The space telescope surveying the entire universe to understand dark matter and dark energy

This weekend saw the launch of the European Space Agency (ESA)’s Euclid mission: a space telescope which aims to uncover the mysteries of dark matter and dark energy. The 2.2 ton spacecraft with its 1.2 meter telescope was carried into space by a SpaceX Falcon 9 rocket and is now on its way to its orbit around the sun.

The mission had originally been slated to launch using a Russian Soyuz rocket from Europe’s spaceport in French Guiana, but following Russia’s invasion of Ukraine cooperation between ESA and Russia was halted. So instead, the telescope launched from Cape Canaveral Space Force Station in Florida, lifting off at 12:11AM ET on Saturday July 1st.

The telescope is headed for an orbit called L2, the second Lagrange point, which is the same orbit used by the James Webb Space Telescope and other space telescopes. This orbit offers high stability which is particularly important for a mission like Euclid which aims to collect extremely detailed observations of the universe.

Euclid should arrive at L2 within four weeks, then conduct two months of preparations before beginning science observations around the beginning of October.

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Euclid will perform both wide and deep surveys of the universe, stitching together images to create a map of the universe to help learn about two mysterious concepts: dark matter, which makes up around 27 percent of everything which exists, and dark energy, which accounts for around 68 percent of the universe. Every atom, molecule, and piece of matter that we can observe makes up the tiny remaining 5 percent known as ordinary or baryonic matter.

The telescope is headed for the same orbit used by the James Webb Space Telescope

We know that dark matter and dark energy must exist because of the movements of galaxies and the way that the universe expands. However, they are extremely difficult to study because dark matter does not interact with light and dark energy is an unknown form of energy. So to find evidence of them, we need to look on a very large scale.

“If you want to do cosmology and observe the cosmos as a whole, you need to take a big survey,” explained Giuseppe Racca, Euclid Project Manager at ESA in a press briefing. “And Euclid is specially designed with a very wide angle telescope to cover most of the universe that can be observed in a very short time.”

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The Euclid telescope will survey 36 percent of the sky over its six year mission, and to observe an area that large the telescope has a very wide field of view. This refers to the amount of the sky which can be observed through the telescope, and in Euclid’s case the field of view is 2.5 times the size of the moon.

Compare that to, say, the Hubble Space Telescope, which has a field of view that is just 1/12th the size of the moon. Hubble can image objects like galaxies or nebulae in great detail, but it would take Hubble around 1,000 years to survey a comparable area of the sky to Euclid.

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And if you're wondering why Euclid will only be surveying just over a third of the sky, it's because it is impossible to see distant galaxies in other areas of the sky, because these distant objects are blocked by closer stars and dust within our own galaxy.

Euclid will have two instruments: the VISible instrument or VIS, which operates in the visible light wavelength, and the Near-Infrared Spectrometer and Photometer or NISP, which operates in the near-infrared. Having both these wavelengths covered allows researchers to see galaxies which are redshifted, meaning that because they are moving away from us the light coming from them is shifted toward the red end of the spectrum.

By combining observations from both instruments, Euclid observations can be used to create a 3D map showing the distribution of the visible matter in the universe.

But dark matter isn't visible – that's why it's so hard to study. It can't be observed directly, but its presence can be inferred by looking at the distribution of the matter we can see.

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“Dark energy and dark matter reveal themselves by the very

subtle changes they make to the appearance of objects in the visible universe," René Laureijs, Euclid Project Scientist, explained.

The two main methods for studying dark energy and dark matter used by Euclid will be weak lensing and galaxy clustering. Using two methods for examining the same thing allows the researchers to check their results against each other, hopefully resulting in more accurate findings.

Gravitational lensing is an effect in which the gravity of very large objects like galaxies or galaxy clusters warps spacetime, acting like a magnifying glass and changing the light coming from distant objects behind the foreground object.

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By seeing how strong this lensing effect is, scientists can calculate the mass of the foreground object – and they can compare this calculated mass to the mass of the visible matter in the foreground galaxy. If there's a large difference between the calculated and observed masses, that suggests the presence of large amounts of dark matter in the foreground.

The other effect, galaxy clustering, refers to how galaxies are distributed in three dimensions across the universe. As the universe expands, galaxies are moving away from us, resulting in redshift. Scientists can compare the actual distance to a galaxy with its redshift using a phenomenon called baryon acoustic oscillations, and this can show how fast the universe is expanding – which is directly related to dark energy.

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In combination, these methods should help cosmologists learn more about dark matter and dark energy than ever before. To gather the data, Euclid will take around 1 million images from 12 billion objects over the course of its mission. That should get us one step closer to being able to both detect and study these elusive phenomena, and to understanding the composition of the universe around us.

“It’s more than a space telescope,” Laureijs said, “it’s really a dark energy detector.”

https://www.theverge.com/2023/7/4/23783648/euclid-space-telescope-esa-dark-matter-dark-energy-explain