EYES ON THE SKIES

400 YEARS OF TELESCOPIC DISCOVERY

Contents (w. minimum durations)

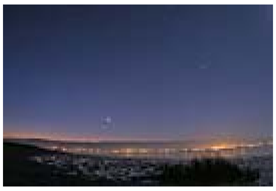
Total duration: 60 MIN

Yellow background: narrator
Blue background: presenter (Dr. J.)

Legend:

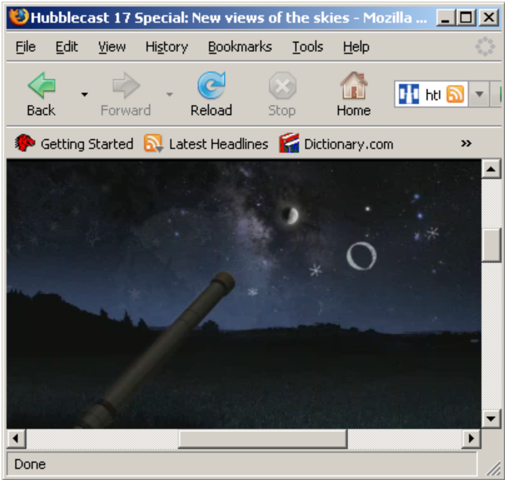
(red)	No Image
(red)	File downloaded, low resolution, questionable copyrights
(yellow)	File downloaded, resolution medium, questionable copyrights
(teal)	File downloaded, good resolution, questionable copyrights
(green)	File downloaded, rights good, resolution good
(grey)	File requested
(purple)	Contact information

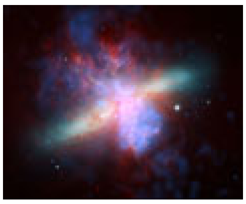
0. Prelude (1:13)

00:00 **[A5]** **By taking our sense of sight far beyond the realm of our forebears' imagination, these wonderful instruments, the telescopes, open the way to a deeper and more perfect understanding of nature.** ***—René Descartes, 1637*** **00:10 (1)** **Narrator**: For millennia mankind gazed out into the mesmerising night sky without recognising the stars of our own Milky Way Galaxy as other suns... or the billions of sister galaxies making up the rest of our Universe... ...or that we are merely punctuation in the Universe's 13.7 billion year-long story. With only our eyes as observing tools we had no means of finding solar systems around other stars, or of determining whether life exists elsewhere in the Universe. **00:38 Dr. J [1.1.a.3 or 1.a.1.5]** Today we are well on our way to unravelling many of the mysteries of the Universe, living in what may be the most remarkable age of astronomical discovery. I am Dr. J and I will be your guide to the telescope – the amazing instrument that proved to be mankind's gateway to the Universe. 0:53 TITLE SEQUENCE	Stars moving above landscapes. No people. No telescopes. TWAN footage. Captivating. Deep. Cosmic. Back to our roots.    CFHT_FullMoon_1080p_Cuillandre.avi (Credit: Canada-France-Hawaii Telescope / Coelum) TITLE music

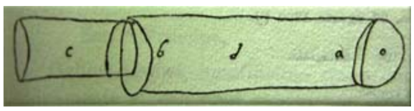
EYES ON THE SKIES The story of the telescope 01:13	

1. New views of the skies (09:20)

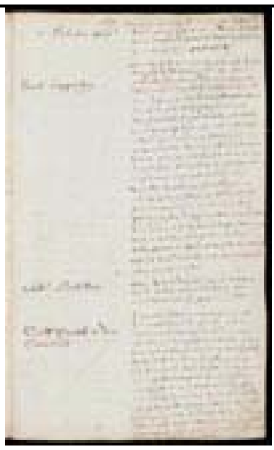
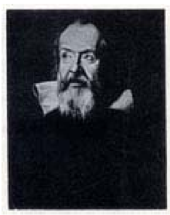
00:00 (2) **Narrator**: Four centuries ago, in 1609, a man walked out into the fields near his home. He pointed his homemade telescope at the Moon, the planets and the stars. His name was Galileo Galilei.	 Image of Galileo Galilei 
Astronomy would never be the same again.	 http://www.spacetelescope.org/images/original/heic0719a.tif (heic0719a.tif) 

	http://www.spacetelescope.org/images/html/opo0328a.html (Hubble_sombrero_galaxy_opo0328a.tif)     
01:40 (3) Today, 400 years after Galileo first pointed a telescope to the skies, astronomers use giant mirrors on remote mountaintops to survey the heavens.	VLT video

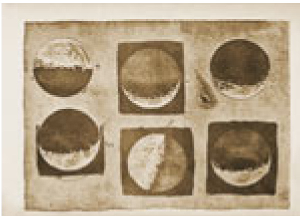
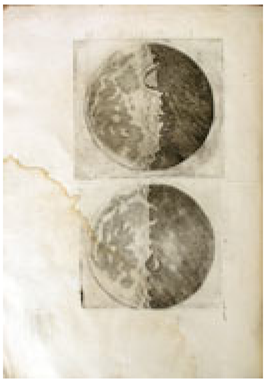
	 CFHT_Moonlight_720p_Cuillandre.avi (Credit: Canada-France-Hawaii Telescope / Coelum) NRAO DVD With GBT, ALMA and VLA
Radio telescopes collect faint chirps and whispers from outer space.	Australian Telescope Array 
Scientists have even launched telescopes into space, high above the disturbing effects of our atmosphere.	Shuttle launch 
And the view has been breathtaking!	 [MUSIC UP – dramatic fanfare, celebration, earth shattering]
02:10 (4) (Take 1.6) **Dr. J**: However Galileo did not, in fact, invent the telescope. That credit goes to	Dr. J. in Virtual Studio

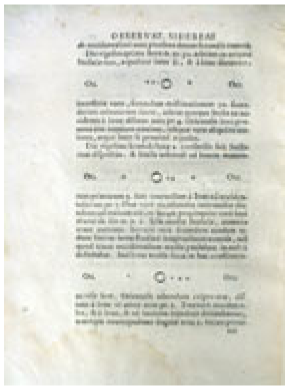
Hans Lipperhey, a slightly obscure Dutch-German spectacle maker. But Hans Lipperhey never used this telescope to look at the stars. Instead, he though his new invention would mainly benefit seafarers and soldiers.	 H412034.jpg (Credit: Science Photo Library) See P. Borellus: De vero telescopii inventore, 1655
Lipperhey came from Middelburg, then a large trading city in the fledgling Dutch Republic.	Zoom on Middelburg 2D View(s) of Middelburg. Marketplace noises  (Middelburg_1657_Janssonius.jpg)  Middelburg _22547_cleaned.tif
02:30 (5) (Take 5.3) In 1608 Lipperhey found that when viewing a distant object through a convex and a concave lens the object would be magnified, if the two lenses were placed at just the right distance from one another.	Simple animation: parchment paper extruded to tube with two lenses.  Dissolve to 3D model of Lipperhey's telescope

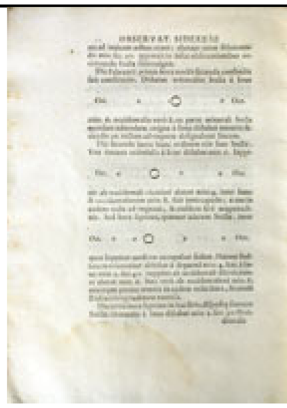
The telescope was born!	Celebration sounds [aaahhh]
In September 1608 Lipperhey revealed his new invention to Prince Maurits of the Netherlands.	Look at picture through a lens  (Middelburg_Stadhuis.JPG) (GNU)
[6] (Take 6.5) He could not have chosen a more advantageous moment because at that time the Netherlands were embroiled in the 80 Years' War with Spain. The new spyglass could magnify objects and so it could reveal enemy ships and troops that were too distant to be seen by the unaided eye. A very useful invention indeed!	Full screen: Scene(s) from 80-year war.  **Prince Maurice at the Battle of Nieuwpoort** **Ch.1_battle_of_Nieuwpoort.jpg** Noise, cannons, screams, horses, weapons, the smell of gun smoke
But the Dutch government never granted Lipperhey a patent for his telescope.	Lipperhey's patent application. Nationaal Archief + p.15 in De Telescoop

	 (Hans_Lipperhey_Patent_Application.jpg) (info@nationaalarchief.nl) USE PROPER CITATION
The reason was that other merchants also claimed the invention, especially Lipperhey’s competitor Sacharias Janssen. The dispute was never resolved.	Portrait of Janssen.  03:04 – img31.gif http://pages.sbcglobal.net/ttauri/page5.html
And to this day, the true origins of the telescope remain shrouded in mystery.	The whole scene (of Dr. J. in Virtual Studio) slowly goes up in smoke.
03:30 (6) **Narrator**: Italian astronomer Galileo Galilei, the father of modern physics, heard about the telescope and decided to build his own.	Galileo’s portrait. 

	Ch_1_Galileo-SPC-003-det.jpg (OU)  Ch_1_Galileo-SPC-002.jpg (OU)
03:40 (7) **[Deep male voice]** **[B2]** **Galileo**: *About ten months ago, a report reached my ears that a certain Fleming had constructed a spyglass by means of which visible objects, though very distant from the eye of the observer, were distinctly seen as if nearby.*	 Ch_1_Galileo-SPC-004.jpg (OU)  Ch_1_Galileo-SPC-001-det.tif (OU)
03:55 (8) **Narrator**: Galileo was the greatest scientist of his time. He was also a strong supporter of the new worldview advocated by Polish astronomer Nicolaus Copernicus, who proposed that the Earth orbited the Sun instead of the other way around.	Animation changing from the Ptolemaic world view into the Copernican world view 
Based on what he had heard of the Dutch telescope, Galileo constructed his own instruments. They were of a much better quality.	3-d Galileo Telescope  telescope_galileo4comp.tif

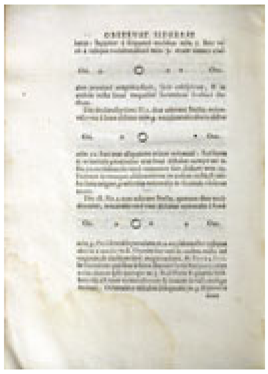
04:15 [Deep male voice:] (9) **[C2]** **Galileo**: *Finally, sparing neither labour nor expense, I succeeded in constructing for myself so excellent an instrument that objects seen by means of it appeared nearly one thousand times larger than when regarded with our natural vision.*	USE MARTIN'S DRAWING The photo extrudes from a drawing on parchment to a 3D computer model of the telescope, slowly turning  telescope_galileo4comp.tif
04:30 (10) **Narrator**: It was time to train his telescope on the heavens.	Image of Galileo  R102087.jpg (Credit: Science Photo Library)
04:48 [Deep male voice:] (11) **[D2]** *I have been led to the opinion and conviction that the surface of the moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the Earth.*	Map of Padua and Padua night scene Galileo's drawings of the moon on old parchment ...  Ch_1_Galileo_moon_3.tif 

	Ch_1_Galileo_moon_4.tif
05:05 (12) (Take 12.1.1) **Dr. J**: A landscape of craters, mountains, and valleys. A world like our own!	The parchment extrudes to the real Moon that flies past Dr. J Credit for the images: NASA/Goddard Space Flight Center Scientific Visualization Studio.  **Ch_1_moonrot_still.2161.tif**
A few weeks later, in January 1610, Galileo looked at Jupiter. Close to the planet he saw four pricks of light that changed their position on the sky night after night along with Jupiter. It was like a slow, cosmic ballet of satellites orbiting the planet. These four pricks of light would come to be known as the Galilean moons of Jupiter.	Galileo’s drawings of the Jovian satellites. Extrudes to the real view of Jupiter Take drawings on the following pages and show them so that it looks like the pricks of light are moving   Ch_1_Galileo-1610-020v.tif

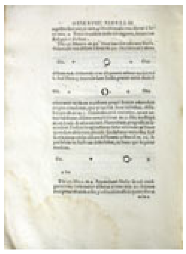


Ch_1_Galileo-1610-022v.tif

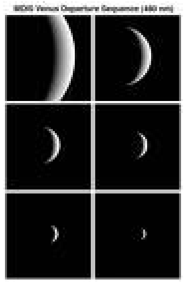
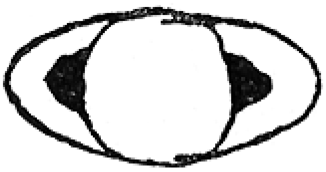
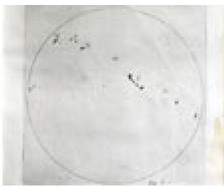
Ch_1_Galileo-1610-024v.tif



Ch_1_Galileo-1610-025v.tif

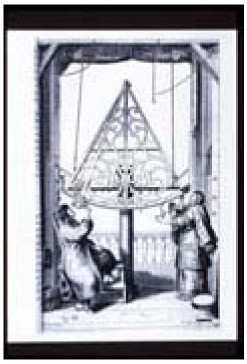


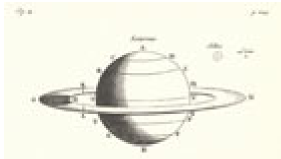
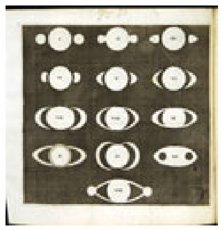
J:\EyesSkies\images\ch1\Ch_1_Galileo-1610-026v.tif

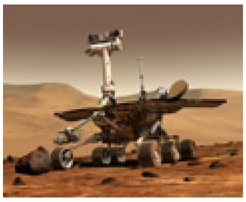
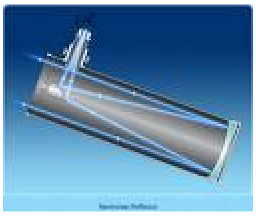
What else did Galileo discover? The phases of Venus! Just like the Moon, Venus waxes and wanes from crescent to full and back again.	Galileo’s drawings of the phases of Venus. Extrudes to the real view of Venus.  Galileo_venus_cleaned.jpg (OU)  (Credit: NASA/Johns Hopkins Applied Physics Lab)
Strange appendages on either side of Saturn.	Galileo’s drawings of Saturn, Extrudes to the real view of Saturn. 
Dark spots on the face of the Sun.	Galileo’s drawings of sunspots. Extrudes to the real view of the Sun.  Ch_1_Galileo-1613-Pt2-60-detail.jpg (OU) **Credit:** Science@NASA

	 sunspot_bigspotfd.tif http://sohowww.nascom.nasa.gov/gallery/images/bigspotfd.html (Credit: SOHO (ESA & NASA))
And, of course, stars. Thousands of them, maybe even millions. Each too faint to be seen by the naked eye.	Galileo's drawings of the Pleiades. Extrudes to the real view of the Pleiades.  Galileo-1610-016c-r_pleiades_clean.jpg  (Davide 10K tiff)
It was as if mankind had suddenly thrown off its blindfold. There was a whole Universe to discover out there.	Zoom out from Davide's Pleiades, so that huge amounts of stars become visible.
06:00 (13) **Narrator**: News about the telescope spread across Europe like wildfire.	Old map of 17^{th}-century Europe with arrows radiating away from Padua.
In Prague, at the court of Emperor Rudolph II, Johannes Kepler improved the design of	Zoom into Prague on map.

the instrument.	 blaue_europe_2.tif Portrait of Kepler comes up  (Johannes_Kepler_1610_cleaned.tif)
In Antwerp, Dutch cartographer Michael van Langren produced the first reliable maps of the Moon, showing what he believed to be continents and oceans.	Mark Antwerp. Van Langren's map of the moon comes up.  http://www.lpod.org/?m=20060128 06:12 – cat65.JPG
And Johannes Hevelius, a wealthy brewer in Poland, built huge telescopes at his observatory in Danzig. This observatory was so large that it covered three rooftops!	 06:20 – Hevelius-1647-062_1920.TIF (OU)

	 Johannes_Hevelius_portrait.png (PD)  http://www.sil.si.edu/Exhibitions/Voyages/2-24-Hevelius.jpg (Ch_1_2-24-Hevelius.jpg) (Smithsonian)  06:27 – Hevelius-1647-qtr_1080.JPG
But the best instruments of the time were probably constructed by Christiaan Huygens in the Netherlands.	Portrait of Huygens, image of his telescope come up.  06:30 – SIL14-H006-17a_1080.TIF

	 Huygens-SPC-001.tif
In 1655, Huygens discovered Titan, the largest moon of Saturn.	Huygens' drawing of Saturn and Titan comes up  **Huygens_Saturn_1.jpg** (http://www.phys.uu.nl/~huygens/huygens_en.htm)
A few years later, his observations revealed Saturn's ring system – something Galileo had never understood.	Huygens' drawing of Saturn's ring system comes up.  Huygens_Phases_of_Saturn_1.tif
And last but not least, Huygens saw dark markings and bright polar caps on Mars.	Huygens' drawing(s) of Mars comes up  06:48 – Huygens-Mars

Could there be life on this remote, alien world? The question occupies astronomers to this day.	 Alien.avi (martin) Mars Rover image
07:08 (14) (Take 14.1.2) **Dr. J:** The earliest telescopes were all refracting telescopes that used lenses to collect and bring together the starlight. Later the lenses were replaced with mirrors. This reflecting telescope was first built by Niccolò Zucchi and later refined by Isaac Newton.	Dr. J. demonstrates the principle of the refractor  And then a reflector  Portrait of Newton.  Newton-LPC-Vanderbank_cleaned.tif (Credit: Image courtesy History of Science Collections, University of Oklahoma Libraries; copyright the Board of Regents of the University of Oklahoma)

Now in the late 18th century the largest mirrors in the world were cast by William Herschel, an organist turned astronomer, who worked with his sister Caroline.

