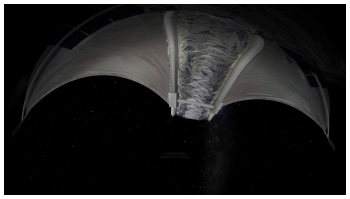
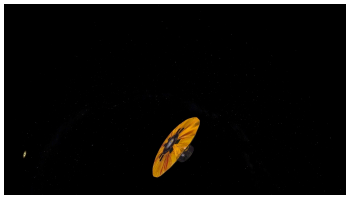
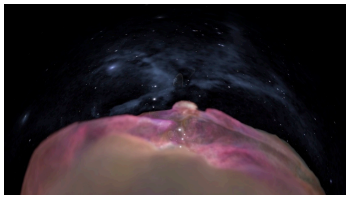
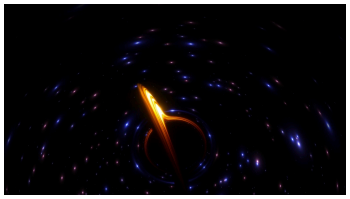
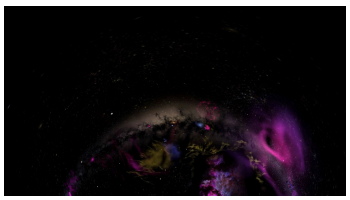
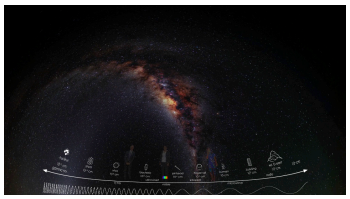
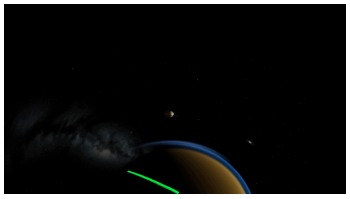
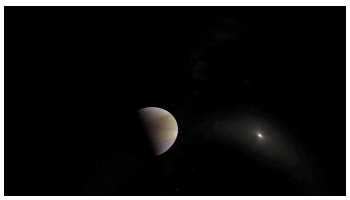
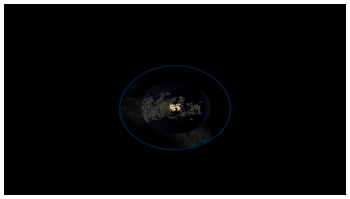
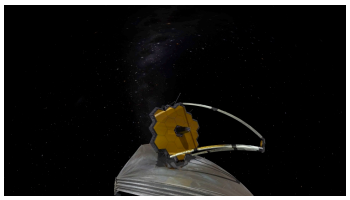
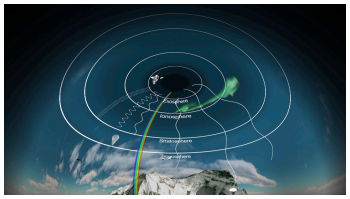
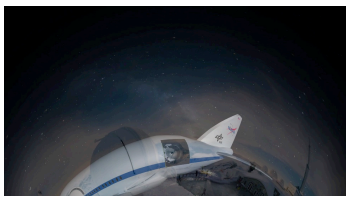
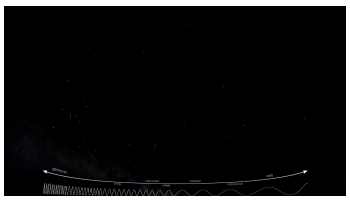
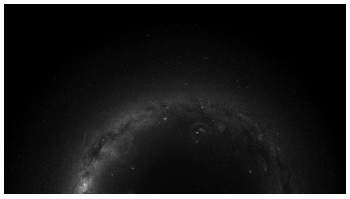
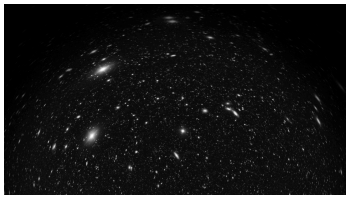
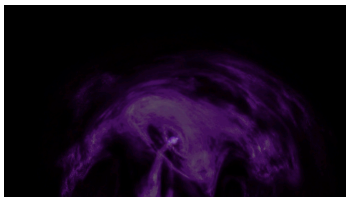
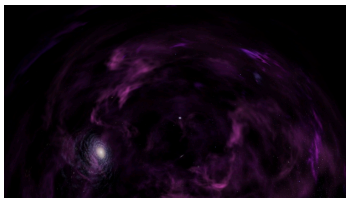
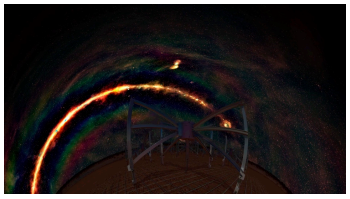
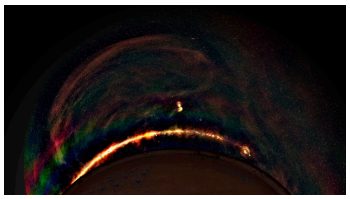
