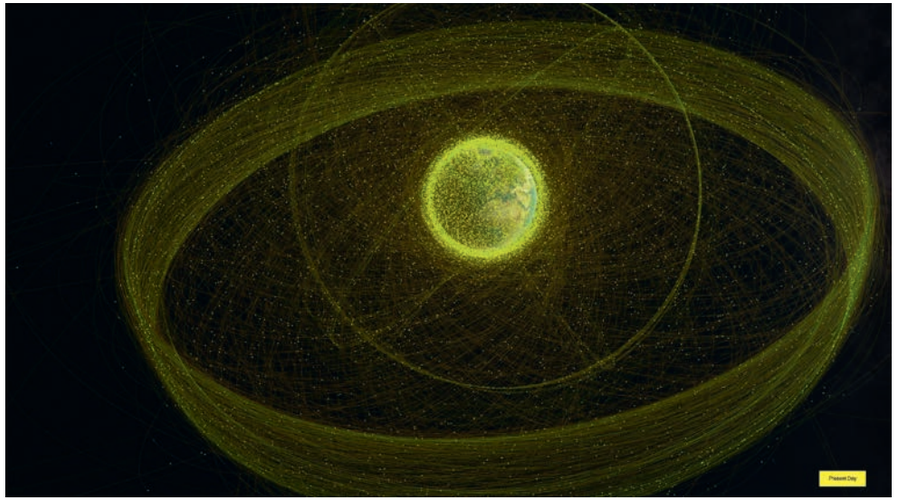


As our increasingly interconnected digital societies rely more heavily on space-based infrastructure, satellites have become crucial for the operation of a multitude of technological systems. According to NASA, US Department of Defense sensors are also tracking at least 27,000 of the estimated hundred million pieces of space junk orbiting the near-Earth environment. This pollution is the result of decades of unsustainable practices in space exploration and its exploitation. There are also countless orbital objects that are too small to be tracked. Yet, in the words of Jérôme Barbier, Head of Outer Space, at Paris Peace Forum, 'Protecting Earth's orbital environment is key to ensure everyone's ability to benefit from outer space. Space debris have no nationality, nor rationality'.

How can we get a total understanding of this web of satellites orbiting the Earth? *Dark Cloud of Debris* is a visualization of tens of thousands of satellites and human debris. Conceived by Theodore Kruczek, it shows the evolution of this pollution over time, from 1959 to the present. Each type of object appears as a different colour: space satellites, debris, and rocket body parts. Aimed at a wide public, this visualization enables anyone to learn about orbital mechanics as well as the burgeoning realm of satellite operations.







Images: Courtesy of KeepTrack.space.

4 *analog_artefacts* 2022

Video loop. Project curator: Claudia Schnugg.

Florian Voggeneder

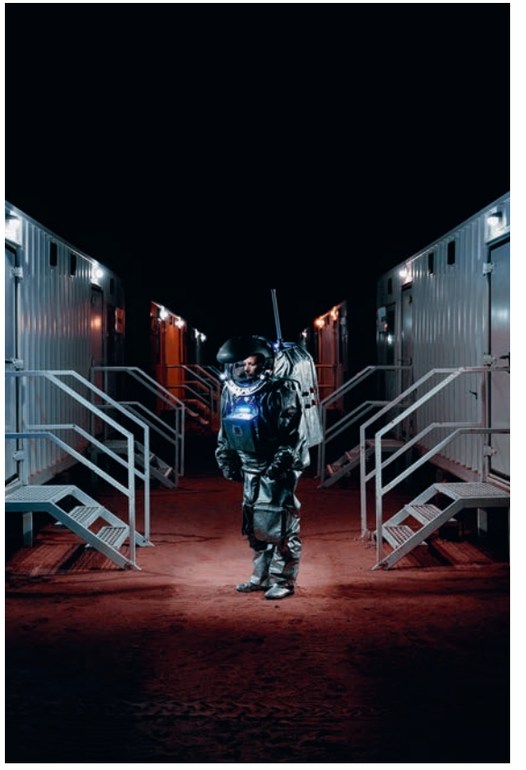
is a photographer and media artist based in Austria.

Images: Courtesy of Florian Voggeneder.

Conceived for *Cosmos Archaeology*, Florian Voggeneder's most recent video, *analog_artefacts*, reflects on the potential of humans to inhabit Mars, such as living in harsh conditions, and being bound to garments, tools, and technological environments. It is a preliminary result of the artist's long-term photographic investigation of the simulation of human space exploration.

Inspired by analogue astronauts scaling glaciers in the Austrian Alps in 2015, Voggeneder participated in simulated space missions undertaken in remote, terrestrial landscapes similar to Mars, the Moon, and other planetary bodies. He graduated from the Analog Mission Basic and Advanced program at the Austrian Space Forum in order to qualify for the month-long Mars simulations, including with AMADEE-18 in Oman and AMADEE-20 in Israel. Integrated as a field crew member and deputy support crew commander, the artist himself became the subject of experiments and studies. In 2022, he was embedded in the ARCHES Demo Mission by the German Aerospace Center atop Mount Etna, Italy.

Voggeneder's photographs capture astronauts going about their work in the field, collecting specimens, testing equipment, and operating rovers, also temporally isolated from Earth by the time it would take for their messages to travel between the two planets. As *analog_artefacts* revisits Voggeneder's archive, it aims to correlate photography, video, and experimental data into a video loop, fathoming the boundaries between science and fiction, simulation, and reality.



5 *Space Heroes* 2022

Interactive installation, archival videos, Linear Navigator, 55-inch LCD monitor on a 10-metre rail. Concept: Sarah Kenderdine. Research development, engineering: Giacomo Alliata. Interactive graphic design: Patrick Donaldson. Linear Navigator: eM+, original design Jeffrey Shaw, engineers Nelissen Decorbouw. Produced with the support of EPFL Cultural Heritage and Innovation Centre.

eM+

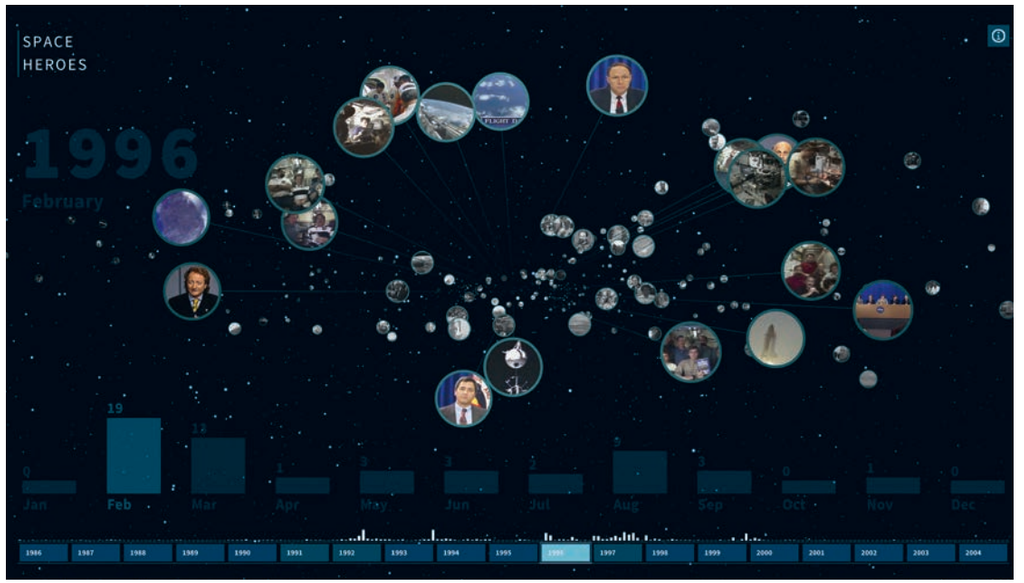


Image: Courtesy of eM+.

While time flows continuously, life sometimes seems to be a constellation of transitory moments whose succession form a story. The story of Claude Nicollier, born in 1944, unfolds in several chapters: astrophysicist, pilot, astronaut, professor, and science communicator. All these activities are united by Nicollier's intense passion for space, both as a subject of study and a territory for exploration.

Space Heroes is a virtual navigation in time through a digital archive that reconstructs the biography of Claude Nicollier. The archive contains extensive video footage shot throughout his career. The selection of a year prompts the robotically driven screen to move along the interactive frieze. A cloud of videos corresponding to the time marker is then displayed, allowing the exploration of the astronaut's relationship to space at that given moment. The navigator can also be seen as memory. The interface offers the means to partially break with the temporal linearity of the same period as the mosaic of video windows randomly changes their configuration over time. These videos manifest a life dedicated to exploring and sharing fascination with space.

Image: Courtesy of NASA.CC-BY-0.3.

Image: Courtesy of eM+.

6 *The Secret World of Space Junk* 2022

Series of five artworks. Creative technologist Daniel Jones. Producer Anya Tavkar. Co-produced by Project Adrift and EPFL Pavilions.

Project Adrift

is the creation of artists Cath Le Couteur and Nick Ryan, based in London, United Kingdom.

A spatula. An astronaut's suit. A piece of satellite debris. These objects are among the hundred million fragments of space debris orbiting the Earth, some of which are also being tracked in real time by space agencies. When these objects enter the Earth's atmosphere, they burn up and disintegrate. But most of them remain in orbit, forming a dangerous dance, otherwise capable of inflicting considerable damage on the International Space Station and operational satellites. Project Adrift aims to make the invisible overpopulation of our space neighbourhood tangible through the manifestation of the materiality of these objects. The works presented in *The Secret World of Space Junk* elevate our awareness of the equal urgence of ecological issues on the Earth's surface as well as in space.

6.1 *Machine 9* 2017

Sound installation, 8 speaker-array, orbital mechanics simulator, display unit.

Nick Ryan

is a sound artist based in the based in London, United Kingdom.

Image: Michael Bowles, Courtesy Nick Ryan.

