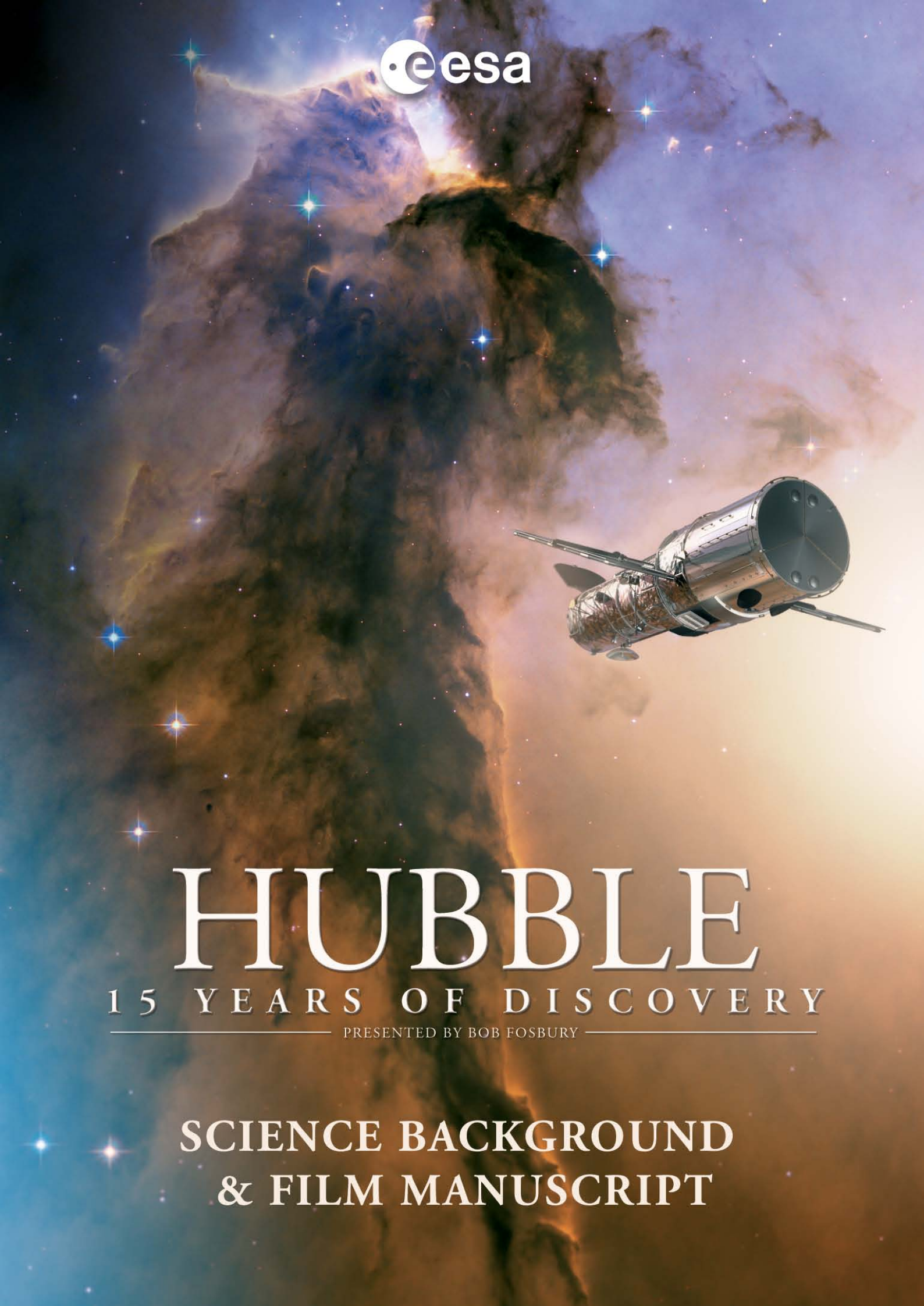

esa

HUBBLE

15 YEARS OF DISCOVERY

PRESENTED BY BOB FOSBURY

SCIENCE BACKGROUND & FILM MANUSCRIPT

CONTENTS

0 Introduction

24 April next year the NASA/ESA Hubble Space Telescope will have been in orbit around the Earth for 15 years! In many ways Hubble is the most successful scientific project in the World, and this event is not likely to go unnoticed.

The European Space Agency, ESA, has decided to celebrate this anniversary with the production of a Hubble 15th Anniversary movie called "Hubble, 15 years of discovery". The movie covers all aspects of the Hubble Space Telescope project – a journey through the history, the trouble and the scientific successes of Hubble.

This portrait of one of the biggest scientific projects of all time contains large amounts of previously unpublished footage in uncompromised quality. With the beautiful backdrop of Hubble's visual image treasures running as a red line through the movie the light and dreaming style tells the most interesting stories about our fascinating Universe and about the change vision that Hubble has brought us. The movie is accompanied by custom-made music that is second to none in quality and aesthetic expression.

The movie is distributed on standard DVDs and contains bonus material such as stills, movies, 'space music videos' and interactive content. There is also room for content tailored to fit local national requirements (localised content).

0.1 Hubble's scientific successes[1]

Hubble is an upgradeable, space-based telescope orbiting at almost 600 km, placing it well above most of our image-distorting atmosphere. It is designed to take high-resolution images and accurate spectra by concentrating starlight to form sharper images than are possible from the ground, where the atmospheric 'twinkling' of the stars limits the clarity. Therefore, despite its relatively modest size, 2.4 metres, Hubble is more than able to compete with ground-based telescopes that have light-collecting (i.e. mirror) areas 10 or even 20 times larger.

Hubble's second huge advantage over ground-based telescopes is its ability to observe near-infrared and ultraviolet light that is otherwise filtered away by the atmosphere before it can reach the ground.

0.1.1 Planet atmospheres

Hubble's extremely high resolution and sensitivity have made unique observations of objects within the Solar System possible, obtaining amazing images and rich streams of data about the nature of these bodies. Hubble has seen unprecedented detail in Jupiter's aurorae, which are similar to those seen above the Earth's Polar Regions, but almost 1000 times more energetic and much more complex. Jupiter's Aurorae can only be seen in ultraviolet light, so they can never be studied with ground-based telescopes.

Astonishing images of Saturn's aurorae were also taken and reveal that the spectacular curtains of ultraviolet light rise more than a thousand miles above the cloud tops of the planet's north and south poles.

In comparison with spaceprobes, which have to travel vast distances and require years of planning to visit the planets, Hubble is able to react quickly to dramatic events occurring in the Solar System. This allowed it to witness the stunning plunge of comet Shoemaker-Levy 9 into Jupiter's atmosphere. The consequences of the impact could be seen for days afterwards and, by studying the Hubble data, astronomers were able to gain fundamental information about the composition and density of the giant planet's atmosphere.

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[1] Serves as basis for the scientific content of the movie.

Although Hubble's high resolution images are surpassed by close-up pictures taken by planetary spaceprobes, Hubble has the advantage of being able to carry out long-term monitoring. This is crucial for the study of planetary atmospheres and geology.
Weather systems can reveal much about the underlying atmospheric processes, and Hubble regularly observes the global seasonal dust storms on Mars, producing astonishing data.

0.1.2 Other planetary systems

Hubble had been in orbit for five years when the first planet around a Sun-like star was discovered. Although it was not designed to study these objects, Hubble versatility has allowed it to make significant contributions to the field. For example, Hubble's high resolution has been indispensable in the investigation of the gas and dust disks, dubbed proplyds, around the newly born stars in the Orion Nebula. The proplyds may very well be young planetary systems in the early stages of creation. The details revealed by Hubble are superior to anything seen to date with ground-based instruments and, thanks to Hubble, we have visual proof today that dusty disks around young stars are common.

With ground-based telescopes the gas giant planet HD 209458b, 150 light-years from Earth, was discovered in 1999 through its slight gravitational tug on its 'mother-star'. In 2001 Hubble made highly accurate measurements of the dip in the star's light when the planet passed in front. The first detection of an atmosphere around an extrasolar planet was also seen in this planet. The presence of sodium as well as evaporating hydrogen, oxygen and carbon was detected in light filtered through the planet's atmosphere when it passed in front of the star.

Hubble has also measured the mass of a planet – only the second time such a calculation has been performed with any accuracy – by detecting the way in which the planet causes its star to wobble. Hubble also found the oldest planet so far discovered. The planet orbits a tiny stellar husk, which was once a blazing star like the Sun, and is located 5,600 light years away. Astonishingly, the planet was once like Jupiter and is around 13 billion years old, almost three times older than our own planetary system.

0.1.3 The life cycle of stars

Hubble has gone beyond what can be achieved with other observatories by linking together studies of the births, lives and deaths of individual stars with theories of stellar evolution. In particular Hubble's ability to probe individual stars in other galaxies enables scientists to investigate the influence of different environments on the lives of stars. These are crucial data that allow us to extend our understanding of the Milky Way galaxy to other galaxies.

Hubble uses its exceptionally sharp focus to reveal changes on cosmic scales over periods of only a few years. From the ground it is not possible to see such evolution taking place on a cosmic scale. In the Universe this kind of action normally takes place on timescales of many thousands or even millions of years, so being able to follow real time changes in astronomical objects is truly progressive.

- Time-lapse movies made by Hubble show that young stars and their surroundings can change dramatically in just weeks or months. XZ Tauri and HH 30 reside about 450 light-years from Earth and the Hubble movies show jets of gas ploughing into space at hundreds of thousands of kilometres per hour. Both star systems are probably less than a million years old, making them relative newborns.

- Hubble has monitored supernova SN 1987A since 1991, four years after it exploded. The result is a series of stunning observations that show the evolution of the last stages of a star's life.

- The ongoing monitoring of the Crab Nebula has enabled Hubble to capture the display of matter and antimatter propelled to speeds close to lightspeed by the Crab pulsar, a rapidly rotating neutron star. Thanks to Hubble, scientists can follow directly the explosive motion of the gas remnant left behind by the supernova that exploded in 1054.

- Hubble was also able to track the evolution of the old star V838 Monocerotis located about 20,000 light-years from Earth. The star put out enough energy in a brief flash to illuminate the surrounding dust. Hubble made a film-like sequence of unprecedented clarity that shows the gas being illuminated by the sudden flash of light from the bizarre star.

- Also in planetary nebulae – gas shrouds ejected by dying Sun-like stars – Hubble has directly observed the expansion of the nebula itself. The Cat's Eye Nebula, for instance, has been observed with Hubble over a period of eight years and is a marvellous example of the resolving power of the telescope.

Ground-based telescopes show planetary nebulae as round (planet-shaped) objects with rather simple geometries. Numerous Hubble observations have revealed that their structures are much more varied and complex than was expected. How a normal Sun-like star evolves from a relatively featureless gas sphere to a nebula with intricate glowing patterns is still one of the unsolved mysteries in astronomy. Each new image of the glowing patterns of gas intrigues astronomers anew: sprinkling jets, pinwheels, ghostly filaments, supersonic shocks, concentric rings, intricate tendrils of gas and fiery lobes…

Hubble was the first telescope to directly observe white dwarfs in globular star clusters. White dwarfs are stellar remnants and provide a 'fossil' record of their progenitor stars that shone so brightly they long ago exhausted their nuclear fuel. These measurements make it possible to determine the ages of these ancient clusters - an important cosmological tool for astronomers.

0.1.4 Black holes and quasars

Although the existence of black holes has been hypothesized for more than 200 years, a central tenet of the theory is that a black hole will be impossible to observe directly. X-ray satellites had hinted that black holes existed, by detecting the emission of X-rays from superheated gas about to be swallowed. Then came Hubble. Its high resolution made it possible to see the gravitational effects on matter surrounding the largest black holes in the Universe. Hubble has also proved that a black hole is most likely present at the centre of most galaxies. This has important implications for the theories of galaxy formation and evolution, as it means that the black hole might be the 'seed' that begins a galaxy's formation.

For many years, quasars were considered to be isolated star-like objects of a mysterious nature. Then astronomers became suspicious that each might be the superbright centre of a so-called active galaxy. Hubble has now observed several quasars and found that each resides in a galaxy's centre. Today most scientists believe that all quasars are powered by a central black hole.

0.1.5 Gamma Ray Bursts

Gamma Ray Bursts emit intense gamma-ray radiation for short periods and are observed a few times per day by special gamma-ray detectors on observatories in space. Today, partly due to Hubble, we know that these bursts originate in other

galaxies - often at extreme distances. Their origin had eluded scientists for a long time, but, after Hubble's observations of the atypical supernova SN1998bw and the Gamma Ray Burst GRB 980425, scientists began to see a physical connection between these two phenomena.

