ASTRONOMY & PHYSICS

JPL missions are redrawing the limits of the physically possible, from the quantum to the barely quantifiable. A giant light filter will unmask planets circling other stars, a near-infrared observatory will take snapshots of the kinetic cosmos, and a collaboration with the European Space Agency has started to expose the hidden forces scattering the visible universe.

Left: *Euclid's snapshot of the Horsehead Nebula is among the space telescope's first images. Scientists will use Euclid to create the most extensive three-dimensional map of the universe to date.*

Right: Scientists examine major components of the SPHEREx telescope in a lab at Caltech's Cahill Center for Astronomy and Astrophysics.

Three of a Kind

A new extraordinary space-based observatory, SPHEREx, aims to map the entire sky in unprecedented detail and color.

Over two years, SPHEREx will map the sky four times, including over 450 million galaxies and 100 million stars, creating a huge database of celestial objects.

The observatory's three science objectives are to look at three main periods of the lifetime of the universe.

The first goal is to gain a better understanding of where water and other ingredients necessary for life originated by measuring the abundance of water ice in interstellar clouds of gas and dust, places where new stars form and where planets are eventually created.

The second will be to study the cosmic history of galaxies, learning more about when they began to form and how they've changed over time.

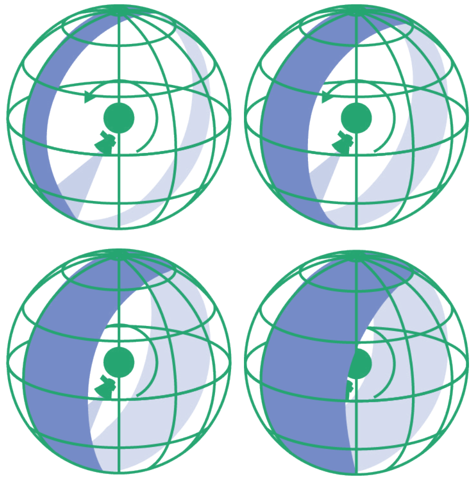
Thirdly, scientists will use SPHEREx's maps to find out more about how the rapid expansion of the universe occurred a fraction of a second after the Big Bang.

Scientists at JPL have been assembling the telescope, joining its various components together into its final form. Some, however, may think this telescope looks a bit odd. Its cone shape looks more like something you may find around a dog's head after going to the vet.

SPHEREx's main telescope uses three mirrors and six detectors shielded by three nested cones. Without this shielding, SPHEREx would be blinded from the light and heat of the Sun and Earth.

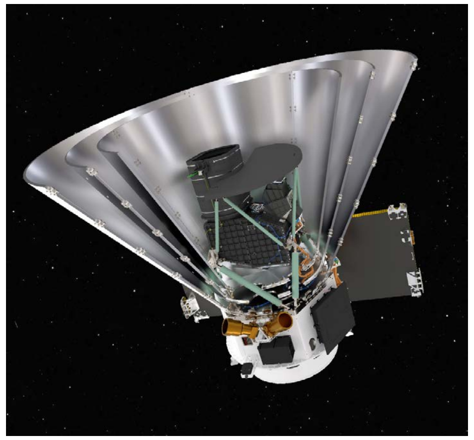
SPHEREx is scheduled to launch aboard a SpaceX rocket from Vandenberg Space Force Base in California by April 2025.

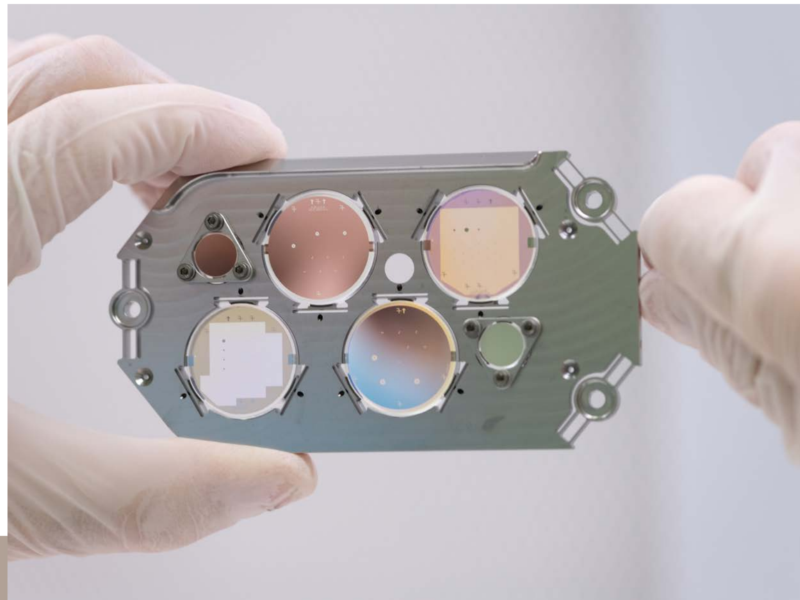
Right: SPHEREx captures multiple successive exposures in a circular sequence, producing a complete spectral sampling of the entire sky twice a year.