In their house in Bath, in England, the Herschels poured red-hot molten metal into a mould and when the whole thing had cooled off, they would polish the surface so that it would reflect starlight.

During the course of his life, Herschel built more than 400 telescopes.

The largest of these was so huge

(Take 14.2.6)

that he needed four servants to operate all the various ropes, wheels and pulleys that were required to track the motions of the stars across the night sky, which is of course caused by the Earth’s rotation.

(SOUNDS OF WHEELS AND PULLEYS)

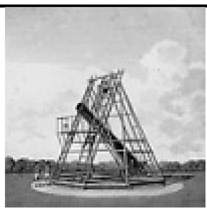
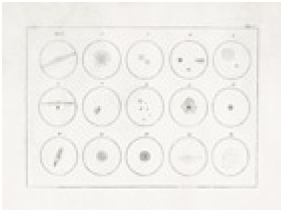
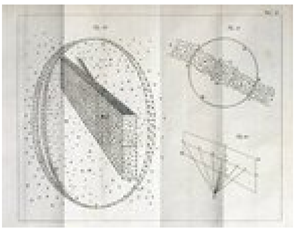
R102151.jpg (Credit: Sheila Terry / Science Photo Library)

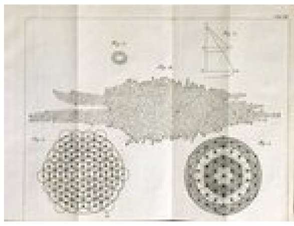
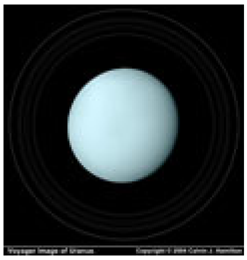
12.jpg (Credit: Kate Crennell {see fortran@dpmail.co.uk})

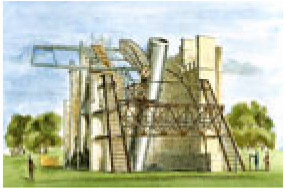
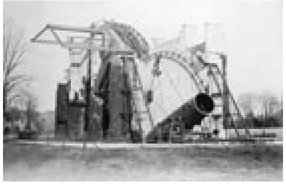
herschel_houseDSC_0699.JPG

R102175.jpg (Credit: Royal Astronomical Society / Science Photo Library)

R102176.jpg (Credit: Royal Astronomical Society / Science Photo Library)

	 R102154.jpg (Credit: Royal Astronomical Society / Science Photo Library)  R102155.jpg (Credit: Royal Astronomical Society / Science Photo Library)  R102151.jpg (Credit: Sheila Terry / Science Photo Library)
Now Herschel was like a surveyor, he scanned the heavens and catalogued hundreds of new nebulae and binary stars.	 HerschelW-1791-pl1_cleaned.tif
He also discovered that the Milky Way must be a flat disc. And he even measured the motion of the Solar System through that disk by observing the relative motions of the stars and the planets.	Herschel's view of the Milky Way.  Ch_1_HerschelW-1791-pl2.tif

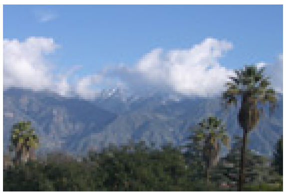
	 Ch_1_HerschelW-1791-pl3.tif
And then on the 13th of March in 1781, he discovered a new planet – Uranus.	Voyager images of Uranus and its satellites.  Uranus4.jpg (Credit: Calvin Hamilton)  Voyager_Uranus_computer_enhanced_GPN-2000-000440.jpg
It was over two hundred years until NASA's Voyager 2 spacecraft gave astronomers their first close-up look of this distant world.	
08:24 (15) **Narrator**: In the lush and fertile countryside of central Ireland, William Parsons, the third Earl of Rosse, built the largest telescope of the 19th century.	Zoom-in on central Ireland.  Portrait of Lord Rosse.
With a metal mirror a whopping 1.8 metres across, the giant telescope became known as "The Leviathan of Parsonstown".	

	 William_Parsons_Earl_of_Rosse.jpg Dissolving views of Lord Rosse's telescope. Both current views and historical engravings.  R102124.jpg (Credit: Science Photo Library)  R102226.jpg (Credit: Royal Astronomical Society / Science Photo Library)
On the occasional clear, moonless nights, the Earl sat at the eyepiece, and sailed on a journey through the Universe.	Try to visualize how he peered through the telescope (...). Astro images
To the Orion Nebula – now known to be a stellar nursery.	Lord Rosse's drawing of the Orion Nebula, dissolving into Hubble image.

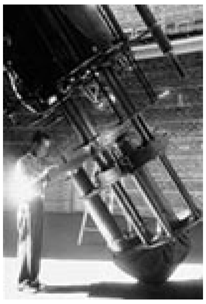
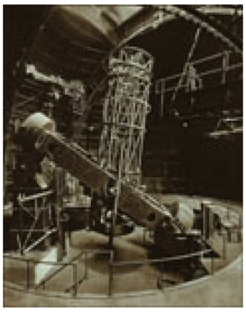
	  http://www.spacetelescope.org/images/html/heic0601a.html
On to the mysterious Crab Nebula, the remnant of a supernova explosion.	Lord Rosse's drawing of the Crab Nebula, dissolving into VLT image.  V700281-Lord_Rosses_drawing_of_the_Crab_Nebula-SPL_2.jpg 08:47 – m1rosse  Crab_Nebula.jpg (Credit: NASA and StSci)

And the Whirlpool Nebula? Lord Rosse was the first to note its majestic spiral shape. A galaxy like our own, with intricate clouds of dark dust and glowing gas, billions of individual stars, and who knows – maybe even planets like the Earth.	Lord Rosse's drawing of the Whirlpool Nebula, dissolving into Hubble image. Zoom in on M51 and pan along its spiral arms.  v700026_interted.tif  (whirlpool_galaxy_heic0506a.tif)
The telescope had become our vessel to explore the Universe. **09:20**	Quick zoom out of M51; lots of other stars and galaxies come into view.  [use http://www.spacetelescope.org/videos/html/heic0506c.html]
2. Bigger is better (06:30)	
0:00 (16) (Take 16.1.2) **Dr. J:** At night, your eyes adapt to the dark. Your pupils widen to let more light into your eyes. As a result, you can see dimmer objects, and fainter stars.	Dr. J. outside, at night. Pan to starry background, where more stars become visible.

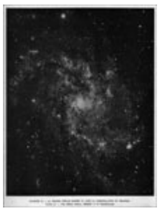
Now imagine you had pupils one metre across. You'd look pretty strange but you'd also have supernatural eyesight! And that's what telescopes do for you.	Dr. J. walks out of view. Starry background becomes 'overexposed'
(Take 16.2.4) A telescope is like a funnel. Its main lens or mirror collects the starlight and brings it all together into your eye.	Dr. J. walks in. Background: Graphic of telescope principle. Real telescopes: Celestron refractor and reflector
The bigger the lens or the mirror of a telescope, the fainter the objects you can see. So size really is everything. But how big can you make a telescope?	
Well actually not too big if it's a refractor. The starlight has to pass through the main lens. And so you can only support it around its edge. Now if you make the lens too big it becomes too heavy, and it starts deforming under its own weight. That means that the image will be distorted.	
(Take 16.3.5) The largest refractor in history was completed in 1897, at Yerkes Observatory outside Chicago. Its main lens was just over one metre across. But its tube was an incredible 18 metres long.	Full screen Image(s) of Yerkes Observatory and 40-inch refractor. 40_300_1.jpg (8-9 images credit: Richard Dreiser)  http://www.astrosurf.com/re/ritchey_1929_plate01.jpg (**Ch.2_3_Old_Yerkes_40.jpg**)

	(Pedro Ré)
With the completion of the Yerkes telescope, the builders of refracting telescopes had pretty much reached their limit. You want bigger telescopes? Think mirrors.	More Yerkes images.  Yerkes_40_inch_Refractor_Telescope-2005.jpg (Ch_1_Yerkes_40_inch_Refractor_Telescope-2006.jpg) (Credit: Alain Riazuelo) [requested two more from daniel_salo@wired.com and rdd@yerkes.uchicago.edu]
In a reflecting telescope, the starlight bounces off a mirror instead of passing through a lens. That means that you can make the mirror a lot thinner than a lens, and you can support it from the back. The result is that you can build a lot larger mirrors than lenses.	Dr. J. has mirror in hand to show what he's talking about. Supported by background graphic.
1:18 (17) **Narrator**: Big mirrors came to southern California a century ago.	Full-screen Google Earth zoom-in on Southern California. **MARTIN**
Back then, Mount Wilson was a remote peak in the wilderness of the San Gabriel mountains. The sky was clear and the nights were dark.	Old photographs of snow-capped mountains.  SnowInPasadena05Jan05_large.jpg https://netfiles.uiuc.edu/walther/www/archive.html (credit: Dirk Bernhardt-Walther)

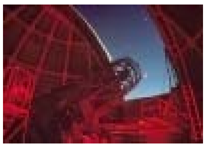
	 Mill_Creek_drainage,_San_Bernardino_National_Forest.jpg (Credit: jcookfisher Creative Commons Attribution 2.0)
Here, George Ellery Hale first built a 1.5 metre telescope. Smaller than Lord Rosse's retired Leviathan, it was of much better quality. And at a much better site, too.	Historical images of Hale and his first reflectors.  http://www.fi.edu/learn/case-files/hale-2863/ (hale_2863_photo.jpg) (Credit: The Franklin Institute)  e-mail Peter Abrahams (60inch-MWO-Apr49-GeneHancock-BillMillerPhoto.jpg) from http://www.europa.com/~telscope/binotele.htm (Credit: Bill Miller) ALSO: http://www.astro.ucla.edu/~obs/images/hale2.jpg. Credit: Huntington Library

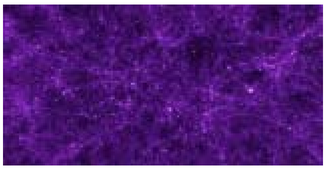
Hale talked local businessman John Hooker into financing a 2.5 metre instrument. Tonnes of glass and riveted steel were hauled up Mount Wilson.	Historical images of the construction of the Hooker telescope.  R110/327.jpg (Credit: EMILIO SEGRE VISUAL ARCHIVES / AMERICAN INSTITUTE OF PHYSICS / SCIENCE PHOTO LIBRARY)
The Hooker telescope was completed in 1917. It would remain the largest telescope in the world for 30 years.	Images of the Hooker telescope, both old and current.  http://sunearthday.nasa.gov/2006/images/locations_hale1.jpg (locations_hale1.tif) (NASA: Courtesy of the University of Chicago)  ritchey_1929_plate31.tif (Credit: Pedro Ré, George Willis Ritchey) 24_60_100inch_mount_wilson_small.jpg (Credit: Pedro Ré, George

	Willis Ritchey)
A big piece of cosmic artillery, ready to attack the Universe.	 R110328.jpg (Credit: HALE OBSERVATORIES / SCIENCE PHOTO LIBRARY)
2:14 (18) (Take 18.1.4) **Dr J**: And attack it did.	Dr. J. in Virtual Studio In a telescope dome?
Along with the incredible size of the new telescope came transformations in the way the image was viewed. Astronomers no longer peered through the eyepiece of the new giant. But instead collected the light on photographic plates for hours on end.	 whipple_moon.jpg (Credit: Pedro Ré and Whipple)
Never before had anyone peered so far into the cosmos.	**(LIKE OLD SLIDES ON THE DOME) (SLIDE PROJECTOR CLICKING 6 TIMES)** Early photographic image(s) of the sky.  **Old_NGC4565_ritchey_1929_plate13.jpg** (Credit: Pedro Ré, George Willis Ritchey)  **Old_M81_ritchey_plate14.jpg** (Credit: Pedro Ré, George Willis Ritchey)

	 **Old_M33_ritchey_1929_plate16.jpg** (Credit: Pedro Ré, George Willis Ritchey)  **Old_M33_ritchey_1929_plate15.jpg** (Credit: Pedro Ré, George Willis Ritchey)
Spiral nebulae turned out to be brimming with individual stars. Could they be sprawling stellar systems like our own Milky Way?	Early photographic images of spiral nebulae.  **Old_M31_ritchey_1929_plate17.jpg** (Credit: Pedro Ré, George Willis Ritchey)  **Old_M31_ ritchey_1929_plate18.jpg** (Credit: Pedro Ré, George Willis Ritchey)  **Old_M31_ritchey_1929_plate19.jpg** (Credit: Pedro Ré, George Willis Ritchey)

In the Andromeda Nebula, Edwin Hubble discovered a particular type of star that changes its brightness with clocklike precision. From his observations Hubble was able to deduce the distance to Andromeda: almost a million light-years.	Portrait of Hubble.  http://www.fi.edu/learn/case-files/hubble/ (use form: http://www.fi.edu/learn/aboutus.php) (undated_hubble_portrait.jpg) (Credit: The Franklin Institute)  Hubble.mtwilson.tif Hubble's photo of M31, with cepheid variable marked VAR.
(Take 18.2.1) Spiral nebulae, like Andromeda, were clearly individual galaxies in their own right.	More photos of galaxies.  http://www.spacetelescope.org/images/html/heic0401e.html (Ground_based_heic0401e.tif) (Credit: ESA/INT/DSS2)
But that wasn't the only incredible thing. Most of these galaxies were found to be moving away from the Milky Way. At Mount Wilson, Hubble discovered that the nearby galaxies were receding at small velocities, whereas the distant galaxies	Hubble with Hooker telescope.