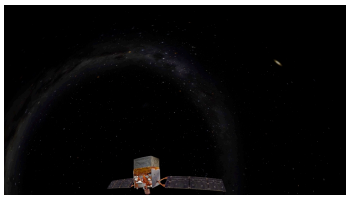
UNSEEN UNIVERSE

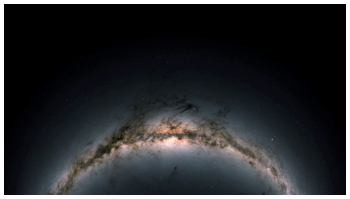
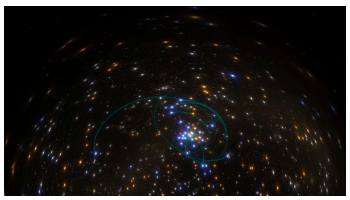
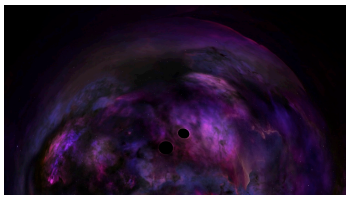
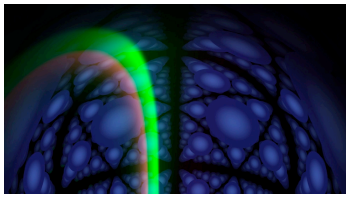
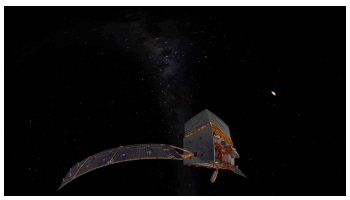
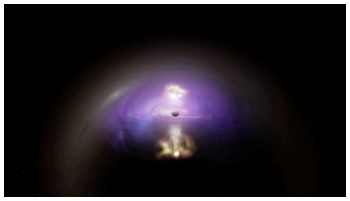
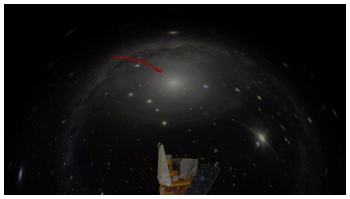
VERSION (SUBTITLES) REVISED: SEP 11, 2019

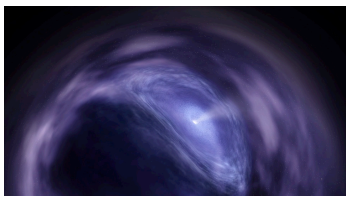
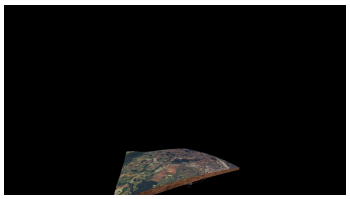
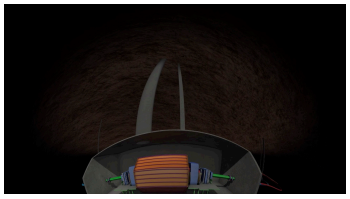
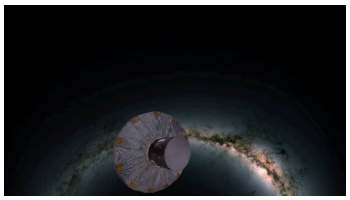
SCENE	TIME	SCRIPT
TITLES		**OPENING TITLES**
	01:00	UNSEEN UNIVERSE
INTRO		**INTRODUCTION**
	00:40	We are creatures of sight, always trying to see farther and in greater detail, exploring the distant universe far beyond our other senses.
