



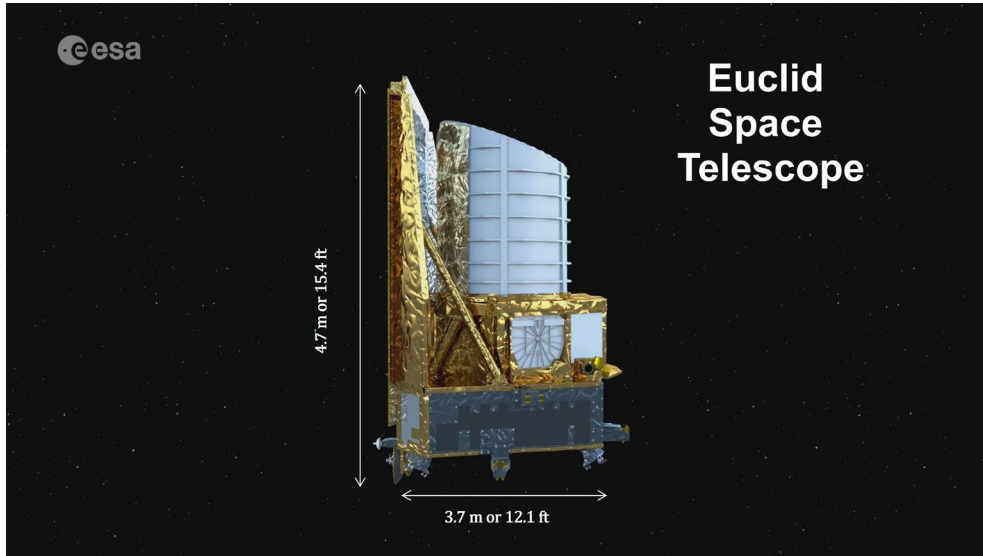
## Euclid Space Telescope

### Introduction

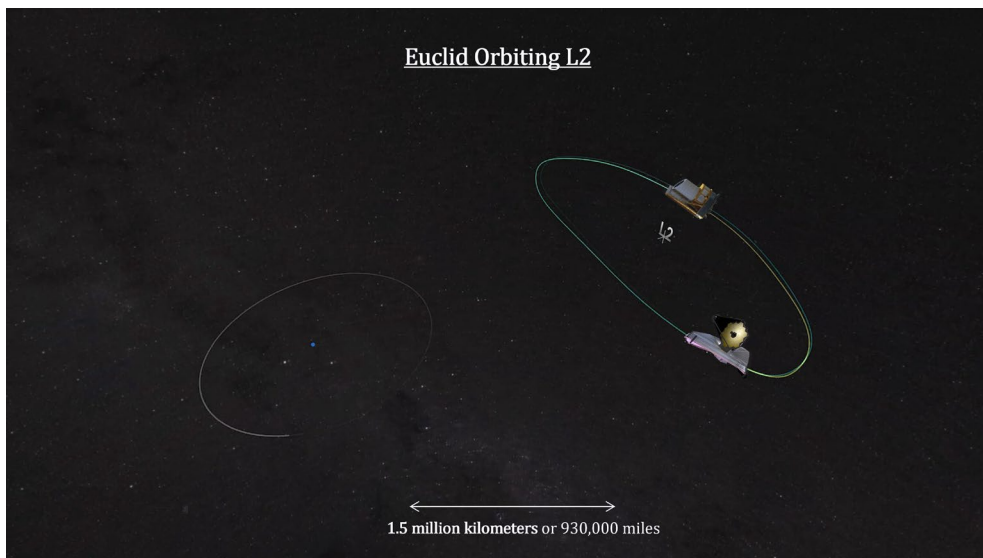
Here's an image of IC 342, 11 million light years away, taken by the new European Space Agency's Euclid space telescope launched in 2023. The spiral galaxy is also known as Caldwell 5. It's nicknamed is 'Hidden Galaxy' because it lies behind the disc of our Milky Way where large amounts of dust, gas and stars obscure our view. Like other space telescopes, Euclid uses a near-infrared instrument to see through the dust. But unlike other space telescopes, it was able to image the galaxy in just one shot. It can then zoom in to distinguish single star clusters and even single stars. This makes it possible to trace the history of star formation and better understand how stars formed and evolved over the lifetime of the galaxy.



Euclid weighs 2 tones including the propellant which will be used up over its 6-year mission. It has a visible-wavelength camera and a near-infrared spectrometer and photometer. These instruments have a  $45 \times 45$  arc-minute field of view. That's more than 100 times larger than the James Webb Space Telescope and 200 times larger than Hubble. This allows Euclid to capture huge swathes of the sky quickly. Webb and Hubble typically image smaller, focused areas with greater detail.



Both Euclid and Webb are currently orbiting the Lagrange point 2. From this vantage point, Euclid will measure the shapes and the emitted light frequencies of over a billion galaxies out to 10 billion light-years, across more than a third of the entire sky. Telescopes like Webb and Hubble will follow up with detailed, high-resolution observations of selected areas. By working together, these telescopes will combine sky-wide surveys with in-depth analysis to better understand cosmic evolution. The space telescope was named in honor of the Greek mathematician Euclid of Alexandria who lived around 300 BC. He founded the subject of geometry. As the density of matter and energy in the Universe is linked to the geometry, the name of the telescope is very appropriate.