Above: A scientist assembles SPHEREx's Medium Wave InfraRed focal plane array.

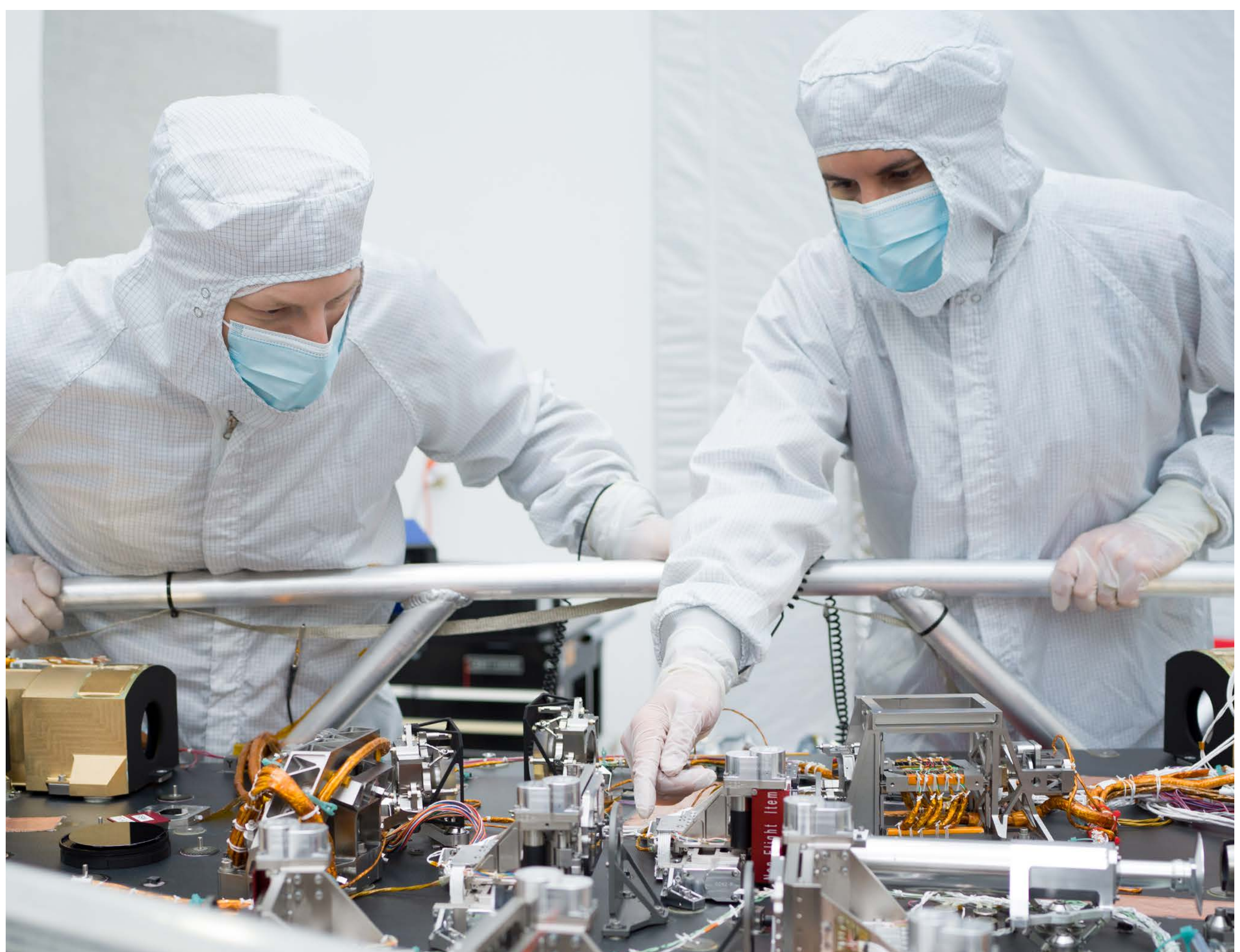
Right: An artist's concept of a cross-section of the SPHEREx telescope in space