0.1.6 Gravitational lenses

Light does not always travel in straight lines. Einstein's Theory of General Relativity predicts that massive objects will deform the structure of space itself. When light passes one of these objects, such as a cluster of galaxies, its path is curved slightly. The effect is called gravitational lensing.

Hubble's sensitivity and high resolution allow it to observe numerous faint and distant gravitational lenses that cannot be detected with ground-based telescopes due to the blurring of their view by the Earth's atmosphere. The gravitational lensing results in multiple images of the original galaxy, many with a characteristically distorted, banana-like shape.

Since the amount of lensing depends on the total mass of the cluster, gravitational lensing can be used to 'weigh' clusters. This has considerably improved our understanding of the distribution of the 'hidden' dark matter in galaxy clusters and hence in the Universe as a whole.

0.1.7 Deep fields

Deep fields are lengthy observations of a particular region of the sky. They are intended to reveal faint objects by collecting their light for an appropriately long time. The 'deeper' the observation (i.e. longer exposure time), the fainter are the objects that become visible. Astronomical objects can either look faint because their natural brightness is feeble, or because of their great distance.

The first deep fields – Hubble Deep Field North and South - gave astronomers a peephole to the ancient Universe for the first time, and have caused a revolution in modern astronomy.

The Hubble Ultra Deep Field from 2004 represents the deepest portrait of the visible universe yet achieved by mankind. It reveals the first galaxies to emerge from the "dark ages", the time shortly after the big bang when the first stars reheated the cold, dim universe. Some may be the farthest ever seen, existing when the universe was just 400 million years old.

0.1.8 The expansion of the Universe

Several groups of astronomers have used Hubble to observe a special type of variable star, the Cepheids. With very stable and predictable brightness variations, a Cepheid's period of variation depends on physical properties of the star such as mass and true brightness. This means that astronomers, just by looking at the variability of their light, can effectively determine their distance. For this reason, cosmologists call Cepheids 'standard candles'.

One of Hubble's 'core' purposes was to determine the rate of expansion of the Universe, known to astronomers as the "Hubble Constant". After eight years of Cepheid observations this work was concluded by finding that the expansion increases with 70 km/second for every 3.26 million light-years you look further out into space.

The Cepheids have also been used as 'stepping-stones' to make distance measurements for supernovae further out in the Universe. This, in turn, has given a measure of the scale of the Universe.

Hubble's sharp vision means that it can see supernovae, exploding stars billions of light years away that are difficult to study with other telescopes. A supernova image from the ground usually blends with the image of its host galaxy. Hubble can distinguish the light from the two sources and thus measure the supernova directly.

For many years cosmologists have discussed whether the expansion of the Universe would reverse in the distant future or continue ever more slowly. From the new supernova results it seems clear that the expansion is nowhere near slowing down. In fact, due to some mysterious property of space itself, called dark energy, the expansion is accelerating and will continue forever. This surprising conclusion came from combined measurements of remote supernovae made with most of the world's top-class telescopes, including Hubble.

Furthermore, recent supernova results indicate that the cosmos did not always accelerate, but began accelerating when it was less than half its current age. This hints at a fantastic end for the Universe because it implies that the anti-gravity force is becoming more dominant with time. If this continues, it will eventually overwhelm all gravity and catapult space into a super fast acceleration that will shred everything into its constituent atoms. Cosmologists have called this nightmare scenario, the Big Rip.

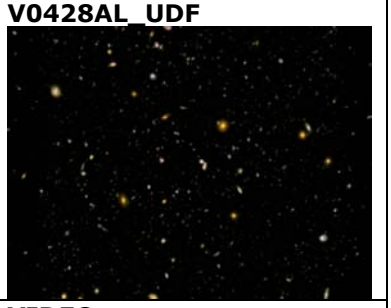
1 The Hubble Story (10:56)

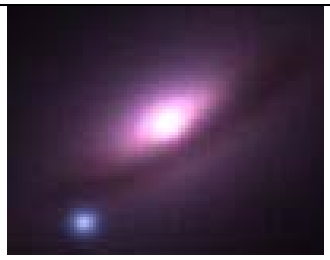
1. The idea. The conception
2. Edwin Powell Hubble: the man behind the name
3. Launch: fast cuts, fast music, excitement,
4. Mirror problem: tension, drama,
5. Servicing Mission 1: drama, solution, release,
6. After Servicing Mission 1 soft music, sharp images
7. More Servicing Missions
8. Future of Hubble
9. JWST – Hubble's Successor

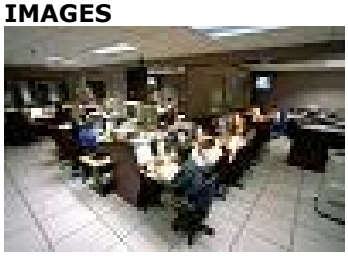
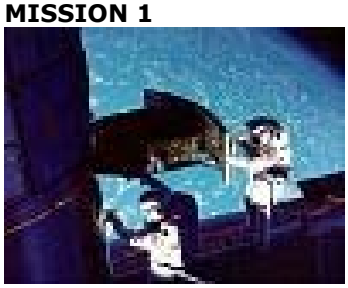
Messages

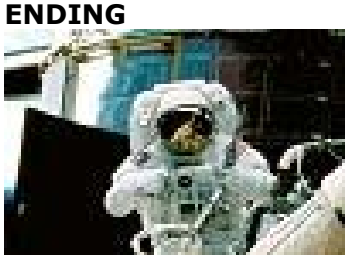
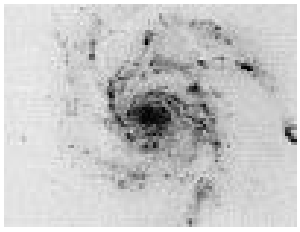
1. A revolution in the history of astronomy, dreamed of for so long.
2. Long underway, international collaboration, not possible for one country alone.
3. A project which was incredibly hard to realise, but succeeded due to perseverance. Upgradeable telescope, keep it fit.

1. **00:00** ***BOB:*** *This film takes you on a journey…* *…..a journey through time and space.*		**BOB OUTDOORS**
1. **00:23** ***BOB:*** *I want to tell you the story of an instrument that has vastly improved our view of the skies, sharpening our perception of the Universe, and penetrating ever deeper toward the furthest edges of time and space.*		**FUNDAMENTAL ZOOM BACKWARDS: BIG BANG, FAST, FLY-BY OBJECTS: DISTANT GALAXIES (UDF 3D MOVIE), COMING INSIDE THE MILKY WAY, FLYING OUT OF HUBBLE.**
2. **01:10** **TITLES** **ESA PRESENTS** ***Hubble – 15 years of discovery*** *- A closer look at the World's most successful science project*		**HUBBLE OVER THE EARTH**
3. **01:30** ***BOB:*** *Looking at the night sky we see the familiar twinkle of starlight. Light that has travelled enormous distances to reach us. But we are not seeing the stars themselves flicker…*		**NIGHT SKY** 

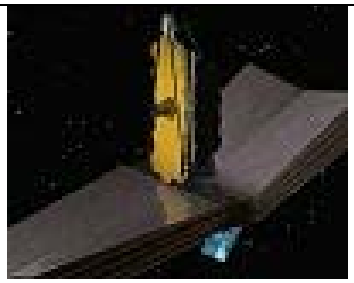
4. **01:47** ***NARRATOR:*** *The universe is gloriously transparent. The light from distant stars and galaxies can travel unchanged across space for thousands, millions, even billions of years.*		**VIDEO:** **STARZOOM: FAST JOURNEY THROUGH STARS AND OTHER OBJECTS** **MAYBE** **V0428AL_UDF** 
5. **02:01** ***NARRATOR:*** *But then, in the last few microseconds before that light reaches our eyes, the accurate view of those stars and galaxies is snatched away. This is because, as light passes through our atmosphere, the ever changing blankets of air, water vapour and dust, blur the fine cosmic details.*		**VIDEO:** **ENTERING EARTH'S SWIMMING TURBULENT ATMOSPHERE** 
6. **02:29** **BOB, VS** ***BOB:*** *So, for many years, astronomers around the world longed for an observatory in space. As early as 1923, the famed German rocket scientist Hermann Oberth suggested a space-based telescope. However, it was decades before technology caught up with the dream. The American astronomer Lyman Spitzer proposed a more realistic plan for a space telescope in 1946.*		**ON THE SCREEN:** **IMAGE: OBERTH01** 
7. **02:55** ***NARRATOR:*** *From a position in space, above Earth's atmosphere, a telescope would be able to detect the pristine light from stars, galaxies, and other objects, well before it was distorted by the air we breathe. The result: much sharper images than even the largest telescopes on the ground can achieve; images limited in sharpness only by the quality of the optics.*		**HST OVER THE GROUND, IMAGES OF GROUND BASED OBSERVATIONS COMPARED WITH SPACE-BASED, E.G. NGC 1316 OR:** **SN1994D_GROUND**

		 **SN1994D_HUBBLE** 
8. **03:24** ***NARRATOR:*** *In the 1970s, NASA - the National Aeronautics and Space Administration - and ESA - the European Space Agency - began working together to design and build what would become the Hubble Space Telescope.*		**HUBBLE UNDER CONSTRUCTION** 
9. **03:42** ***NARRATOR:*** *The name is a tribute to Edwin Powell Hubble - the founder of modern cosmology - who, in the 1920s, proved that not all we see in the sky lies within the Milky Way. Instead, the cosmos extends far, far beyond. Hubble's work changed our perception of mankind's place in the Universe forever and the choice of naming the most magnificent telescope of all time after Edwin Hubble could not have been more appropriate.*		**E. HUBBLE'S PICTURE** 
10. **04:15** ***NARRATOR:*** *It took two decades of dedicated collaboration between scientists, engineers and contractors from many countries before Hubble was finally finished.*		**ON THE SCREEN:** **SPACE SHUTTLE LAUNCH** 

11. **04:32** ***NARRATOR:*** *On April 24, 1990, five astronauts aboard the space shuttle Discovery left on a journey that changed our vision of the universe for ever! They deployed the eagerly anticipated Space Telescope in an orbit roughly 600 km above the Earth's surface.*		**IMAGES OF THE LAUNCH, FAST CUTS, FAST MUSIC, EXCITEMENT** 
12. **05:00** ***NARRATOR:*** *On Earth, the astronomers waited impatiently for the first results.* *But less than two months later it was clear that Hubble's vision was anything but sharp.* *The mirror had a serious flaw…*		**DISTURBED ASTRONOMERS, FUZZY IMAGES** 
13. **05:23** **MUSIC: TENSION, DRAMA** ***BOB:*** *A defect in the shape of the mirror prevented Hubble from taking sharp images. The mirror's edge was too flat, by only a mere fiftieth of the width of a human hair. But to accomplish its mission, Hubble had to be perfect in every tiny detail… The disappointment was almost too great to bear. Not only amongst astronomers, but also for American and European taxpayers…*		
14. **05:59** ***BOB:*** *Nevertheless, over the following two years, scientists and engineers from NASA and ESA worked together to design and build a corrective optics package, named COSTAR, for Corrective Optics Space Telescope Axial Replacement. Hubble's masters now faced another tough decision: which science instrument should they remove so that COSTAR could be fitted to Hubble?* *They eventually chose the High Speed Photometer.*		**IMAGES OF THE NEW OPTICS AND SERVICING MISSION 1** 

15. **06:40** ***NARRATOR:*** *Hubble's First Servicing Mission in 1993 has gone down in history as one of the highlights of human spaceflight. It captured the attention of both astronomers and the public at large to a degree that no Space Shuttle mission since has achieved. Meticulously planned and brilliantly executed, the mission succeeded on all counts. COSTAR corrected Hubble's eyesight more perfectly than anyone had dared to hope.*		**SERVICING MISSION 1, THE MUSIC OF A HAPPY ENDING**  **HAPPY ASTRONOMERS:** 
16. **07:10** **BOB IN VS.** **SOFT MUSIC** ***BOB:*** *When the first images after the servicing came up on the computer screens it was instantly clear that the glasses taken up by the astronauts were completely correcting Hubble's nearsightedness.* *Hubble was finally in business!*		**ON THE SCREEN:** **SHARP IMAGES FROM HUBBLE** 
17. **07:30** ***NARRATOR:*** *That was only the first time the Space Shuttle visited Hubble.* *The telescope was designed to be upgraded, to keep utilizing new capabilities. When more advanced instruments, electrical or mechanical components become available, they could be installed.*		**OTHER SERVICING MISSIONS** 
18. **07:50** ***NARRATOR:*** *Plus, just as your car needs servicing, so Hubble needs tuning-up from time to time. Engineers and scientists periodically send the Shuttle to Hubble, so that astronauts can upgrade it, using wrenches, screwdrivers and power tools, just as your mechanic does with a car.*		**SERVICING MISSION FOOTAGE SCREWDRIVER**