At the centre of a 360-degree soundstage, made of a circle of eight speakers, is a glass case containing *Machine 9*. This complex sound instrument was crafted by the artist to calculate the real-time location of 52,829 of the largest pieces of space junk orbiting Earth. The name, altitude, speed, and size of each debris object that passes directly overhead appears on the display. Each appearing piece triggers *Machine 9* to select a sound from a library of 1000 foley sound recordings of 'Earthly Debris' (see 6.2). Among other factors, the size of an object determines which sound is selected: low pitched recordings represent large objects and higher pitched sounds, small objects. The position of sounds in the eight speakers indicates the changing location of the object in the sky. The moment that an object disappears over the detectable horizon, it falls silent.

6.2 *Earthly Debris Cabinet* 2017

Installation of 17 objects, 12-inch display monitor, iPad.

Nick Ryan

Space Debris, Impressions. Avec l'aimable autorisation de l'Institut de Space Systems, TU Braunschweig.

Earthly Debris Cabinet is a museological display of 17 terrestrial objects chosen by project volunteers as symbolic pieces of space debris, offering a link between everyday objects and space junk. Over 250 objects were submitted to the artist who used them to generate a library of 1000 sounds for the sound instrument *Machine 9*. An interactive screen invites visitors to create an illustration of a piece of space debris to be added to the display.

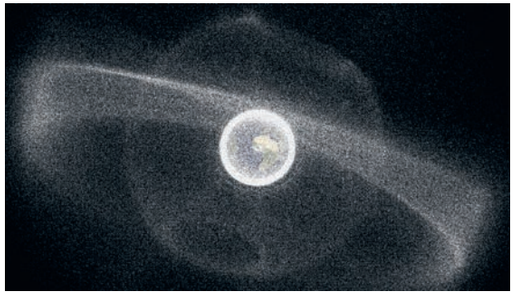
6.3 *Secret World of Space Junk* 2017 / 2018

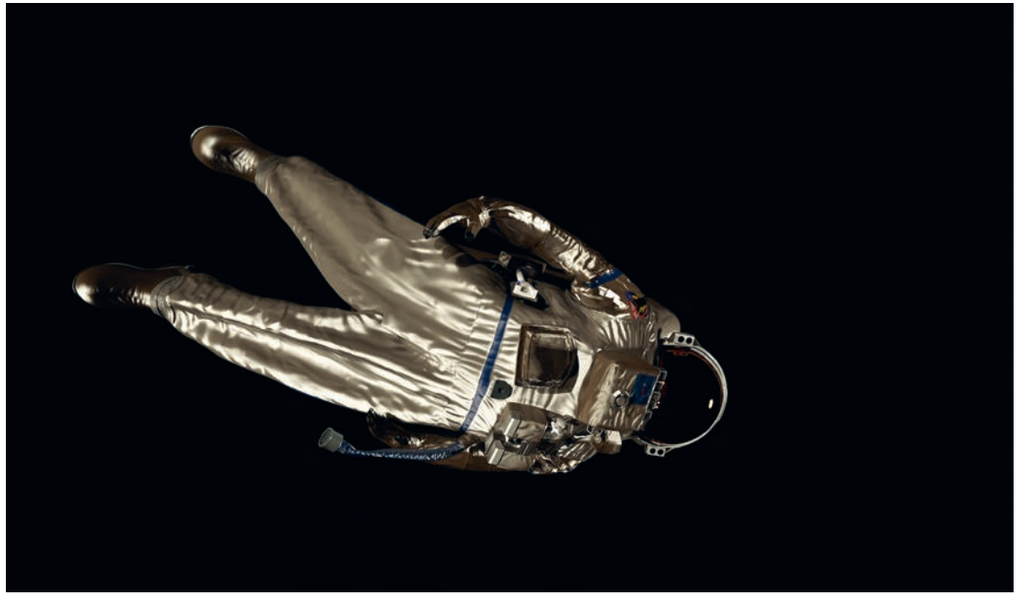
Adrift, 2017, film, 11:03 minutes. Director and Producer: Cath Le Couteur. Vanguard voice: Sally Potter. Subtitles: Clément Martin. Full credits at the end of the film.

SuitSat, 2018, film 2:30 minutes. Director: Cath Le Couteur. SuitSat voice: Gruff Rhys. Subtitles: Clément Martin. Funded by The Space. Full credits at the end of the film.

Cath Le Couteur

is a filmmaker based in London, United Kingdom.





Images: Cath Le Couteur, Daffy London. Courtesy of the artists.

The first of two short films, *Adrift*, highlights the paradox between the short-term use of hardware in space and their long-term harmful trajectories in perennial orbit. It begins with the tale of the astronaut Piers Sellers, who dropped his spatula in space in 2006, which became a deadly instrument, travelling at 7,500 kilometres per second. The film then takes us to Chile's Collowara Observatory, the International Space Station, and finally to Thailand to view debris burning up on Earth re-entry.

The second film, *SuitSat*, is a digital visualization of a Russian astronaut's suit that was pushed out of the International Space Station in 2006. Fitted with a radio transmitter, it was meant to communicate with Earth as a satellite. But when the device failed a few days later, the suit was burnt up in Earth's atmosphere as a piece of space junk.

6.4 *Debris-o-Gram* 2017

Hologram, bespoke orbital mechanics simulator, round cabin.

Cath Le Couteur and Nick Ryan

Presented in an enclosed viewing cylinder, *Debris-o-Gram* is a live holographic projection of the Earth and the cloud of space debris that encircles it. Each dot in the visualization represents a real piece of junk, with its position calculated in real time. *Debris-o-Gram* thus materializes a dectable swarm of 52,829 objects surrounding the Earth.

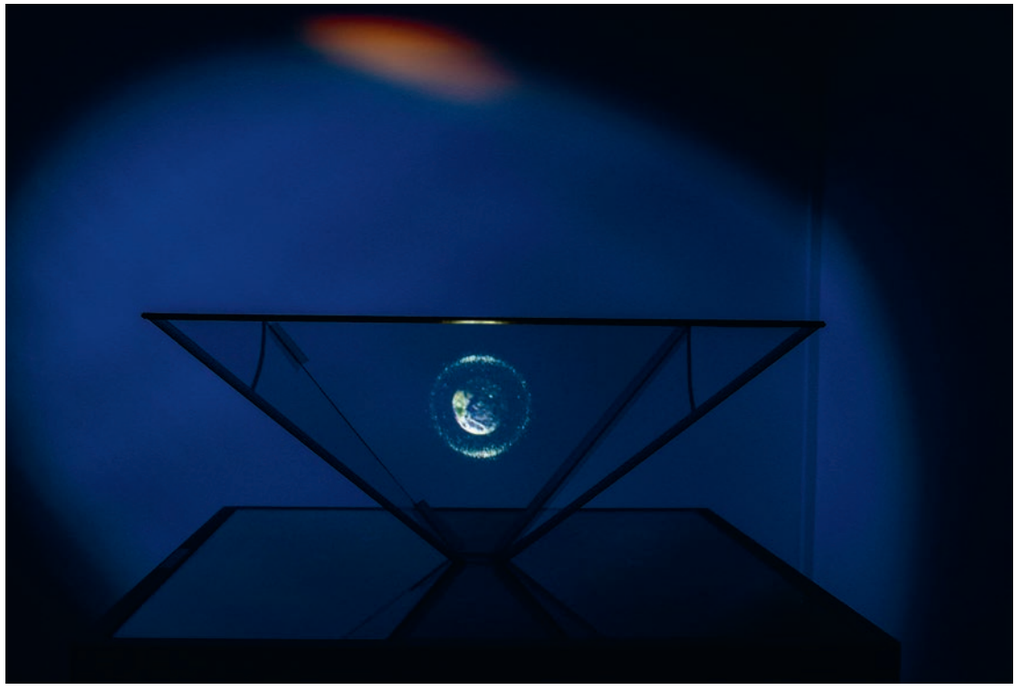


Image : Nick Ryan. Courtesy of the artist.

7 *Space Cleaner AR* 2022

Interactive AR installation, animation, iPad.

Foxar for ClearSpace

Louis Jeannin and Nicolas Caligiurim are the co-founders of Foxar and are based in France.

EPFL start-up, ClearSpace aims to eliminate space debris for the sustainable use of space.

Image: Artistic impression of the ClearSpace-1 Mission capturing the VESPA, 2022. Courtesy and © ClearSpace.

To be launched in 2025, ClearSpace-1 will be the first ever space debris removal mission. Its aim is to rendezvous, capture, and take down for re-entry the upper part of a Vespa (Vega Secondary Payload Adapter) from Europe's Vega launcher. This object was left in an approximately 800 by 660 kilometre altitude orbit. ClearSpace-1 will use a European Space Agency developed robotic arm to capture the Vespa, then perform a controlled atmospheric re-entry. In 2019, ClearSpace was selected by the European Space Agency to lead the first mission to remove debris from Orbit by 2025.

The *Space Cleaner AR* animation demonstrates the ClearSpace-1 robot satellite in the process of catching Vespa. Manipulating and moving the iPad, the participant discovers the shape and size of the satellite. Other visitors can interact with a large screen to observe what is unfolding on the iPad.