were moving away at a much faster pace.	 H408137.jpg (Credit: HALE OBSERVATORIES / SCIENCE PHOTO LIBRARY) Original version of Hubble diagram. http://spiff.rit.edu/classes/phys301/lectures/expand/hubble_fig1_full.gif from http://spiff.rit.edu/classes/phys301/lectures/expand/expand.html (Creative Commons License Michael Richmond)
The conclusion? The Universe was expanding.	More detailed graphic of receding galaxies / expanding Universe.  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010135/index.html (Credit: NASA)
The Hooker telescope had given scientists the most profound astronomical discovery of the 20th century.	Zoom / pan of image of Hooker telescope.  R110264.jpg (Credit: DAN SCHECHTER / SCIENCE PHOTO LIBRARY)
3:27 (19) **Narrator**: Thanks to the telescope, we have traced the history of the Universe.	Google Earth zoom-out from Southern California into space. **MARTIN**

A little less than 14 billion years ago, the Universe was born in a huge explosion of time and space, matter and energy, called the Big Bang.	Animation of big bang.  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010128/index.html animations\ch2\010128 (credit: NASA) Frank Summers animation of galaxies forming and clustering
Tiny quantum ripples grew into dense patches in the primordial brew. From these, galaxies condensed.	Supercomputer simulation of formation of large-scale structure and galaxies:  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010118/index.html animations\ch2\010118 (Credit: NASA/NCSA University of Illinois)  http://www.spacetelescope.org/videos/html/heic0804d.html (Credit: Klaus Dolag (MPA, Garching)) heic0804d.avi
A stunning variety of sizes and shapes.	Voyage through zoo of galaxies.

	 http://www.spacetelescope.org/videos/html/heic0714g.html (Credit: NASA, ESA and F. Summers (STScI)) heic0714g.avi
Nuclear fusion in the cores of stars produced new atoms. Carbon, oxygen, iron, gold.	Zoom in onto a star, peer inside the core; animation of nuclear fusion.  http://www.spacetelescope.org/videos/html/astro_ac.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)
Supernova explosions blew these heavy elements back into space. Raw material for the formation of new stars. And planets!	Animation of supernova explosion and resulting dust clouds.  http://www.spacetelescope.org/videos/html/heic0515a.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen) heic0515a.avi Formation of solar system with

	planets.
Someday, somewhere, somehow, simple organic molecules evolved into living organisms. Life is one miracle in an ever-evolving Universe. We are stardust. It's a grand vision and a sweeping story. Brought to us through telescopic observations.	 http://www.spacetelescope.org/videos/html/heic0712i.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0712i.avi +astro ao http://www.nasa.gov/multimedia/imagegallery/image_feature_398.html
Imagine: without the telescope we would know about just six planets, one moon, and a few thousand stars. Astronomy would still be in its infancy. (13:50)	Change into beautiful, impressive rotating night sky. TWAN or Cuillandre or Proschold
4:32 (20) **[Male voice:]** **[E2]** *Like buried treasures, the outposts of the Universe have beckoned to the adventurous from immemorial times. Princes and potentates, political or industrial, equally with men of science, have felt the lure of the uncharted seas of space, and through their provision of instrumental means the sphere of*	More impressive night sky footage, ending in twilight and daybreak. TWAN or Cuillandre or Proschold **MISSING** POEM. George Ellery Hale MUSICAL INTERLUDE (0:30)

<table>
<tr><td>exploration has rapidly widened.</td><td></td></tr>
<tr><td>4:56 (21)

Narrator: George Ellery Hale had one final dream: to build a telescope twice as large as the previous record holder.

Meet the grand old lady of 20th century astronomy. The five metre Hale telescope at Palomar Mountain.

Over five hundred tonnes of moving weight, yet so precisely balanced that it moves as gracefully as a ballerina.

Its 40 tonne mirror reveals stars 40 million times fainter than the eye can see.</td><td>Old images of Hale telescope.

Hale_200_Jarrett.tif

Hale_200_Jarrett_notext.tif

(Contact: Tom Jarrett - jarrett@ipac.caltech.edu)</td></tr>
<tr><td>Completed in 1948, the Hale telescope gave us unsurpassed views of planets, star clusters, nebulae and galaxies.</td><td>Outsidedome.avi (Scott Kardel)

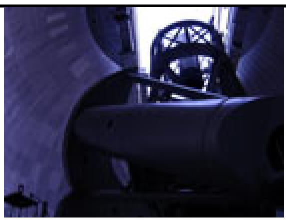
HaleDome_from_backside.JPG (Credit: Tom Jarrett)

HaleDome_inTrees.JPG

(Credit: Tom Jarrett)

Hale_Sunset_throughSlit.JPG

(Credit: Tom Jarrett)</td></tr>
</table>



Hale_Sunset_insideDome.JPG

(Credit: Tom Jarrett)

HaleDome_PalomarInterferometer.jpg

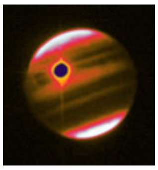
(Credit: Tom Jarrett)

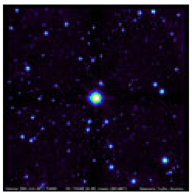
HaleDome_from_below.jpg

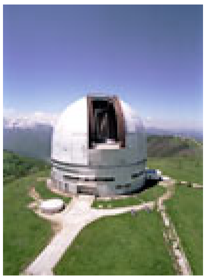
(Credit: Tom Jarrett)

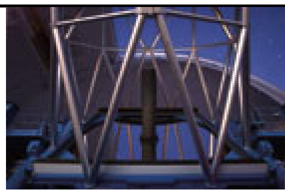
Hale_IMG_1573.JPG (Scott Kardel)

Hale_IMG_2449.JPG (Scott Kardel)

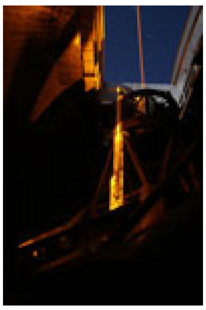
	 Hale_IMG_7758.jpg (Scott Kardel)  Hale_IMG_7884.jpg (Scott Kardel)  halelapse.jpg (Scott Kardel)  halemilkyway.jpg (Scott Kardel)  Hale_palomarlgs.jpg (Scott Kardel)
Giant Jupiter, with its many moons.	Hale telescope image of Jupiter (slow, panning zoom-out).  http://www.astro.caltech.edu/palomar/images/jarrett_jupiter-color.jpg (Ch_2_jarrett_jupiter-color.jpg) (Kardel)

	jarrett_jupiter-invertbig.jpg jarrett_jupiter-color.jpg jup_JHK.jpg jup_H.jpg jup_K.jpg jup_J.jpg
The stunning Flame Nebula.	 ngc2024 Flame Nebula.jpg (Scott Kardel)
Faint wisps of gas in the Orion Nebula.	Hale telescope image of the Orion Nebula (slow, panning zoom-out).  m42 orion nebula.jpg (Scott Kardel)  M26mosaic6.tiff (Scott Kardel)
	 heic0512d.tif (Credit: © 2002 R. Gendler, Photo by R. Gendler)
5:49 (22) (Take 22.1.5)	Dr. J. in Virtual Studio. Telescope

Dr J: But could we go bigger still?	Dome.
Well, soviet astronomers tried in the late 1970s. High up in the Caucasus mountains, they built the Bolshoi Teleskop Azimutalnyi – sporting a primary mirror six metres in diameter.	BTA_film1.avi BTA_film.avi
But it never really lived up to its expectations. It was simply too big, too expensive, and too difficult.	 Optical_telescopes_SAO-RAS.jpg
So did telescope builders have to give up at that point? Did they have to bury their dreams of even bigger instruments?	 Mirror.jpg
Had the history of the telescope come to a premature end?	 001bolshoi  BTA-gor.jpg
Well, of course not. Today we have 10 metre telescopes in operation. And even bigger ones are on the drawing board.	**gemini_north_ppt_lgs_timelapse.mov (archive)**

	 **silver_reflections_gemini_south.tif** http://www.gemini.edu/index.php?q=node/16 **observing_floor_hdtv.mov**
What was the solution? New technologies. (6:30)	

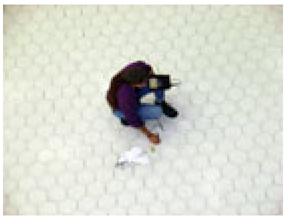
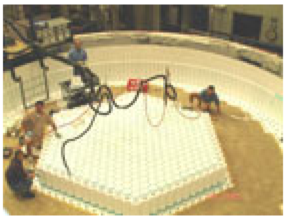
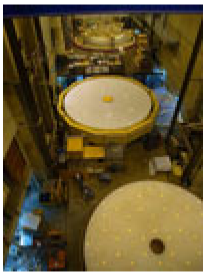
3. Technology to the rescue (06:30)

0:00 (23) (Take 23.1.2) **Dr. J**: Just as modern cars don't look like a Model T Ford anymore, so are present day telescopes radically different from their classic predecessors, like the five metre Hale telescope. For one thing, their mounts are much smaller.	Dr. J. in front of MR image wall. Background: black/white footage of 1920's cars in New York.  NYC Beach Resort street scene 2_xx.jpg http://www.tpcug.org/newsletter/nl_2004/march2004/epson_scanner.htm [e-mailed lamartin@tampabay.rr.com 05/08/08] Image of 5-meter Hale telescope.  Hale_2675ds.jpg (Scott Kardel)

	 Hale_IMG_0657.JPG (Scott Kardel)
The old-style mount is an equatorial one where one of the axis is always mounted parallel to the Earth's rotation axis. In order to keep track of the sky's motion, the telescope simply has to rotate around this axis at the same speed with which the Earth rotates.	Graphic animation to show the principle of an equatorial mount. **MountEq-telescope2.mp4**
Easy, but space-hungry.	Examples of big, equatorially-mounted telescopes.
The modern day altitude azimuth mounts are much more compact. With a mount like that, the telescope is pointed much like a cannon. One simply chooses the bearing, chooses the altitude, and off you go.	Graphic animation of an alt-az mount. **MountAz-telescope.mp4**
The problem is to keep track of the sky's motion. The telescope pretty much has to rotate around both axis, and at varying speeds. Essentially this only became possible once telescopes were computer controlled.	
(Take 23.2.2) A smaller mount is cheaper to build. Moreover, it fits into a smaller dome which reduces the cost even further and it improves the image quality.	Photos of compact alt-az mounts. **(FULL SCREEN)**

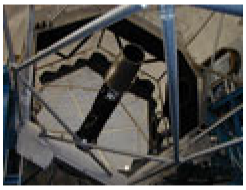
	 **Ch.3_1_Compact_Alt_Az_Mount.JPG**
Take the twin Keck Telescopes on Hawaii, for example. Although their 10 metre mirrors are twice as large as the one of the Hale telescope, they nevertheless fit into smaller domes than the one on Palomar Mountain.	Keck _mirrors.mov Keck_aerials.mov Keck_Exterior Views.mov Backup stills:  **Ch.3_5_Keck_Telescope_View_Inside.jpg** (Courtesy W. M. Keck Observatory)  **Ch.2_1_Keck_Telescope_Inside.jpg** (Courtesy W. M. Keck Observatory) Comparison of Keck domes to Hale dome.

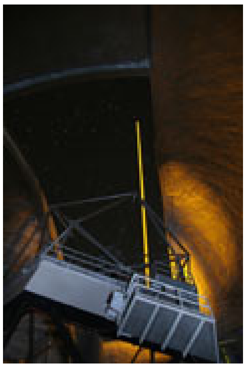
	 **Ch.3_3_Keck_Telescope_Two_Domes.jpg** (Credit:) CF015301-2.tif
1:05 (24) **Narrator**: Telescope mirrors have evolved too. They used to be thick and heavy. Now they're thin and lightweight.	Gemini mirror. (Dr. J. no longer in view) **MirrorCoatHDSelfCont.mov**
Mirror shells that can be many metres wide are cast in giant, rotating ovens. And they are still less than 20 centimetres thick.	Footage of Arizona Mirror Lab. http://thanks.arizona.edu/telescope/ Look on the IAU400YrsClpLstDVD (MAKE SURE THAT YOU FOLLOW THE EDITING GUIDE PROVIDED ON THE OTHER DVD) LSST oven spinning 02.avi S08Mar24'20080329 12.31.33.avi (from computer room) LSST install cores 24.avi (pan of oven without glass) LSST glass load 04.avi (loading glass in the oven) LSST glass load 02.avi (loading glass – almost empty) (Credit: Large Binocular Telescope Observatory (Ray Bertram), the University of Arizona's Steward Observatory Mirror Laboratory) DVD from

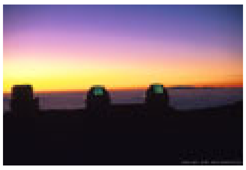
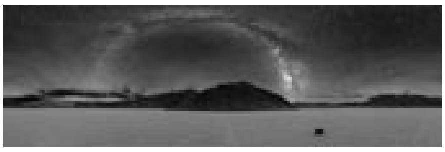
	rbertram@email.arizona.edu
An intricate support structure prevents the thin mirror from cracking under its own weight.	Footage/images of mirror cell structure.  http://www.spaceref.com/news/viewpr.html?pid=18145 (Gmt1443.jpg)  http://www.gmto.org/newsitems/news_item.2005-05-19.6941718209 (DSC00315.jpg)  http://www.gmto.org/newsitems/news_item.2005-04-14.6941718209 (DSC00169.jpg)  http://mirrorlab.as.arizona.edu/TECH.php?navi=cast (030123.17r.jpg) http://mirrorlab.as.arizona.edu/TECH.php?navi=gload
Computer controlled pistons and actuators also help to keep the mirror in perfect	Close-ups of actuators. **(Japanese Subaru DVD video 1**