19. **08:12** ***NARRATOR:*** *There have been four Servicing missions so far– in 1993, 1997, 1999 and 2002 – all undertaken by astronauts, transported into space by NASA's Space Shuttle.–* *The next one was supposed to occur in 2005, but was unfortunately cancelled in the aftermath of the tragic Columbia crash.*		**SERVICING MISSION FOOTAGE**
20. **08:35** **BOB IN VS** ***BOB:*** *Hubble's future is uncertain. It was originally designed to operate for 15 years, but it is now expected that its life could be extended to 20 years. Hubble is still producing the most astonishing results that astronomers have ever known, but it will soon need a maintenance visit.*		
21. **08:55** ***NARRATOR:*** *If Hubble is to continue producing science, another Servicing Mission must be executed. Currently, there are novel plans for a robotic Servicing Mission in 2007 or 2008. An unmanned probe will link up with Hubble in orbit and dock with it.* *The robot will exchange batteries and upgrade instruments with a dexterous pair of highly advanced robotic arms.* *When leaving Hubble, the robot will leave behind a rocket-module so that, after some more years of fruitful observing, engineers on the ground can activate these rockets to control Hubble's final descent into the atmosphere and to a peaceful final resting place, in the ocean.*		**ROBOTIC SERVICING**
22. **10:30** ***NARRATOR:*** *Regardless of whether such a robotic mission proves to be possible, Hubble's important mission will eventually come to an end.* *However, the retirement of the Hubble Space Telescope will not signal the end of our unrivalled view of the universe. Rather, it will mark a new beginning, an era of even more amazing discoveries and images from space. For Hubble has a successor.*		**HUBBLE ORBITING FASTER AND FASTER, TO GIVE THE SENSE OF TIME PASSING** **JWST VIDEO: JWST_A**

The James Webb Space Telescope is being designed right now and may be launched as early as 2011. When that day comes, scientists using the James Webb Space Telescope hope to discover and understand even more about our fascinating universe. **11:10** **END**		

2 Hubble Up Close (05:05)

Messages:

1. How the thing works.
2. A very advanced tool.
3. The large size (school bus).
4. The many different instruments.

1. **00:00** ***NARRATOR:*** *Hubble is an upgradeable, space-based telescope orbiting at almost 600 km, placing it well above most of our image-distorting atmosphere. It takes about 97 minutes to complete each orbit.* *It is designed to take high-resolution images and accurate spectra by concentrating starlight to form sharper images than are possible from the ground, where the atmospheric 'twinkling' of the stars limits the clarity.*		**HUBBLE ORBITING THE EARTH**  **ZOOM ON HUBBLE**
2. **00:30** **BOB, VS.** ***BOB:*** *To gather as much light as possible from the faint objects it studies, any telescope needs the largest mirror it can get.* *Despite Hubble's relatively modest mirror size of 2.4 metres, it is more than able to compete with ground-based telescopes that have mirrors 10 or 20 times larger in collecting area.*		**ON THE SCREEN:** **PHOTONS FROM DISTANT GALAXY ENTER HUBBLE.**
3. **01:00** **BOB IN VS** ***BOB:*** *Hubble is a large satellite, about 16 metres long or the size of a small bus. It is also one of the most complicated pieces of technology ever built. It contains more than 3000 sensors that continuously read out the status of the hardware so that technicians on the ground can keep an eye on everything.* *Time on the Hubble is a precious commodity. Astronomers across the world regularly ask for much more time than is available.* *Keeping Hubble working 24/7 is no small task. Not a single second must be lost and all tasks – either*		**ON THE SCREEN:** **EXPLODED VIEW**

observations or so-called 'housekeeping' tasks, such as repositioning of the telescope, or uploading new observing schedules – are meticulously planned.		
4. **01:55** ***BOB:*** *For astronomers, the most important components of Hubble are its scientific instruments.* *There are two groups of instruments in Hubble, here and here. The different instruments serve different purposes – some are for making images, some are designed to dissect the light from the stars and galaxies by spreading it out to form a rainbow-like spectrum.* *Hubble's unique vantage point in space makes it capable of observing the infrared and ultraviolet light that is otherwise filtered away by the atmosphere before it can reach telescopes on the ground.* *These forms of light reveal properties of celestial objects that are otherwise hidden from us.* *Some instruments, like ACS – the Advanced Camera for Surveys – are better for visible and ultraviolet observations, some, like NICMOS – the Near Infrared Camera and Multi-object Spectrograph – are best for infrared observations.*		**MAKE HUBBLE TRANSPARENT, LOOK AT DIFFERENT COMPONENTS (DISSECTION)** **HIGHLIGHT RADIAL AND AXIAL INSTRUMENT BAYS** **3D TEXTS?**
5. **2:55** ***NARRATOR:*** *Different mechanical and electrical components keep Hubble functioning.* *The power for Hubble comes from solar panels on the side, which convert sunlight into electricity.* *Gyroscopes, star trackers and reaction wheels keep Hubble steady and pointing in the right direction – not too close to the Sun, Moon or Earth as they would destroy the light-sensitive instruments – and accurately towards the objects being studied for hours or days at a time.*		**HIGHLIGHT SOLAR PANELS** **3D TEXTS?**

6. **03:30** ***NARRATOR:*** *Hubble has several communication antennae on its side that are necessary for sending observations and other data down to Earth. Hubble sends its data first to a satellite in the Tracking and Data Relay Satellite System, which then downlinks the signal to White Sands, New Mexico. The observations are sent from NASA in the United States to Europe where they are stored in a huge data archive in Munich.*		**HUBBLE COMMUNICATES WITH THE GROUND VIA TDRSS SATELLITE**
7. **04:05** ***NARRATOR:*** *No single nation could undertake such an enormous project. Hubble has been a major collaboration between NASA and ESA, the European Space Agency from an early stage in its life.* *Hubble has been of paramount importance to European astronomy. European astronomers regularly win more than 15% of the observing time with Hubble, resulting in several thousand scientific publications over the years.* *Two groups of European specialists work with Hubble. There are 15 people from ESA currently working at the Space Telescope Science Institute in the USA, and 20 others make up the Space Telescope-European Coordinating Facility in Munich, Germany.* **04:42** **END**		**EUROPE SEEN FROM SPACE** **ASTRONOMERS AT ESO (STOCK)** **FOOTAGE FROM STSCI?** **FOOTAGE FROM ECF/ESO (STOCK?)**

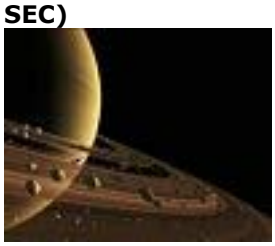
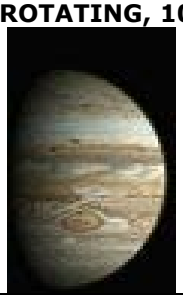
3 Planetary Tales (08:40)

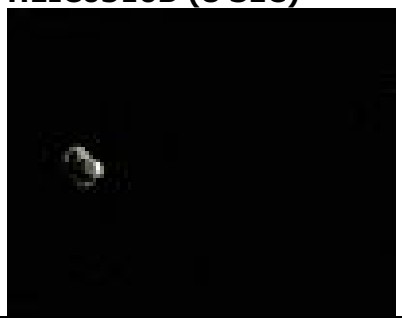
Messages

1. No physical boundaries in space.
2. The solar system is the left-over from the formation of the Sun. Today lots of debris is still around (SL-9 on Jupiter, large asteroids (Sedna))
3. From the formation rocky and gaseous planets naturally emerged (Mars, Jupiter/Saturn).
4. The formation of the Solar System was most like due to a SN and the flux from hot stars
5. Hubble can study planet atmospheres continuously
6. Looking for extra-solar planets. No chance to see them directly. Need to look at its disturbing effect on the orbit of the star their orbiting or see the light through their filtering atmosphere.

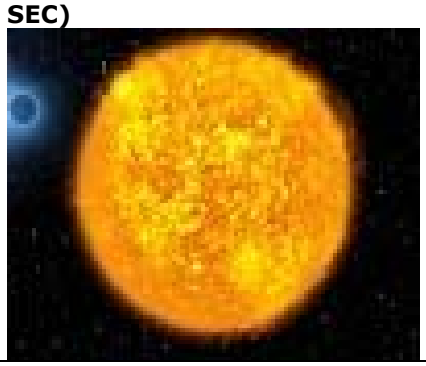
1. **00:00** **SOUND OF WIND, DESERTED, ARID, SOLITUDE.** ***NARRATOR:*** *There are no boundaries in space.* *In this vast Universe, our closest relatives are the objects within the Solar System.* *We share the same origin and the same destiny…*		**STARZOOM** 
2. **00:20** ***BOB:*** *Our Solar System was formed about four and a half billion years ago from a huge gas cloud.*		**PROTOPLANETARY_GAS_DISK, MAKE IT ROTATE** 
3. **00:35** ***BOB:*** *Ironically, it could have been the deadly force of a thermonuclear blast from an exploding star in the vicinity that triggered our creation…*		**VIDEO:** **HEIC0211F (SN EXPLODING, 9 SEC):** **MODIFY INTRODUCING A GAS CLOUD CLOSE BY, BEING COMPRESSED, ~15SEC TOTAL** 
4. **00:45**		**VIDEO:** **SSC2004-08V2 (SEE ALSO**

NARRATOR: *The devastating force of the blast may have disturbed the precarious equilibrium of the original gas cloud, Causing some of the matter to collapse inwards, towards the centre, creating a new star, our Sun, and a minute percentage of the collapsing matter became the multifaceted assembly of planets that we have around us today.* *We are, in other words, just the leftovers of our Sun's birth. The planets were born in the rotating disk of dust and gas left behind as our mother star was formed.* *The rocky planets formed in the inner Solar System while the enigmatic gas giants were formed further out.* *And then, when a fierce wind of smashed atoms began to blow from the Sun –, or perhaps from hot nearby stars or a nearby supernova – only sizable planets could maintain their gaseous surroundings and the last wisps of the tenuous cloud between the planets was whipped away.*		**SSC2004-08V3)**    **SOLAR SYSTEM CREATION ??, SEE AN EXAMPLE IN 'GAS_COLLAPSING_MODEL' (15 SEC), BUT THE NEW ONE HAS TO LAST ~40 – 45 SEC**
5. **01:43** ***NARRATOR:*** *So in our Solar System's zoo of celestial bodies there are rocky worlds…*		**VIDEOS:** **EARTH_B, (ANI, 20 SEC, COULD BE FASTER)**  **ASTRO_Z (ANI, 11 SEC, COULD BE FASTER)**

		
6. **01:50** ***NARRATOR:*** *… and giant gaseous planets.*		**VIDEOS:** **ASTRO_AA (ANI, SATURN, 9 SEC)**  **ASTRO_L(ANI, JUPITER ROTATING, 10SEC) OR ASTRO_M (ANI, JUPITER ROTATING, 10 SEC):** 
7. **2:00** **BOB IN VS.** ***BOB:*** *Even now, there is no exact estimate of how much matter or even how many planets exist within our Solar System…* *Since Pluto's discovery in the 1930s, and its satellite Charon's in the 1970s, astronomers have tried to figure out if there's anything else out there, beyond the ninth planet.*		**ON THE SCREEN:** **IMAGE: PLUTO+CHARON (FOR 3 SEC)** **VIDEO:** **PLUTO_ROTATING (7 SEC)**
8. **02:25** **MYSTERIOUS SOUND** ***BOB:*** *In 2003, Hubble spotted something moving fast enough across the background of faraway stars to be an object within the Solar System. Estimates show that it could be about the size of a planet and it has been named Sedna, after an Inuit goddess.*		**ON THE SCREEN:** **SPITZER ASTEROID** 

Sedna may be 1500 km in diameter, that's about three quarters the size of Pluto, but so far away that it appears as just a small cluster of pixels even to Hubble. Nevertheless, it is the largest object discovered in the Solar System since Pluto.		
9. **03:05** **ZOOM ON THE SCREEN.** ***NARRATOR**: The Sun is about 15 billion km from Sedna – 100 times further than Earth's distance from the Sun – and barely gives out as much light and heat as the full moon. So Sedna is engulfed in an eternal bleak winter…*		**VIDEO:** **SEDNA_FROM_SUN.MOV, ANI (~18 SEC, CAN BE FASTER)** 
10. **03:20** **BOB IN VS .** ***BOB:** Sedna is not the only mysterious object out there.* *Debris from the formation of the planets is still floating everywhere in the form of asteroids and comets of various shapes and sizes. Sometimes their orbits can lead them on catastrophic courses …*		**ON THE SCREEN:** **VIDEO: ASTRO_Y (8 SEC)** **ASTRO_V (8 SEC)** **HEIC0310B (8 SEC)** 
11. **03:45** ***NARRATOR:** The Hubble Space Telescope witnessed the final journey of the comet Shoemaker-Levy 9… It was torn into numerous pieces by Jupiter's gravitational pull when it passed the massive planet in the summer of 1992. Two years later, these fragments returned and drove straight into the heart of Jupiter's atmosphere.* *Hubble followed the comet fragments on their last journey and delivered stunning high-resolution images of the impact scars. Our Earth could easily fit into any of these black bruises…*		**NEW SL9 ANI** **NEW SL9 ANI CLOSE UP ON IMPACTS**
12. **04:25**		**BALLET:** **HST IMAGES OF IMPACT ZONES ON JUPITER: OPO9434A, OPO9433B, OPO9437A AND OPO9433A.**