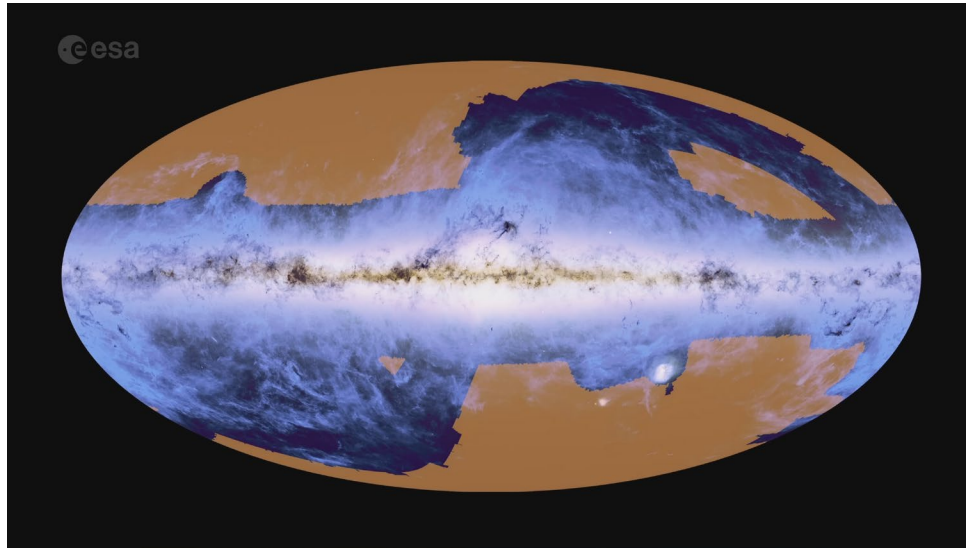


## 02 - Sky Areas Covered

The largest fraction of the mission's observations will be devoted to the Euclid wide survey, covering about 15,000 square degrees – that's more than one third of the entire sky. It will avoid the

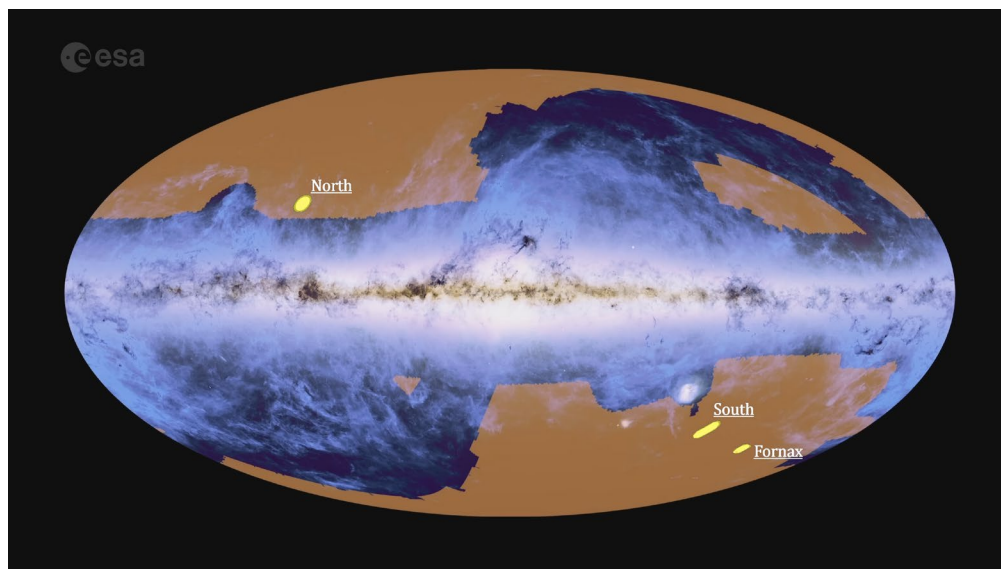


Galactic plane where local stellar density is too high. Euclid will make roughly 30,000 single-visit observations of this area to fully cover the Euclid wide survey. Each visit will target a field slightly apart from the others and with only minimal overlap. In total, the survey will use two thirds of the total mission time.



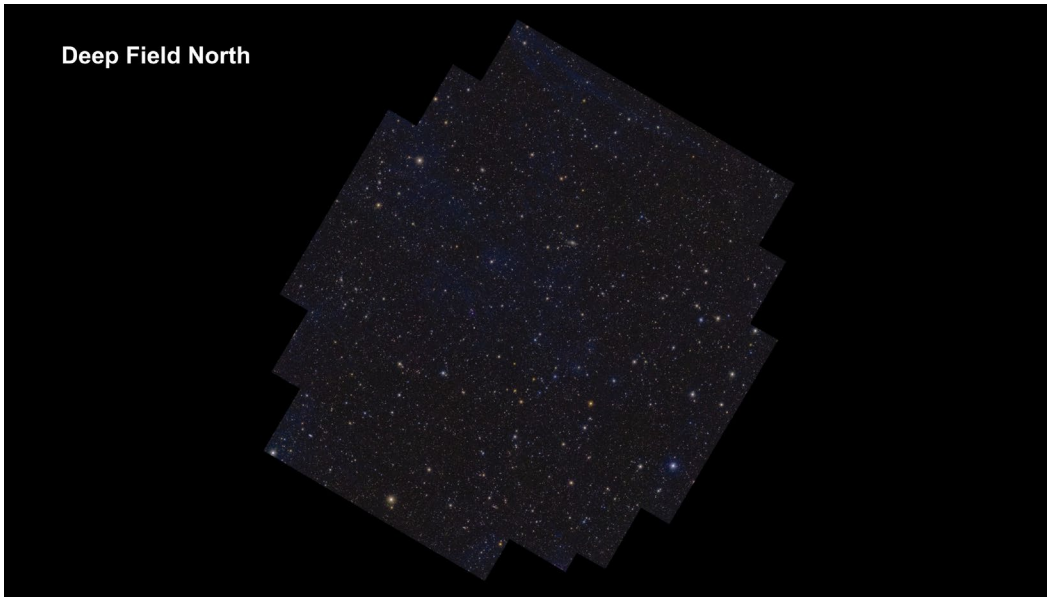
### Deep Fields

Scientists in the Euclid Consortium selected three extremely dark patches of the sky called the Euclid Deep Fields. They will be the subject of the mission's deepest observations, aiming at exploring faint and rare objects in the Universe. These fields are designated “North”, “South” and “Fornax”. They have a cumulative area of 40 square degrees. That’s equivalent to just over 200 times the footprint of the full Moon in the sky. Each deep field will be observed at least 40 times to cover them from different observation angles. The Deep Fields will take up 13% of Euclid's total survey time. It is estimated that Euclid will detect several hundred thousand galaxies per square degree.