	01:15	A fleet of huge instruments are our new eyes on the cosmos, tuned to all the colors of light. Airborne telescopes scan the heavens. Observatories on high mountain peaks stare through Earth's clear skies, and spread across vast dry deserts, huge telescopes watch the sky. Radio ears as big as a football stadium capture the lowest frequencies of light.
	01:53	Another radio device the size of a kitchen table discovered that the stars first began to shine nearly 13 billion years ago, just after the universe began. To capture some of the most elusive particles buried detectors are deep underground, even under the ice, at the south pole, at the Ice Cube Observatory.
	02:35	Why so many instruments in so many different places? Because so much is happening that we cannot see we need devices to reveal what our eyes cannot. These instruments show us a universe that is real but not visible to our eyes. We see the result of powerful forces - nuclear, gravitational and magnetic, driving change in the universe.
	03:09	There is a cosmic drama in the heavens above, with scenes and characters we've never seen before. It's magnificent, it's beautiful, it's fascinating, it's startling, surprising, enigmatic, and forever puzzling.

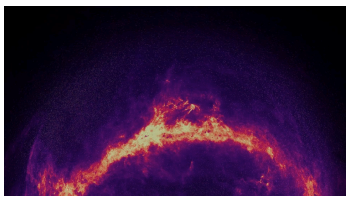
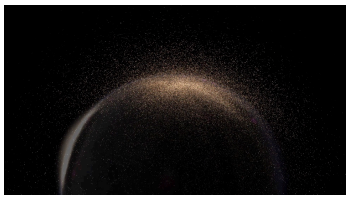
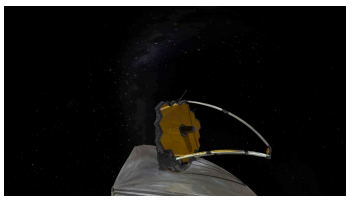
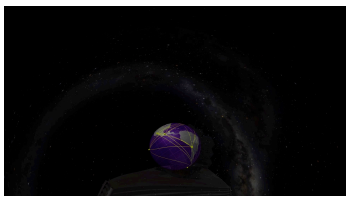
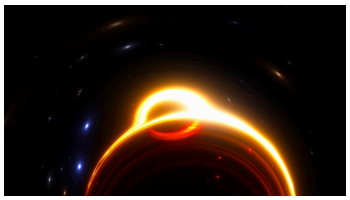
	03:36	We are physically bound to Earth but our vision has been freed to explore a universe we never knew existed, just waiting to be discovered.
	03:58	For millions of years our eyes limited our view to a narrow band of electromagnetic radiation we call visible light. But most light is invisible. Just in the last 90 years we have developed instruments that detect and translate this invisible light for us. From the short and dangerous gamma rays, to the long waves we call radio.
	04:31	Most of us have seen output of devices that turn infrared heat emissions and shadows cast by x-rays into visible light images.
	04:59	Some spacecraft use targeted radio waves called radar to see through dense clouds such as the haze covering Saturn's moon, Titan.
	05:15	We've used both radar and infrared instruments to see through the clouds of Venus. Their data suggest the heat signature of volcanic eruptions on the surface.
	05:46	We were once puzzled by what appeared to be a vast artificial structure surrounding a star. Observations from Earth and space have identified the heat signature of orbiting dust particles rather than any form of an alien sphere.
	06:11	In research astronomy, the ability of infrared to see through dust and gas clouds is amazing. Hidden objects appear clearly. Images of the most distant and oldest objects appear in reddened hues. For this reason space telescopes beyond Hubble will be tuned for infrared light.