13. **05:25** ***NARRATOR:*** *Space probes with sophisticated instruments are frequently sent to the planets of our Solar System. They provide close-up investigations of these distant places.*		**VIDEO:** **USE CASSINI VIDEO FROM HTTP://REAL-ESA.CAPCAVE.COM/QT/ARRSATU_06072004_QTHIGH.MOV OR HTTP://REAL-ESA.CAPCAVE.COM/QT/HUYGTI_06072004_QTHIGH.MOV** 
14. **05:40** ***NARRATOR:*** *Hubble, too, provides its own unique service, by opening a window on our Solar System that is never closed.*		**ZOOM FROM HUBBLE TO OUR SOLAR SYSTEM** 
15. **05:50** ***NARRATOR:*** *That's how we've gained unprecedented views of storms on other planets,* *… their changing seasons*		**BALLET: IMAGE_D.** 
16. **06:10** ***NARRATOR:*** *…and unprecedented views of other atmospheric events, such as aurorae, known on Earth as the northern and southern lights.*		**BALLET:** **AURORAE: IMAGES: HEIC0009A, OPO9804A, OPO9805A, 30 SEC** 

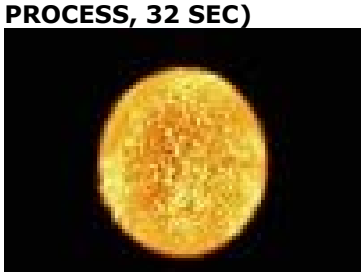
17. **06:30** ***NARRATOR:*** *Even though the solar system clearly has many more surprises in store for us, Hubble has also turned its eye out towards other stars, looking for planetary systems.* *Astronomers are beginning their search for life elsewhere in the Universe. To start with, they are concentrating on finding earth-like planets.*		**VIDEO:** **ASTRO_I (FLIGHT THROUGH THE SOLAR SYSTEM, 20 SEC)** 
18. **06:55** ***NARRATOR:*** *In 2001, Hubble made the first direct detection of the atmosphere of an extra-solar planet and partially determined its composition. Measuring the chemical makeup of extra-solar planetary atmospheres will one day allow us to search for the markers of life beyond Earth All living things breathe and this changes the composition of the atmosphere in readily detectable ways.*		**VIDEOS:** **HEIC0303D (ZOOM, 12 SEC), HEIC0303F (TRANSIT, 9 SEC), HEIC0303B (EVAPORATING, 13 SEC)** 
19. **07:30** **MUSIC: POETIC, SWEET** ***NARRATOR:*** *Astronomers believe there are many planetary systems similar to ours, orbiting other stars throughout the Galaxy. The birth, life, death and rebirth of stars continues in an unending cycle, in which stars, born of gas and dust, will shine for millions or billions of years, die and return as gas and dust to form new stars.*		**VIDEO:** **A FLIGHT THROUGH STARS, SUPERNOVAE EXPLODING AND STARBURSTS, HERE AND THERE** **VIDEO SSC2004-04V2.MPG???**

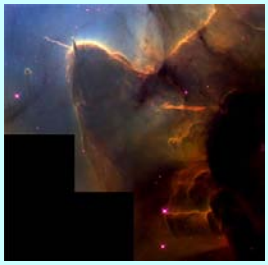
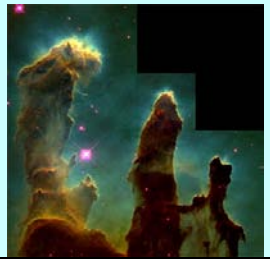
The by-products of this continual process include planets and the chemical elements that make life possible. *So through the entire vastness of space the eternal ebb and flow of life continues…* **08:05** **END**		

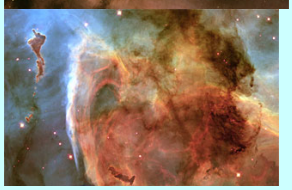
4 The Lives of Stars (12:24)

Messages

1. The Sun is a typical star
2. Stars are spheres of glowing gas
3. Stars live and die - Hydrogen burning, Different stars evolve in different ways. But we can't see stars evolve so we have to learn by looking many stars as examples to get the full picture
4. The birthplaces of stars – hydrogen clouds, SN shocks
5. Birth of a star – disk and jet (xz tauri, hh30)
6. Stars in a star cluster are born in the same place and evolve together
7. Stellar deaths: red giants (v838, nova-like outburst). White dwarfs, SNe, BHs. Neutron stars. SN - estimation of the age of universe
8. Planetary nebulae: End of sun-like stars, ejection of gas (cat's eye motion), puzzling how a spherical gas cloud can evolve to become so messy (hen 3-1475 – maybe the structure/jet is created by a companion star or magnetic field interaction? Cat's ani – companion star) ,
9. Link: Hubble can observe motion -> cosmic collisions

1. **00:00** ***NARRATOR**: Our Sun, that vital source of energy for life on Earth, is a star. A totally unexceptional star, just like billions of others that we can find throughout the Galaxy.*		**ON THE SCREEN:** **THE SUN GLOWING, USE THE FOLLOWING VIDEOS:** **HEIC0303C (A FLIGHT TO THE SUN, 10 SEC)** **HEIC0303E (GOING INTO THE SUN, 5 SEC)** 
2. **00:18** ***BOB**: A star is nothing but a sphere of glowing gas. It forms out of a compressed cloud of gas and releases energy steadily, throughout its life, because a continual chain of nuclear reactions takes place in its core.* *Most stars combine hydrogen atoms to form helium through the process called nuclear fusion - the same process that powers a devastating hydrogen bomb. In fact, stars are nuclear factories that convert lighter elements into heavier elements in a series of fusion reactions. They will keep glowing until they run out of 'fuel'.* *And that's it - a star's life: a quiet beginning and a steady progress to a sometimes violent end. But how can we be certain of this picture when an individual star like the Sun outlives humans by a factor of a few hundred million?*		**VIDEO:** **ASTRO_AC (3D ANIMATION OF A STAR FUSION PROCESS, 32 SEC)** 

3. **01:20** ***NARRATOR****: To investigate the lifecycle of a particular organism on Earth, we don't have to track an individual specimen's entire life. Instead, we can observe many of the organisms at once. This will show us all the different phases of its life cycle.* *For example, each stage of a person's life is a snapshot of the human experience. And so it is with stars...*		**IMAGES OF FLOWERS, BIRDS, FORMS OF LIFE** **VIDEO OF A PARK WITH PEOPLE OF ALL AGES??**
4. **01:55** **BOB IN VS.** ***BOB:*** *Stars live and die over millions, or even billions, of years. Even the most reckless stars live for at least one million years – longer than the entire history of mankind! And that's why it is extremely unusual to be able to track age-related changes in individual stars.* *To learn more about stars, we must sample different stars at every stage of life and piece together the whole cycle from birth to death.* *Hubble's vivid images have documented the tumultuous birth of stars and delivered many astonishing pictures in colourful detail.*		**ON THE SCREEN:** **IMAGES OF LIFE OF STARS FROM HUBBLE, FOR EXAMPLE:** **VIDEO:** **HEIC0312A (STAR FORMING REGIONS, 15 SEC)**  **IMAGE: OPO9623A (ETA CARINAE)** **VIDEO: A FEW PLANETARY NEBULAE, 10 SEC**
5. **02:40** ***NARRATOR:*** *The birth of stars in neighbouring stellar 'maternity wards' can be used as a time machine to replay the events that created our Solar System.* *Hubble has often had to work hard for this information because these important clues about our genesis lie hidden behind the veil of gently glowing, dust-laden molecular clouds where stars are formed.*		**VIDEO:** **STAR FORMING REGION BALLET: EAGLE NEBULA, ETA CARINA, N11B, CONE, TRIFID …**  



6.
04:00

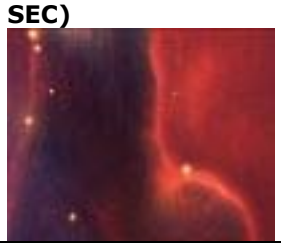
NARRATOR: *Right now there are stars forming everywhere in the Universe.*

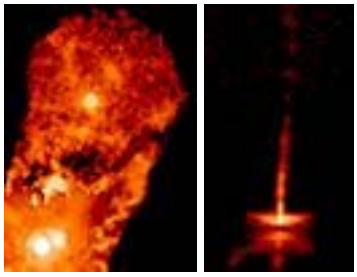
Enormous glowing pillars of dusty hydrogen gas stand sentinel over their cradles, basking in the light of nearby, newly-formed stars.

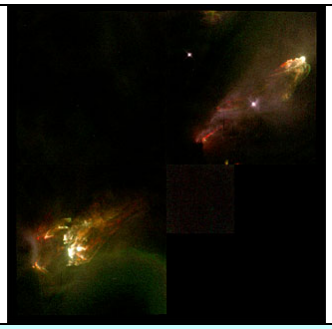
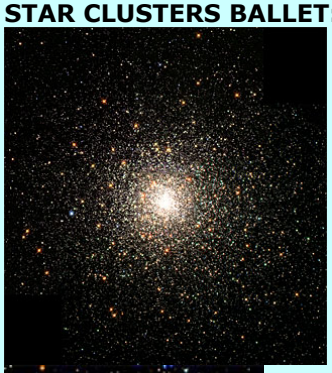
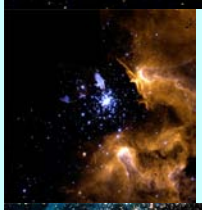
VIDEOS:

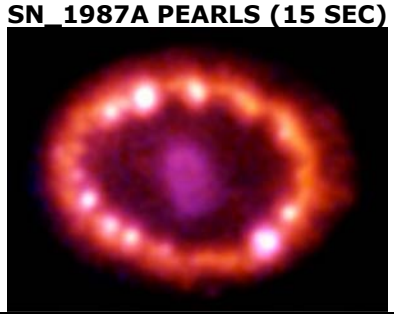
ASTRO_C (EAGLE NEBULA, 8 SEC)
ASTRO_D (EAGLE NEBULA CLOSE UP, 8 SEC)

ASTRO_W (CONE NEBULA, 6 SEC)



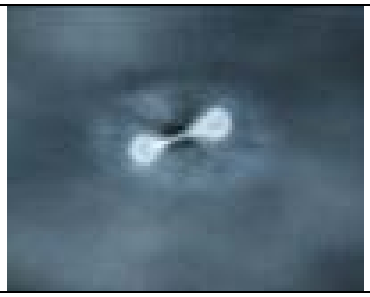
7. **04:20** ***BOB:*** *Hubble's ability to observe infrared light enables it to penetrate the dust and gas and reveal the newly born stars as never before.*		**IMAGE: HEIC0207A (START ZOOMING ON THE ACS IMAGE TOWARDS RIGHT HAND SIDE, BLEND TO NICMOS IMAGE – LABELS: VISIBLE/INFRARED).** 
8. **04:35** ***BOB:*** *One of the most exciting of Hubble's many discoveries was the observation of dust disks surrounding some newborn stars, buried deep inside the Orion Nebula.* *Here we are actually seeing the creation of new Solar Systems where planets will eventually form. Just as they did in our own Solar system four and a half billion years ago.*		**ON THE SCREEN:** **IMAGE: ZOOM ON ORION NEBULA (OPO9545A), PROPLYDS, OPO0205A**  
9. **05:10** **BOB, VS.** ***BOB:*** *In the first stages of their lives, stars can stock up on gas from their original birth cloud. Material falling into the star creates bubbles or even jets as it is heated and blasted along a path that follows the star's rotation axis, like an axle through a wheel.*		**ON THE SCREEN:** **IMAGE:** **OPO9524C1, HH-47 (OPO9524G)** **VIDEO:** **MORPH FROM ORION PROPLYD TO HH30. XZ_TAURI_ANIMATED_GIF (LOOP OF ~ 10 SEC)** **VIDEO:** **HH30_ANIMATED_GIF (LOOP OF ~ 10 SEC)** 