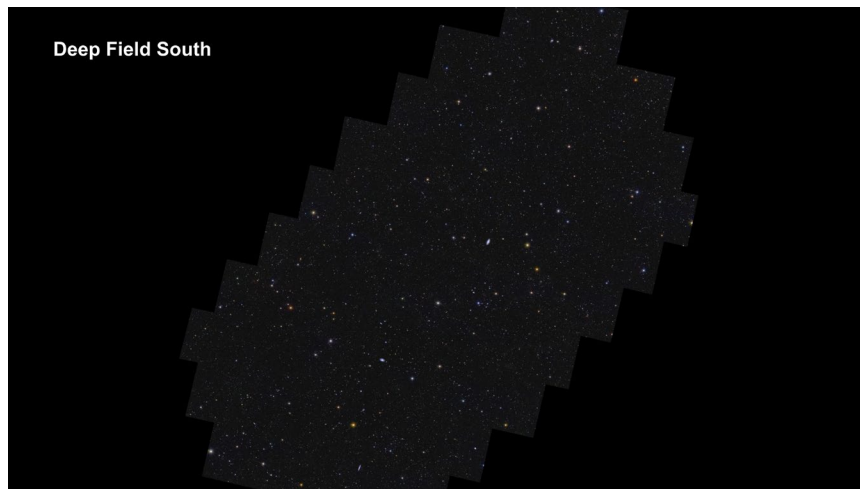




One of the three fields, the Euclid Deep Field North. It has an area of 10 square degrees located very close to the Northern Ecliptic Pole. This is the point in the northern sky directly perpendicular to Earth's orbital plane. The proximity to the ecliptic pole ensures maximum coverage throughout the year. The exact position was chosen to obtain maximum overlap with one of the deep fields surveyed by NASA's infrared Spitzer Space Telescope.



This is Euclid's Deep Field South. It is the largest and covers over 20 square degrees. This region has never been covered before. Therefore, it has a huge potential for new discoveries. After only one observation, the space telescope already spotted more than 11 million galaxies in this field. In the coming years, Euclid will make over 50 additional observations of this field to reach its full depth.





This is Euclid's Deep Field Fornax. It spans 10 square degrees. It encompasses the much smaller Chandra Deep Field South survey conducted a few years ago. In addition, this region of the sky has been extensively surveyed in the past couple of decades with Chandra and the Newton X-ray observatories, as well as the Hubble Space Telescope and major ground-based telescopes. After only one observation, the space telescope has already spotted 4.5 million galaxies in the field. In the coming years, Euclid will make 52 observations of this field to reach its full depth.



### 03 – Euclid's Missions

Euclid's Missions

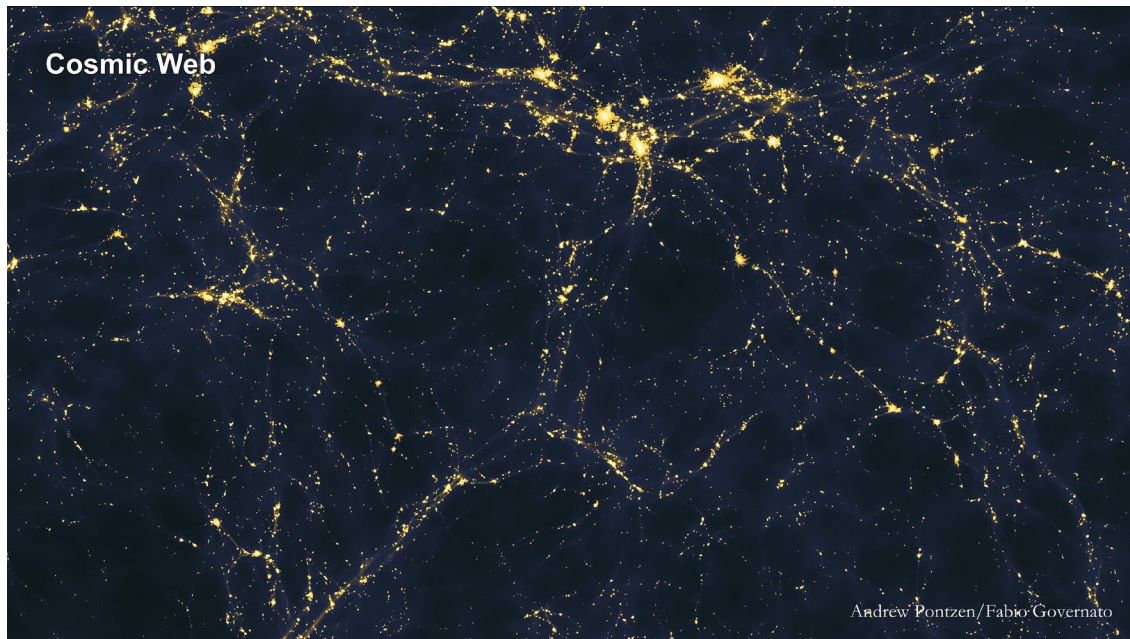
- What is the structure and history of the cosmic web?
- What is the nature of dark matter?
- What is the nature of dark energy?
- Is our understanding of gravity complete?