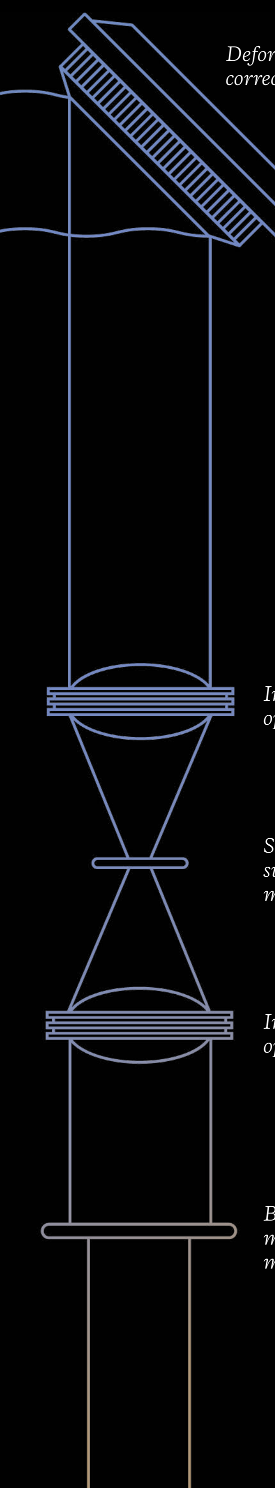
Left: *The focal plane mask for the Coronagraph Instrument on NASA's Nancy Grace Roman Space Telescope suppresses starlight, making it possible to see planets orbiting a star.*

Below: *Members of the Roman Coronagraph Instrument team collaborate on assembling the components of the instrument's optical bench.*



A Piano-sized Instrument to Orchestrate Discovery

Scientists have discovered more than 5,000 planets outside our solar system. However, these exoplanets are difficult to directly image for signs of life because light from their host star hides them with its glare.



To block that light, a new instrument is in development: the coronagraph. Roughly the size and shape of a baby grand piano, its deformable mirrors are essential to seeing planets just one ten-billionth the brightness of their Sun.

The Coronagraph Instrument team has already designed the cutting-edge instrument and built the components. With all the pieces assembled, the team kicked off testing the instrument in late 2023 at JPL to make sure all of its components operate as intended. Over the next year, ongoing testing will resemble a well-choreographed ballet that involves heavy duty cranes, lasers, and vacuum chambers the size of buses.

Once complete, the Coronagraph will be shipped to the Goddard Space Flight Center and incorporated into NASA's Roman Space Telescope, which will launch by May 2027, to test this next-generation technology. Following the recommendations of the 2020 Astrophysics Decadal Survey, NASA is laying the groundwork to develop this technology further to enable the Habitable Worlds Observatory mission concept, a telescope that would be as large as Webb, operating in the same wavelengths as Hubble — but designed to find Earth-like exoplanets around other stars and search them for signs of life.

Finding and studying Earth-like planets orbiting nearby stars is critical to understanding whether we are playing life solo or if there are potential duets or more across the universe.

Right: *The journey of light through a coronagraph*

The Dazzling Edge of Darkness

Above: *JPL detectors shown integrated on Euclid's Near Infrared Spectrometer and Photometer instrument*

Photo credit: Euclid Consortium/CPPM/LAM

The European Space Agency's latest space telescope, Euclid, released its first five science images in November 2023.

Euclid is the first space telescope dedicated to dark matter and dark energy studies.

Dark matter, an invisible substance five times more common in the cosmos than "regular" matter, can only be observed by its gravitational effect on objects around it, like stars, galaxies, and planets.

Dark energy is the mysterious driver behind our universe's unexplained accelerating expansion. While gravity should pull everything in the universe together, everything instead is moving apart faster and faster.