		
10. **05:35** ***NARRATOR:*** *Often many stars are born from the same cloud of gas and dust. Some may stay together through their whole lifetime, keeping step as they evolve, like childhood friends that you keep for life.* *The stars in a cluster will all have the same age, but will have a range of different masses. And this means that very different destinies await them.*		**IMAGES:** **STAR CLUSTERS BALLET:**    

11. **06:35** ***NARRATOR:*** *Human existence is the mere blink of an eye compared with the life of a star.* *So the direct observation of a transition between different stages of a star's life can only come about by lucky chance.* *In fifteen highly productive years, Hubble has allowed us to observe some stars ageing in real time. The telescope has produced startling "movies" that allow us to witness how some of them DO modify their appearance over this minute span of astronomical time.*		**VIDEO:** **BALLET: HEIC0405 (40 SEC)** 
12. **07:15** ***NARRATOR:*** *The stars containing the most mass end their lives cataclysmically, destroying themselves in titanic stellar explosions known as supernovae. For a few glorious months, each becomes one of the brightest objects in the entire Universe, outshining all the other stars in its parent galaxy.*		**VIDEO:** **SN EXPLOSION** **IMAGE: OPO9919I** 
13. **07:35** ***NARRATOR:*** *Since its launch in 1990, Hubble has watched the drama unfold in supernova 1987A, the nearest exploding star in modern times. The telescope has been monitoring a ring of gas surrounding the supernova blast.*		**SN1987A ANI** **IMAGE: OPO9719B (SN 1987A, LOW RES** 
14. **07:50** ***NARRATOR:*** *Hubble has observed the appearance of bright spots along the ring, like gemstones on a necklace. These cosmic "pearls" are now being lit by supersonic shocks unleashed during the explosion of the star.*		**VIDEO:** **SN_1987A PEARLS (15 SEC)** 

15. **08:05** ***BOB:*** *The ruins of an exploding star can hide a powerful engine.* *Hubble has probed the mysterious heart of the Crab Nebula, the tattered remains of an exploding star, vividly described by Chinese astronomers in 1054, and has revealed its dynamic centre.* *The innermost region of this nebula harbours a special type of star, a pulsar. Like a beacon, this star rotates, emitting light and energy in a beam. And it powers the vast nebula of dust and gas surrounding it.*		**IMAGE: ZOOM ON ESO CRAB.**  **VIDEO: HUBBLE CRAB MOVIE.**
16. **08:45** ***BOB:*** *However, not all stars end their lives so violently. Sun-like stars cool down once they run out of hydrogen. The centre collapses in on itself and the heavier elements are burnt, causing the outer layers to expand and leak slowly into space.* *At this stage in a star's life, it is called a "red giant".* *Our Sun will become a "red-giant" in a few billion years. At that time, it will expand so much that it will swallow Mercury, Venus and our planet, too.* *But these stars are not finished quite yet. They can still become something extraordinary…*		**SWELLING SUN BECOMES RED GIANT ANI** **SWALLOWS INNER PLANETS**
17. **09:25** ***NARRATOR:*** *Just before they breathe their last breath, stars like our Sun go out in a final blaze of glory.* *In its final stages of nuclear fusion, stellar winds blow from the star, causing the red giant to swell to an enormous size.* *At the heart of this expansion, the exposed heart of the star floods the gaseous envelope with powerful ultraviolet light, making it glow.* *Because to early telescopic astronomers, these amazing constructions looked a bit like the newly discovered planet Uranus, they became known as planetary nebulae.* *Hubble's keen perception shows that planetary nebulae are like butterflies: no two are alike.*		**PN FORMATION ANI** **OPO9839A(NGC 3132) AND HEIC0414B (CAT'S EYE) OPO9607A (HOURGLASS) (MORE??)**  

		
18. **10:10** **MUSIC: SLOW, RELAXING** ***NARRATOR:*** *Hubble's dazzling collection of planetary nebulae show surprisingly intricate, glowing patterns: pinwheels, swirling jets, elegant goblet shapes, barrel shapes, or even rocket engine exhausts.*		**VIDEO:** **BALLET: PLANETARY NEBULAE, MAYBE LIKE IMAGES_A? MAYBE LIKE THE BUTTERFLY POSTER?** 
19. **11:30** ***NARRATOR:*** *From its unique position high above the distorting atmosphere Hubble is the only telescope that can observe the swollen outer envelope of these dying stars in full detail.* *Here we flip back and forth between Hubble images from 1994 and 2002.*		**VIDEO:** **HEIC0414D (CAT'S EYE_EXPANDING)** 
20. **11:50** ***NARRATOR:*** *One of the greatest mysteries in modern astrophysics is how a simple, spherical gas ball such as our Sun, can give rise to these intricate structures..!!* *For some planetary nebulae it is as if a cosmic garden sprinkler created the jets that stream out in opposite directions.*		**VIDEO:** **HEIC0308B (FORMATION OF THE SPRINKLER, 14 SEC)** 
21. **12:10** ***NARRATOR:*** *...Or could these amazing patterns possibly be sculpted by the magnetic field of a companion star that funnels the emitted gas into a jet?*		**VIDEO:** **HEIC0414C(CAT'S EYE_FORMATION, ~ 23 SEC, TAKE JUST 15)**

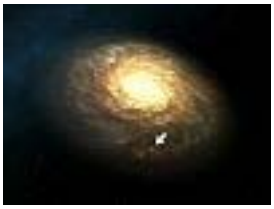
		
22. **12:25** ***NARRATOR:*** *Whatever their cause, in only ten thousand years these fleeting cosmic flowers disperse in space. Just as real flowers fertilize their surroundings as they decompose, the chemical elements produced inside the star during its life are dispersed by the planetary nebula to nourish the space around it, providing the raw material for new generations of stars, planets and possibly even life.* *Because they disappear so quickly on a cosmic timescale there are never more than about 15000 planetary nebulae at any one time in our Milky Way.* *A more lasting monument to the dead star, is the tiny heart it leaves behind. Known as a white dwarf, each of these exceptionally dense, Earth-sized stars are fated to spend the rest of eternity gradually leaking their residual heat into space, until eventually, in many billions of years, they approach the frigid –270 degrees centigrade of space.* **13:25 END**		**VIDEO:** **HEIC0414A (ZOOM ON CAT'S EYE NEBULA, 31 SEC)???** 

5 Cosmic Collisions (07:56)

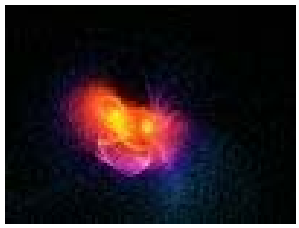
Messages:

1. Relate the scale of the Solar System to the scale of the Milky Way.
2. Show that the MW is nearly empty. Give a feeling for the vastness of space.
3. Tell that the Universe is in constant evolution.
4. and that galaxies can violently collide. The stars don't collide, but the shocks can give rise to fireworks of starbirth.
5. The galaxies change appearance, can merge and change morphology (e.g. spiral -> elliptical)

1. **0:00** **BOB, VS.** ***BOB:*** *We live inside a huge star system, or galaxy, known as the Milky Way. Seen from outside, the Milky Way is a gigantic spiral, consisting of a central hub embraced by long arms. The whole system slowly rotates. Between the stars are vast amounts of gas and dust - that we can see - and some unknown material called "Dark Matter" that is invisible to us.* *Far from the centre, out in one of the arms, the suburbs of the Milky Way, there's a tiny star system, our home, the Solar System.*		**MW ROTATE ON SCREEN** 
2. **0:40**		**ZOOM TO SCREEN. ZOOM ON THE SOLAR SYSTEM.** 
3. **0:48** ***NARRATOR:*** *When we look up on a clear night, we can see about 5000 of the closest stars.*		**NIGHT SKY – FUJII IMAGE SLOWLY ROTATING** 

4. **0:55** ***NARRATOR:*** *Our eyes struggle to see beyond a thousand light-years because of the dust that blankets space and dims the distant starlight. So without a telescope we can only see a minute portion of the entire 100000-light-year-wide Milky Way.* *For the Milky Way contains several hundred billion stars, many like our own Sun!! Although several hundred thousand million is an almost unfathomable number, it is only the beginning. Astronomers believe there are more than a hundred billion galaxies in the Universe. How many stars would that be?*		**FAST ZOOM OUT ON THE MILKY WAY AGAIN. 1000 LIGHT-YEAR SPHERE AROUND THE SUN** 
5. **1:29** **BOB OUTDOORS, LET SAND RUN THROUGH HIS HAND** ***BOB:*** *In a handful of sand there can easily be 50,000 individual grains of sand. Even so, on an entire beach there are only just enough grains of sand to represent each star in the Milky Way. There are so many stars in the Universe that we would need to count every grain of sand on every beach on the entire Earth to get anywhere near the right number!* **BOB SHOWS GRAIN OF SAND, PLACES IT SOMEWHERE** *Let's take a grain of sand, 1 mm across, and place it here to represent the size of the Sun.* **BOB STARTS TO WALK AWAY** *If we started walking towards the nearest star it would take us the better part of a day to complete the journey because the star would be nearly 30 kilometres away.*		**OUTDOOR SCENERY: SANDY AREA.** **BOB FAST WALKING AWAY** **F/X TRANSITION TO SPACE**
6. **2:32** ***NARRATOR:*** *So, galaxies are mostly large collections of emptiness.* *If we could squeeze together all the stars in the Milky Way, they would easily fit into the volume of space between our Sun and the nearest star.* *In fact, to completely fill that volume, we would have to pack in all the stars from all the galaxies in the entire Universe!!*		**VIDEO:** **ZOOM OUT FROM ANIMATED TWO STARS**  **FILL VOLUME WITH STARS**

		
7. **3:10** ***NARRATOR:*** *When looking at the night sky, the universe seems motionless. This is because our life spans are nothing but brief drops in the universal ocean of time. In fact, the universe is in constant motion, but we would need to watch for vastly longer than a lifetime to perceive that motion in the night sky.* *Given enough time, we would see stars and galaxies move. Stars orbit the centre of the Milky Way and galaxies are pulled together by each other's gravity. Sometimes they even collide. Hubble has observed numerous galaxies crashing together.*		**VIDEO:** **NIGHT SKY, SLOWLY ROTATING**  **DUBINSKI SIMULATION**
8. **3:50** **BALLET: HST IMAGES OF GALAXIES COLLIDING, MUSIC** ***NARRATOR:*** *Like majestic ships in the grandest night, galaxies can slip ever closer until their mutual gravitational interaction begins to mould them into intricate figures that are finally, and irreversibly, woven together. It is an immense cosmic dance, choreographed by gravity.*		.   

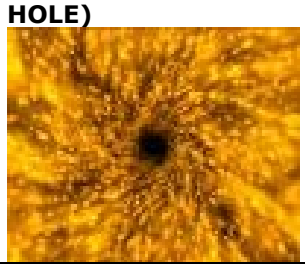
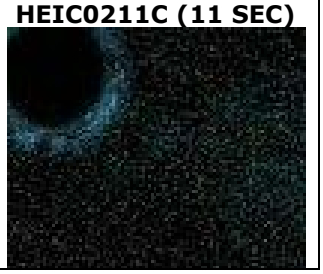
		
9. **5:15** **SOUND: COG-WHEELS TURNING, BIG DOOR CREAKING. LIKE IN THE IMAX FILM TITANIC. MUSIC. POETIC. DRAMATIC.** ***NARRATOR:*** *When two galaxies collide, it's not like a car crash or two billiard balls hitting each other, it is more like interlocking your fingers. Most of the stars in the galaxies will pass unharmed through the collision.* *At worst, gravity will fling them out, along with dust and gas to create long streamers that stretch a hundred thousand light-years or more. The two galaxies, trapped in their deadly gravitational embrace, will continue to orbit each other, ripping out more gas and stars to add to the tails. Eventually, hundreds of millions of years from now, the two galaxies will settle into a single, combined galaxy.* *It is believed that many present-day galaxies, including the Milky Way, were assembled from such a coalescence of smaller galaxies, occurring over billions of years.* *Triggered by the colossal and violent interaction between the galaxies, stars form from large clouds of gas in firework bursts, creating brilliant blue star clusters.*		**DUBINSKI COLLISION SIMULATION** 
10. **6:10** **ANDROMEDA COLLISION** ***NARRATOR:*** *Our own Milky Way is on a collision course with the nearest large galaxy, the Andromeda galaxy. They are approaching each other at almost 500000 kilometres per hour and, in three billion years, will collide head-on. The direct collision will lead to a magnificent merger between the two galaxies, during which the Milky Way will no longer be the spiral galaxy we are familiar with. Instead, it will evolve into a huge elliptical galaxy, containing all of its own stars and all those of the Andromeda galaxy too.*		**VIDEO:** **COLLISION IN THE SKY**  **DUBINSKI MWA1 OR MWA2**