#### Cosmic web

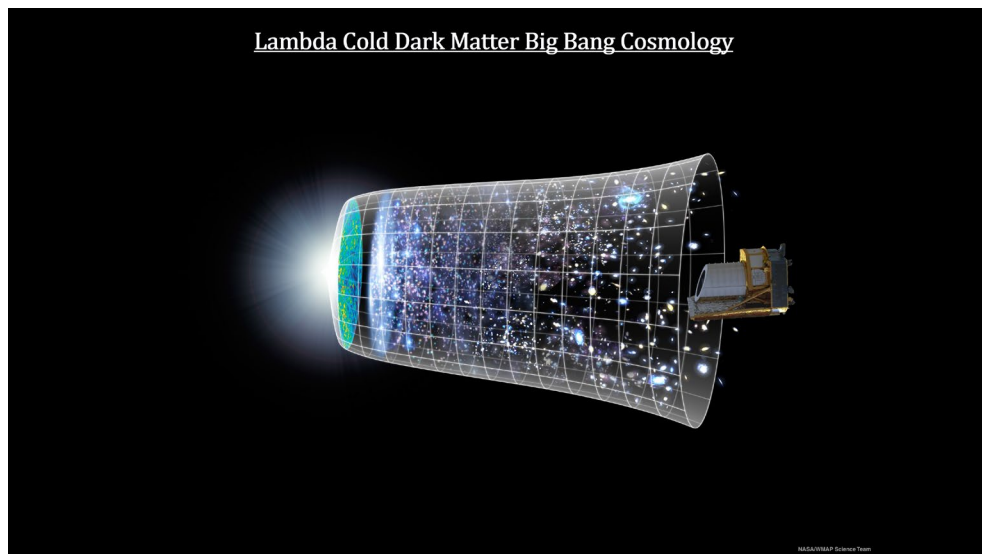
Euclid has a number of very complex missions and they're all primarily cosmological. For example, the Universe is arranged in an enormous network of structures resembling a cosmic web. One of Euclid's key missions is to study the structure and history of this cosmic web. Today, it consists of



huge clusters of galaxies connected to one another by strands of gas and dark matter. Between these are gigantic empty regions called cosmic voids. Investigating the web as it is today is difficult because of its size. For example, voids measure hundreds of millions of light years across. By accurately mapping the shape and distribution of a huge number of galaxies, Euclid will provide a deeper understanding of its current structure.

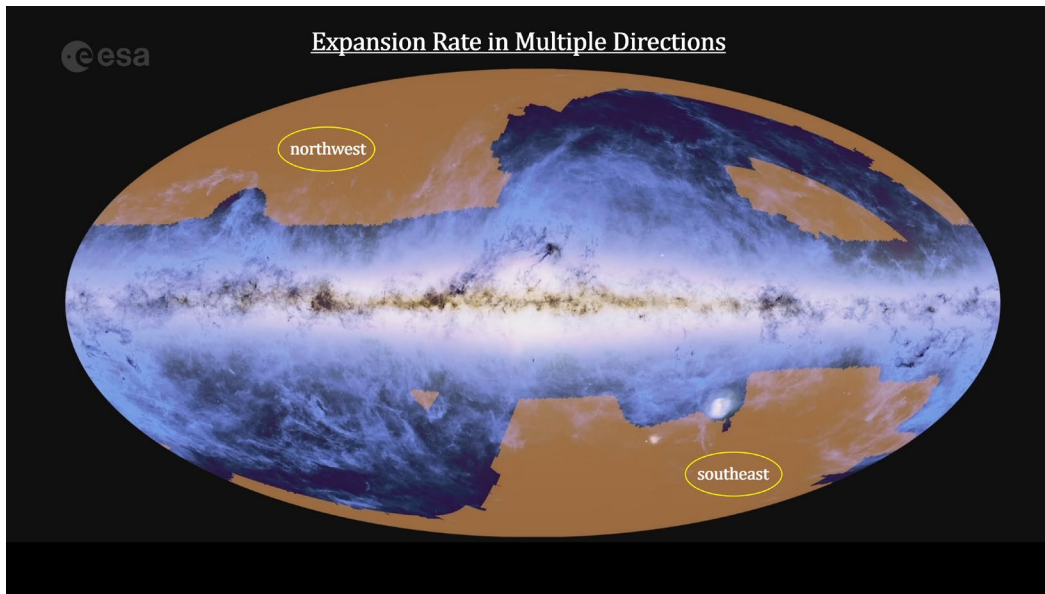


Euclid will also investigate the expansion rate of the universe over time that brought us from the very small beginning 13.8 billion years ago to this current giant web. For a deeper look at our current understanding, watch the 'How Old Is It' chapter on the Big Bang. [add the video to the YouTube page <https://studio.youtube.com/video/6aRz2o55MO0>]





In addition, Euclid will investigate to see if the expansion rate is the same in all directions. For example, the results looking to the northwest would have to be the same as the results when looking to the southeast. If it's not, this would violate one of the fundamental cosmological principles that, on a large-enough scale, the Universe looks the same in all directions (it's isotropic). If it's not isotropic, we'll need a major change for the Lambda Cold Dark Matter Big Bang Theory. We'll cover other missions in detail as Euclid begins to collect and publish its findings over the next 6 years.