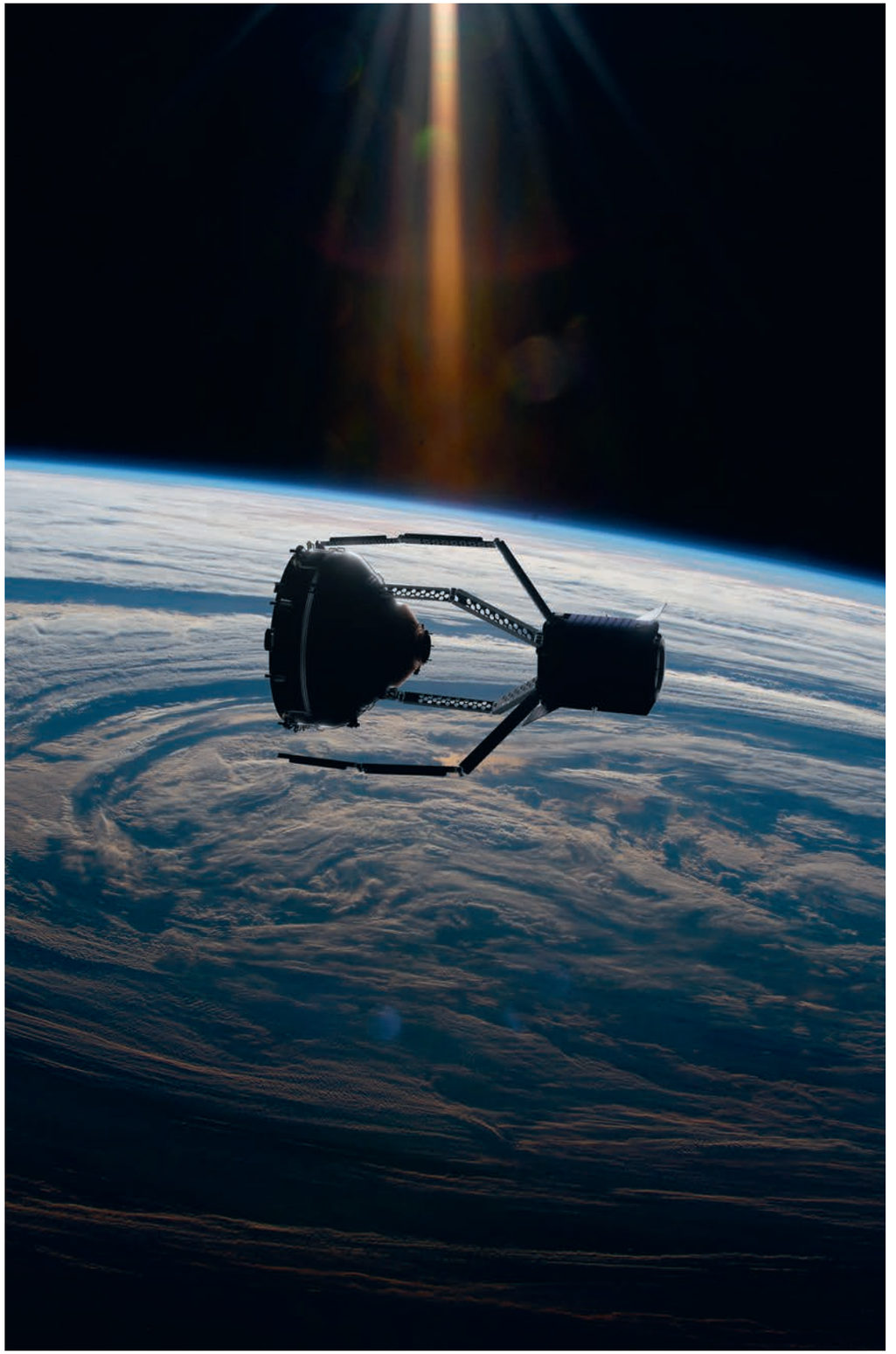
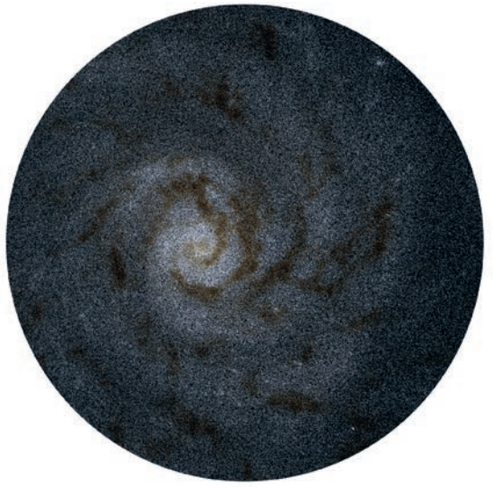


Image: Concept rendering of the capturing of the VESPA during the ClearSpace-1 Mission, 2022. Image by Jamani Caillet EPFL. Courtesy and © ClearSpace.

8 *Virtual Orbital Visit* 2022

Looped video on two circular screens.
Engineers: Florian Cabo, Laurent Novac.
Production: EPFL Pavilions. Realised with the support of the EPFL Interdisciplinary Seed Fund.

LASTRO, eM+



Images: Courtesy of LASTRO and eM+.

As the most successful effort ever to map the cosmos, the Sloan Digital Sky Survey (SDSS) has created remarkably detailed 3D maps of the Universe. The SDSS includes deep multicolour images encompassing one third of the sky and data on many millions of astronomical objects. Yet another project called IllustrisTNG has developed simulations for cosmological galaxy formation and for large-scale cosmic structures. These cosmological numerical simulations have now reached a level that allows for the inclusion of several billion mass elements.

Despite extraordinary advances to build a tangible model of the Universe, much more needs to be done for this information to become accessible to everyone. Astrophysicists are now developing new tools to translate and to explore very big cosmological datasets. This is an arduous enterprise, not only because of the nature of these datasets but also in terms of their complexity for our perception and cognition. This is why LASTRO and eM+ are developing new methods to explore these big datasets through large-scale immersive systems and custom interfaces, and scientific observation and simulation.

Virtual Orbital Visit is a portal into the results of this collective and interdisciplinary scientific endeavour. Generated from five of the most important datasets available to this collaborative project, we start with a trip from our home planet to the International Space Station. The Sloan Digital Sky Survey then explodes this perspective of the Universe as it provides insights into deep space, allowing us to appreciate its full extent for the first time. Farthest beyond our imagination yet, IllustrisTNG shows us a model of the entire Universe and its formation over time as far back as 13.7 billion years. Our only remaining task is to dismiss stereotypes of science illustration and look at the true data of the Universe with open eyes.

9

Cosmic Collisions

2022

Interactive installation, interface. Concept: Sarah Kenderdine. Engineers: Sylvain Cardin, Samy Mannane, Loïc Serafin, Nikolaus Völzow. Interface graphic design: Sascha Fronczek. Cupola eM+, engineering Zendome.

eM+

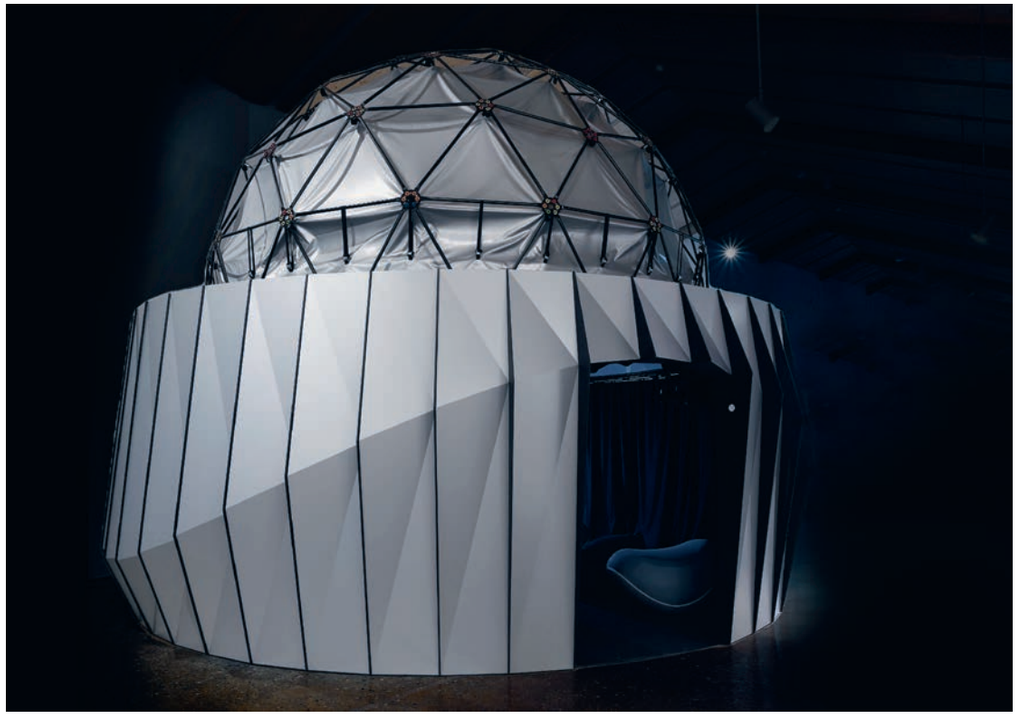


Image: Courtesy of eM+.

Humans have always looked up to the sky to contemplate the stars that transit the firmament. From the dawn of civilization, the movement of the Sun during daytime inspired the creation of systems to measure time. During the night, constellations of stars were used as a guide for navigators and as landmarks for farmers. The advent of astronomical instruments made it possible to reconstruct the history of the Solar System and the Universe. But beyond the observation of celestial objects for technological and scientific purposes, the contemplation of the sky opens a portal to infinity.

Cosmic Collisions houses an interactive astrophysical visualization installation within a fulldome environment, allowing us to reproduce the ancient gesture of looking up to the sky to observe the stars. The projection of approximately 500 images collected by NASA telescopes abolishes the distance between the human eye and the stars. The dome also augments our vision so that we can perceive structures normally indiscernible to the naked eye. Immersion in this reimagined hemisphere is a playful and informative experience that connects us more intimately to the Universe all around us.