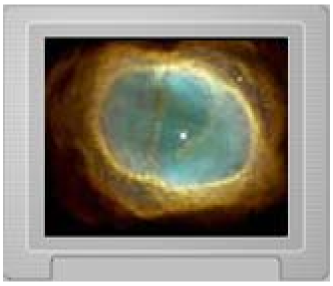
shape.	**on disk (3:34 to 4:06))**
1:32 (25) (Take 25.1.5) Dr. J: This system is called active optics. The idea is to compensate and to correct any deformations of the main mirror caused by gravity, the wind, or temperature changes.	If available: graphics animation showing active optics at work. More of the Subaru video active optics (**Japanese Subaru DVD video 1** 03:34-04:06 http://www.eso.org/gallery/v/Videos/Paranal/vid-07gb-99.mpg.html (VERY LOW RES)
Now, a thin mirror also weighs much less. That means that its whole supporting structure, including the mount, can also be a lot trimmer and lighter. And cheaper!	Drawing of telescope with thick mirror (and heavy structure) and of telescope with thin mirror (with light-weight structure). **MARTIN**
Now here's the 3.6 metre New Technology Telescope, built by European astronomers in the late 1980s. It served as a testbed for many of the new technologies in telescope building. And even its enclosure has nothing in common with traditional telescope domes.	Footage of NTT, interior views. Footage of NTT enclosure. (requested from Herbert – ask Lars) http://www.eso.org/gallery/v/Videos/ESO_ENGL.flv.html (5.54)
The New Technology Telescope was a great success.	More NTT footage, and/or NTT science results.
It was time to break the six metre barrier.	
2:13 (26) **Narrator**: Mauna Kea Observatory sits on the highest point in the Pacific, 4200 metres above sea level.	Mauna Kea footage. Maunakea_moonrise_720p_Cuillan2.avi (Credit: Canada-France-Hawaii Telescope / Coelum) **mouna_kea_zoom.avi (archives)** **OR MAYBE JUST SHOW IT SITTING ABOVE THE CLOUDS – GOOD PAN (Subaru Japanese DVD video 1 0:52 to 1:16 OR video 2 0:00 to 0:22)**
On the beaches of Hawaii, tourists enjoy	Hawaiian beach scene: easy-going,

the Sun and the surf. But high above them astronomers face chilling temperatures and altitude sickness in their quest to unravel the mysteries of the Universe.	tropical. Cross to scene of astronomers/scientists in the snow at Mauna Kea. **Maunaloa_inversion_hdtv_25fps.avi** **FOOTAGE FROM MAUNA KEA VIDEO (Subaru Japanese DVD video 2 3:58 to 4:30), BUT NO TOURISTS – MAYBE SOME FOOTAGE OF THE VOLCANO (Subaru Japanese DVD video 2 13:04 to 13:36)????**  subaru_summit_snow_300.jpg (Fill out form: http://subarutelescope.org/Information/Image/use.html) from http://subarutelescope.org/Gallery/tele_dome.html
The Keck Telescopes are among the largest in the world. Their mirrors are 10 metres across, and wafer-thin.	Keck_telescope.mov Backup stills:  CF015288.tif (Courtesy of W. M. Keck Observatory, Photo credit: Rick Peterson © 2007) **USE THIS IMAGE IF ANY**

	 **keckTwilight-hi.tif**  **IAUkecklaser1.jpg** (Courtesy W. M. Keck Observatory)
Tiled like a bathroom floor, they consist of 36 hexagonal segments, each controlled to nanometre precision.	Keck_mirrors.mov Backup stills:  **Ch.3_4_Keck_Telescope_View_Inside.jpg** (Courtesy W. M. Keck Observatory)  **Ch.3_17_Keck_Mirror.tif** (Credit: Courtesy NASA/JPL-Caltech)  **Ch.3_18_Keck_Primary_Mirror.jpg** (Credit: Courtesy NASA/JPL-Caltech)

	 **Keck_12_32.jpg (**Courtesy W. M. Keck Observatory)
These are true giants, devoted to observing the heavens. The cathedrals of science.	More impressive views of the Keck telescopes: Keck_exterior_views.mov Backup still:  **Ch.3_10_Keck_Inside_View.jpg (**Courtesy W. M. Keck Observatory)
Nightfall on Mauna Kea. The Keck Telescopes begin collecting photons from the far reaches of the cosmos. Their twin mirrors combining to be effectively larger than all earlier telescopes.	**(Subaru Japanese DVD video 2 16:03 to end or video 1 7:47 to 8:01))** Sunset / nightfall on Mauna Kea. Night shots of Keck telescopes. Keck_Exteriour_views.mov Backup stills:

	 CF015288.tif (Courtesy W. M. Keck Observatory)  **Ch.3_9_Keck_at_Sunset.jpg** (Courtesy of W. M. Keck Observatory, Photo credit: Rick Peterson © 2007)
What will be tonight’s catch?	Zoom-in on starry sky.  **Ch.3_15_Starry_Sky.jpg**  **Ch.3_16_Starry_Night_2.jpg**
A pair of colliding galaxies, billions of light-years away?	Zooming pan across image of colliding galaxies.  http://www.spacetelescope.org/videos/html/mov/180px/heic0810c.html (Credit: NASA, ESA, the Hubble

	Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University), K. Noll (STScI), and J. Westphal (Caltech))
A dying star, gasping its last breath into a planetary nebula?	Zooming pan on planetary nebula.  http://www.spacetelescope.org/videos/html/images_a.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))
Or maybe an extrasolar planet that might harbour life?	Zooming pan on artistic rendering of extrasolar planet.  http://www.spacetelescope.org/videos/html/mov/180px/astro_am.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))  http://www.spacetelescope.org/videos/html/heic0807d.html (Credit: ESA/Hubble (M. Kornmesser & L.

<table>
<tr><td></td><td>L. Christensen)) heic0807d.avi</td></tr>
<tr><td>On Cerro Paranal in the Chilean Atacama Desert — the driest place on Earth — we find by far the biggest astronomy machine ever built: the European Very Large Telescope.</td><td>Zoom from space down to Paranal:

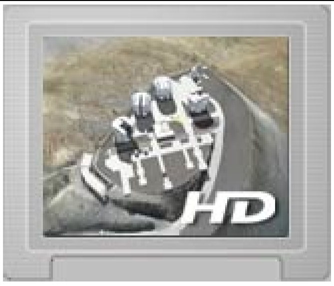

http://www.spacetelescope.org/videos/html/hubblecast06b.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen), ESO) hubblecast06b.avi

SPEED CHANGE

MUSICAL INTERLUDE

080727-P12-Paranal-from_Vista-20d-14mm (Credit: Stephane Guisard)

Zodet movies
VLT1_HD_720p50.mov (Very Large Telescope General Views)
VLT2_HD_720p50.mov (VLT Unit Telescope)
VLT3_HD_720p50.mov (VLT Instruments)
VLT4_HD_720p50.mov (Laser Guide Star Facility)
VLT7_HD_720p50.mov (VISTA Telescope)
VLT9_HD_720p50.mov (desert impressions)
VLT10_HD_720p50.mov (observations)</td></tr>
</table>

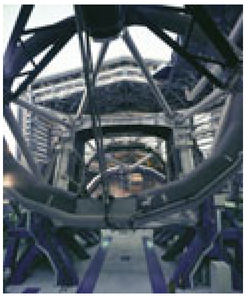
	VLT footage. Timelapse. From Gonzalo. VLTnight_hires.mov Copyright ©ESO. Credits: Author: Gonzalo Argandoña; Photography: Alejandro Carrasco;
The VLT is really four telescopes in one. Each sporting an 8.2 metre mirror.	 http://www.spacetelescope.org/videos/html/hubblecast06b.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen), ESO)
Antu. Kueyen. Melipal. Yepun. Native Mapuche names for the Sun, the Moon, the Southern Cross and Venus.	Pan across the four UT's. Names in view.  http://www.spacetelescope.org/videos/html/hubblecast06c.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen), ESO) hubblecast06c.avi
The huge mirrors were cast in Germany, polished in France, shipped to Chile, and then slowly transported across the desert.	Close ups of VLT mirror production and transportation. http://www.eso.org/public/outreach/press-rel/pr-1997/phot-35-97.html

VLT_phot-35b-97-hires.jpg (Credit:

VLT_phot-35e-97-hires.jpg (Credit:

VLT_phot-35f-97-hires.jpg (Credit:

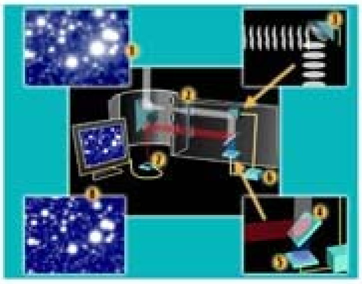
vlt_phot-35j-97-hires.jpg (Credit:

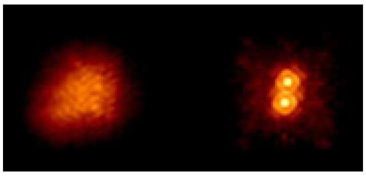


VLT_Kueyun_phot-15f-00.jpg (Credit: ESO)

	 VLT_Kueyun_phot-15ac-00.jpg (Credit: ESO)
At sunset, the telescope enclosures open up. Starlight rains down on the VLT mirrors. New discoveries are made.	VLT enclosures open. Sunset / nightfall at VLT platform.  Credit: Stephane Guisard MUSICAL BREAK SGU-Paranal-Voie-lactee-V4-720x576-mus-ok-en.avi SGU-Paranal-Sagittaire-AT1-V8-480x720-mus_sgu-ok-en.avi SGU-Paranal-Magellan-UT4-V5-720x480-mus-en.avi SGU-Paranal_3_rotating_galaxies_960x720.wmv

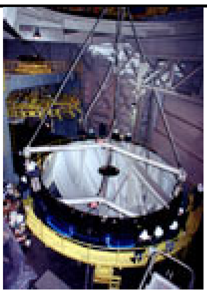
4:10 (27) (Take 27.1.3) **Dr. J**: A laser pierces the night sky. It projects an artificial star into the atmosphere, 90 kilometres above our heads.	Dr. J. in front of MR image wall. Footage of Yepun AO laser. Credit: Stephane Guisard

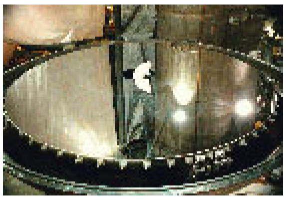
	SGU-Paranal_and_The_Laser_Guide_Star_1200x800.wmv (waiting for high resolution – guisard (ask Lars))
Wavefront sensors measure how the star's image is distorted by the atmospheric turbulence.	Gemini animation of AO. Luis' animation of AO **end of GeminiNorthAnim.mov**  http://www.gemini.edu/files/docman/press_releases/pr2003-2/aoanim.mov (from http://www.gemini.edu/index.php?q=node/72)
Then, fast computers tell a flexible mirror how it has to deform itself in order to correct the distortion. In effect untwinkling the stars.	
This is called adaptive optics and it's *the* big magic trick of present day astronomy. Without it, our view of the Universe would look blurred by the atmosphere. But with it, our images are razor-sharp.	Gemini animation of AO. X-fade from non-AO image to AO-image, to show the effect. **GeminiNorthAnim.mov** \http://www.cfht.hawaii.edu/Instruments/Imaging/AOB/Images/gc_red.gif

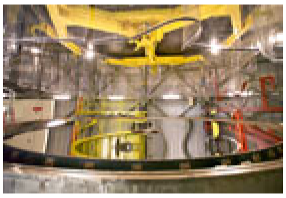
	 **gemini_ao_bullets_orion_north_lgs.jpg**
(Take 27.3.5) (NO 27.2.x) The other piece of optical wizardry is known as interferometry. The idea is to take the light from two separate telescopes and to bring it together in a single point, while preserving the relative shifts between the lightwaves. If it is done precisely enough the result is that the two telescopes act as if they were part of a single, colossal mirror as large as the distance between them.	VLT5_HD_720p50.mov (VLT Delay Lines and Interferometric Laboratory) Interferometry tunnels buried below VLT platform. Animation to show principle of interferometry. http://planetquest.jpl.nasa.gov/technology/technology_index.cfm Animations of installation of adaptive optics in the Hale Telescope **AOSETUP.AVI**
In effect, interferometry gives your telescope eagle-like vision. It allows smaller telescopes to reveal a level of detail that would otherwise only be visible with a much larger telescope.	Again: non-AO image compared to AO-image.  ao_aooffon.jpg http://www.astro.caltech.edu/palomar/AO/ (Scott Kardel)

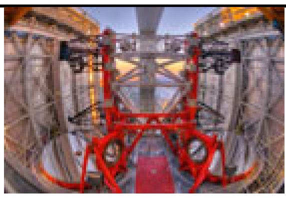
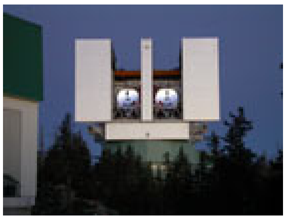
	http://www.astro.ucla.edu/~ghezgroup/gc/pictures/aoMovie.shtml
The twin Keck Telescopes on Mauna Kea regularly team up as an interferometer.	Keck_instruments.mov Backup still: PAN ACROSS THIS IMAGE  Keck_Interferometer_basepan.JPG http://www2.keck.hawaii.edu/news/science/if_science/if_science.html
In the case of the VLT, all four telescopes can work together. In addition, several smaller auxiliary telescopes can also join the ranks in order to sharpen up the view even more.	Footage of VLT, with auxiliary telescopes. What hasn't been used VLT1_HD_720p50.mov (Very Large Telescope General Views) VLT2_HD_720p50.mov (VLT Unit Telescope) VLT3_HD_720p50.mov (VLT Instruments)
5:37 (28) **Narrator**: Other big telescopes can be found all over the globe.	Google Earth globe on background, rotating in a way to show the locations of big telescopes. **MARTIN**
Subaru and Gemini North on Mauna Kea.	Footage of Mauna Kea. SUNSET AND NIGHT SHOTS – VIDEO TWO OF SUBARU (15:04 TO 15:50)
Gemini South and the Magellan Telescopes in Chile.	Footage of Cerro Pachon and Las Campanas. GNOutPAL.mov http://apod.nasa.gov/apod/ap060901.html

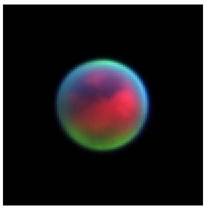
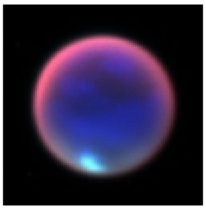
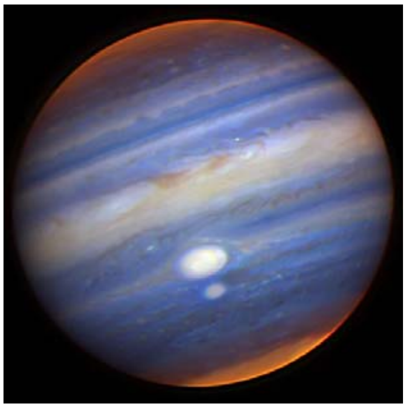
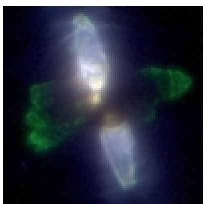
	 Gemini_South_gs_cp_ext_tl_1ksq.mov (http://www2.gemini.edu/index.php?set_albumName=Video&option=com_gallery&Itemid=39&include=view_album.php)  Gemini_South_GSNightTimeLapse.mov (http://www2.gemini.edu/index.php?set_albumName=Video&option=com_gallery&Itemid=39&include=view_album.php)
The Large Binocular Telescope in Arizona.	Footage of LBT. [requested footage from sally@firehousepictures.com] video_oct05_large.AVI video_zoom.mp4 video_aluminize.mpeg video_newsrelease.mpg
They are constructed at the best available sites. High and dry, clear and dark.	**Maunaloa_inversion_hdtv_25fps.avi**
Their eyes are as large as swimming pools.	Footage of LBT. Generic images of large telescope mirrors.