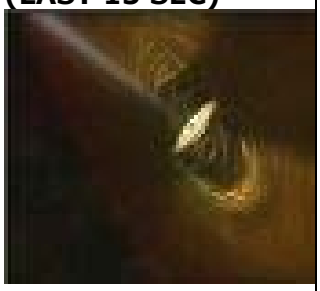
11. **6:45** **MUSIC: GLOOMY MUSIC STARTS** ***NARRATOR:*** *Seen from the Earth the collision will look something like this.* *Although this will not happen for a very long time, there are other dark forces of nature in play everywhere around us, even as we speak…* **7:05 END**		**VIDEO:** **DUBINSKI MERGER SEEN FROM SUN SIMULATION**

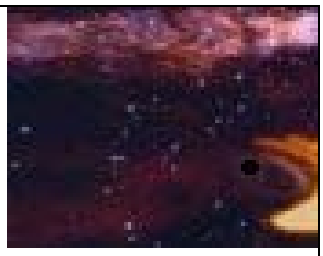
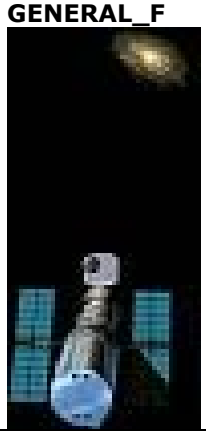
6 Monsters in Space (07:52)

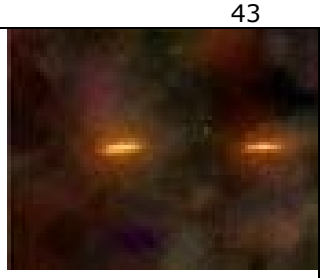
Messages:

1. Black holes are mysterious, impressive, fascinating objects.
2. BHs are disruptive entities, the nature of which we can only imagine.
3. The only way to have a look at them is to watch their interaction with the surrounding medium. Hubble has seen that.
4. Astronomers believe that they are the final collapse of a very massive star our, that keep feeding itself and becomes bigger and bigger.
5. Disruption of stars, merging of BHs
6. Mysterious effects? frame-dragging, incomprehensible GR effects, time dilation, bending of light, wormholes, maybe important for galaxy evolution?
7. Our Universe is full of enormously powerful objects.
8. Quasars fed by BH
9. GRB, enormous blasts (encounter of two super-dense objects?)

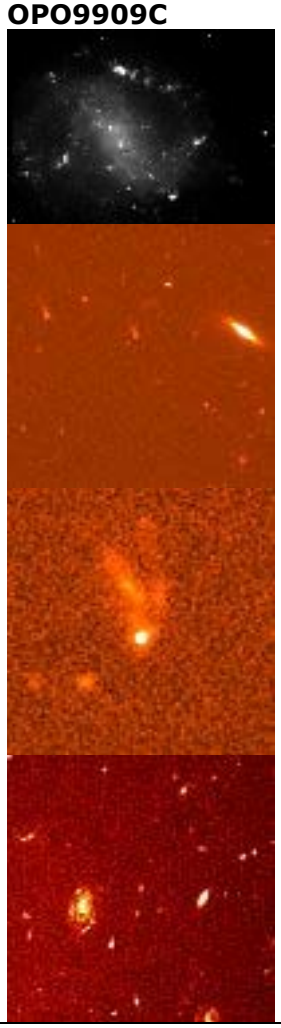
1. **00:00** **MUSIC: SCREAMING FIDDLES, DRAMATIC, DEEP RUMBLING, CAPTIVATING, SCARY** ***NARRATOR:*** *Black holes are the enigmatic villains of the Universe: swallowing all that comes their way, allowing nothing to escape.*		**VIDEO:** **0:11-0:17 OF BLACK_HOLE_LG (2 X LONGER)** 
2. **00:30** **MUSIC: VOLUME GOES UP, STOPPING AT THE END OF THE VIDEO)** ***NARRATOR:*** *So for astronomers, the centre of a black hole is the ultimate unknown…*		**VIDEO:** **BH.AVI (TO THE CENTRE OF A BLACK HOLE)** 
3. **00:40** ***NARRATOR:*** *No information can escape from within a black hole's gravitational stronghold. There is no way to find out what is in there.* *Not even light can escape. So how do we know that they are even there?*		**VIDEO:** **HEIC0211C (11 SEC)** 

4. **01:00** **BOB, VS.** ***BOB:*** *Black holes themselves cannot be observed directly. However, astronomers can study the indirect effects of Black Holes because the one thing they have in abundance is gravity.* *Hubble's high resolution has revealed the dramatic distorting effects of black holes on their surroundings.* **AUDIO: SOUND_OF_A_BLACK_HOLE (WAV FILE, IS THE REAL SOUND OF A BLACK HOLE, SPACELINK.NASA.GOV)** *And not just gravity, astronomers have found that when material is packed tightly enough around a black hole it can ring like a bell. This is the actual note produced by a black hole 250 million light years from Earth. It reverberates through the disc of matter surrounding the black hole and has been altered to bring it within the range of human hearing. In reality it is a B flat, 57 octaves below middle C.*		**ON THE SCREEN:** **IMAGES:** **NGC_4261_2**  **NGC_6251**  **OPO9822B** 
5. **01:50** **BOB, VS.** ***BOB:*** *Astronomers believe that black holes are singularities – simple points in space. No volume, no extension, but infinitely dense! Black holes can be created during the final collapse of a massive star, many times the size of the Sun.* *The stellar corpse left over from the demise and collapse of a massive star can be so heavy that no force in nature can keep it from crumpling under its own weight into an infinitely small volume.* *Although the matter has apparently disappeared, having been compacted into nothingness, it still exerts a powerful gravitational pull and stars and other objects that come too close can be pulled in.*		**ON THE SCREEN** **VIDEO: G0601CENTAURU (LAST 15 SEC)** 
6. **02:35** ***NARRATOR:*** *For any black hole there is a point of no-return, called the "event horizon". Once something – a nearby star say - is pulled in past this point it will never been seen again. On its way towards the event horizon, the*		**VIDEO:** **RXJ1242_ TIDAL_DISRUPTION_ LG (43 SEC)**

doomed star will begin to follow a fatal, spiralling orbit. *As the star approaches the black hole still further, the matter closest to the hole feels a greater attraction than the rest of the star, sucking and stretching the star out towards the hole until…* *… the immense tidal forces pull it to pieces and devour it.*		
7. **03:25** ***NARRATOR:*** *There are quirkier aspects to these objects too, a twisting of space and time that warps and slows even the passage of time. All objects with a mass deform the very fabric of space and time, but black holes do this to an extreme degree.* *According to Einstein's famous theory of general relativity, an intrepid traveller who could visit a black hole and hang above the event horizon without being swallowed would eventually return to find himself younger than the people he had left behind.*		**RUBBER-MEMBRANE ANIMATION (ALSO FOR CORNELIA/DW)**
8. **04:10** ***NARRATOR:*** *Perhaps the most curious objects astronomers have hypothesized about are wormholes. A wormhole is essentially a "shortcut" through space time from one point in the universe to another point in the universe. Maybe wormholes, if they exist, will some day allow travel between regions in space faster than it would take light to make the journey through normal space.*		**WORMHOLE ANI (ALSO FOR CORNELIA/DW)**
9. **04:40** **BOB, VS.** ***BOB:*** *Hubble has proved that black holes are most likely to be present at the centre of all galaxies. There is one at the centre of our Milky Way – a giant, super-massive Black Hole, perhaps a million times bigger than those created from the collapse of massive stars.* *It could be the result of the merger of many star-sized black holes that were formed during the remote history of the galaxy.*		**ON THE SCREEN:** **GENERAL_F** 
10. **05:15** ***NARRATOR:*** *When two galaxies collide, the black holes at each of their centres will perform an elaborate dance.*		**VIDEO:** **BH_MERGE_LG (42 SEC, COULD BE FASTER)**

Long after the two galaxies have merged into one, their central black holes continue to orbit each other for hundreds of millions of years before their final violent merger into a single, weighty black hole. This final process is so powerful that it changes the fabric of spacetime enough that we may be able to observe it from the Earth with a new breed of gravitational-wave telescopes or from special spacecraft in orbit. *However, compared with the millions of years it takes for galaxies to merge, the final cataclysm at the cores would be relatively brief. So the odds of seeing such an event are small.*		
11. **06:10** **BOB, VS.** ***BOB:*** *Until as recently as 50 years ago, astronomers thought the universe was a mostly peaceful place.* *But this is far from the truth…* *Space is often shaken by violent events: cataclysmic explosions of supernovae, collisions of whole galaxies and the tremendous outpouring of energy due to the large amount of matter crashing into Black Holes…* *The discovery of quasars gave us the first clear glimpse of this turmoil …*		**ON THE SCREEN:** **~ 10 SEC OF A PEACEFUL FLIGHT THROUGH STARS** **~ 20 SEC OF EXPLOSIONS AND CATASTOFIC EVENTS**
12. **06:40** ***BOB:*** *To ground-based telescopes, quasars look like normal stars. And that is exactly what astronomers first thought they were, naming them "Quasi stellar" objects.* *But Quasars are in fact much brighter and further away than stars…* *They can shine more brightly than 1000 normal galaxies and are powered by supermassive Black Holes.*		**GROUND BASED IMAGES OF QUASARS**
13. **07:05** ***NARRATOR:*** *Stars that orbit too close are pulled apart, draining into the quasar like water into an enormous cosmic sink.* *The spiralling gas forms a thick disk, heated to a high temperature by its free-fall motion towards the black hole. The gas blasts its energy into space above and below the disk in colossal jets.*		**VIDEO:** **QUASAR ANI**

14. **07:30** ***BOB:*** *Quasars are found in a wide range of galaxies, many of which are violently colliding. There may be a variety of mechanisms for igniting quasars.* *Collisions between pairs of galaxies could trigger the birth of quasars, but Hubble has shown that even apparently normal, undisturbed galaxies harbour quasars.* *But quasars are not the only high energy objects astronomers have found….*		**ANOTHER QUASAR ANI** **IMAGES: OPO9635A, OR SEPARATELY: OPO9635A1, OPO9635A2. OPO9635A3, OPO9635A4, OPO9635A5, OPO9635A6** 
15. **08:00** **BOB OUTDOORS** ***BOB:*** *A serendipitous discovery is something you find while you're looking for something else. Such discoveries have often changed the course of astronomy.* **BOB LOOKS UP AT SKY (CAMERA FOLLOW), BOB SEES GRB** *Gamma Ray Bursts were discovered serendipitously in the late 1960s by U.S. military satellites that were on the lookout for Soviet nuclear tests. Instead of finding the most powerful detonations produced by humans, some of the most powerful blasts in the Universe itself were spotted…*		**OUTDOOR SCENERY WITH BOB** **F/X GRB**
16. **08:35** ***NARRATOR:*** *These astoundingly energetic blasts of gamma rays are detected at least once per day from random directions in the sky.* *Although Gamma Ray Bursts last only a few seconds, the energy they release is equal to the amount of energy radiated by our whole Milky Way over a couple of centuries.*		**VIDEO:** **GAMMA RAY (4 SEC, LONGER AND MORE POWERFUL)** 

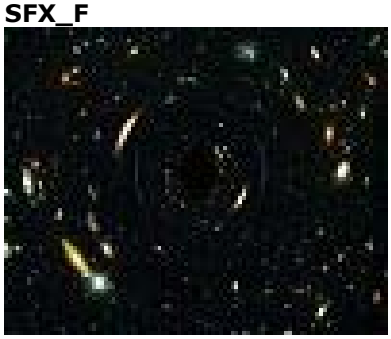
17. **08:58** ***NARRATOR:*** *Gamma rays are not visible to the human eye, and special instrumentation is needed to detect them. For 30 years, no one knew what caused these bursts. It was like seeing the gamma-ray bullet fly by Earth without ever glimpsing the weapon that fired it.* *Together with nearly all other telescopes in the world Hubble looked for the "smoking gun" for many years. It observed the positions in the sky where gamma ray explosions had been seen, trying to find any object at that location. But all efforts were in vain, until…*		**VIDEO??**
18. **09:40** ***NARRATOR:*** *In 1999 Hubble observations were fundamental in determining that these monstrous outbursts take place in far distant galaxies.*		**ON THE SCREEN:** **IMAGES: HEIC0003B, OPO9909B, OPO9909C** 
19. **10:00** ***NARRATOR:*** *The cause could be the blast produced in the final cataclysmic collapse of a massive star…*		**VIDEO: SUPERNOVA EKSPLOSION (HYPERNOVA)**