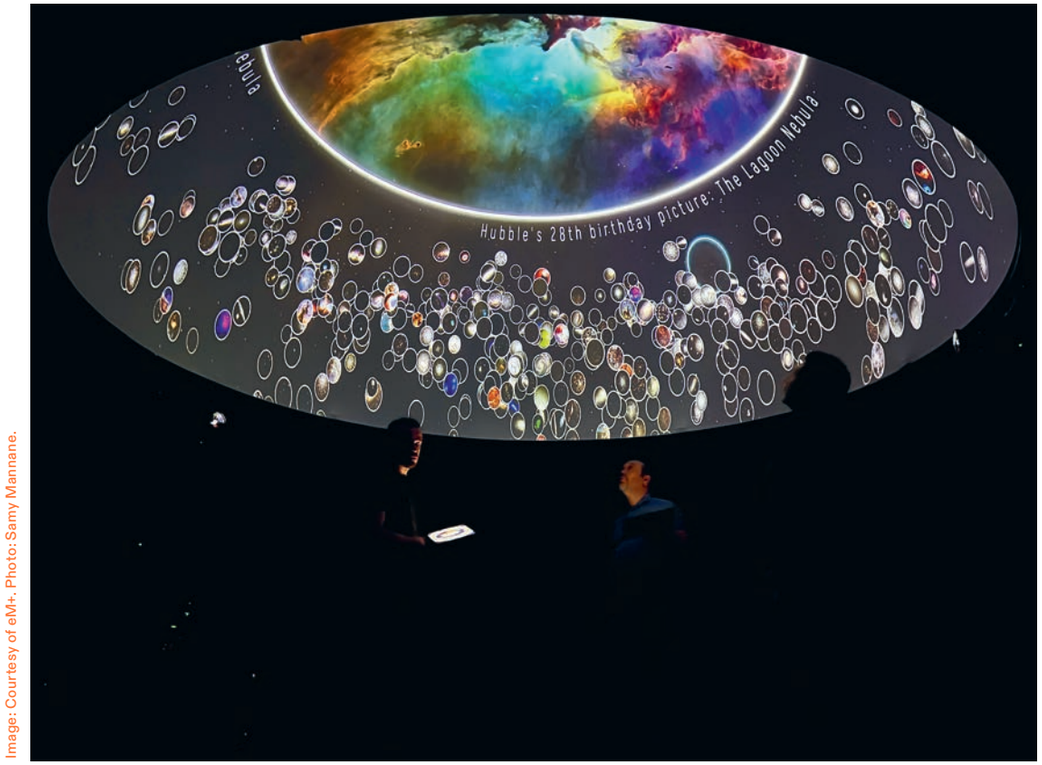
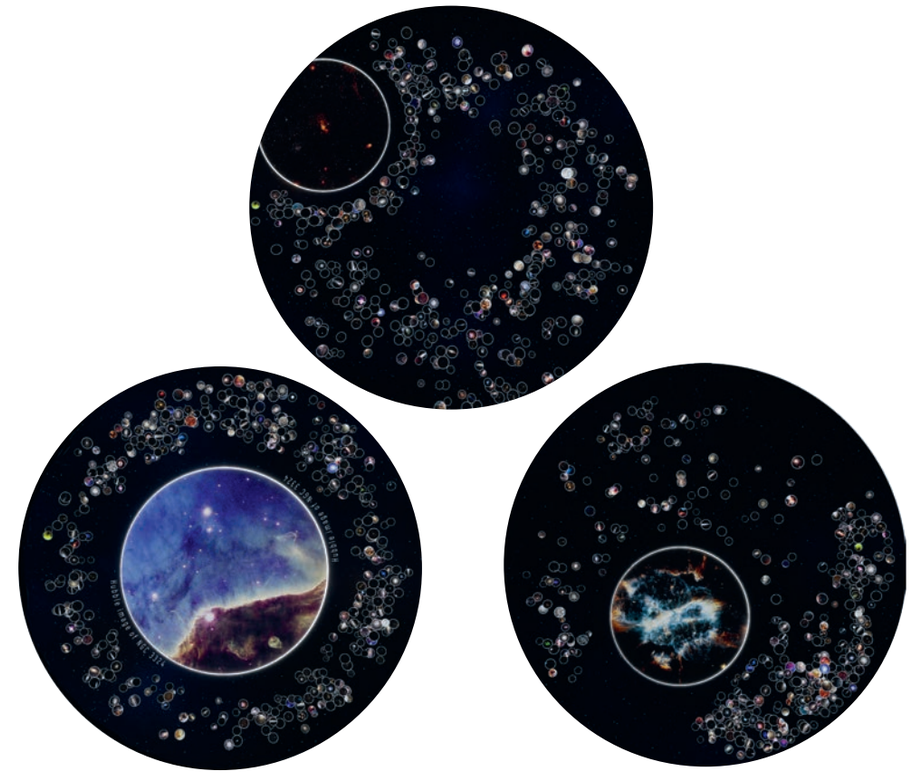


Image: Courtesy of eM+. Photo: Samy Mannane.



Images: Courtesy of eM+.

10 *Space Time Elastic* 2022

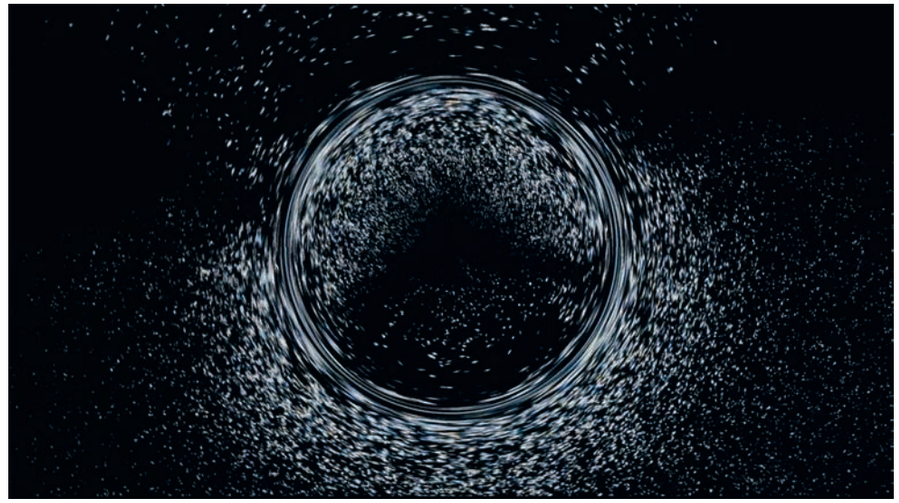
Interactive installation, 3DoF interface. Engineers: Austin Peel, Laurent Novac, Loïc Serafin, Georgios Vernardos. Production: EPFL Pavilions.

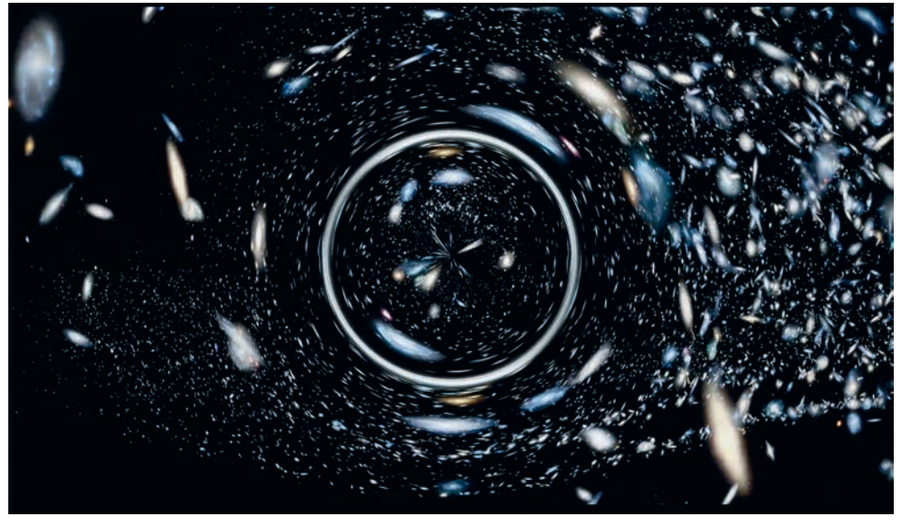
LASTRO, eM+

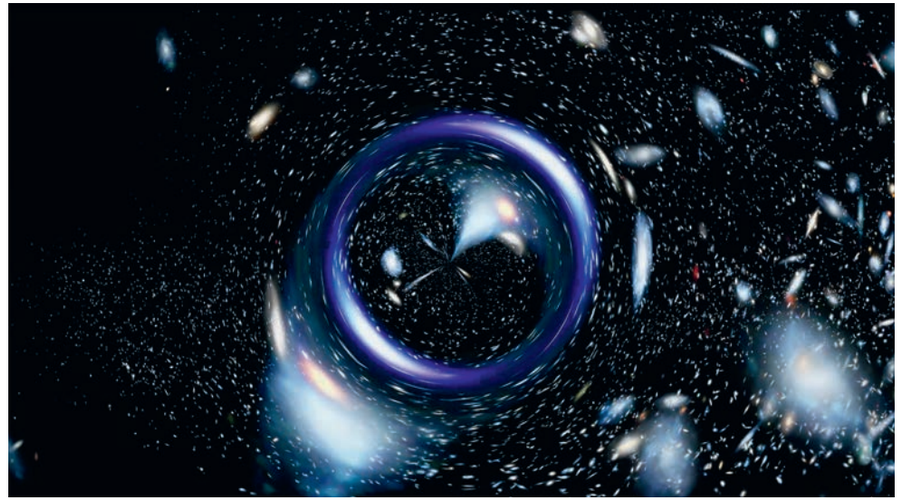
Images: Courtesy of LASTRO and eM+.

Albert Einstein's theory of gravitation for general relativity demonstrates that space-time is not flat because it is distorted by the presence of massive objects such as the Sun, stars, galaxies, galaxy clusters, or black holes. As light travels through space, it is also weakly curved by the gravitational effects of large-scale structures in the Universe. In some cases, the most massive structures distort space-time to the point of creating a gravitational lens. Curvature in this situation is so strong that the path of light rays is strongly tilted, as if it were passing through a magnifying glass. This phenomenon can be seen in space as the light from a galaxy behind a massive structure is distorted to appear elongated and curved like a ring of light. By studying the characteristics of gravitational lenses in space, astrophysicists can reconstruct the distribution of massive structures in the Universe and their nature.

Space Time Elastic is an interactive visual application that allows us to perceive the phenomenon of gravitational lensing as we directly generate these curves. For this project, LASTRO laboratory created a representation of the Universe, generated in real time from astronomical data, which can be explored in three dimensions. As the participant places a virtual lens at a specific location, they select the size and elongation of the lens to observe the resulting light deformation. To witness the effects of this action demonstrates exactly how scientists deduce the properties of objects based on their gravitational impact on their surrounding environment: the warping of light. Achieved without seeing the object directly, these excavations of space-time allow for the invisible to be made perceptible.