### TBD

In another project, Euclid will precisely map the matter distribution (both visible and dark) in a large number of galaxy clusters. This will lead to significantly improved gravitational lensing used to measure the distance to and the shape of more distant galaxies. This project will also map how dark matter is distributed throughout the Universe. This project will also 'test' Einstein's General Theory of Relativity. No test of the theory has ever been made with high precision over the large distances and times that Euclid will cover. This way, Euclid will reveal if general relativity breaks down at the largest scales. If it does, physicists will need to go back to the drawing board. Einstein's General Relativity predicts that the amount of light bending in a galaxy cluster is proportional to the amount of matter present and follows the formula  $\alpha = 4GM/rc^2$ . Where  $\alpha$  = the angle a light beam will be bent by the mass of the cluster.  $G$  is the Newton's gravitational constant,  $M$  is the mass of the cluster including dark matter.  $C$  is the speed of light and  $r$  is the closest distance the light ray passes to the galaxy cluster's center of mass. Euclid will accurately measure the mass and the amount of light bending providing a test for General Relativity. The matter power spectrum is a statistical tool—specifically the Fourier transform of the density correlation function—that measures the clustering intensity of matter at different cosmic scales, ranging from small-scale galaxies to large-scale galaxy clusters. It quantifies how density fluctuations in the universe depend on scale (wavelength). 'clustering intensity' = Galaxy clustering intensity refers to the measure of how strongly galaxies are grouped together in space compared to a random distribution. It is a fundamental statistical tool in cosmology used to map the large-scale structure of the universe, quantifying the tendency of galaxies



to reside in high-density regions rather than being spread uniformly. It is crucial for testing cosmological models, as its shape is determined by the initial conditions set by inflation, the expansion rate, and the composition of the universe (baryons and dark matter). The matter power spectrum provides a detailed map of cosmic structure at a given time and is a primary tool for understanding the universe's evolution.

**END**

#### **04 - M78 – 1,300 ly**

Here's a Euclid infrared camera image of M78, 13 hundred light years away. It features a volume of star formation enveloped in interstellar dust. It exposes hidden regions of star formation for the first time, mapping its complex filaments of gas and dust in unprecedented detail, and uncovering newly formed stars and planets. Euclid's sensitive instruments can detect objects just a few times the mass of Jupiter, and its visible and infrared instruments reveal over 300,000 new objects in this field of view alone. Scientists are using this data to study the number and ratio of stars and sub-stellar objects. This information is key to understanding the dynamics of how star populations form and change over time.



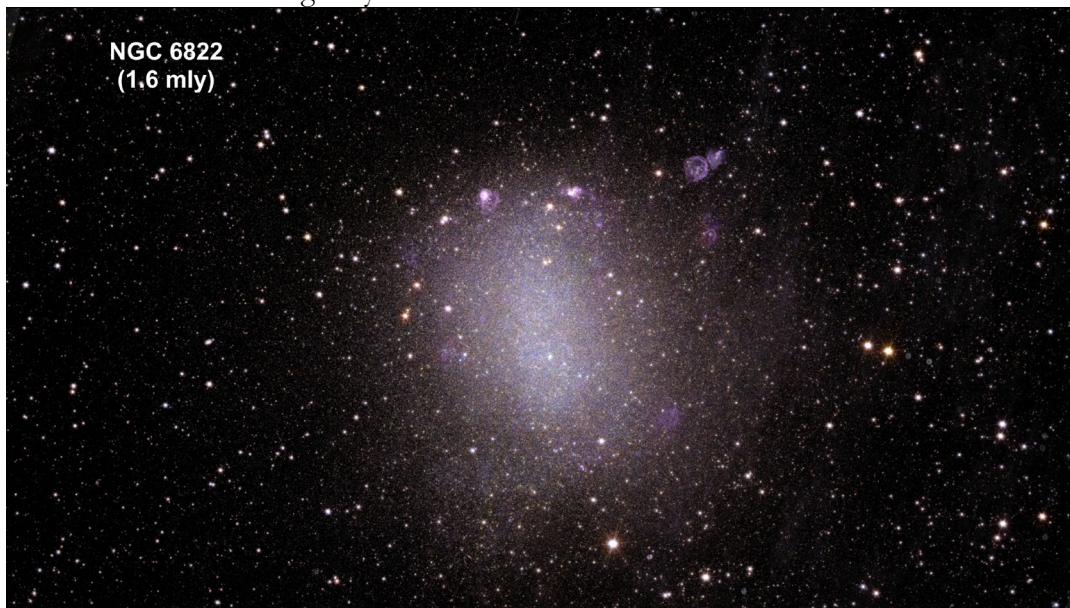
#### **05 - NGC 6397 – 7,800 ly**

NGC 6397 is the second-closest globular cluster to us. It was once outside the Milky Way. The center contains an enormous number of stars, but the brightest drown out the fainter ones. The outer regions contain mostly low-mass, faint stars. It's these faint stars that tell us about previous interactions with the Milky Way. Currently Euclid is the only telescope that can observe the entire globular cluster and at the same time distinguish its faint stellar members in the outer regions from other cosmic sources. With Euclid's observations, the team also wants to determine the age of globular clusters, to investigate the chemical properties of their stellar populations, and to study ultra-cool dwarf stars – the lowest mass members of the cluster.