	06:50	We need telescopes in space to see all colors of light because Earth's atmosphere shields us from much of the incoming radiation some of it dangerous. Good for us, not so for astronomers.

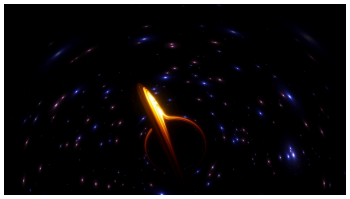
	07:04	Fortunately there are some windows that astronomers can exploit on Earth. Mountaintops are much preferred as the air is thin and sometimes quite stable.
	07:25	Higher still, and better for some infrared observations, the Sophia Telescope rides in a modified 747 aircraft.
	07:41	5000 meters above sea level, on one of the driest places on Earth, 66 giant dishes of ESO's ALMA Telescope look at the universe between infrared and radio waves. It targets dense, cold clouds, and regions of dust where stars and planetary systems are forming. This amazing image shows protoplanetary rings around a young star. The explosive debris from a star birth, and now, molecular clouds, fueling a giant galactic black hole.
	08:27	Tuning our eyes to different wavelengths has revealed a wondrous and mysterious universe. For 250 years, our telescopes were like giant eyeglasses. Producing brighter and sharper image in visible light. But without cameras, astronomers could share their vision only through hand drawings.
	08:57	In 1840's Ireland, the third Earl of Rosse built the world's biggest telescope that gave unprecedented views of the heavens. In his vivid and most accurate drawings. he recorded details never before seen. in many magnificent celestial objects.
	09:18	In the constellation of Taurus he focused in on a tiny, distant, wispy object. Because of its many tendrils, he called it the Crab Nebula, the name we still use today. It is a most fascinating object. We now know it as the debris of an exploded star, with an intriguing object in its heart.
	09:40	The giant telescope enabled the Earl to see deeper into space and resolve more information than anyone before, particularly in this object that he called the Whirlpool Nebula. This is his drawing, and this is the view from the Hubble Space Telescope. In the 1920's it was realized that this was a galaxy of billions of stars and later, that it was two galaxies in collision. It turns out that collisions and explosions are keys to our understanding the fundamental forces of nature.

	10:24	For most of the 20th century, we viewed the universe in black and white because color photography was not scientifically accurate. Then in the 1970's David Malin, an Australian astronomer, used special filters and combined red, green, and blue images. He created the first accurate scientific color and revealed to us the true splendors of the heavens.
	11:05	This is the Crab Nebula that was named by the Earl of Rosse. It's a composite image of shells of excited gasses in non-visual wavelengths. Layer by layer, we peel them back and discover the nebula's secret, a neutron star, more massive than our Sun, but only the size of a city. it's the remnant of a supernova explosion almost 1000 years ago.
	11:32	In 1987 the brightest and closest supernova in 400 years suddenly flared. 5 hours before, flashes of light were detected in a huge underground laboratory in Japan. For the first time we had captured elusive particles called neutrinos, generated by the collapse of a star's core during a monumental nuclear explosion. At this moment, trillions of neutrinos are harmlessly passing through our bodies. Most will have come from the Sun, but others will have come from exploding galaxies and stars.
	12:00	The 1987 supernova was about 30 times more distant than the Crab, yet modern instruments have allowed us to watch the drama unfold. Light appeared first, then we saw the explosive debris shoot through space illuminating and later colliding with nearby material. Recent images from the ALMA observatory show a dense central red dust cloud possibly hiding a neutron star or even a black hole.
	13:12	If our eyes viewed the sky in different radio wavelengths we'd see the Milky Way illuminated by the glow of countless ancient supernovas. Supernova bubbles litter the scene.
	13:25	This is the debris of the Vela supernova, which exploded 11,000 years ago at a distance of 800 light years. The expanding shockwave, 100 light years across, creates glowing filaments as it collides with dark gas clouds. Each dot here is not a star but a giant active galaxy with a black hole at its center.