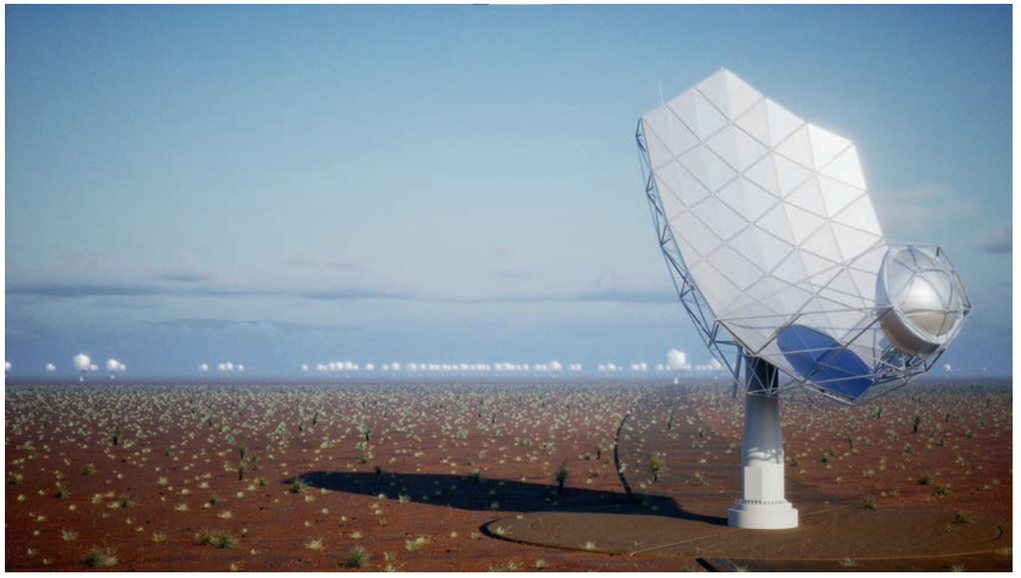




11 *SKA Simulator* 2022

Interactive installation, 6DoF interface.
Concept: Sarah Kenderdine. Engineers: Hadrien Gurnel, Samy Mannane, Loïc Serafin.
Production: EPFL Pavilions, with the support of SKAO.

eM+



Images: Courtesy of LASTRO and eM+.

The Universe resonates with radio waves at similar frequencies to those used for radiocommunication systems. Some of these waves have been propagating in the cosmos for up to 13.7 billion years. Analysis of these signals allows astrophysicists to study the formation of the first stars and galaxies. They can also reveal the potential of molecules to signal extraterrestrial life, and the investigation of the theory of gravitation on cosmological scales. Detecting these extremely faint waves requires huge observatories in very remote terrestrial locations to avoid the 3G / 4G / 5G mobile network, as well as other radiocommunication systems. The Square Kilometre Array telescope, or SKA, for which LASTRO is a collaborator, consists of an array of antennas and dishes at two sites, one each in South Africa and Australia. Construction began in 2021 and will eventually form the largest telescope in the world, with a total collecting area of one square kilometre.

SKA Simulator offers the chance to descend into and explore the heart of the South African SKA site. In an arid and silent natural terrain, parabolic radio dishes protrude from the ground, detecting radio waves from the Universe. A six degrees of freedom (6DoF) controller lets us navigate in between, around, and above the instruments. The monumentality of the SKA project is palpable in its expansive network of dishes. Wandering the observatory site witnesses the extent of these dimensions. It also reflects the vast spatio-temporal scale involved in exploring the Universe and in the study of the apparition of the galaxies that host our planet.

12 *OrbitsTriptychon* 2017 / 2022

Audiovisual installation of live data for three screens, multi-channel sound system. 16:26 minutes. Project curator: Claudia Schnugg. Realised with funding from Stiftung Kunstfonds and Neustart Kultur.

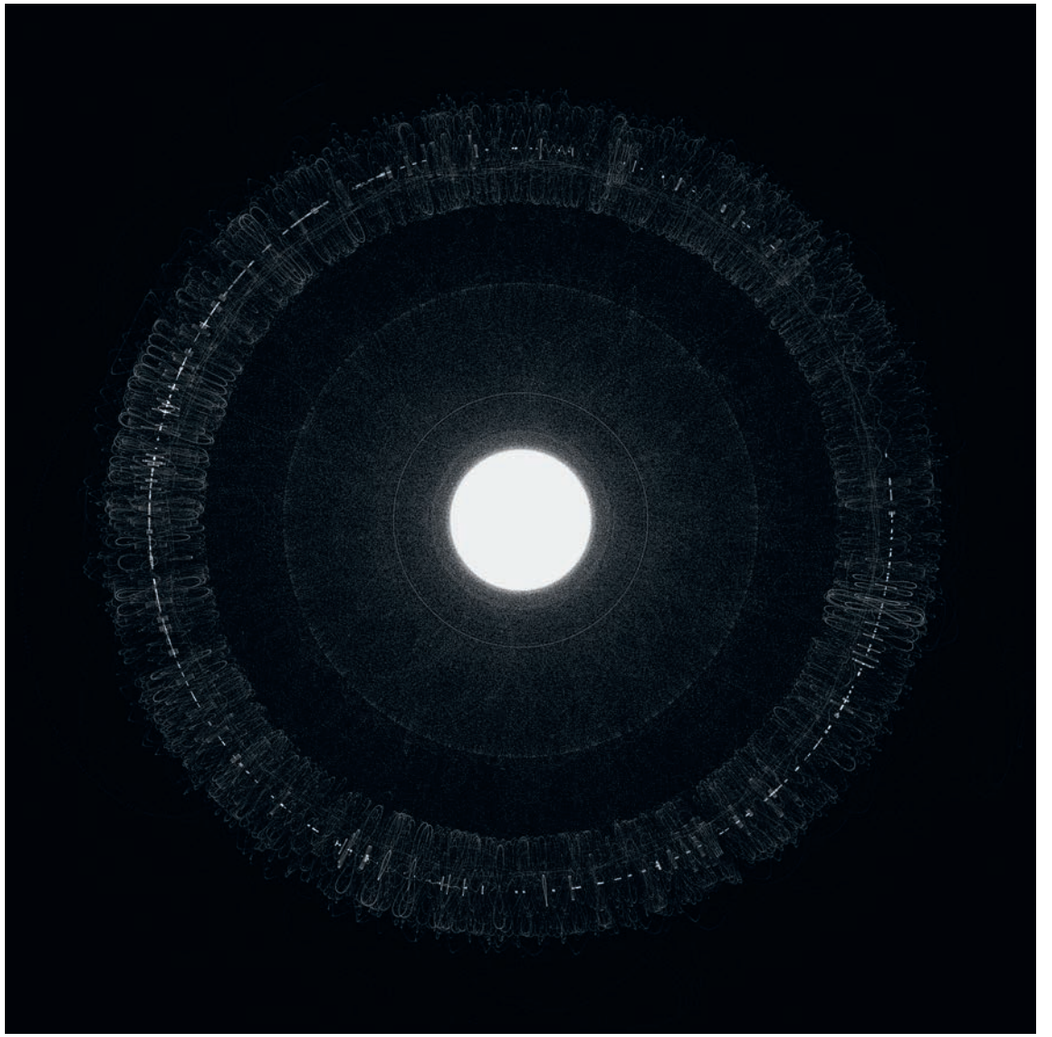
Quadrature

is an artistic collaboration between Juliane Götz and Sebastian Neitsch, based in Germany.

Image: *OrbitsTriptychon*, Matsudo, Japan, 2018. Courtesy of Quadrature.

*OrbitsTriptych*on is a live audiovisual experiment whose aesthetic emulates the poetic dance of about 25,000 manufactured objects in orbit around the Earth, most of which are space trash, except for about 3000 satellites. The objects' movements are visualized based on Quadrature's calculation of their trajectories in space and in-depth research into global satellite data. The artists' first source of information was a US Air Force website. Yet, compared with unofficial databases, a number of classified objects such as military or surveillance satellites were missing. Fortunately, data on classified satellites is generated by enthusiastic amateur astronomers observing the night skies. Merging these two sources, the work harmonizes artistic autonomy and scientific rigour.

In this work, Quadrature transforms their original 2017 live performance *Orbits* into an experimental installation. Referring to the art historical use of the triptych, the work is a trilogy of: the data of the continuous orbit of objects around Earth, the live re-enactment of this event, and its subsequent restaging in an art installation. Its minimalist visualization follows the orbits of these satellites to reveal a hidden layer of human infrastructure. Seemingly chaotic paths mutate to form surprising patterns of an almost organic nature. Everything is ordered according to the physical necessities of orbital mechanics: each satellite is propelled by its own velocity; none lingers. In a play on the aesthetics of space (zooming in and out) and time (speeding up and slowing down), the artists expose the disproportionate space that these objects occupy.



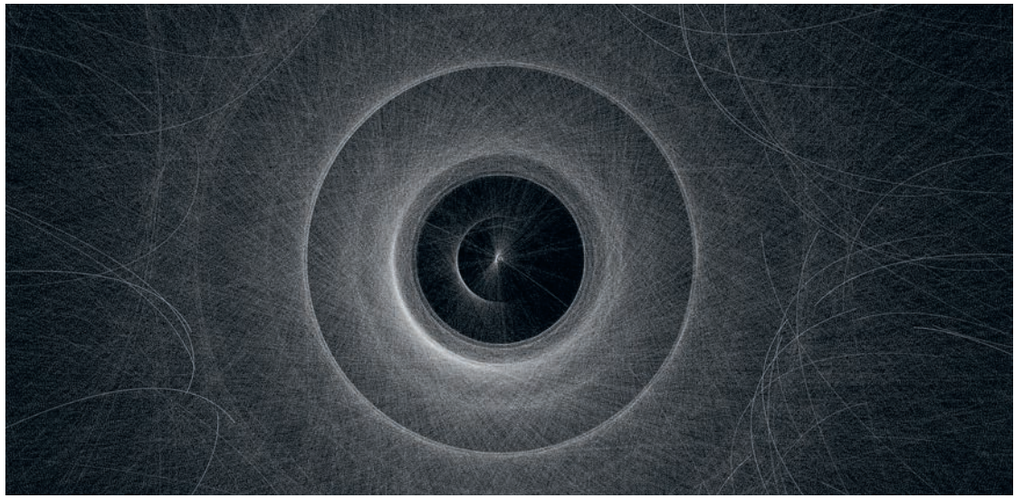


Image: OrbitsTriptychon, 2018. Courtesy of Quadrature.

13 *The Dynamic Universe* 2022

Interactive installation in 0.5 Cave, 6DoF interface. Engineers: Florian Cabo, Hadrien Gurnel. Original 0.5 Cave concept and engineering: eM+. Realised with the support of the EPFL Interdisciplinary Seed Fund.