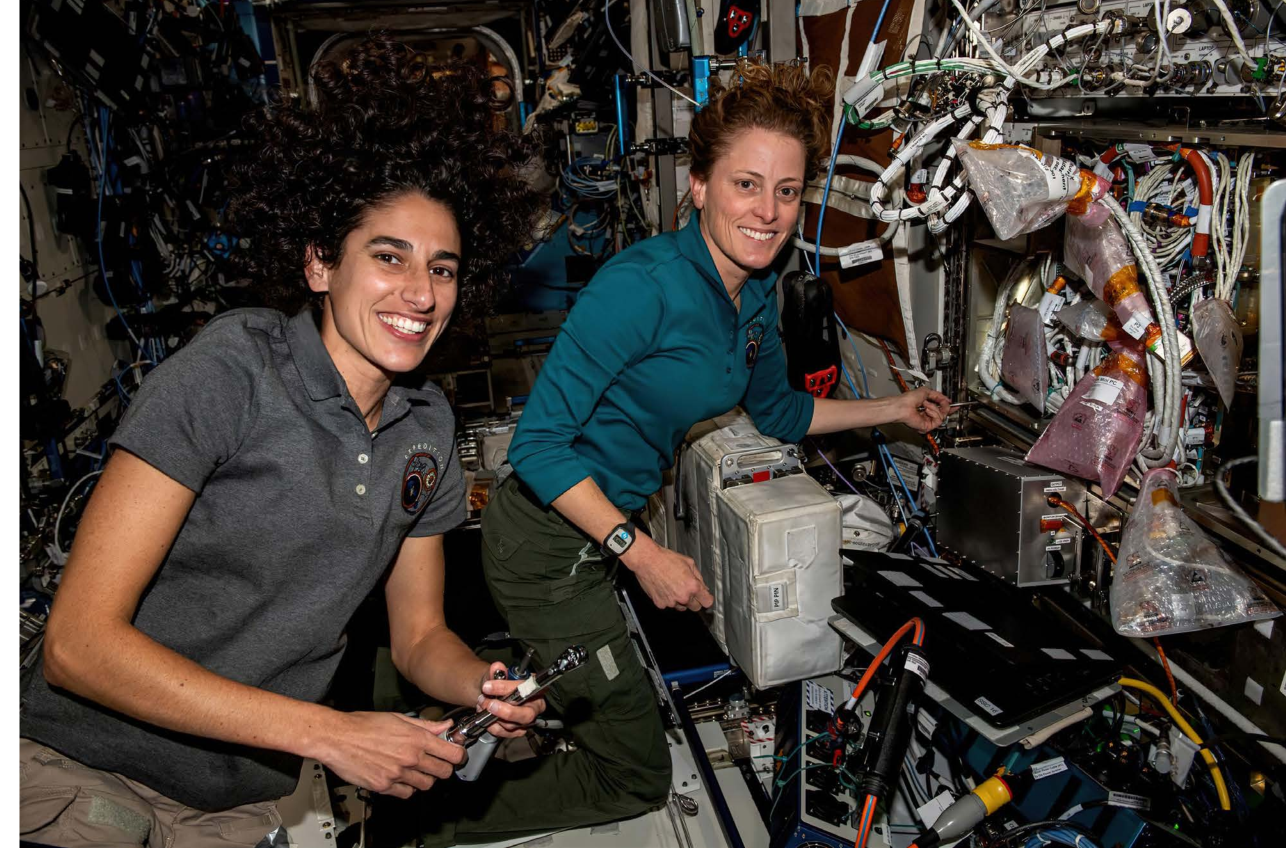
The new images include views of a large cluster of thousands of distant galaxies, close-ups of two nearby galaxies, a gravitationally bound group of stars called a globular cluster, and a nebula (a cloud of gas and dust in space where stars form), all depicted in vibrant colors. These targets were chosen to demonstrate the full potential of Euclid's two instruments.

JPL supplied detectors and other critical hardware for Euclid's planned six-year mission to produce the most extensive three-dimensional map of the universe yet, covering nearly one third of the sky and containing billions of galaxies up to 10 billion light-years away from Earth.

In addition, NASA has established a U.S.-based Euclid science data center and is also providing science teams to the mission.

Euclid was scheduled to start routine observations in early 2024, collecting vast amounts of dazzling data on dark matter and dark energy.

Right: *Euclid's view of globular cluster NGC 6397 — one of the telescope's first images*



Pulling Apart Gravity's Pull

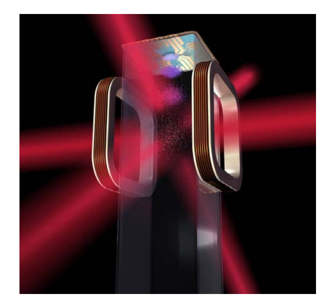
The physical world around us depends on atoms and molecules staying bound together, according to an established set of rules.

But a mystery in modern physics is why the laws of gravity don't seem to match up with the laws of quantum physics, and physicists have been unable to unite them into a single description of the universe.

In August 2023, NASA sent a major update to its Cold Atom Laboratory on the International Space Station. About the size of a small refrigerator, the lab enables dozens of scientists on Earth to do experiments in quantum science, the study of the fundamental behaviors of atoms and molecules. The upgrade will produce two to three times more atoms: That's like upgrading a telescope with higher resolution.

With more atoms, scientists will have new ways of testing theoretical concepts such as the equivalence principle, part of Einstein's general theory of relativity, the backbone of modern gravitational physics. The famous principle holds that gravity and an equivalent constant acceleration are indistinguishable in their effect on objects. An astronaut in a windowless room on Earth or in a spaceship accelerating at a force of 1g would perceive no difference.

This new capability marks the start of an era where it is possible to study not only the quantum properties of atoms, but also quantum chemistry, which focuses on how isotopes of different atomic elements interact and combine with each other in a quantum state. That knowledge will be essential for harnessing the one-of-a-kind facility to develop new space-based quantum technologies.



Top: *NASA astronauts (from left) Jasmin Moghbeli and Loral O'Hara work on the Cold Atom Lab aboard the International Space Station.*

Bottom: *An artist's concept of a magneto-optical trap and atom chip used by Cold Atom Lab*