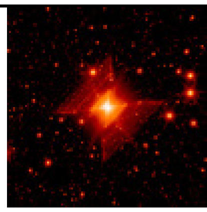
<table>
<tr><td></td><td>
Ch.3_6_Subaru_Very_Large_Mirror.jpg (Credit: Michael Richmond, Creative Commons License)


Gemini_MirrorPV.tif (Credit: Gemini Observatory/AURA) ****
http://www2.gemini.edu/index.php?set_albumName=album05&id=MirrorPV&option=com_gallery&Itemid=39&include=view_photo.php

phot-44-99.jpg

Gemini_Mirror1104-wide.jpg (http://www.gemini.edu/index.php?q=node/110) (Credit: Gemini Observatory/Kirk Pu'uohau-Pummill)</td></tr>
<tr><td>All kitted out with adaptive optics to counteract the blurring effects of the atmosphere.</td><td>Footage of LBT.</td></tr>
</table>

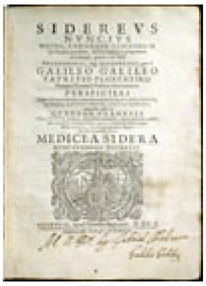
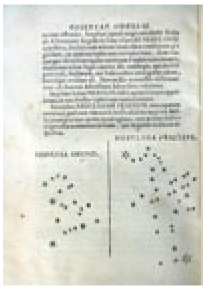
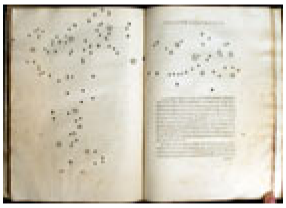
	 Ch.3_14_LBT_Large_Mirror.jpg (Credit: Photo courtesy of Large Binocular Telescope Observatory/Marc-Andre Besel and Wiphu Rujopakarn (Photographers))
And sometimes they can have the resolution of a virtual behemoth, thanks to interferometry.	More twin telescopes (LBT, Keck, Magellan).  Ch.3_20_LBT_Dual_Mirrors.jpg (Credit: Photo courtesy of Large Binocular Telescope Observatory/John Hill (Photogrpaher))  Ch.3_21_LBT_Dual_Mirrors.jpg (Credit: Photo courtesy of Large Binocular Telescope Observatory/Aaron Ceranski (Photogrpaher)) 
Here’s what they’ve shown us.	

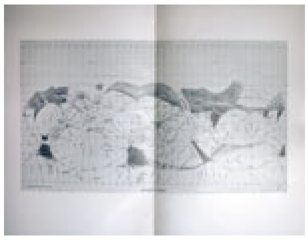
Planets. Nebulae.	Keck/Gemini/VLT images  **keck_ao_4_68.jpg**  **keck_ao_4_145.TIF**  **keck_ao_4_146.JPG**  **gemini_ao_fig1full.tif**  **keck_ao_5_56.jpg**

	 **keck_ao_5_125.jpg**  **gemini_ao_gc_color_med.jpg**
The actual sizes – and squashed shapes – of some stars.	VLT 'images' of Regulus.
A cool planet orbiting a brown dwarf.	VLT image of 2M1207. http://www.eso.org/public/outreach/press-rel/pr-2004/pr-23-04.html http://www.eso.org/esopia/images/html/phot-19b-06.html
And giant stars whirling around the core of our Milky Way Galaxy, governed by the gravity of a supermassive black hole.	AO-movie of stars in galactic center.
We've come quite a way since Galileo's day. 6:30	Back to naked eye night sky view, with horizon. TWAN

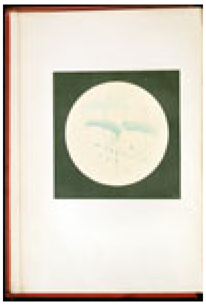
4. From silver to silicon (05:15)

0:00 (29) (Take 29.1.4) **Dr. J:** 400 years ago, when Galileo Galilei wanted to show others what he saw through his telescope, he had to make drawings.	Dr. J. in virtual studio, holding and flipping through an old book which shows some of Galileo's drawings.
The pockmarked face of the Moon. The dance of the Jovian satellites. Sunspots. Or the stars in Orion.	Galileo's pencil sketches. **(in the background. Large!)** (whichever you haven't used in the first

	chapter) 03-48-1_cleaned.tif Ch_1_Galileo-1613-Pt2-90-detail.tif Ch_1_Galileo_Moon_5.tif
He took his drawings and published them in a small book, *The Starry Messenger*. That was the only way he could share his discoveries with others.	Images of *Sidereus Nuncius*.  Galileo-1610-001r.tif (OU)  Galileo-1610-016c-v.tif (OU)  Galileo-1610-pleiades.tif (OU)
For well over two centuries, astronomers also had to be artists. Peering through their eyepieces, they made detailed drawings of what they saw.	Engraving of astronomer at eyepiece (and/or Christoph Scheiner with his sun projection setup). atlas_fotografico_lua-3.tif (Pedro Ré and Lewis Morris Rutherfurd) http://www.astrosurf.com/re/atlas_fotografico_lua.pdf
The stark landscape of the Moon. A storm	Examples of astronomical

in the atmosphere of Jupiter. The subtle veil of gas in a distant nebula.	drawings. http://www.sil.si.edu/Exhibitions/Voyages/2-25-Silberschlag.jpg http://www.sil.si.edu/Exhibitions/Voyages/2-28-Smyth.jpg http://www.sil.si.edu/Exhibitions/Voyages/1-31a-kircher.jpg  Scheiner-1630-141.tif (OU)
And sometimes they over-interpreted what they saw. Dark linear features on the surface of Mars were thought to be canals suggesting civilised life on the surface of the red planet.	Drawings and maps showing Martian canals. IMAGE FROM BOOK HIGH RESOLUTION:  Lowell-1906-00384-plate.tif (OU) THE FOLLOWING IMAGES ARE LOW RESOLUTION, SO MAKE A COLLAGE… 

<table>
<tr>
<td></td>
<td>Lowell-1895-00001-plate5.tif (OU)

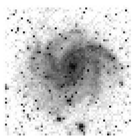
Lowell-1895-00001-plate7.tif (OU)

Lowell-1895-00000-fp.tif (OU)

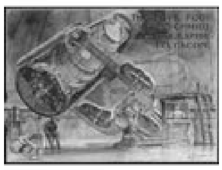
Lowell-1906-00044-plate.tif (OU)</td>
</tr>
<tr>
<td>We now know that the canals were an optical illusion.

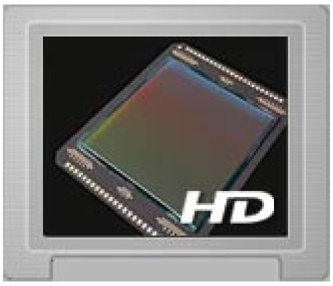
What astronomers really needed was an objective way to record the light collected by the telescopes without the information first having to pass through their brains and their drawing pens.

Photography came to the rescue.</td>
<td>Cross from canal-drawing to current photograph of Mars (Full-


screen, Dr. J. not in view)</td>
</tr>
</table>

	http://www.spacetelescope.org/videos/html/astro_q.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))  http://www.spacetelescope.org/videos/html/astro_z.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))
(Take 29.2.1) The first daguerreotype of the Moon. It was made in 1840 by Henry Draper. Photography was less than 15 years old, but astronomers had already seized on its revolutionary possibilities.	Dr. J. in front of MR image wall. **FULL SCREEN** First daguerrotype of the moon. ch4_1whipple_history_astrophotography_timeline-7.tif (low res, need rights) atlas_fotografico_lua-2.tif (Pedro Ré)
So how did photography work? Well the sensitive emulsion of a photographic plate contained small grains of silver halide. Expose them to light, and they turn dark. So the result was a negative image of the sky, with dark stars on a light background. But the real bonus was that a photographic plate can be exposed for hours on end.	Footage showing the workings of photographic emulsion (?).  http://www.astro.caltech.edu/palomar/galaxies.html (Scott Kardel) or ngc6946r.gif

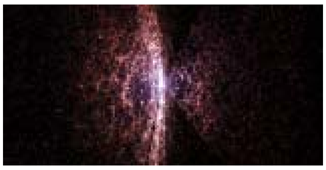
When you take in the night sky with your own eyes, once they're dark adapted, you don't see more and more stars just by looking longer.	Image of starry sky, as seen with the naked eye. **MARTIN**
But with a photographic plate you can do just that. You can collect and add up the light over hours on end. So a longer exposure reveals more and more stars. And more. And more. And then some.	Same image as seen through a camera (camera viewer information visible). Starry sky gets brighter and brighter. **FULL SCREEN** **MARTIN**
(Take 29.3.3) In the 1950s, the Schmidt telescope at the Palomar Observatory was used to photograph the entire northern sky.	48inch_schmidt_insidefull.mov Alternatively: Images of Schmidt telescope in operation.  http://www.astr.ua.edu/keel/telescopes/palomar.html (Palomar_p200b.jpg)  Old_Palomar_Drawing_1.jpg (Credit: Pedro Ré, Russell W. Porter)  Old_Palomar_Drawing_2.jpg (Credit: Pedro Ré, Russell W.

	Porter)
Almost 2000 photographic plates, each exposed for nearly an hour. A treasure trove of discovery.	Photographic plate from the book
Photography had turned observational astronomy into a true science. Objective, measurable, and reproducible. But silver was slow. You had to be patient.	More and more astrophotographs.  plate01_keeler.jpg ... ... plate69_keeler.jpg (20 images)
2:14 (30) **Narrator:** The digital revolution changed all that. Silicon replaced silver. Pixels replaced grains. Even in consumer cameras, we no longer use photographic film. Instead, images are recorded on a light-sensitive chip: a charge coupled device, or CCD for short.	High-tech footage of digital equipment and (for instance) Sloan Digital Sky Survey CCD camera.  http://www.spacetelescope.org/videos/html/hubblecast10c.html (Credit: Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) hubblecast10c.avi
Professional CCDs are extremely efficient. And to make them even more sensitive, they are cooled down to well below freezing, using liquid nitrogen.	ESO: Footage of astronomers pumping liquid nitrogen into a cryocamera.

	 ccd.jpg http://astrwww.cwru.edu/news/NewCamera.shtml (Credit: Warner and Swasey Observatory, Case Western Reserve University) Herschel_Cryostat+IR-source.TIF (Credit: ESA) http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=40183
Almost every photon is registered. As a result, exposure times can be much shorter.	Animation of the working of a CCD (?).  http://www.spacetelescope.org/videos/html/hubblecast10d.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) hubblecast10d.avi
What the Palomar Observatory Sky Survey achieved in an hour, a CCD can now do in a few short minutes. Using a smaller telescope.	Random astro-images
The silicon revolution is far from over. Astronomers have built huge CCD cameras with hundreds of millions of pixels. And there's more to come.	Views of big astronomical CCD cameras being developed / built / installed / used. http://www.eso.org/instruments/omegacam/ http://www.eso.org/gallery/v/Video

	s/ESO_ENGL.flv.html  phot-04a-07-fullres.tif http://www.eso.org/public/outreach/press-rel/pr-2007/phot-04-07.html http://www.vista.ac.uk/camera_images.html  VISTA_IR_Camera_To_Telescope_2.JPG  VISTA_IRCamera_in_PrepLab1.jpg  VISTA_Camera_to_Telescope.JPG  VISTA_Camera_on_Telescope.JPG

	 IMGP4957-2048x1536.JPG
3:07 (31) (Take 31.1.5) **Dr. J:** The big advantage of digital images is that they're, well, digital. They're all set and ready to be worked on with computers.	Image processing timelapse running in the background (cut out computer screen)  http://www.spacetelescope.org/videos/html/hubblecast10f.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) hubblecast10f.avi
Astronomers use specialised software to process their observations of the sky.	OR: Closeup of computer screen where Antennae Galaxies is being tweaked.
Stretching, or contrast enhancing, reveals the faintest features of nebulae or galaxies.	Antennae Galaxies being stretched
Colour coding enhances and brings out the structures that would otherwise be difficult to see.	
Moreover, by combining multiple images of the same object that were taken through different colour filters, one can produce spectacular composites that blur the boundary between science and art.	Antennae Galaxies being colourised
You too can benefit from digital astronomy. It has never been so easy to dig up and enjoy the amazing images of the cosmos.	

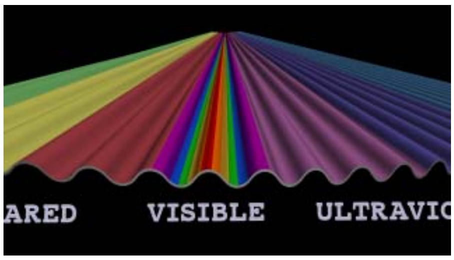
Pictures of the Universe are always just a mouse click away!	
4:01 (32) **Narrator**: Robotic telescopes, equipped with sensitive electronic detectors are keeping watch over the sky, right now.	Telescope in operation GEMINI? CFHT/Cuillandre?
The Sloan telescope in New Mexico has photographed and catalogued over a hundred million celestial objects, measured distances to a million galaxies, and discovered a hundred thousand new quasars. But one survey is not enough. The Universe is an ever-changing place.	Footage of the Sloan telescope.  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010136/index.html (Credit: NASA/University of Chicago and Adler Planetarium and Astronomy Museum)
Icy comets come and go, leaving scattered debris in their wake.	Comet:  http://www.spacetelescope.org/videos/html/heic0508a.html  http://www.spacetelescope.org/videos/html/heic0310d.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))

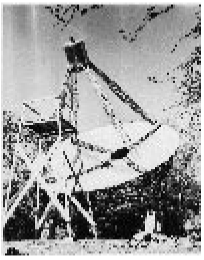
Asteroids zip by.	 http://www.spacetelescope.org/videos/html/heic0508b.html (Credit: (ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0508b.avi  Flyby of an asteroid. http://www.spacetelescope.org/videos/html/astro_v.html Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)
Distant planets orbit their mother stars, temporarily blocking part of the star's light.	Animation of transiting exoplanet.  http://www.spacetelescope.org/videos/html/heic0807e.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))

Supernovas explode, while elsewhere new stars are born.	Animation of supernova explosion and of star formation.  http://www.spacetelescope.org/videos/html/heic0712c.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))
Pulsars flash, gamma-ray bursts detonate, black holes accrete.	Animation of pulars, exploding GRB, colliding galaxies.  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010144/index.html animations\ch4\a010144 (Credit: NASA)
To keep track of these grand plays of Nature, astronomers want to carry out all-sky surveys every year. Or every month. Or twice a week. At least that's the ambitious goal of the Large Synoptic Survey Telescope. If completed in 2015, its three-gigapixel camera will open up a webcam window on the Universe. More than fulfilling astronomers' dreams, this reflecting telescope will photograph almost the entire sky every three nights. (5:15)	Back to night sky as seen from Earth. Animation of LSST. HD-LSST-lossless.mov (HUGE) HD-comp-H.264.mov LSST-50-H.264-high.mov credit: Todd Mason, Mason Productions / LSST Corporation LSST glass load 04.avi (see note from rbertram@email.arizona.edu – not all of this video can be used.) LSST install cores 11.avi (see note

	from rbertram@email.arizona.edu – not all of this video can be used.)