LASTRO, eM+

Image: Courtesy of eM+. Photo: Alain Herzog.

All around the Earth, on the ground and in space, dozens of astronomical observatories collect the light scattered through the Universe. This data is then analysed by astrophysicists to study the sources emitting that light. The Virtual Reality Universe Project (VIRUP) proposes the novel use of this data for sensory immersion for scientific analysis. The raw data from astronomical observation campaigns has been transformed into visualizations of cosmic structures. Their appearance is reproduced in real time using a custom graphics rendering engine specially developed by EPFL's LASTRO and eM+ laboratories.

A zoom function over 27 orders of magnitude — one thousand billion of a billion billion times — allows us to plunge into the Universe on different scales and in three dimensions. This vertiginous dive into immensity connects perception with knowledge, breaking down the artificial gap between scientific abstraction and visual experience. In *The Dynamic Universe* space becomes a territory for boundless exploration, far beyond the map of the vault of heaven usually observed from the Earth.

Image: Courtesy of eM+. Photos: Hadrien Gurnel.

14 / 15 *The Silent Pulsar of the Universe* and *The Lost Astronaut*

Ben Proudfoot

is a Canadian filmmaker from Nova Scotia.

While astrophysicists trace the past of the Universe, astronauts envisage the future of humanity in space. Until recently, these professions were unofficially reserved for a minority from which women and people of colour were excluded. The integration of a wider diversity of people into these domains required exceptional resilience of an unrelenting few motivated by their unlimited fascination with space. Presented in *Cosmos Archaeology*, two films re-establish the contribution of two pioneers who were unjustly dismissed by the scientific institutions of their time and forgotten in the history of space exploration.

14 *The Silent Pulsar of the Universe* 2020

Documentary film, sound. 16:09 minutes. Director Ben Proudfoot, featuring Jocelyn Bell Burnell. Produced by Breakwater Studios.




Images: Stills from *The Silent Pulsar of the Universe*, courtesy of Breakwater Studios.

Motivated by her passion for physics, every single day of her entire PhD, Jocelyn Bell single-handedly operated a Cambridge University radiotelescope and analysed the unpredictable signals it detected. Her scientific knowledge and tenacity led to the discovery of the first pulsars, remnants of stars that behave like cosmic clocks that are now used to study the laws of gravitation. Although the Nobel committee chose to ignore Bell by awarding her thesis director the prize for her work, subsequent controversy gave rise to a new scientific prize that was awarded to Bell 50 years later in recognition of her scientific discoveries.

15 *The Lost Astronaut* 2020

Documentary film, sound. 12:59 minutes. Director Ben Proudfoot, featuring Edward Dwight Jr. Produced by Breakwater Studios.




Images: Stills from *The Lost Astronaut*, courtesy of Breakwater Studios.

As a child, Edward Dwight was fascinated with the sky he saw from his family's farm in Kansas City. He became a pilot and was the first African American selected to join NASA's astronaut training programme. Despite his unwavering commitment and achievements, the NASA administration did not allow him to pursue any space missions. Undaunted, Dwight became an artist, advancing African American representation through his artwork in lieu of his space visits.

16

Sounds of Space

2022

Sound installation, 8-speaker array, circular sofa. 30 minutes, looped. Sound samples from ESA and NASA. Produced by EPFL Pavilions.

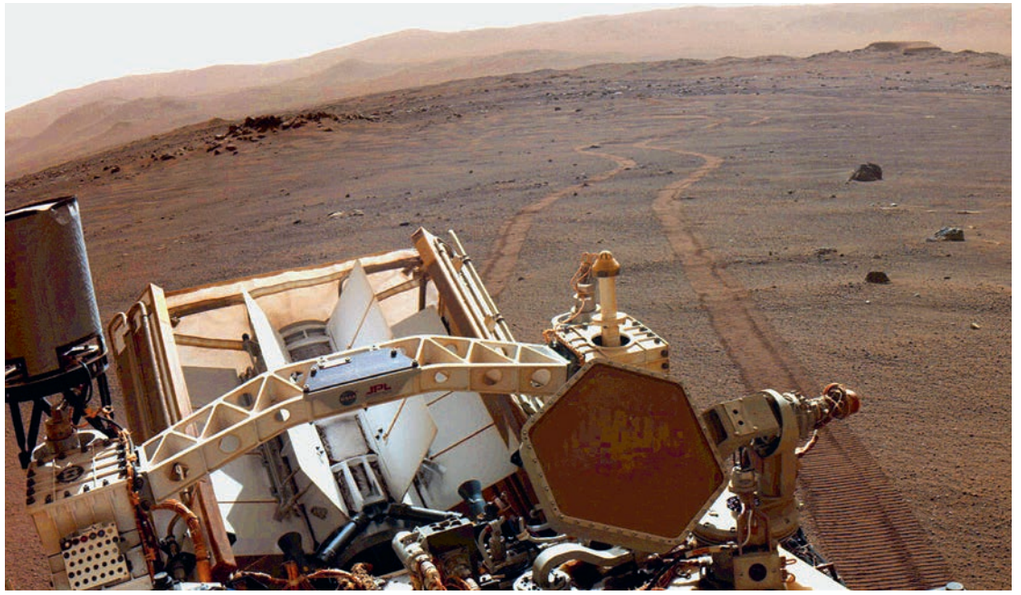
Simone Aubert

is a Swiss-based multidisciplinary artist.

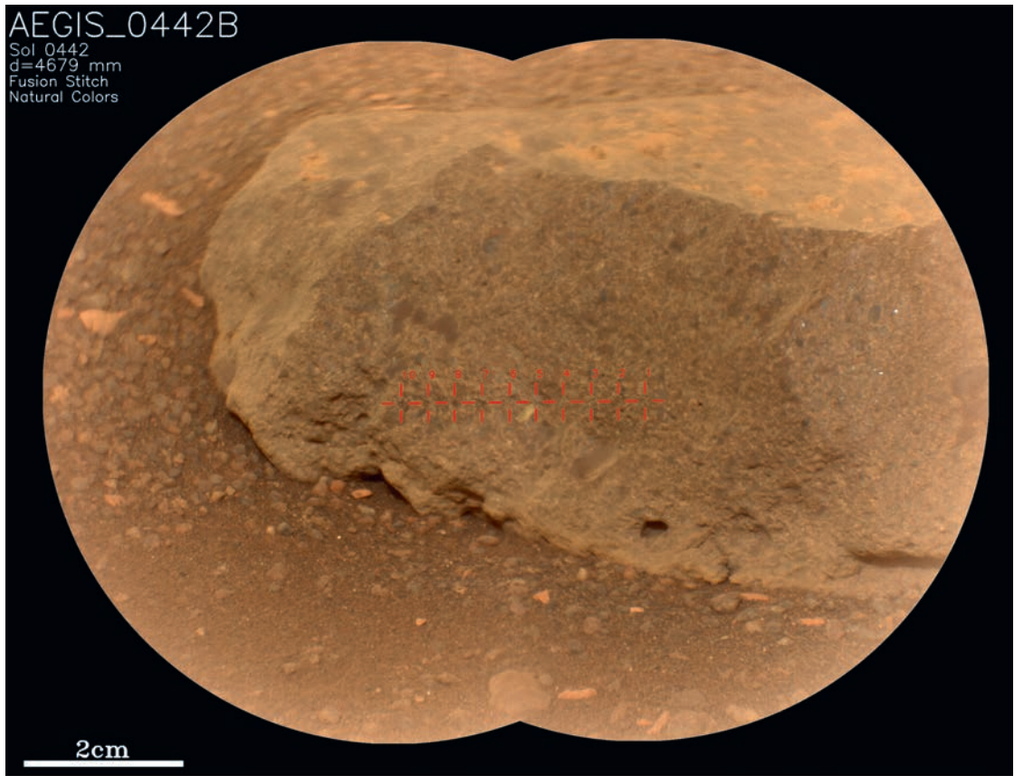
Most people imagine that the observation of the Universe is undertaken by visual means. New technologies and approaches are however expanding the sensory range of our encounters with space, most notably with sound. Today, space probes that cross the solar system send us radio waves emitted by the magnetic fields of gaseous planets. These signals are then transcribed into sounds. For artist Simone Aubert, these sound bites are at odds with the vacuum of space, which is silent. We need the unique atmospheric conditions of the planets for our voices to resonate beyond Earth.

At the outset of her composition work, Simone Aubert noticed that much of the data derived from space and converted to sound was noisy and not very melodious. Instead, she decided to work with live sounds recorded on or around planets. For *Sounds of Space*, Aubert collected recordings from European Space Agency (ESA) and NASA datasets of Saturn, Jupiter, and Earth from its stratosphere.

The only 'authentic' sounds she could find were recorded on Mars by NASA's Perseverance rover, including the noise of Martian wind, the vehicle's wheels rolling over the surface, and the sound of Ingenuity, the first Martian helicopter. With this raw material, the artist made an original score: an 'octophonic' sound creation of space sounds composed around a single voice, in a physical manifestation of our connection to the Solar System and the Universe.



Images: CC-BY-0.3. Courtesy of NASA.



Images: CC-BY-0.3. Courtesy of NASA.

Image: Courtesy of eM+.

17 *Venusian Rover* 2022

Three-screen video installation on circular screens, looped.