**06 - Barnard's Galaxy NGC 6822 – 1.6 mly**

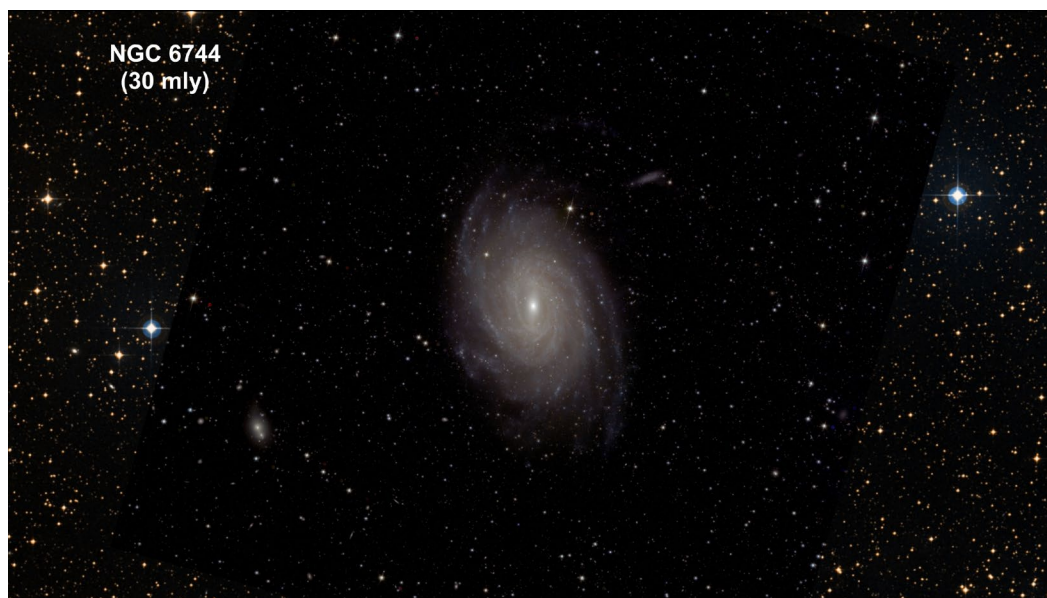
Barnard's Galaxy NGC 6822 is located approximately 1.6 million light-years away. As a member of the Local Group, this barred irregular dwarf galaxy is one of the closest neighbors to the Milky Way. This galaxy has been observed many times, but Euclid is the first to capture the entire galaxy and its surroundings in high resolution. One interesting aspect is that its stars contain low amounts of elements heavier than hydrogen and helium. Called 'metals' they are produced and spread by exploding stars. Therefore they are not common in the early Universe. In addition to studying the star-formation history of this galaxy, scientists have spotted many globular star clusters in this image that reveal clues as to how the galaxy was assembled.





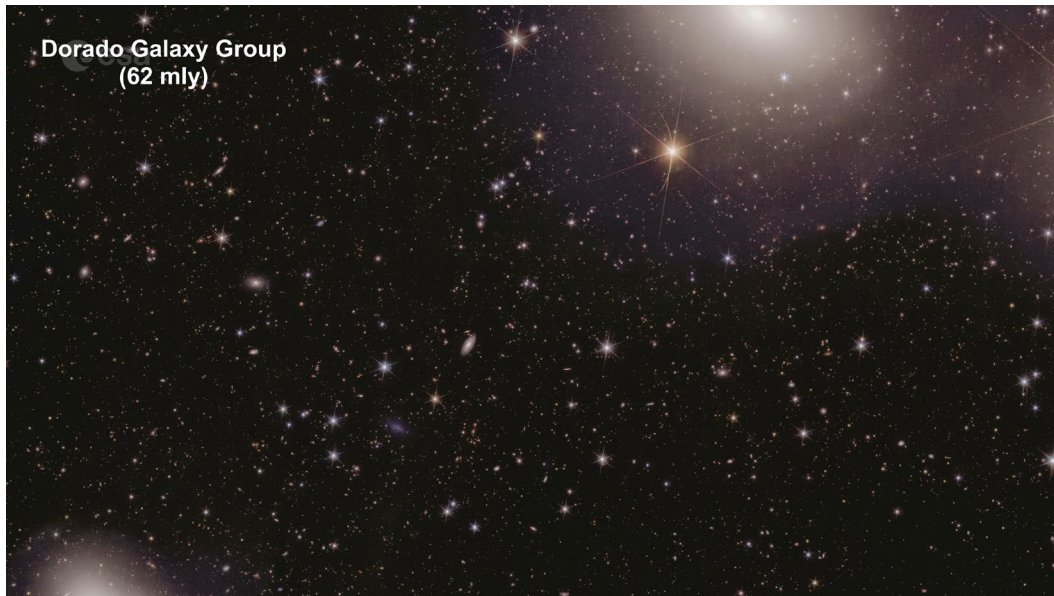
### 07 - NGC 6744 – 30 mly

Here, Euclid captures NGC 6744, one of the largest spiral galaxies just beyond our local group. It's a typical example of the type of galaxy currently forming most of the stars in the nearby Universe. Euclid's large field-of-view covers the entire galaxy, revealing its spiral structure on a larger scale. This detail includes feather-like lanes of dust emerging as 'spurs' from the spiral arms. Euclid's observations will allow scientists to not only count the galaxy's individual stars but also trace the wider distribution of stars and dust as well as mapping the dust associated with the gas that fuels new star formation. Spiral arms are important in galaxies, as they move and compress gas to foster star formation, not seen between spiral arms. It's important to note that spiral arms are still not well understood, even though they have been seen in countless galaxies for over 100 years! Remember that all the gas and solar systems revolve around the center of a galaxy, but the spiral arms do not. Euclid hopes to unravel the physics behind the structure of spirals.



### 08 - Dorado Galaxy Group - 62 mly

This is the Dorado Galaxy Group. It's one of the richest galaxy groups in the southern hemisphere. Euclid captured signs of galaxies evolving and merging, with beautiful tidal tails and shells visible as a result of ongoing interactions. Several of Dorado's constituent galaxies are still forming stars. Others show signs of having merged relatively recently. This image is enabling scientists to study how galaxies evolve and collide over time. A wide array of galaxies are visible here, from very bright to very faint. For the first time we can deeply study small objects the size of star clusters, the central parts of a galaxy, and extended tidal merger tails over a large part of the sky. Scientists are also using Euclid observations of the Dorado Group to compile a full list of the individual globular clusters around the galaxies seen here. Once we know where these clusters are, we can use them to trace how the galaxies formed and study their history and contents. All this will improve our models of cosmic history and increase our understanding of how galaxies form within halos of dark matter.