	13:57	The active galaxies are similar to this one, Centaurus A, which is the closest to us at a mere 11 million light years away. This is a cannibal galaxy. The band of dust across the center is probably the remnants of its last galactic meal. Warm dust surrounds its heart, and radio images expose the feeding frenzy of an enormous, central black hole, 55 million times more massive than our Sun.

	14:40	Most galaxies have central black holes including our own Milky Way. The Fermi Space Observatory discovered huge lobes of gamma radiation extending 25,000 light years from the center of our Milky Way. Its central massive black hole had a huge feast about 9 million years ago and these Fermi bubbles are the cosmic leftovers.
	15:04	Astronomers use ESO's giant Chilean telescopes to penetrate the obscuring dust in the galactic center. Huge stars moving at over 400,000 kilometers swirl around an invisible object. A black hole?
	15:26	In 2017, a consortium of telescopes using radio and other wavelengths combined to make an instrument the size of the Earth. Their task, to image the black hole in our galaxy, and another in the M87 galaxy. The computations would take years.
	15:44	Just a year earlier, in 2016, it was announced that a pair of orbiting black holes which had collided over a billion years ago. had finally made their presence felt. In a fraction of a second about 3 times the mass of the Sun had been converted into gravitational waves. For 1.3 billion years, those waves traversed the universe rippling space-time itself.
	16:13	For years astronomers had tried to detect such waves and had just completed a system of laser-based observatories, LIGO and Virgo. Our planet slightly trembled as the space-time warp passed by, and the delicate detectors responded, proving the effectiveness of this new way to observe the universe.
	16:41	On the morning of August 17, 2017, the Fermi Gamma Ray Telescope picked up a pulse of high energy light from a powerful explosion 130 million light years away two tiny, but massive, neutron stars were spiraling to their doom, producing gravitation waves as they swirled. Seconds earlier, LIGO had detected and then narrowed down the region where the source would be found. 70 observatories on 7 continents and in space turned to capture this observable "kilonova". Observations in wavelengths from gamma waves to radio waves located the source of the intense gravity waves.
	17:37	The slowly cooling fireball of hot debris with a probable black hole, became a perfect target for all the new instruments astronomers had been constructing for decades. Multi-messenger astronomy was born - possibly the greatest advance since Galileo turned his telescope to the sky in 1610.

	18:03	Follow-up studies of the glowing, but fading, fireball revealed new elements being created. The cataclysmic kilonova produced mysterious short gamma-ray bursts as well as the heaviest, and most precious elements in the universe. We estimate that this kilonova created enough gold to make 3 pure gold planets the size of the Earth.
	18:37	Then a few weeks later another event brought together many different observatories. Ice Cube's detectors at the South Pole caught a high energy neutrino. Its undisturbed path pointed to the core of a galaxy billions of light years away.
	18:51	A variety of telescopes caught the action. A jet of high energy particles from a feeding super-massive black hole, was pointed directly at Earth. This jet expels many extremely high energy cosmic particles making our own particle accelerators seem quite puny.
	19:19	The largest of our particle detectors, called the Large Hadron Collider, is buried hundreds of meters below ground on the border of France and Switzerland.
	19:31	Inside, the vast circular tunnel, the beam lines, and an amazing array of superconducting magnets control the fast moving particles. Here the building blocks of matter are magnetically focused into opposing beams and accelerated to near light speeds. Particles must collide inside a massive camera. This concentration of energy recreates the conditions about 1 millionth of a second after the Big Bang and of the birth of the universe.
	20:08	It's ironic that we need this gigantic machine to study the smallest particles known to exist. Making the machines and creating the collisions are the easy part. Understanding the fundamental structure of matter and discovering the secrets of time and space are something else.
	20:32	We're entering an amazing new age, of exploration and understanding. Revolutionary giant telescopes are under construction. They dwarf anything we have built so far. Supercomputers link cluster of telescopes continents apart. Ingenious designs allow us to view the heavens with superhuman sight and accuracy.

	21:32	In space, the European GAIA spacecraft with its 1 billion pixel camera has produced this amazing image of our Milky Way galaxy and has accurately mapped over 1.7 billion stars. Compare this number with the 9,000 bright stars that we can observe directly. Here we see stars shifting position the nearest moving more as we orbit the Sun.