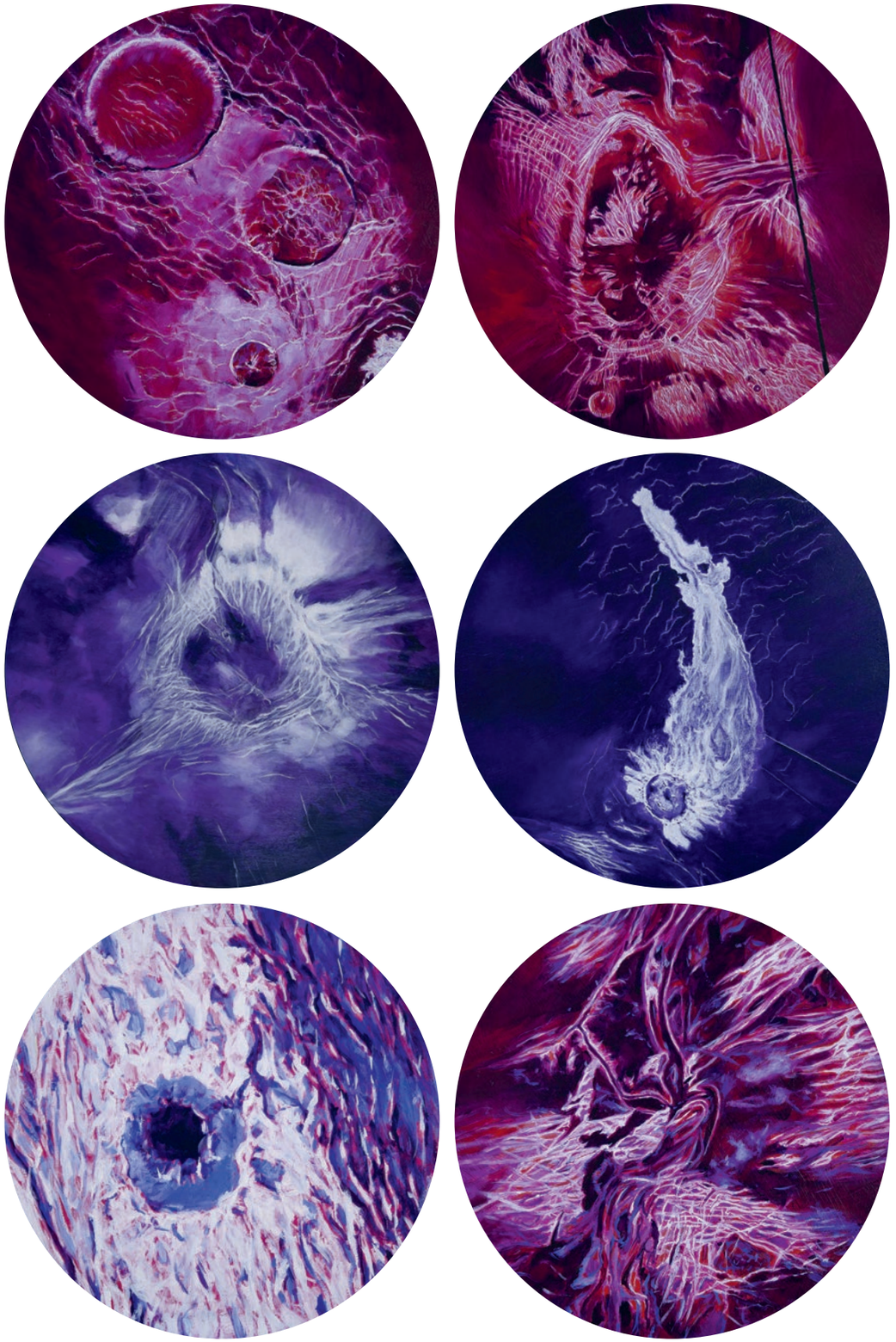
Lily Hibberd

is an interdisciplinary artist based in France.

Images: Courtesy of Lily Hibberd.

Venusian Rover probes the surface of Venus through a series of 50 paintings. These painted images are based on scientific imaging of the surface of Venus made by Synthetic Aperture Radar, mostly from the NASA Mariner 10 mission of 1974. Known as our sister planet, Venus also possesses more than 2000 places named after females and mythological women of Earth.

Starting on the edge of Didilia Corona, the site of the first Russian landing of the Venera 4 probe on 18 October 1967, we encounter 50 locations and their female counterparts. Valleys, mountains, volcanic peaks, craters, and deep crevasses, all usually shrouded under the planet's impenetrable atmosphere are finally revealed. In this intimate encounter with Venus, Earth's sister planet reflects our own civilization back to us. As such, we discover craters named for the Ancient Greek astronomer Aglaonice, Ba'het Corona dedicated to the Egyptian personification of abundance, and Wheatley for Phillis Wheatley the first black writer to be recognized in the United States of America. Lise Meitner, the Nobel prize winning Austrian-Swedish physicist has her own crater, while Carmenta Farra embodies the Roman goddess of springs, and Baker Crater is named in memory of the French American pilot and activist Josephine Baker.



18 *Aphrodite Terra, Venera 00307-00310*

2021

Installation of four ceramic landscapes, coloured engobe with transparent glaze. 60 × 60 cm per tile. Project curator: Claudia Schnugg. Produced with the generous support of the European Ceramic Work Center, Mondriaan Fonds, Stichting Stokroos, Stichting Van Achterbergh-Domhof.

Anna Hoetjes

is a visual artist and filmmaker based in the Netherlands.

The four ceramic 3D landscapes in this series represent mountain ranges on Venus in the poetically named region of Aphrodite Terra. These landscapes are based on radar images capable of piercing the thick atmosphere of the planet, to reveal details that cannot be observed by the human eye. Disconnected from the planet on which they are observed, these coloured reliefs seem to float freely in space. As isolated tiles and surfaces without a base, they underline the fact that our vision of outer space is a complex patchwork made of many different fragments and perspectives.

The extraterrestrial terrains of *Aphrodite Terra* are made of earthly clay, connecting the soil of both planets. The amalgamation of colours in the series refers to temperature scales made of Venus's surfaces that the artist sourced from NASA's database. The scientific visualization of wavelengths from space is a technique used to translate imperceptible and abstract data into information our retina can perceive. Paradoxically, the use of colour in space science often entails a relatively subjective translation of data. The colours of *Aphrodite Terra* are likewise fantastical imaginings of Venus's surface, reminding us of our limited perception of the natural world around us.

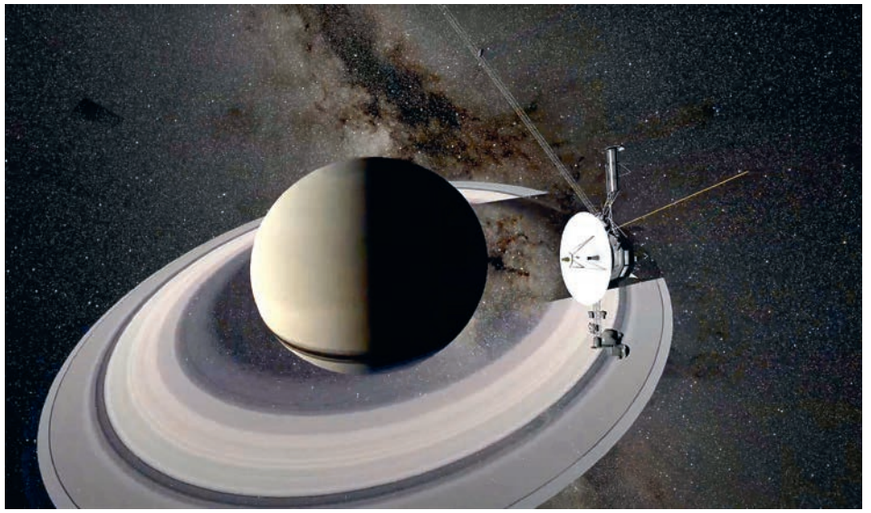
The glazed tones of *Aphrodite Terra* also reference a specific light analysis technique known as spectroscopy. From the mid-19th century, this technique transformed astronomy as it revealed the chemical composition of astronomical objects from their colour spectrum. Spectroscopic technology is still used today, as in the SDSS project of *Star Mapping Sculpture* (see #1). Even though they are not renowned as such, 19th-century Harvard College Observatory astronomers Annie Jump Cannon, Williamina Fleming and Henrietta Swan Leavitt pioneered stellar spectroscopy. *Aphrodite Terra* thus reminds us of the forgotten contribution of female labour to contemporary astrophysics.

Images: Courtesy of Anna Hoetjes. Photo: Annelies Verhelst.

19 *Archaeology of Light* 2022

3D film, sound. 21:41 minutes. Realised with the support of the EPFL Interdisciplinary Seed Fund.

LASTRO, eM+

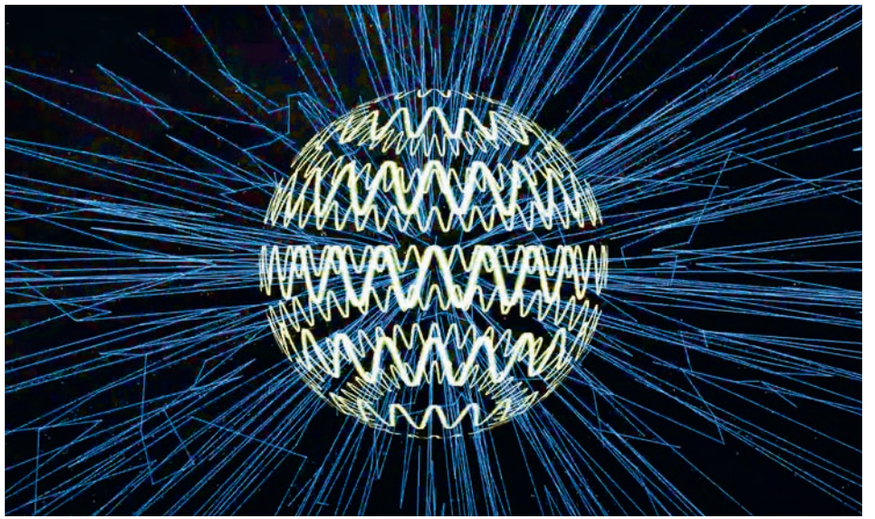


For an astrophysicist, light is equivalent to a fossil for an archaeologist: a tool to study the past and define the laws of evolution and the Universe. Earth continually receives photons, particles of light that travel through space at a constant speed. These photons originate from different cosmic structures located between our galactic neighbourhood and the edge of the observable Universe.

Conceived at EPFL, drawing on shared astrophysics datasets, the film *Archaeology of Light* departs from the Earth and retraces the journey of these light rays to visualize the composition of the cosmos. This epic navigation also allows us to discover different stars and sources of light in the Universe. It also uncovers the technological advances behind these discoveries and the early stages of robotic exploration of space.