### 09 – Abell 2764 – 1 bly

This new Euclid view shows the galaxy cluster Abell 2764, a very dense region of space containing hundreds of galaxies orbiting within a halo of dark matter. It captures a range of objects including many background galaxies, more distant galaxy clusters, interacting galaxies that have thrown off streams and shells of stars. This complete view allows scientists to ascertain the radius of the cluster and study its outskirts with faraway galaxies still in the frame. These observations are also allowing scientists to witness some of the most distant galaxies that existed during the cosmic dark ages - back when the Universe was only 700 million years old. Viewing this early light is a Euclid specialty that allows us to see how the first galaxies formed.

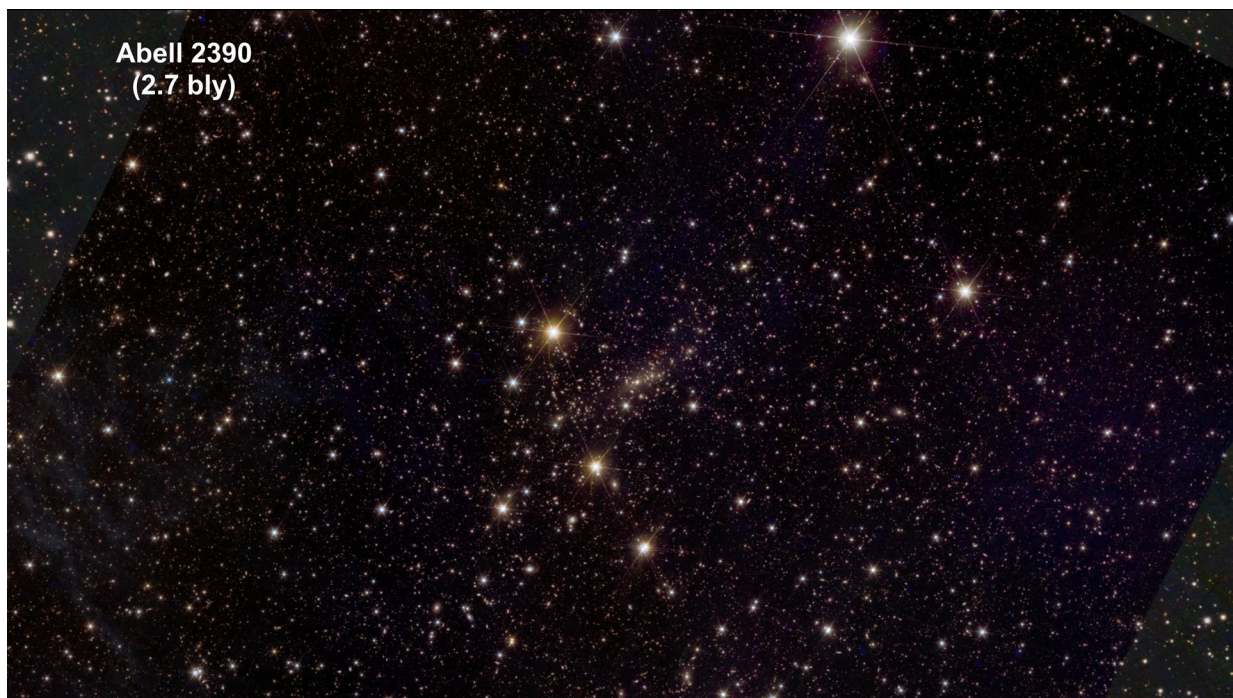




## 10 - Abell 2390 – 2.7 bly

This is a Euclid image of the galaxy cluster Abell 2390, 2.7 billion lightyears away containing more than 50,000 galaxies. Such clusters contain huge amounts of mass (up to 10 trillion times that of the Sun). Much of this is in the form of dark matter. Once Euclid begins its main survey it will capture many thousands of galaxy clusters like this one to map dark matter distribution across the cosmos. Euclid's new view of the cluster showcases one of the telescope's key techniques for this job by indirectly measuring the amount and distribution of dark matter in a galaxy cluster by measuring the strength of its gravitational lensing of light from even more distant galaxies. Here's an example with multiple giant curved arcs, some of which are actually multiple views of the same distant object.

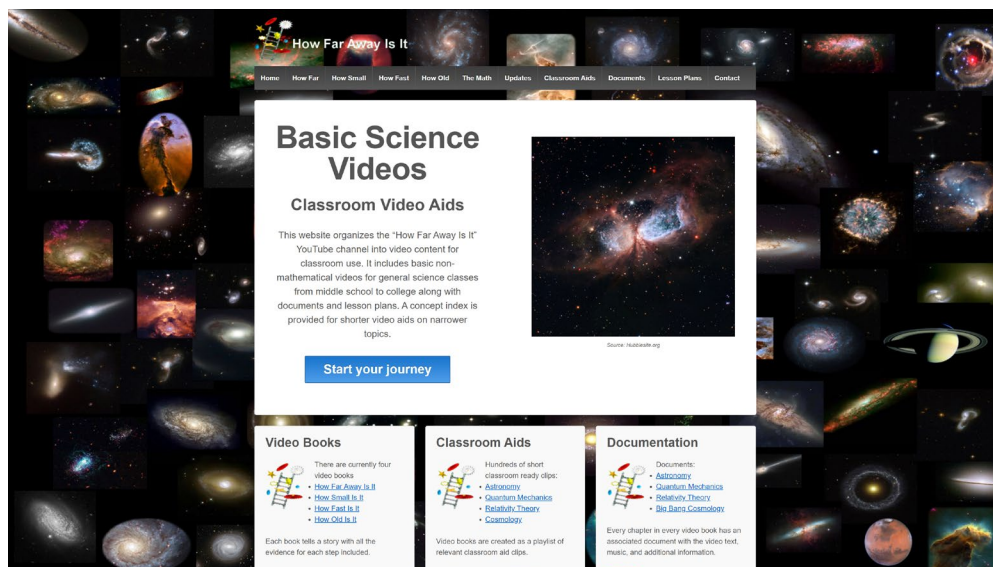
Alongside understanding more about dark matter, scientists are using Euclid data to measure how the masses and number of galaxy clusters on the sky change over cosmic time, revealing more about the evolution of the Universe (and by extension more about dark energy, which is thought to influence this evolution). Euclid's can measure the faint 'intracluster light' emitted by stars that have been ripped away from their parent galaxies into intergalactic space. The light has been added in the image to make it more clearly visible. Viewing this light is a specialty of Euclid, and these stellar orphans may allow us to 'see' where dark matter lies.