5. Seeing the invisible (06:32)

0:00 (33) (Take 33.1.1) **Dr. J:** When you listen to your favourite piece of music, your ears pick up on a very wide range of frequencies, from the deepest rumblings of the bass to the very highest pitched vibrations.	Dr. J. in a concert hall? Music: Orchestra playing Beethoven's Ninth.
Now imagine your ears were only sensitive to a very limited range of frequencies. You'd miss out on most of the good stuff!	Same, but with adapted music score, with limited frequency range (but same overall volume!).
But that's essentially the situations that astronomers are in. Our eyes are only sensitive to a very narrow range of light frequencies: visible light. But we are completely blind to all other forms of electromagnetic radiation. However, there are many objects in the Universe that do emit radiation at other parts of the electromagnetic spectrum.	Graphic showing the electromagnetic spectrum (from Hidden Universe). OR  http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010282/index.html (not downloaded)
For example, in the 1930s it was discovered by accident that there are radio waves coming from the depths of space. Some of these waves have the same frequency as your favourite radio station,	Old images of the first radio telescopes.

but they are weaker and of course there’s nothing to listen to.	 Dwingeloo_radio_telescope.JPG http://commons.wikimedia.org/wiki/Image:Dwingeloo_radio_telescope.JPG (1950s) (Credit: Bryan Tong Minh GNU Free Documentation License, Version 1.2 or later)  Grote_Antenna_Wheaton.gif http://en.wikipedia.org/wiki/Image:Grote_Antenna_Wheaton.gif (Public Domain) Maybe Dr. J. tuning transistor radio, and hearing the faint hiss and crackle of radio noise?
(Take 33.2.2) In order to “tune in” to the radio Universe, you need some sort of receiver: a radio telescope. Now for all but the longest wavelengths, a radio telescope is just a dish. Much like the main mirror of an optical telescope. But because radio waves are so much longer than visible lightwaves, the surface of a dish doesn’t have to be nearly as smooth as the surface of a mirror. And that’s the reason why it’s so much easier to build a large radio telescope than it is to build a large optical telescope.	Footage of Green Bank Telescope or Effelsberg Telescope. DVD from Robert Wagner [footage of Green Bank requested info@nrao.edu] NRAO DVD With GBT, ALMA and VLA Extra stills: http://www.mpifr-bonn.mpg.de/public/vortraege_e.html

<table>
<tr>
<td></td>
<td>
GB_historic_hi.tif (Credit: Image courtesy of NRAO/AUI)

http://www.nrao.edu/imagegallery/php/level3.php?id=288

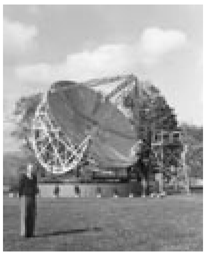
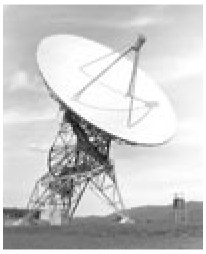
gbt2_2005_hi.tif (Credit: NRAO/AUI and Photographer Lee Shapiro)

Aerial2001-Image22_hi.tif (Credit: NRAO/AUI)

Aerial2001-Image3_hi.tif (Credit: NRAO/AUI)

GBTDusk_hi.tif (Credit: NRAO/AUI)

GBTSnow_hi.tif (Credit: NRAO/AUI)
</td>
</tr>
</table>

	http://www.nrao.edu/imagegallery/php/level2a.php?class=Historical&subclass=Telescopes (NRAO)  300ft_before_hi.tif (Credit: NRAO/AUI)  ReberTelescope1984_hi.tif (Credit: NRAO/AUI)  ReberandRestoredTelescope1960_hi.tif (Credit: NRAO/AUI)  Reber_telescope_hi.tif (Credit: NRAO/AUI) 

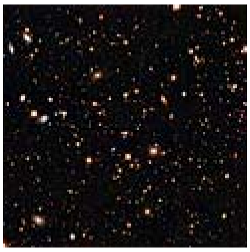
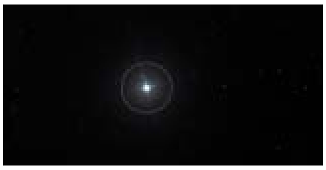
	85foot_hi.tif (Credit: NRAO/AUI)  goldstone7.jpg (Credit: NRAO/AUI)
Also, at radio wavelengths, it is much easier to do interferometry. That is, to increase the level of detail that can be seen by combining the light from two separate telescopes, as if they were part of a single, giant dish.	Views of relatively small interferometers (Cambridge? Westerbork?)  Westerbork-sunset.jpg http://commons.wikimedia.org/wiki/Image:Westerbork-sunset.jpg (Creative Commons Attribution ShareAlike 3.0 Unported License Roman Feiler)
(Take 33.3.1) The Very Large Array in New Mexico, for example, consists of 27 separate antennas, each measuring 25 metres across. Now each antenna can be moved around individually, and in its most extended configuration, the virtual dish mimicked by the array measures 36 kilometres across.	Footage of Very Large Array (full screen, Dr. J. not in view anymore). [VLA footage requested 25/06] And again 30.7 Dave Finley <dfinley@aoc.nrao.edu>
So what does the Universe look like in the radio? Well, for a start our Sun shines very brightly at radio wavelengths. So does the centre of our Milky Way Galaxy. But there's more.	Sweep across the sky (sun / Milky Way centre), with radio contours or color-coded radio map overlaid on optical image (?) OR

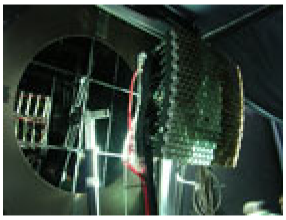
	 http://www.spacetelescope.org/videos/html/mov/180px/astro_aq.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))
Pulsars are very dense stellar corpses that emit radio waves only into a very narrow beam. In addition, they rotate at speeds of up to several hundred revolutions per second. So in effect, a pulsar looks like a rotating radio lighthouse. And what we see from them is a very regular and fast sequence of very short radio pulses. Hence the name.	 http://www.spacetelescope.org/videos/html/hst15_pulsar_beacon.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen))
(Take 33.4.3 OR was it 33.4.4? (The last)) The radio source known as Cassiopeia A is in fact the remnant of a supernova that exploded in the 17th century.	 http://www.spacetelescope.org/videos/html/heic0609h.html  http://www.spacetelescope.org/videos/html/heic0609b.html

	FULL SCREEN Radio image of Cas A (and/or combination with optical image and Photoshop-effect of radio waves)  cas_a_vla_lg.jpg (Credit: NRAO/AUI) http://www.nrao.edu/imagegallery/php/level3.php?id=395
Centaurus A, Cygnus A and Virgo A are all giant galaxies that pour out huge amounts of radio waves. Each galaxy is powered by a massive black hole at its centre.	Views of Cen A (and maybe the others?), with radio wave effect. or overlaid with radio image.  http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010200/index.html (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab) **FULL SCREEN**
(Take 33.5.3) Some of these radio galaxies and quasars are so powerful that their signals can still be detected from a distance of 10 billion light-years.	 http://www.spacetelescope.org/videos/html/hst15_light_speed.html
And then there's the faint, relatively short-wavelength radio hiss that fills the entire Universe. This is known as the cosmic microwave background, and it is the echo of the Big Bang. The very afterglow of the	Full-screen WMAP image, zooming in until you just see (and hear!) noise.

hot beginnings of the Universe.	J:\EyesSkies\animations\ch4\a0101 44
2:22 (34) **Narrator**: Each and every part of the spectrum has its own story to tell. At millimetre and submillimetre wavelengths, astronomers study the formation of galaxies in the early Universe, and the origin of stars and planets in our own Milky Way. But most of this radiation is blocked by water vapour in our atmosphere. To observe it, you need to go high and dry.	Animation of electromagnetic spectrum (from Hidden Universe). Show how certain wavelengths are blocked by the atmosphere. jcmt.jpg http://outreach.jach.hawaii.edu/pressroom/2003_casa/jcmt.jpg (CREDIT: Nik Szymanek) jcmt1.jpg http://outreach.jach.hawaii.edu/pressroom/2004_marsperoxide/index.html (CREDIT: Nik Szymanek)
To Llano de Chajnantor, for example. At five kilometres above sea level, this surrealistic plateau in northern Chile is the construction site of ALMA: the Atacama Large Millimeter Array.	NRAO DVD With GBT, ALMA and VLA Alma.avi Footage of Chajnantor. http://www.eso.org/public/outreach/broadcast/compilations/alma/hd/ALMA2_PART1_HD_720p50.mov http://www.eso.org/public/outreach/broadcast/compilations/alma/hd/ALMA2_PART2_HD_720p50.mov http://www.eso.org/public/outreach/press-rel/pr-2007/vid-32-07_broadcast.html CHAJNANTOR_HRES.mov (the desert)

When completed in 2014, ALMA will be the largest astronomical observatory ever built. 64 antennas each weighing 100 tonnes, will work in unison. Giant trucks will spread them out over an area as large as London to increase the detail of the image, or bring them close together to provide a wider view. Each move will be made with millimetre precision.	Footage of ALMA. http://www.eso.org/public/outreach/press-rel/pr-2007/vid-32-07_broadcast.html ANIMATIONS_HRES.mov
3:20 (35) (Take 35.1.7) **Dr. J:** Many objects in the Universe also glow in the infrared. Discovered by William Herschel, infrared radiation is often also called "heat radiation" because it is emitted by all relatively warm objects, including humans.	Dr. J. in virtual studio. Image of Herschel discovering infrared radiation.  H408384.jpg (Credit: CCI Archives / Science Photo Library)
You may be more familiar with infrared radiation than you think. Because on Earth, this kind of radiation is used by night vision goggles and cameras. But to detect the faint infrared glow from distant objects, astronomers need very sensitive detectors, cooled down to just a few degrees above absolute zero, in order to suppress their own heat radiation.	Examples of night vision. Robert Hurt's images? Cryogenically cooled detector. http://solarsystem.nasa.gov/multimedia/gallery/ SIRTF_Infrared.jpg
(35.2.3 or was it 35.2.4? (the last)) Today, most big optical telescopes are also equipped with infrared cameras. They allow you to see right through a cosmic dust cloud, revealing the newborn stars inside, something that just cannot be seen in the optical.	Views of big IR instruments on big ground based telescopes.
For example, take this optical image of the famous stellar nursery in Orion. But look how different it is when seen through the eyes of an infrared camera!	M42 image; crossfade to infrared image (McCraughean). http://www.spacetelescope.org/ima

	ges/html/heic0601a.html http://www.spacetelescope.org/images/html/opo9713c.html
Being able to see in the infrared is also very helpful when studying the most distant galaxies. The newborn stars in a young galaxy shine very brightly in the ultraviolet. But then this ultraviolet light has to travel for billions of years across the expanding Universe. The expansion stretches the lightwaves so that when they are received by us, they've been shifted all the way into the near-infrared.	Pan/zoom across infrared deep field.  http://www.spacetelescope.org/images/html/heic0406b.html (Credit: NASA, ESA and R. Thompson (Univ. Arizona))
4:30 (36) **Narrator**: This stylish instrument is the MAGIC telescope on La Palma. It searches the sky for cosmic gamma rays, the most energetic form of radiation in Nature.	(Time lapse) Footage of MAGIC telescope on La Palma. rwagner@mppmu.mpg.de Getting MAGIC footage and animations from Peter Rixner and the project scientist.
Lucky for us, the lethal gamma rays are blocked by the Earth's atmosphere. But they do leave behind footprints for astronomers to study. After hitting the atmosphere, they produce cascades of energetic particles. These, in turn, cause a faint glow that MAGIC can see.	http://www.nasa.gov/mpg/108531main_flashcam0001_NASA%20WebV_1.mpg from http://tv.gsfc.nasa.gov/G05-016_space.htm  http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010245/index.html animations\ch5\010245 (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab)

	proton_1EeV.mov http://astro.uchicago.edu/cosmus/projects/aires/ (Credit: to author, Creative Commons 2.5 Generic) gamma_60zen_5km_800x600.mpeg protonshoweroverchicago.mpeg gamma_60zen_5km_800x600_left.mpeg gamma_60zen_5km_800x600_right.mpeg (give credit to us and to Sergio Sciutto for AIRES) Graphic showing cosmic gamma rays and production of Cerenkov radiation.
And here's the Pierre Auger Observatory in Argentina. It doesn't even look like a telescope. Pierre Auger consists of 1600 detectors, spread over 3000 square kilometres. They catch the particle fallout of cosmic rays from distant supernovas and black holes.	Footage of Pierre Auger Observatory. **See DVD** [REQUESTED FROM oficina@pierre]  Pierre_Auger_Ingo_FD 01.tif (Ingo 04/07)  Pierre_Auger_Ingo_FD 02.tif (Ingo 04/07)

Pierre_Auger_Ingo_SD 01.tif

(Ingo 04/07)

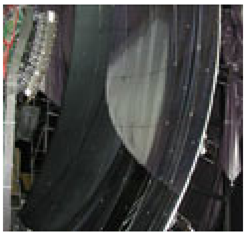
Pierre_Auger_Ingo_SD 02.tif

(Ingo 04/07)

Pierre_Auger_Ingo_SD 03.tif

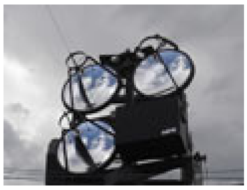
(Ingo 04/07)

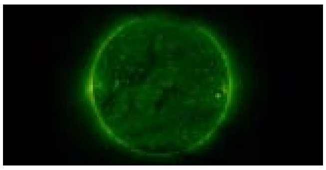
tanque en los leones3.JPG

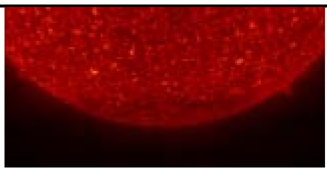
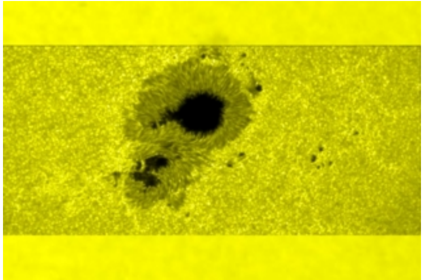


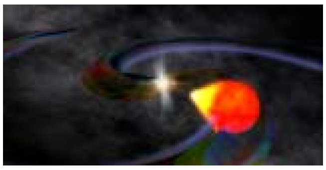
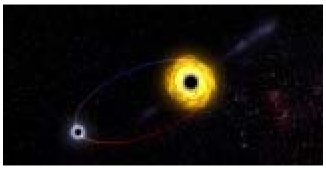
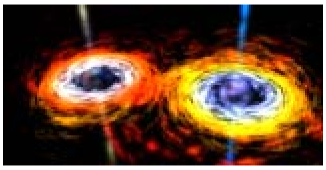
http://www.auger.org.ar/Auger_Sur/Img/Fluorescencia_espejo.jpg
Auger_6.jpg
(ingo@cab.cnea.gov.ar)

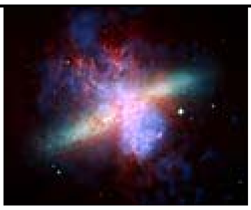
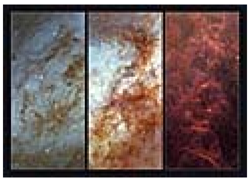
http://www.auger.org.ar/Auger_Sur/Img/los_leones_interior2.jpg
Auger_5.jpg

	(ingo@cab.cnea.gov.ar)  http://www.auger.org.ar/Auger_Sur/Img/Lidar2.jpg Auger_4.jpg http://www.auger.org.ar/Auger_Sur/Img/Vista%20anterior_Los%20Leones.jpg Auger_3.jpg (ingo@cab.cnea.gov.ar)  http://www.auger.org/photos/megapix/panorama/DSC01655.jpg Auger_2.jpg (ingo@cab.cnea.gov.ar) http://www.auger.org/media/image_highlights.html  http://www.fcaglp.unlp.edu.ar/~extension/228/Allekotte/030.jpg Auger_1.jpg (ingo@cab.cnea.gov.ar) http://www.fcaglp.unlp.edu.ar/~extension/228/Allekotte/
And what about neutrino detectors, built in deep mines or beneath the surface of the ocean, or in the Antarctic ice. Could you call those telescopes? Well, why not? After all, they do observe the Universe, even if they don't capture data from the electromagnetic spectrum.	SPstory07.mov Icecube2007.mov Footage or images of underwater or under-ice neutrino detectors. Animation of how they respond to traversing neutrinos.