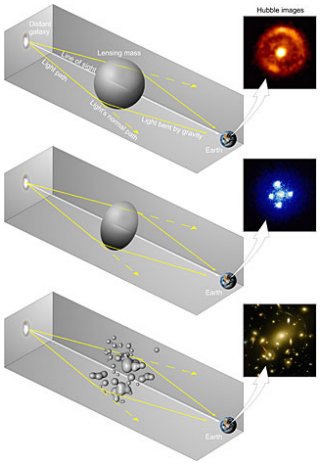
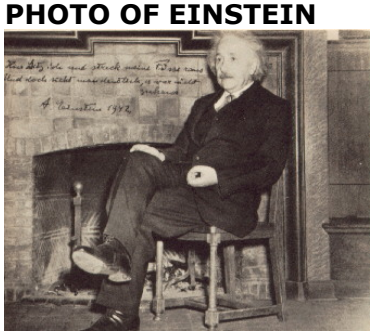
20. **10:10** ***NARRATOR:*** *... or the dramatic encounter of two very dense objects, such as two Black Holes, or a Black Hole and a neutron star.*		**VIDEO:** **GRB.MOV (~ 8 SEC)** 
21. **10:20** ***NARRATOR:*** *Black holes are certainly some of the most exotic objects in the Universe. As well as affecting matter they can also show up in some other spectacular ways because their enormous gravitational fields can also deflect light.* *In fact, rays of light that pass close to a Black Hole will not follow straight lines, but will be bent onto new paths, creating a natural telescope that can peer further into space than ever thought possible.* **10:50** **END**		**VIDEO: ??**

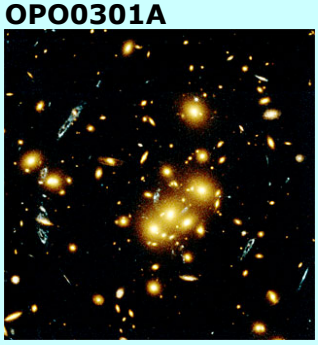
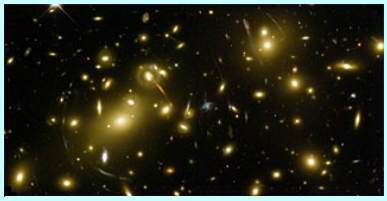
7 Gravitational Illusions (06:07)

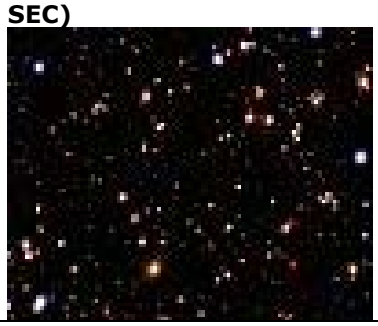
Messages:

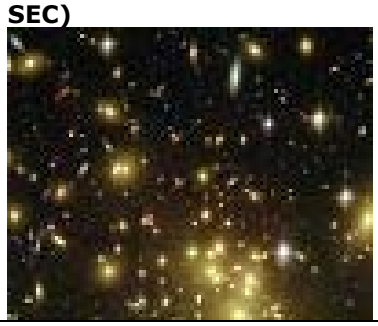
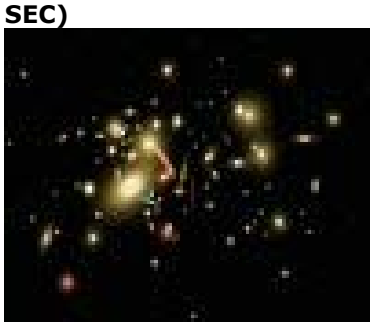
1. Mass can bend light.
2. Gravitational telescopes can boost, amplify and stretch light from distant objects
3. Hubble has seen the most distant galaxy known so far with this method.
4. Lenses make multiple images of the original galaxy each with a characteristically distorted banana-like shape.
5. Hubble has had the best view of these arcs.
6. Lenses come in many shapes, so the 'images' of the distant objects vary.
7. gravitational lensing can be used to 'weigh' clusters.
8. Lensing can be used to probe the 'hidden' dark matter in galaxy clusters and hence in the Universe as a whole.
9. Weak lensing??

1. **00:00** ***NARRATOR:*** *Just as a wanderer in the desert sees a mirage when light from remote objects is bent by the warm air hovering just above the sand, we may also see mirages in the Universe.* *The mirages we see with a modern telescope such as the Hubble Space Telescope do not arise from warm air, but instead from remote clusters of galaxies - huge concentrations of matter.*		**VIDEO: A WANDERER IN A DESERT**
2. **00:30** **BOB, OUTDOORS, BOB SHOWS HORIZON/FLATNESS WITH HAND** ***BOB:*** *Long ago some people thought the Earth was flat. This is in some way understandable - in our daily life we can't see the curvature of our planet. Space itself is actually curved, even though we can't see this for ourselves on a starry night. But the curvature of space does create phenomena that we can observe…*		**OUTDOOR SCENERY WITH BOB**
3. **01:00** ***NARRATOR:*** *One of Albert Einstein's predictions is that gravity warps space and therefore distorts rays of light, in the same way that ripples on a pond create a warped honeycomb pattern of light on the sandy bottom.* *Light from distant galaxies is distorted and magnified by the gravitational field of massive galaxy clusters on its path to Earth.* *The effect is like looking through a giant magnifying glass and the result is called gravitational lensing.*		**ANI:** **RIPPLES MAKING CAUSTICS.** **VIDEO:** **SFX_F** 

4. **01:40** ***BOB**: The weird patterns that rays of light create when they encounter a weighty object depend on the nature of the "lensing body". Thus, the background object can appear in several guises….* **FIRST PART OF THE IMAGE, GREY SCHEME AND THEN ZOOM ON THE HUBBLE IMAGE.** *…Einstein rings where the whole image is boosted and squeezed in a circle of light…* **SECOND PART OF THE IMAGE, THEN ZOOM ON THE HUBBLE IMAGE OPO9020A.** *…multiple images, ghostly clones of the original distant galaxies…* **THIRD PART OF THE IMAGE, THEN ZOOM ON HEIC0113C (ABELL 2218)** *…or distorted into banana-like arcs and arclets.*		**ON THE SCREEN:** **IMAGE HEIC0404B** 
5. **02:20** **BOB, VS.** ***BOB:** Though Einstein realized in 1915 that this effect would happen in space, he thought it could never be observed from Earth.* *However in 1919 his calculations were indeed proved to be correct. During a solar eclipse expedition to Principe Island near the west coast of Africa, led by the renowned British astronomer Arthur Eddington, the positions of stars around the obscured solar disk were observed. It was found that the stars had moved a small but measurable distance outwards on the sky, compared with when the Sun was not in the vicinity.*		**ON THE SCREEN:** **PHOTO OF EINSTEIN**  **SUN WITH AND WITHOUT OUTWARDS DEFLECTION OF BACKGROUND STAR**
6. **03:05** ***NARRATOR:** Nowadays, faint gravitational images of objects in the distant Universe are observed with the best telescopes on Earth, and, of course, with the sharp-sighted Hubble.*		**VIDEO:** **HEIC0404B (42 SEC, WE COULD SHORTEN THE PART WITH HUBBLE)** 

7. **03:20** ***NARRATOR:*** *Hubble was the first telescope to resolve details within the multiple arcs, revealing the form and internal structure of the lensed background objects directly.*		**BALLET:** **OPO0301A**  **HEIC0113C**  **OPO9610A?** 
8. **04:20** ***NARRATOR:*** *In 2003, astronomers deduced that a mysterious arc of light on one of Hubble's images was the biggest, brightest and hottest star-forming region ever seen in space.*		**VIDEO:** **HEIC0312J (9 SEC) AND**  **FLOATING TEXT: 'LINX ARC'** **HEIC0312C (15 SEC, CAN BE LONGER)** 

9. **04:40** **BOB, VS.** ***BOB:*** *It takes fairly massive objects, for example, clusters of galaxies, to make space curve so much that the effect is observable in deep images of the distant Universe - even with Hubble's astonishing resolution.* *And so far gravitational lenses have mainly been observed around clusters of galaxies, which are collections of hundreds or thousands of galaxies and are thought to be the largest gravitationally bound structures in the Universe.*		**ON THE SCREEN:** **VIDEO:** **HEIC0312H (14 SEC)**  **HEIC0312G (12 SEC)** 
10. **05:15** ***NARRATOR:*** *Astronomers know that the matter we see in the Universe is just a tiny percentage of the total mass that must be there. For matter exerts a gravitational force, and the visible stuff is simply not enough to hold galaxies and clusters of galaxies together.* *Since the amount of warping of the 'banana'-shaped images depends on the total mass of the lens, gravitational lensing can be used to 'weigh' clusters and to understand the distribution of the hidden dark matter.*		**VIDEO:** **HEIC0309A (52 SEC, CAN BE SHORTENED, NO LONG ZOOM FROM HUBBLE)**  **?? VIDEO:** **CXODARKMATTER_640.MPG (24 SEC)??** 
11. **05:55** ***BOB:*** *On clear images from Hubble one can usually associate the different arcs coming from the same background galaxy by eye.* *This process allows astronomers to study the details of galaxies in the young Universe and too far away to be seen with the present technology and*		**VIDEO: HEIC0309B (11 SEC)** 

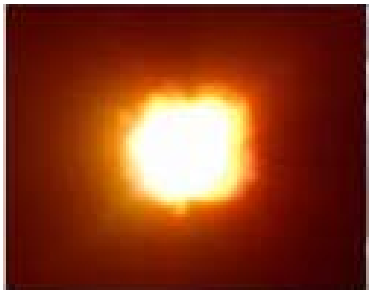
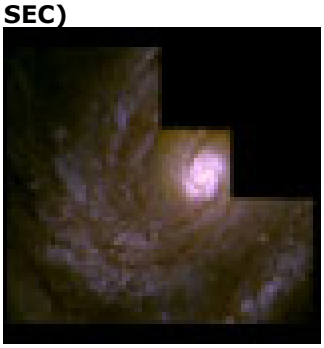
telescopes.		**VIDEO: HEIC0309C (11 SEC)** 
12. **06:15** ***NARRATOR:*** *A gravitational lens can even act as a kind of 'natural telescope'. In 2004, Hubble was able to detect the most distant galaxy in the known Universe, using the magnification from just such a 'gravitational lens' in space.* **06:40** **END**		**VIDEO: HEIC0404A (32 SEC)** 

8 Birth and Death of the Universe (05:54)

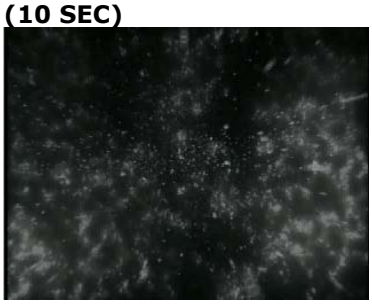
Messages:

1. The scales of time and space are huge. It's hard even to imagine.
2. To look further away means looking further back in time, because the speed of light is finite.
3. Cepheids, Hubble constant key project, age
4. SN - > acceleration
5. Dark energy
6. Change of acceleration

1. **00:00** **BOB IN VS.** ***BOB:*** *Light may travel through a vacuum at the highest speed anything can ever reach, but it is still a* ***finite*** *speed.* *This means that it takes a while for rays of light to travel between two points in space.* *The speed of light through space is about 300000 kilometres per second. 300 thousand kilometres is nearly the distance from the Earth to the Moon.* *So it takes light just over a second to travel from the Moon to the Earth. When we look at the Moon we see it as it was just over a second ago.*		**ON THE SCREEN** **TRAVELLING AT THE SPEED OF LIGHT** **A LIGHTNING** **THE MOON**
2. **00:45** ***NARRATOR:*** *Who hasn't thought about what it would be like to travel in time?* *The finite speed of light enables us to get close by allowing us to look back in time. When looking out into space, we just need to wait for the light from distant places to reach us, and it shows how things were when the light began its journey.* *Powerful instruments, like Hubble, have made it possible to look farther out and farther back than ever before. What cosmologists are seeing is simply astounding.*		**VIDEO: ZOOM ON DISTANT OBJECTS: FOR EXAMPLE HEIC0402A** 