With a duration of 21 minutes, this 3D film commences in Earth's vicinity, populated by natural objects, such as planets and asteroids and anthropological artefacts, including satellites, space debris, and space probes. Beyond our solar system and the solar wind, the Voyager and Pioneer probes mark the most distant traces of human activity. This virtual flight crosses the first radio waves ever broadcast that propagated beyond Alpha Centauri, the second closest star to Earth. These waves form the boundary with the bulk of the Universe. In this place, inaccessible to our species except by the powers of imagination, galaxies cluster in filaments of cosmic voids, forming the gigantic structures of the galaxies where stars live and die.

Archaeology of Light also reveals how each portion of space is bathed in extremely cold radiation: microwave emissions corresponding to the most distant light ever emitted. Relics of the first instants of the Universe, these emissions mark the limits of the archaeology of light.



Images: Courtesy of eM+ and LASTRO.

EPFL Pavilions

Director, curator:	Sarah Kenderdine
Manager:	Anne-Gaëlle Lardeau
Lead exhibition producer:	Marie Carrard
Lead technician:	Adam Bagnowski
Exhibition technician:	Ryan Jones
Communication:	Loïc Sutter
Researcher:	Lily Hibberd
Events coordinator:	Le Thy Nguyen
Administrative assistance:	Sophie Bauer, Stéphanie Romon

Laboratory of Astrophysics (LASTRO)

Director:	Jean-Paul Kneib
Senior scientist:	Yves Revaz
Scientist:	Austin Peel
Scientist:	Georgios Vernardos
Scientist:	Florian Cabot
Scientist:	Emma Tolley
ETS/HES engineer:	Ricardo Araújo
Doctoral assistant:	Aymeric Galan
Administrative assistance:	Estrella Briant, Joanna Jermini

Laboratory for Experimental Museology (eM+)

Director:	Sarah Kenderdine
Lead software engineer:	Sylvain Cardin
Scientist:	Samy Mannane
Scientist:	Loïc Serafin
Scientific assistant:	Lily Hibberd
Doctoral assistant:	Giacomo Alliata
Administrative assistant:	Stéphanie Romon
Technician:	Taras Debera

Supported by

EPFL

Swiss National Science Foundation

Laboratory for Experimental Museology (eM+)

Laboratory of Astrophysics (LASTRO)

EPFL Interdisciplinary Seed Fund: Immersive Environment for Cosmological Big Data

Cosmos Archaeology

EPFL Pavilions Lausanne

Explorations in Time and Space

16.9.2022 – 5.2.2023

Production:
EPFL Pavilions

Organisation:
Laboratory of Astrophysics (LASTRO), Laboratory for Experimental Museology (eM+)

Exhibition Credits

Curators:
Professor Sarah Kenderdine, Professor Jean-Paul Kneib

Chief scientific advisor: Yves Revaz

Guest curator: Claudia Schnugg

Lead exhibition producer:
Marie Carrard

Assistant producer: Lily Hibberd

Project management: Hadrien Gurnel, Sarah Kenderdine

Writing, research: Leïla Haegel, Lily Hibberd, Hillary Sanctuary

Editing, translation: Marie Carrard, Lily Hibberd, Anne-Gaëlle Lardeau, Loïc Sutter, Emma Tolley

Exhibition scenography: Sarah Kenderdine, Manon Pavlowsky

Graphic design exhibition and guide: Knoth & Renner (Konrad Renner), Lamm & Kirch (Florian Lamm, Jakob Kirch)

Technical coordination:
Adam Bagnowski, Ryan Jones, Sylvain Cardin

Interactive graphic design:
Patrick Donaldson, Sascha Fronczek

Software and creative engineers:

- Laboratory for Experimental Museology: Sarah Kenderdine (conceptual design of installations), Sylvain Cardin (project management, *Dark Cloud of Debris* technical integration), Giacomo Alliata (*Space Heroes*), Hadrien Gurnel (*SKA Simulator; The Dynamic Universe*), Samy Mannane (*Cosmic Collisions; SKA Simulator*), Loïc Serafin (*Cosmic Collisions; SKA Simulator; Space Time Elastic*)
- EPFL Laboratory of Astrophysics: Ricardo Araújo (*Army of Robots*), Florian Cabo (*The Archaeology of Light*; *The Dynamic Universe*; *Virtual Orbital Visit*), Austin Peel (*Space Time Elastic)*, Georgios Vernardos (*Space Time Elastic*)
- EPFL Pavilions: Laurent Novac (*Space Time Elastic*, *Virtual Orbital Visit*), Nikolaus Völzow (*Cosmic Collisions*)

Artists: Simone Aubert, Pascal Bettex, Lily Hibberd, Anna Hoetjes, Theodore Kruczek (KeepTrack.space), Project Adrift (Cath Le Couteur and Nick Ryan), Quadrature (Juliane Götz and Sebastian Neitsch), Florian Voggeneder

Exhibition installation technical assistance: G.T.M. Technique Montage

Exhibition fabricators:
Serruriers noirs, Atelier Guggisberg, Maryse Kalonji

Painting: Renov'immeuble

Condition reports:
Pierre-Antoine Héritier

Guide printing:
Repro EPFL Print Center

Poster printing: Birkhäuser, Repro EPFL Print Center

Gallery and window signage:
Décora Publicité

Special thanks to

- Ronan Boulic, Professor, EPFL Immersive Interaction Research Group
- Mohamed Bouri, EPFL REHAssist
- ClearSpace: Luc Piguet, Claudia Durgnat, Hyeonsook Hong Kaiser, Willem Meter, Lucie Mottet
- Alain Dufaux, EPFL Cultural Heritage and Innovation Centre
- European Southern Observatory (ESO image)
- William Garnier, Square Kilometre Array Observatory
- Theodore Kruczek, KeepTrack.space
- NASA
- Claude Nicollier, EPFL Emeritus Professor
- Candice Norhadian, EPFL Space Center
- Sylvestre Maurice, IRAP, France
- Hillary Sanctuary, EPFL Mediacom
- Square Kilometre Array Observatory (*SKA Simulator*)

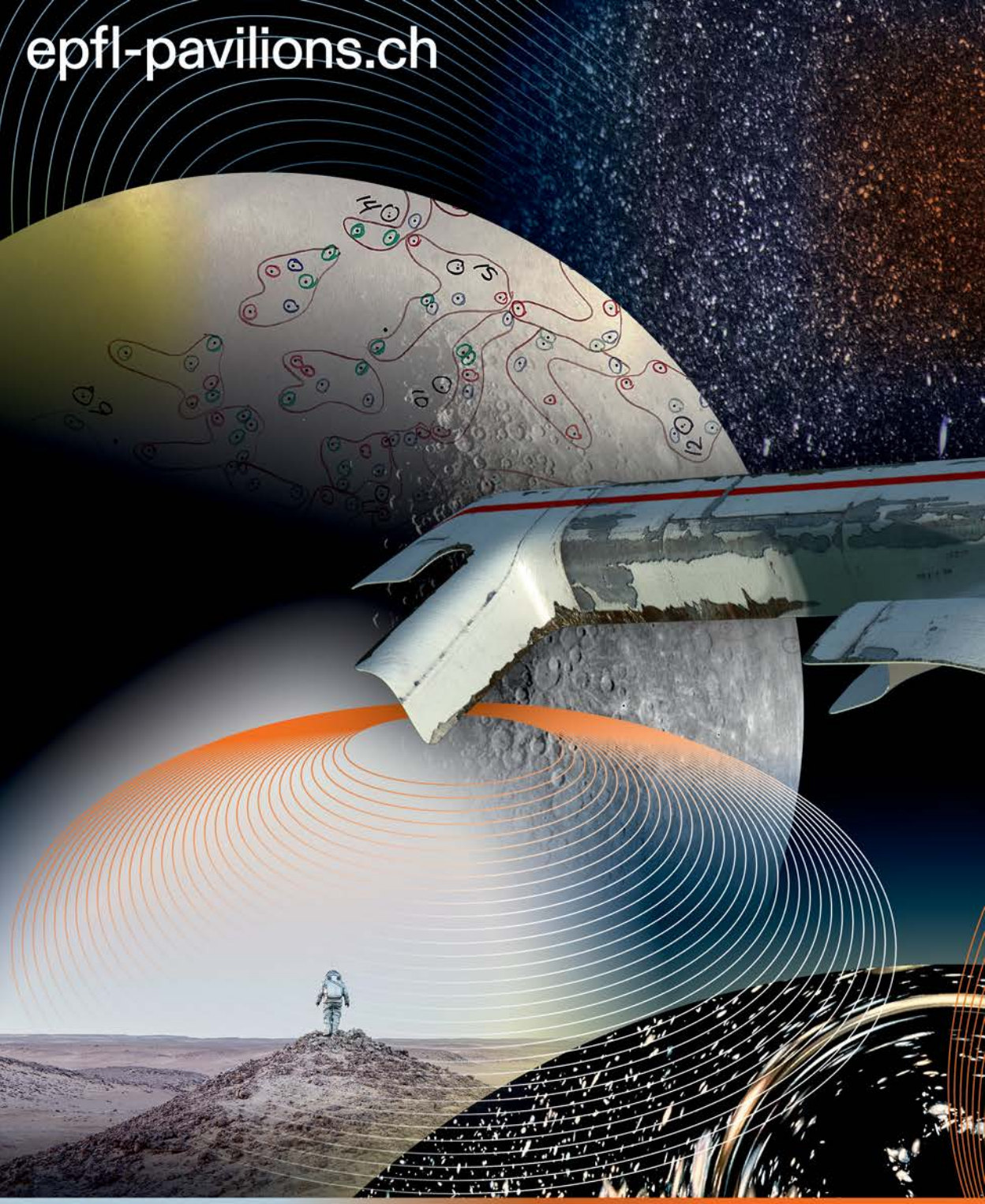
Scientific Partners

- ClearSpace
- EPFL Astrobots
- EPFL Cultural Heritage and Innovation Centre
- European Space Agency
- KeepTrack.space
- Sloan Digital Sky Survey
- Square Kilometre Array Observatory

Exhibition at EPFL Pavilions
École polytechnique fédérale de Lausanne
Place Cosandey
CH-1015 Lausanne
Switzerland

www.epfl-pavilions.ch

epfl-pavilions.ch



EPFL
Pavilions

Free Entry

Place Cosandey
1015 Lausanne
Tuesday—Sunday
11 am — 6 pm