Neutrinos are elusive particles that are produced in the Sun and supernova explosions. They were even produced in the Big Bang itself. Unlike other elementary particles, neutrinos can pass through regular matter, travel near the speed of light and have no electric charge.	http://www.news.wisc.edu/newsphotos/images/IceCube_aerial_view05.jpg from http://www.news.wisc.edu/newsphotos/icecube.html http://www.nsf.gov/news/news_images.jsp?cntn_id=106781&org=NSF http://www.delawareonline.com/blogs/uploaded_images/TwoTanks-747438.jpg from http://www.delawareonline.com/blogs/antarctica.html [public_affairs@suketto.icrr.u-tokyo.ac.jp e-mailed 05/08/08 and requested video footage and permission for images]
Although these particles may be difficult to study, they are plentiful. Each second more than 50 trillion electron neutrinos from the Sun pass through you.	 http://www.spacetelescope.org/videos/html/mov/180px/astro_aq.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) astro_aq.avi Maybe  http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003428/index.html animations\ch5\003428 (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio)

	 http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003426/index.html animations\ch5\003426 (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio) or  http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003412/index.html animations\ch5\003411 animations\ch5\003412 (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio) http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003411/index.html (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio)
Finally, astronomers and physicists have joined forces to build gravitational wave detectors. These “telescopes” do not observe radiation or catch particles. Instead, they measure tiny ripples in the very structure of space-time – a concept predicted by Albert Einstein’s theory of relativity.	Stills of LIGO Animation of how they detect gravitational waves. [emailed jrweiner@caltech.edu] [e-mailed thomson@mit.edu 04/08/08 – responded and has nothing – ccd to Jill Perry]

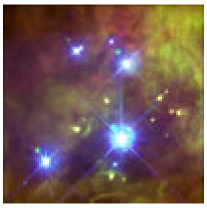
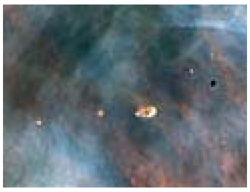
	[e-mailed dbanegas@nsf.gov 04/08/08] Creation of grav. waves:  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010143/index.html animations\ch5\010143 (Credit: NASA)  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010142/index.html animations\ch5\010142 (Credit: NASA)  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010140/index.html animations\ch5\010140 (Credit: NASA)
With a stunning variety of instruments, astronomers have opened up the full spectrum of electromagnetic radiation, and have even ventured beyond.	Cross fade of images in a variety of wavelengths, but at the same scale, of: Milky Way, M31, ...  http://www.spacetelescope.org/images/html/heic0604a.html

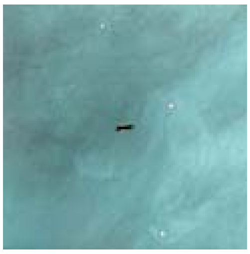
	 http://www.spacetelescope.org/images/html/heic0604d.html  http://www.spacetelescope.org/images/html/heic0604b.html  http://www.spacetelescope.org/images/html/heic0604f.html  http://www.spacetelescope.org/images/html/heic0604e.html  http://www.spacetelescope.org/images/html/heic0103f.html
But some observations simply can’t be done from the ground. The answer? Space telescopes.	Cross to deep space image (slowly panning). Out of the distance Hubble comes into view.

(6:32)	 http://www.spacetelescope.org/videos/html/heic0720b.html
6. Beyond Earth (06:39)	
0:00 (37) (Take 37.1.5) **Dr. J:** The Hubble Space Telescope. It is by far the most famous telescope in history. And for good reason. Hubble has revolutionised so many fields in astronomy.	(Dr. J. not in view) Zoom in on and fly around Hubble Space Telescope.  http://www.spacetelescope.org/videos/html/heic0720b.html  http://www.spacetelescope.org/videos/html/hubblecast06d.html hubblecast06d.avi http://www.spacetelescope.org/videos/html/hubblecast06e.html hubblecast06e.avi http://www.spacetelescope.org/videos/html/hubblecast06f.html
By modern standards, Hubble's mirror is actually quite small. It only measures about 2.4 metres across. But its location is literally out of this world. High above the blurring effects of the atmosphere, it has an exceptionally sharp view of the Universe. And what's more, Hubble can see ultraviolet and near-infrared light. This light just cannot be seen by ground-based telescopes because it is blocked by the atmosphere.	

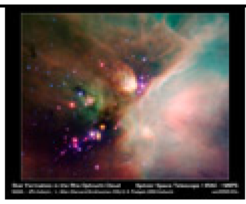
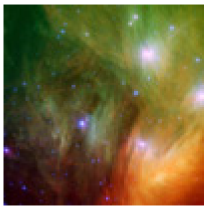
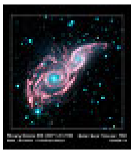
	hubblecast06f.avi **FULL SCREEN**
Cameras and spectrographs, some as big as a telephone booth, dissect and register the light from distant cosmic shores.	 http://www.spacetelescope.org/videos/html/hubblecast10b.html hubblecast10b.avi
Just like any ground-based telescope, Hubble is upgraded from time to time. Spacewalking astronauts carry out servicing missions. Broken parts get refurbished. And older instruments get replaced with newer and state-of-the-art technology.	Footage of servicing missions. Susan.M.Hendrix@nasa.gov http://www.nasa.gov/mission_pages/hubble/servicing/SM4/multimedia/index.html
Hubble has become the powerhouse of observational astronomy. And it has transformed our understanding of the cosmos.	More fly around Hubble, until it points right at you. Zoom in on the mirror, looking out to the stars. **Hst15_big_bang_to_hubble.avi**
1:04 (38) **Narrator**: With its keen eyesight, Hubble observed seasonal changes on Mars... a cometary impact on Jupiter... an edge-on view of Saturn's rings... and even the surface of tiny Pluto.	Hubble images: Changing seasons on Mars. opo9715b.jpg (Credit: Phil James (Univ. Toledo), Todd Clancy (Space Science Inst., Boulder, CO), Steve Lee (Univ. Colorado), and NASA/ESA) http://www.spacetelescope.org/images/html/opo9715b.html +images_d?

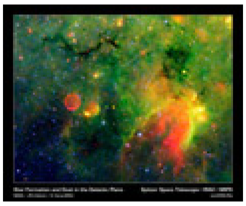
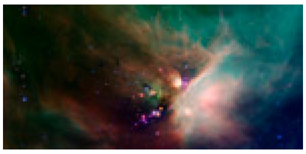
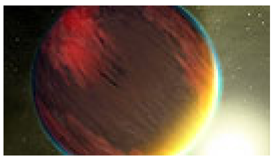
	opo9715b1.tif opo9715b2.tif opo9715b3.tif PIA01248.tif (Credit: NASA Jet Propulsion Laboratory (NASA-JPL)) http://nix.ksc.nasa.gov/info;jsessionid=74u9fgpmst11?id=PIA01248&orgid=10 Impact of SL9 on Jupiter.  +astro_aa? http://www.spacetelescope.org/videos/html/hst15_sl9_crash.html http://www.spacetelescope.org/videos/html/hst15_sl9_jupiter_close.html Reconstructed images of Pluto. opo0609b.tif (Credit: NASA, ESA, H. Weaver (JHU/APL), A. Stern (SwRI), and the HST Pluto Companion Search Team) http://www.spacetelescope.org/images/html/opo0609b.html
It revealed the life cycle of stars, from their very birth and baby days in a nursery of dust-laden clouds of gas, all the way to their final farewell: as delicate nebulae, slowly blown into space by dying stars, or as titanic supernova explosions that almost outshine their home galaxy.	 http://www.spacetelescope.org/videos/html/heic0712d.html heic0712d.avi

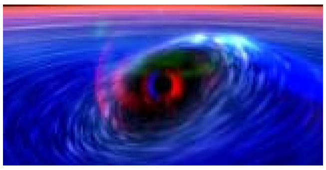
	supernova explosions and remnants. + heic0515a?  http://www.spacetelescope.org/videos/html/heic0712g.html heic0712g.avi
Deep in the Orion Nebula, Hubble even saw the breeding ground of new solar systems: dusty disks around newborn stars that may soon condense into planets.	Martin: Zoom on the Orion Nebula Views of proplyds in M42. **MAKE A COLLAGE OF THESE IMAGES – THEY ARE SMALL**  opo9545n.tif http://www.spacetelescope.org/images/html/opo9545n.html  opo9545o.tif http://www.spacetelescope.org/images/html/opo9545o.html  opo9424b.tif (Credit: C.R.

	O'Dell/Rice University NASA/ESA) http://www.spacetelescope.org/images/html/opo9424b.html  opo0113b.jpg (Credit: J. Bally (University of Colorado) and H. Throop (SWRI)) http://www.spacetelescope.org/images/html/opo0113b.html
The space telescope studied thousands of individual stars in giant globular clusters, the oldest stellar families in the Universe.	 http://www.spacetelescope.org/videos/html/heic0809d.html  http://www.spacetelescope.org/videos/html/heic0715e.html
And galaxies, of course. Never before had astronomers seen so much detail. Majestic spirals, absorbing dust lanes, violent collisions.	Colliding galaxies  http://www.spacetelescope.org/vide

	os/html/heic0810c.html  http://www.spacetelescope.org/videos/html/heic0810b.html
Extremely long exposures of blank regions of sky even revealed thousands of faint galaxies billions of light-years away. Photons that were emitted when the Universe was still young. A window into the distant past, shedding new light on the ever-evolving cosmos.	Hubble Deep Field fly-through Heic0714g
2:16 (39) (Take 39.1.2) **Dr. J:** Hubble is not the only telescope in space.	Dr. J. in front of MR image wall. Background: Hubble flies out of view...
This is NASA's Spitzer Space Telescope, launched in August 2003. In a way, it is Hubble's equivalent for the infrared.	...and Spitzer flies into view. [we should have HD footage already?]
(Take 39.2.1) Spitzer has mirror that is only 85 centimetres across. But the telescope is hiding behind a heat shield that protects it from the Sun. And its detectors are tucked away in a dewar filled with liquid helium. Here the detectors are cooled down to just a few degrees above absolute zero making them very very sensitive.	Footage of Spitzer. Exploded view of telescope. http://www.spitzer.caltech.edu/features/hd/index.shtml http://www.spitzer.caltech.edu/features/hd/files/Showcase4_XPlanets-HD.m4v
Spitzer has revealed a dusty Universe. Dark, opaque clouds of dust glow in the infrared when heated from within.	Full screen: Glowing dust clouds. (Dr. J. no longer visible)

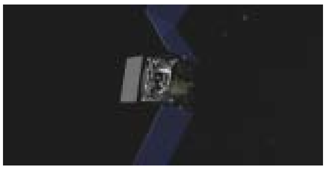
	 Ophcloud_spitzer.jpg (Credit: NASA JPL-Caltech, Harvard-Smithsonian CfA) http://apod.nasa.gov/apod/ap080215.html  m45_spitzerR.jpg (Credit: NASA, JPL-Caltech, J. Stauffer (SSC, Caltech)) http://apod.nasa.gov/apod/ap070413.html
Shock waves from galaxy collisions sweep up dust in telltale rings and tidal features, new sites for ubiquitous star formation.	Dusty structures and super star clusters in galaxy mergers.  http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=ssc2006-11a  http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig06-005 

	http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=ssc2008-14a
(Take 39.3.3) Dust is also produced in the aftermath of a star's death. Spitzer found that planetary nebulae and supernova remnants are laden with dust particles, the prerequisite building blocks of future planets.	Infrared images of planetary nebulae and supernova explosions.  snake_spitzer_big.jpg (Credit: S. Carey (SSC/Caltech), JPL-Caltech, NASA)) http://apod.nasa.gov/apod/ap070924.html
At other infrared wavelengths, Spitzer can also see right through a dust cloud, revealing the stars inside, hidden in their dark cores.	Spitzer view of 'dust-cloaked' star forming region.  ssc2008-03a1.jpg (Credit: NASA / JPL-Caltech / CfA) http://cosmiclog.msnbc.msn.com/archive/2008/02/12/659870.aspx
(Take 39.4.3) Finally, the space telescope's spectrographs have studied the atmospheres of extrasolar planets – gas giants like Jupiter, that race around their parent stars in just a few days.	Animation of transiting planet, combined with representation of Spitzer observations (?).  http://www.spitzer.caltech.edu/features/hd/files/Showcase4_XPlanets-HD.m4v AND/OR

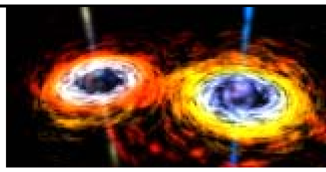
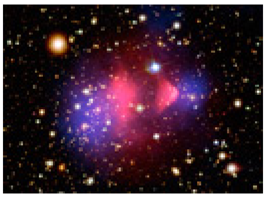
	 http://www.spacetelescope.org/videos/html/heic0807c.html  http://www.spacetelescope.org/videos/html/heic0807b.html heic0807b.avi
(Take 39.5.2) So what about X-rays and gamma rays? Well, they are completely blocked by the Earth's atmosphere. And so without space telescopes, astronomers would be totally blind to these energetic forms of radiation.	Dr. J. in virtual studio. Electromagnetic spectrum (from Hidden Universe) and atmospheric transmission graphic, now focussing on high-energy radiation.
X-ray and gamma ray space telescopes reveal the hot, energetic and violent Universe of galaxy clusters, black holes, supernova explosions, and galaxy collisions.	 http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010141/index.html J:\EyesSkies\animations\ch5\010141 (Credit: NASA)

	 http://www.spacetelescope.org/videos/html/heic0810c.html heic0810.avi
(Take 39.5.2 Pu 4) They are very hard to build, though. Energetic radiation passes right through a conventional mirror. X-rays can only be focused with nested mirror shells made of pure gold. And gamma rays are studied with sophisticated pinhole cameras, or stacked scintillators that give off brief flashes of normal light when struck by a gamma ray photon.	Images of nested mirrors and of gamma-ray detectors.  S68-03354.jpg (Credit: NASA Johnson Space Center (NASA-JSC)) http://nix.larc.nasa.gov/info;jsessionid=4fl8bpr50av80?id=S68-03354&orgid=8  STS037-51-006.jpg (Credit: NASA Johnson Space Center (NASA-JSC)) http://nix.larc.nasa.gov/info;jsessionid=4fl8bpr50av80?id=STS037-51-006&orgid=8  KSC-01PP-0192.jpg (Credit: NASA Kennedy Space Center (NASA-KSC)) http://nix.larc.nasa.gov/info;jsessionid=4fl8bpr50av80?id=KSC-01PP-