3. **01:25** ***BOB:*** *In the 1920s, astronomer Edwin Hubble discovered that most galaxies appear to be moving away from us at a rate proportional to their distance. The farther away a galaxy is, the faster it appears to be moving away from us. This is due to the expansion of the Universe.*		**-RECEEDING GALAXIES ANI** **-> EXPANDING SPACE TIME FRAMEWORK ANI**
4. **01:50** ***NARRATOR:*** *That expansion began in a titanic explosion, called the Big Bang, many billions of years ago.* *The rate of expansion holds the key to estimating the age and size of the universe. This rate is called the* ***Hubble constant****.* *The age and size of the universe can be estimated by "running the expansion backwards" – until everything is compressed into that infinitely small point of energy from which the universe was generated.*		**VIDEO: UNIVERSE EXPANDING (HEIC0306F?, 55 SEC) BIG BANG ANI:**  **RUNNING THE BIG BANG BACKWARDS ANI**
5. **02:15** ***NARRATOR:*** *The top ranked scientific justification for building Hubble was to determine the size and age of the Universe.* *The quest to determine the Hubble constant precisely was headed by the Key Project team, a group of astronomers who used Hubble to look for remote, accurate "milepost markers", a special class of stars called Cepheid variables.*		**VIDEO: M100_CEPHEIDS (22 SEC)** 
6. **02:40**		**BALLET:** **HUBBLE KEY PROJECT GALAXIES** **NGC 300, NGC 4414, NGC 4603**

7. **03:40** ***NARRATOR:*** *Cepheids have very stable and predictable brightness variations. The period of these variations depends strictly on the physical properties of the star, which can be used to determine their distance very effectively.* *For this reason these stars are better known as 'standard candles'.* *The Cepheids have been used as reliable stepping-stones to make distance measurements for supernovae, which are much brighter than Cepheids and so can be seen at far greater distances.*		**BLINKING CEPHEIDS**
8. **04:15** **BOB, VS.** ***BOB:*** *Hubble has measured the light from supernova explosions more accurately than any other instrument, mostly due to its high resolution. From the ground an image of a supernova usually blends in with the image of its host galaxy. Hubble can clearly distinguish the light from the two sources.* *Cepheids and supernovae have given a measure for the scale of the Universe. Today we know the age of the Universe to a much higher precision than ever before: around 14 billion years, thanks to Hubble.*		**ON THE SCREEN.** **VIDEO: SN_IN_ELLIPTICAL(HS) (8 SEC)** 
9. **05:55** ***BOB:*** *For many years astronomers have discussed whether the expansion of the Universe would stop in some distant future, making the universe collapse in a fiery "Big Crunch", or whether it would continue to expand ever more slowly.* *Combined observations of distant supernovae with Hubble and most of the world's top-class telescopes were used to measure distances to remote supernovae. And it looks like the expansion of our universe is nowhere near slowing down. Instead, it seems to be speeding up.*		**VIDEO: HEIC0406A (START AT 13 SEC – NO ZOOM FROM HUBBLE – AND STOP AROUND 28 SEC, WHEN IT LOOKS COLD AND DARK)** 

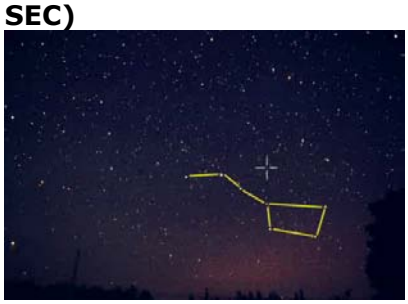
10. **06:35** ***NARRATOR:*** *When Hubble was used to measure how the expansion of the Universe has changed with time, it turned out, quite surprisingly, that during the first half of cosmic history, the expansion rate was actually slowing down. Then, a mysterious force, a sort of "anti-gravity" made the Universe 'hit the gas pedal' starting the acceleration we see today.* *This suggests an extraordinary fate for the Universe because it implies that the anti-gravity force is getting stronger all the time. If this continues, it will eventually overwhelm all gravity and catapult the Universe into a super fast acceleration that will shred everything into its constituent atoms. Cosmologists have called this nightmare scenario, the Big Rip.* **07:30** **END**		**VIDEO:** **BIG_BANG_ACCELERATION(HS)** **(10 SEC)** 

9 Looking to the end of time (11:26)

Messages:

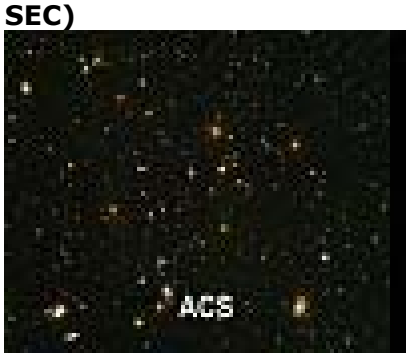
1. Faint objects are the 'fossil' of the young universe. We can directly see how the first stars formed.
2. Looking at different distances allows us to compare different stages of the life of the same kind of objects, which means studying the evolution of our universe.
3. Hubble gave start to a new branch of astronomical observations. Since the first deep field gave its amazing results, every ground-based telescope has started making deep surveys of the sky.

1. **00:00** ***NARRATOR:*** *We are collecting unexpected news from deep space. Just as geologists dig deeper underground to find ever more ancient fossils, bearing witness to ever more remote epochs, so astronomers 'excavate' deeper and deeper towards the beginning of time, by looking for light coming from fainter, and thus more distant, objects.* *Hubble started a new era we could call 'astroarcheology' and it began during Christmas, 1995…*		**VIDEO:** **ARCHEOLOGISTS DIGGING??**
2. **00:30** ***NARRATOR:*** *Pointing the world's most sophisticated telescope at the same piece of sky for ten days in a row may sound a bit strange. And this was what many astronomers thought when they tried it for the first time at the end of 1995.*		**VIDEO: HUBBLE IN ORBIT (15 SEC)** **GENERAL_A (20 SEC) OR GENERAL_H (8 SEC)** 
3. **00:50** **BOB, VS.** ***BOB:*** *Deep field observations are long-lasting exposures pointing at a particular region of the sky. They aim to reveal faint objects by collecting as much light as possible over a long period of time. The 'deeper' an observation goes, the fainter are the objects that become visible.* *Objects in the sky can either look faint because their natural brightness is low, or because their distance is great.*		**ON THE SCREEN:**
4. **01:20** **I/V PIERO ROSATI:**		**I/V PIERO ROSATI** **TAKE IT FROM HEIC0406H**

"When this experiment was first proposed, nobody really knew if this would lead to any interesting scientific results. *But when we first looked at the image we were astonished! We could see more than 3000 galaxies in this small field."*		 **VIDEO:** **HEIC0406F (7 SEC)** 
5. **01:50** ***NARRATOR:*** *The thousands of galaxies observed in the first Deep Field were at various stages of evolution and were strung out along a corridor of billions of light-years. This allowed astronomers to study the evolution of these objects through time, glimpsing different galaxies at different stages of their lives.* *The observed region of sky in Ursa Major, the Big Dipper, was carefully selected to be as empty as possible so that Hubble would look far beyond the stars of our own Milky Way and out past nearby galaxies.*		**VIDEO:** **ZOOM_ON_HDF(HS) (24 SEC)** 
6. **02:30** ***NARRATOR:*** *After the first deep field, another long exposure was taken in the Southern sky.* *Together, the Hubble Deep Field North and South gave astronomers peepholes to the ancient Universe for the first time.* *Some of the objects viewed on the images were so dim that seeing them would be as difficult as discerning a flashlight on the Moon from Earth.*		**VIDEO:** **HDFN_S_TARGETS(HS)** 

7. **03:05** **I/V PIERO ROSATI:** *"We could definitely tell that the Hubble Deep Field opened a whole new era of observational cosmology. It formed our view of the distant universe".*		**I/V PIERO ROSATI** 
8. **03:20** **BOB, VS.** ***BOB:*** *The Hubble Deep Fields have caused a real revolution in modern astronomy.* *After the first Deep Field, almost all ground- and space-based telescopes were pointed to this same area for long periods. Some of the most interesting results in astronomy emerged from this fruitful synergy between instruments of different sizes, in different environments and with sensitivity to different wavelengths.* *They gave us the first clear picture of the rate of star formation throughout the Universe. Astonishingly, it showed that star formation peaked within a few billion years of the Universe's creation. At that time, over ten times more stars were forming than today.*		**ON THE SCREEN:** **VIDEO:** **HEIC0406D** **(18 SEC)** 
9. **04:10** ***NARRATOR:*** *Once they had begun to discover the most distant universe ever seen, Hubble astronomers tried to push their observations even farther back in time.* *In 2003 and 2004, Hubble performed its deepest exposure ever: the Hubble Ultra Deep Field.* *It is a 28 day-long exposure, going much deeper than the earlier Hubble Deep Fields North and South.*		**VIDEO:** **HEIC0406A (38 SEC)** 
10. **04:50** ***BOB:*** *The Hubble Ultra Deep Field reveals the first galaxies to emerge from the so-called "dark ages" - the time shortly after the big bang when the first stars reheated the cold, dark universe.*		**COSMIC HISTORY ANI** **HEIC0406G (37 SEC)**

		
11. **05:20** ***NARRATOR:*** *Just after the Big Bang, in the newborn fast-expanding Universe – before the era of the stars and galaxies - the distribution of matter was fairly smooth.* *As time went on, the king of all forces – gravity – started acting. Slowly, but steadily…* *Under the influence of gravity from the mysterious dark matter, small clumps of normal matter started to coalesce in regions where the density was slightly higher than average. With no stars to light up space, the universe was in its dark age.* *Where the density of the clumps became higher, even more matter was attracted, and a competition between the expansion of space and gravity took place.* *Where gravity won, regions stopped expanding, and started to collapse in on themselves. The first stars and galaxies were born.* *Where the matter density was highest – at the intersections between the large web-like structures of matter - the largest structures we know were formed: clusters of galaxies.*		**DUBINSKI GALAXY FORMATION – KOSMIK KRUZ, GE-LIGHT** **DUBINSKI CLUSTER FORMATION -SWARM**

12. **06:40** ***NARRATOR:*** *The Deep Field images are studded with a wide range of galaxies of various sizes, shapes, and colours.* *Astronomers will spend years studying the myriad shapes of the galaxies in this image to understand how they formed and have evolved since the Big Bang.* *In vibrant contrast to the image's rich harvest of classic spiral and elliptical galaxies, there is also a zoo of oddball galaxies littering the field. Some look like toothpicks; others like links on a bracelet. A few appear to be interacting with each other. Their strange shapes are a far cry from the majestic spiral and elliptical galaxies we see today. These oddball galaxies chronicle a period when the Universe was more chaotic, when order and structure were just beginning to emerge.*		**HEIC0406B (88 SEC, SHORTEN)** 
13. **07:40** ***BOB:*** *One of the great things about Hubble is that there are many instruments onboard that can make different observations at the same time. The Hubble Ultra Deep Field is actually two separate images taken by two instruments: Hubble's ACS camera and the NICMOS instrument. NICMOS sees even farther than the ACS. It detects infrared light, and so it's able to reveal the farthest galaxies ever seen because the expanding universe has stretched and weakened the light from these objects so much that, they're now only visible at infrared wavelengths.*		**VIDEO: HEIC0406C (29 SEC)** 
14. **08:15** **FINAL BALLET WITH THE HUDF 3D ANIMATION.** ***NARRATOR:*** *If we place all the galaxies in the Ultra Deep Field at their correct distances we can make a virtual flight back in time. Only then can we really appreciate this immense archaeological probe of the universe!!*		**VIDEO: V0428AL (58 SEC)** 

15. **09:15** ***NARRATOR:*** *The Hubble Ultra Deep Field is likely to remain the deepest image of the Universe for the next decade or so, until an ESA Ariane rocket launches the James Webb Space Telescope in 2011.* *Up until today, during the first 15 years of its life, Hubble has orbited the Earth 80,000 times. This is the same as three and a half billion kilometres or 24 times the distance from the Earth to the Sun.* *Hubble has taken more than 500000 exposures of the Universe and created a visual heritage that has shaped the way humanity looks at the Universe today.* *But Hubble's perhaps greatest legacy has been to open our eyes to the incredible beauty of nature. Not only 'out there' in the depths of cosmos, but also everywhere around us in our daily lives.* *And it's no where finished yet…* **BACKGROUND MUSIC BECOMES LOUDER.** **10:15** **[TITLE MUSIC]** **END TITLES (SEE 12 BELOW)** **11:00** ***** END *****		**HUBBLE IN SPACE, ORBITING EARTH** **JWST?** **SUMMARY OF HUBBLE IMAGES, MANY, SHORT, BUT SMOOTH TRANSITIONS.** **REAL NATURE IMAGES**

10 End titles

Hubble – 15 years of discovery

This movie is dedicated to all the hard working people in USA and Europe who have made the Hubble Space Telescope an incredible scientific success

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In particular thanks to
Greg Bacon (STScI/NASA)
Lars Bachmann (SDC)
Dimitri Bogdanov (Voksenuddannelsescenter Frederiksberg)
Cornelia Borrmann (Deutsche Welle)
John Dubinski (University of Toronto/CITA)
John Kameel Farah
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And of course: our girlfriends and families!

The Hubble Space Telescope is a project of international cooperation between ESA and NASA.

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