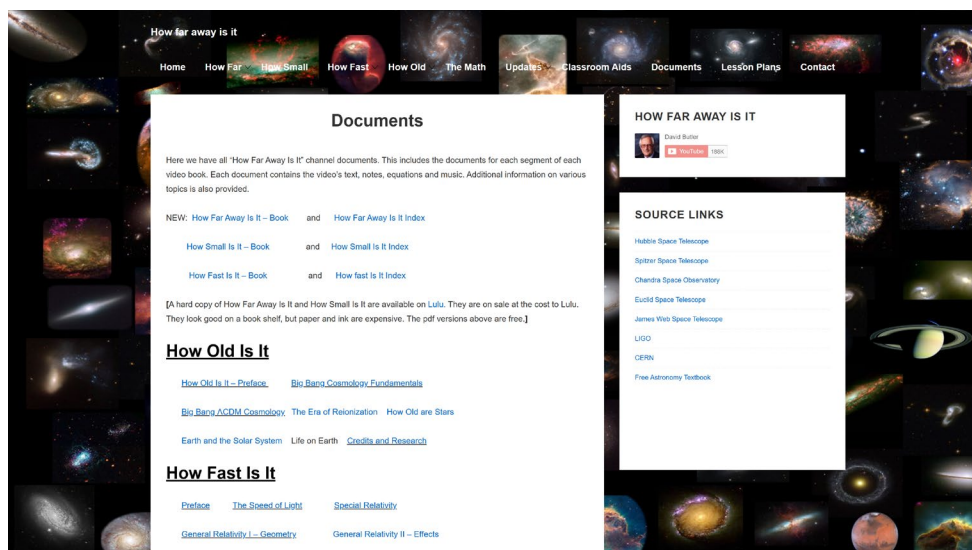
## Credits and Research

Here are the links to Euclid, Webb, Hubble and other locations where I found the information contained in this video. These are also the places where you can begin to do your own research.



<https://howfarawayisit.com/>

And don't forget. Every video has a document on the howfarawayisit.com website containing all the text and pictures. Download and translate as needed. In closing, I want to thank Jonathan Onstead for his excellent editing. And I want to thank everyone for all the great comments and questions posted on my videos. I read them all. Keep them coming, and thanks for watching.



<http://howfarawayisit.com/documents/>



## Introduction

[https://www.esa.int/ESA\\_Multimedia/Missions/Euclid/\(result\\_type\)/images](https://www.esa.int/ESA_Multimedia/Missions/Euclid/(result_type)/images)

[https://www.esa.int/Science\\_Exploration/Space\\_Science/Euclid/Top\\_five\\_mysteries\\_Euclid\\_will\\_help\\_solve](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Top_five_mysteries_Euclid_will_help_solve)

<https://sci.esa.int/web/euclid/-/61403-three-dark-fields-for-euclid-deep-survey>

<https://www.youtube.com/watch?v=c9azB1EJreE>

[https://www.esa.int/Science\\_Exploration/Space\\_Science/Euclid/Euclid\\_s\\_instruments#:~:text=VIS%20technical%20details-](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_instruments#:~:text=VIS%20technical%20details-)

[Near%20Infrared%20Spectrometer%20and%20Photometer%20\(NISP\),galaxies%20at%20different%20infrared%20wavelengths.](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_instruments#:~:text=VIS%20technical%20details-)

[https://www.esa.int/Science\\_Exploration/Space\\_Science/Euclid/Euclid\\_s\\_view\\_of\\_spiral\\_galaxy\\_IC\\_342](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_view_of_spiral_galaxy_IC_342)

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[https://www.esa.int/ESA\\_Multimedia/Images/2024/05/Euclid\\_s\\_new\\_image\\_of\\_star-forming\\_region\\_Messier\\_78](https://www.esa.int/ESA_Multimedia/Images/2024/05/Euclid_s_new_image_of_star-forming_region_Messier_78)

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[https://www.esa.int/Science\\_Exploration/Space\\_Science/Euclid/Euclid\\_s\\_view\\_of\\_globular\\_cluster\\_NGC\\_6397](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_view_of_globular_cluster_NGC_6397)

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[https://www.esa.int/Science\\_Exploration/Space\\_Science/Euclid/Euclid\\_s\\_view\\_of\\_irregular\\_galaxy\\_NGC\\_6822](https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_view_of_irregular_galaxy_NGC_6822)

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<https://www.esa.int/esearch?q=ngc+6744>

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## Music

Josef Suk, Serenade, Op 6 - A Far Cry; LIMO Recording Studio, YouTube



Greek letters:

- α β γ δ ε ζ η θ ι κ λ μ ν ξ ο π ρ σ τ υ φ χ ψ ω

- Α Β Γ Δ Ε Ζ Η Θ Ι Κ Λ Μ Ν Ξ Ο Π Ρ Σ Τ Υ Φ Χ Ψ Ω

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