	22:07	Now the interstellar dust that fills the galaxy.
	22:20	Each dot is a real star, orbiting the galactic center. This is not a flight of fancy, but an excursion through thousands of actual stars. A true star trek, thanks to GAIA.
	22:41	With a mirror 3 times wider than the Hubble's, and hundreds of times more sensitive in the infrared, the James Webb Telescope launches in the 2020's.
	22:53	We now have the first results from the Earth-sized consortium of telescopes. For the first time in the history of mankind, the shadow of a black hole has been imaged. It is hard to comprehend the importance of this single image. Undoubtedly one of the most significant in astronomical history.
	23:13	The black hole is silhouetted by super-heated gas spinning around it about 1000 times more massive than the one in our Milky Way. It's in the center of the galaxy M87, about 50 million light years distant, A gas jet 5000 light years long points directly to it. We're looking at the event horizon. Once any matter reaches the event horizon...it's gone. But as material approaches the event horizon, it greatly speeds up, and emits energy that we can detect.
	23:48	It will be awhile before telescopes give us a view as detailed as this animation, but the data we do have allow us to model how light and matter behave near a massive black hole. Just over 100 years since Einstein's theories predicted black holes, we have seen the unseeable, and the first direct visual proof of their existence.

	24:12	Astronomers with their new eyes are realizing that these fantastic gravitational engines have played a vital role in the evolution of the universe, and ourselves.
CREDITS		**ENDING CREDITS**
	24:34	DEDICATED TO THE MEMORY OF STEPHEN HAWKING CH CBE FRS FRSA 1942-2018
Executive Producer		Kirk Johnson
Director		Terence Murtagh
Script		Terence Murtagh Carolyn Sumners
Narrator		John Billingsley
ESO Liaison		Lars Lindbergh Christensen
GRAPHICS		
DD4SKYART		Don Davis
ESO		Luis Calcada
Evans & Sutherland		Ken arlson Marty Sisam
Digistar 6 Renders		Karen Klamczynski Brian Moore
Houston Museum of Natural Science		Adam Barnes Tony Butterfield
M42 Multi-Wavelength Flight		Space Telescope Science Institute Ccaltech/IPAC
MIRAGE3d 360 8K LIVE-ACTION FILMING		
Camera		Robin Sip Christiaan Daniël Wouda
Compositing		Christiaan Daniël Wouda Marijn Kuipers Manoli Tsigonakis
Post Production		Bryce Buchanan
Administrative Support		Jenn Davis
MUSIC AND SOUND RECORDING		
Original Music Score		Chance Thomas
Music Score Performed by		The Utah Film Orchestra

Conductor		Judd Maher
Engineering and Mix		Glen Niebaur
Orchestra Contract		Jenn Sprague
Sound Design and Effects		Michael McDonough
		EVANS AND SUTHERLAND THANKS THE FOLLOWING INDIVIDUALS, RESEARCH INSTITUTES AND OBSERVATORIES WHOSE ASSISTANCE MADE THIS PRODUCTION POSSIBLE
		European Space Agency Gaia Mission SOFIA Infrared Observatory Pic du Midi Observatory, Pyrenees, France European Southern Observatory Murchison Neutrino Observatory, Australia Kamiokande Neutrino Observatory, Japan Ice Cube South Pole Neutrino Observatory JAXA Japanese Aerospace Exploration Agency NASA James Webb Telescope ESO Alma Observatory (ESO, NAOJ, NRAO) ESO Paranal Observatory Lord and Lady Rosse, Birr Castle, Ireland Grainne O'Malley Birr Castle Gardens and Science Centre Nick Risinger Natasha Hurley-Walker (Curtin/ICRAR) and the GLEAM Team, Australia Robert Gendler NASA Spitzer and Chandra Space Telescopes Event Horizon Telescope (APEX/ALMA/IRAM/SPT/JCMT/LMT/SMA/SMT) Black Hole Cam LIGO Gravitational Wave Observatories, USA Virgo Gravitational Wave Observatory, Italy South African Radio Observatory MeerKAT Array CERN Large Hadron Collider Peter McCready
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