	0192&orgid=5
(Take 39.6.4 (39.6.2 also good)) In the 1990s, NASA operated the Compton Gamma Ray Observatory. At the time, it was the largest and most massive scientific satellite ever launched. A fully fledged physics lab in space.	Footage / animation of CGRO. cgro_iau.tar.gz Zipped file in images folder Deorbit_AEOS-CGRO.mpg cgro_vvu.mov Deploy_CGRO.jpg Cartoon_CGRO.tif cgro_0003356.jpg cgro_9134213.jpg CGRO_launch.tif CGRO_line_labels.tif Deploy_CGRO.jpg Poster_CGRO.tif CGRO_line_nolabels.tif [e-mailed newman@lheamail.gsfc.nasa.gov 23/07/08 and 30/07/08] [e-mailed myersjd@lheamail.gsfc.nasa.gov 04/08/08] [e-mailed gehrels@milkyway.gsfc.nasa.gov 04/08/08] john.d.myers@nasa.gov e-mailed 05/08/08 – will
In 2008, Compton was succeeded by GLAST: the Gamma Ray Large Area Space Telescope. It will study everything in the high-energy Universe from dark matter to pulsars.	Launch of GLAST; animation of GLAST in orbit. Launch: ksc_061108_glast_launch_1080i.mov http://www.nasa.gov/multimedia/hd/index.html

	 http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010251/index.html animations\ch5\010200 (Credit: NASA/Goddard Space Flight Center, Music composed by Nolan Gasser, © 2008, Music performed by the American Brass Quintet)  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010172/index.html animations\ch6\010164_without_map (Credit: NASA/Goddard Space Flight Center) also: http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010166/index.html animations\ch6\a010166 (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab) http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010164/index.html animations\ch6\010164_with_map (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab) Gamma ray sky moving:

	 http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003439/index.html animations\ch6\003439 animations\ch6\010164_without_map (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio) Animation: animations\ch6\003439_2
(Take 39.7.2) Meanwhile, astronomers have two X-ray telescopes in space. NASA's Chandra X-ray Observatory and ESA's XMM-Newton Observatory are both studying the hottest places in the Universe.	Footage of Chandra and XMM-Newton. From Kim and Megan O:\VIDEO\EyesSkies\videos06\CXO_Bshot_AprilHobart/ O:\VIDEO\EyesSkies\videos06\CXO_Bshot_DanaBerry/ XMM1111.jpg http://www.esa.int/esaCP/ESAPPMF18ZC_index_1.html#subhead1
4:46 (40) **Narrator**: This is what the sky looks like with X-ray vision. Extended features are clouds of gas, heated to millions of degrees by shock waves in supernova remnants. The bright point sources are X-ray binaries: neutron stars or black holes that suck in matter from a companion star. This hot, infalling gas emits X-rays.	Chandra Milky Way mosaic (zoom / pan).  gcenter_xray_rgb.ps (Credit: NASA/UMass/D.Wang et al.) Binary black holes?

	 http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010140/index.html animations\ch5\010140 (Credit: NASA)
Likewise, X-ray telescopes reveal supermassive black holes in the cores of distant galaxies. Matter that spirals inward gets hot enough to glow in X-rays just before it plunges into the black hole and out of sight.	X-ray image of distant galaxy, transforming into animation of matter falling into supermassive black hole.  http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010200/index.html (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab)
Hot but tenuous gas also fills the space between individual galaxies in a cluster. Sometimes, this intracluster gas is shocked and heated even more by colliding and merging galaxy clusters.	X-ray images / representations of intracluster gas.  1e0657_H1.jpg 1e0657_H2.tif (Credits: X-ray: NASA/CXC/CfA/M.Markevitch, Optical and lensing map: NASA/STScI, Magellan/U.Arizona/D.Clowe, Lensing map: ESO WFI) http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=Bullet%20Cluster&single=y&start=2

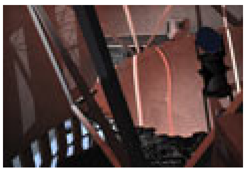
Even more exciting are gamma ray bursts, the most energetic events in the Universe. These are catastrophic terminal explosions of very massive, rapidly spinning stars. In less than a second, they release more energy than the Sun does in 10 billion years.	Animation of a GRB (from precursor to afterglow). OR  http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003439/index.html
5:48 (41) (Take 41.1.2) **Dr. J:** Hubble, Spitzer, Chandra, XMM-Newton and GLAST are all versatile giants. But some space telescopes are much smaller and have much more focused missions.	Dr. J. in front of MR image wall. Background: images of big space telescopes. O:\VIDEO\EyesSkies\videos06\CXO_Bshot_AprilHobart/ O:\VIDEO\EyesSkies\videos06\CXO_Bshot_DanaBerry/
Take COROT, for example. This French satellite is devoted to stellar seismology and the study of extrasolar planets.	Footage of COROT's planet detection technique.  corot 5_vue avant_hires.jpg (Credit: ESA/CNES/D. Ducros) http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=exoplanet&single=y&start=7

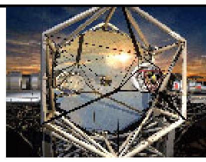
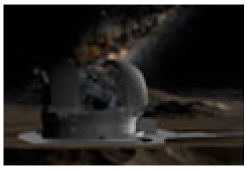
	 corot_2_hires.jpg (Credit: ESA/CNES/D. Ducros) http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=COROT&single=y&start=9 http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=COROT&single=y&start=2 http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=COROT&single=y&start=34 [e-mailed francoise.bailly-poirot@cnes.fr 04/08/08] sequence_complete_courbe_151105.mov anim_corot_ecorche_1205.mov
Or NASA's Swift satellite, a combined X-ray and gamma ray observatory designed to unravel the mystery of gamma ray bursts.	Footage of Swift. J:\EyesSkies\animations\ch6\SWIFT animation (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio) ONLY HAVE STANDARD DEFINITION

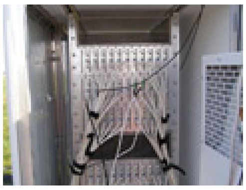
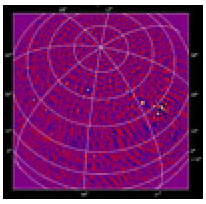
(Take 41.2.1) And then there's WMAP, the Wilkinson Microwave Anisotropy Probe. In just over two years in space, it had already mapped the cosmic background radiation to unprecedented detail. WMAP gave cosmologists the best view yet of one of the earliest phases of the Universe, more than 13 billion years ago.	Footage of WMAP and its results:  http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010121/index.html animations\ch6\010121 (Credit: NASA) also: http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010123/index.html animations\ch6\010123 (Credit: NASA) http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010122/index.html animations\ch6\010122 (Credit: NASA)
Opening up the space frontier has been one of the most exciting developments in the history of the telescope. So what's next? (6:39)	

7. What's next? (06:04)

In Arizona, the first mirror has been cast for the Giant Magellan Telescope. This huge instrument will be built at the Las Campanas Observatory in Chile. Its seven mirrors, each well over eight metres across, will be arranged like the petals of a flower. And together they will capture more than	 CompleteGMTAnim2.mov (Courtesy of Carnegie

four times the amount of light any current telescope can catch.	Observatories) THIS IS THE SAME VIDEO, BUT WITH AN EXTRA SHORT SHOT WITH STARS REFLECTED OFF THE MIRRORS Low GMT-AE-Full-D1-CL.mov (Low) F-D1-CL.mov (Courtesy of Carnegie Observatories) GMT-Wide-sun.tif (Courtesy of Carnegie Observatories)
The Californian Thirty Meter Telescope, planned for 2015, is more like a giant version of Keck. Hundreds of individual segments make up one enormous mirror as tall as a six-storey apartment.	Animation of TMT. **O:\VIDEO\EyesSkies\videos03\Ch.3_tmt_animation.avi** **Or:**  **Ch.3_26_TMT_Concept_1.jpg** (Credit: the TMT Observatory Corporation)  **Ch.3_32_TMT_Concept_tertiary_and_primary_mirrors.jpg** (Credit: the TMT Observatory Corporation)

	 **Ch.3_29_TMT_Concept_4.gif** (Credit: the TMT Observatory Corporation)
In Europe, plans are ready for a European Extremely Large Telescope. At 42 metres in diameter, its mirror will be as large as an Olympic swimming pool - twice the surface area of the Thirty Meter Telescope.	Animation of E-ELT. E_ELT.avi NEW ELT anis from Herbert in 1080p (for Koenig)!
These future monsters, optimised for infrared observations, will all be outfitted with sensitive instruments and adaptive optics.	More E-ELT Extra stills:  **Ch.2_15_ELT_Concept.jpg**  **Ch.2_16_ELT_Concept.tif**  **Ch.2_17_ELT_Concept.jpg**
They should reveal the very first generation of galaxies and stars in the history of the Universe.	Simulations of ELT science.
Moreover, they may provide us with the first true picture of a planet in another solar	Simulations of exoplanet detection.

system.	http://www.eso.org/gallery/v/Videos/ESO_ENGL.flv.html (1.57)
For radio astronomers, 42 meters is peanuts. They hook up many smaller instruments to synthesise a much larger receiver.	Image of radio antenna; zoom out to show it to be part of an array.
In the Netherlands, the Low Frequency Array, or LOFAR, is under construction. Fibre optics will connect 30 000 antennas to a central supercomputer. The novel design has no moving parts, but it can observe in eight different directions simultaneously.	LOFAR footage. DVD Footage requested from: boekhorst@astron.nl  signaalverwerkingskast LOFAR.jpg (Credit: ASTRON)  aardappelplanten plus sensor.jpg (Credit: ASTRON)  Agro sensor.jpg (Credit: ASTRON)  Figure01-LOFAR Press Release-April 2007.png (Credit: ASTRON)

First LOFAR station Exloo.jpg (Credit: ASTRON)

foto 060.jpg (Credit: ASTRON)

Geophone - three-axis vibration sensor.jpg (Credit: ASTRON)

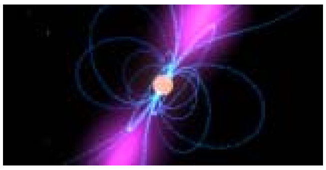
H4 n.jpg (Credit: ASTRON)

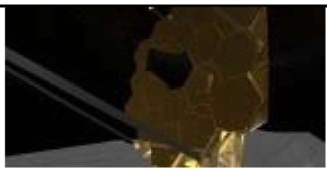
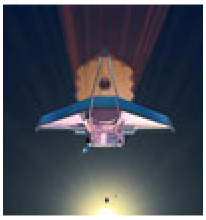
HBA Antennas.jpg (Credit: ASTRON)

LOFAR antennes.jpg (Credit: ASTRON)

Astron_Logo_1000.jpg (Credit: ASTRON)

	[boekhorst@astron.nl] LOFAR animation at lower right of http://www.lofar.org/p/geninfo.htm
LOFAR technology will probably find its way into the Square Kilometre Array, which is now topping the wish-list of radio astronomers. The international array will be built in Australia or South Africa. Large dish antennas and small receivers will team up to provide incredibly detailed views of the radio sky. And with a total collecting area of one square kilometre, the new array will be by far the most sensitive radio instrument ever constructed.	animations. skaAnimation_high.mpg SKA_3.tif (greenwood@skatelescope.org) (Credit: SKA Program Development Office under contract to Xilostudios) Through Helen sim: Colin Greenwood Executive Officer SKA Program Development Office Jodrell Bank Centre for Astrophysics Rm 3.116, Alan Turing Building the University of Manchester Oxford Road Manchester M13 9PL, UK Tel: +44 (0)161 275 4063 Fax: +44 (0)161 275 4049 Email: greenwood@skatelescope.org Web: www.skatelescope.org

Evolving galaxies, powerful quasars, blinking pulsars – no single source of radio waves will be safe from the spying eyes of the Square Kilometre Array. The instrument will even look for possible radio signals from extraterrestrial civilisations.	SKA science.  http://svs.gsfc.nasa.gov/vis/a010000/a010200/a010205/index.html animations\ch7\010205 (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab)
And what about space?	
Well, after its fifth and final servicing mission, the Hubble Space Telescope will be on active duty until 2013 or so. Around that time, its successor will be launched.	Footage of HST servicing. http://science.nationalgeographic.com/science/wallpaper/first-service-mission.html Ariane 5 launch. launch-ariane-atv-2008-03-09_qt_high.mov (Credits: ESA) (super low) http://www.esa.int/esa-mmg/mmg.pl?b=b&type=V&single=y&start=38&size=b
Meet the James Webb Space Telescope, a space infrared observatory named after a former NASA administrator.	 http://svs.gsfc.nasa.gov/vis/a010000/a010100/a010124/index.html animations\ch7\JWST1 (Credit: NASA) animations\ch7\JWST2 (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab

	 jwst_720p.m2v (Credit: NASA/Goddard Space Flight Center Conceptual Image Lab) (low) O:\VIDEO\EyesSkies\videos07\08jwstb_depall_dv.mov O:\VIDEO\EyesSkies\videos07\deployment.mov O:\VIDEO\EyesSkies\videos07\jwst_telescope_stowqt.mov O:\VIDEO\EyesSkies\videos07\JWSTAnimation.mpg **Extra footage: WEBB DVD**
Once in space, its 6.5 metre segmented mirror unfolds like a blooming flower – one seven times as sensitive as Hubble's.	Closeup of mirror deployment.
A large sunshade keeps the optics and the low-temperature instruments in permanent shadow, allowing them to operate near a whopping minus 233 degrees Celsius.	Closeup of sunshade and instruments. Extra:  jwst_new6(nasa).tif OR jwst_new6.jpg (Credit: NASA (Northup Grumman, ESA & CSA) http://www.jwst.nasa.gov/images_jwst.html

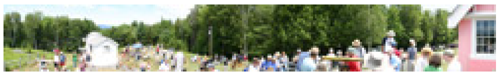
The James Webb Space Telescope won't orbit the Earth. Instead, it will be parked 1.5 million kilometres from our planet, in a wide orbit around the Sun.	Animation showing JWST's orbit. Jwst_g?
Half a century ago, the Hale telescope on Palomar Mountain was the largest in history. Now, an even bigger one will be flying into the depths of space.	hale_5m_outsidefull.mov Zoom out to show more and more surrounding Universe.
We can only speculate about the exciting discoveries it will make. Stay tuned!	
3:27 (43) **(Part 1: 43.1.6** **Part 2: 43.1.7)** **Dr. J:** Meanwhile, creative engineers come up with revolutionary designs for new telescopes all the time.	Dr. J. in virtual studio.
In Canada, scientists have built a so-called "liquid mirror telescope". In this kind of telescope the starlight is reflected not by a solid mirror but rather by the curved surface of a rotating reservoir of liquid mercury. Because of their design, mercury telescopes can only look straight up, but their advantage is that they're relatively cheap and easy to build.	Images of LMT: 180718main_3-7-m1.JPG (Credit: Guy Plante (Laval)) http://www.nasa.gov/centers/ames/multimedia/images/2007/liquidmirror.html  180724main_6-mMirror.jpg (Credit: Paul Hickson (UBC)) Low

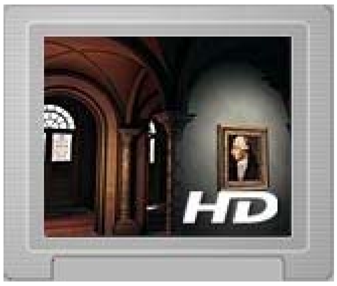
Radio astronomers want to put a LOFAR-like array of small antennas onto the surface of the Moon, as far away as possible from terrestrial sources of interference.	Animation of radio telescope on moon... .  http://www.spacetelescope.org/videos/html/astro_ba.html (SD)
Who knows, one day there might even be a big optical telescope on the far side of the Moon.	...and of big optical telescope on moon. OR just Moon:  http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003444/index.html animations\ch1\a003400 (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio)
And using space telescopes and occulting disks, X-ray astronomers hope to improve their eyesight tremendously in the future. They may even succeed in imaging the very edge of a black hole.	Images of future x-ray space telescopes and what it might deliver.
4:11 (44) Narrator: One day, the telescope may answer one of the most profound questions puzzling humanity: are we alone in the	Zoom in on nebula.

Universe?	http://www.spacetelescope.org/videos/html/heic0715c.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0715c.avi
We know that there are other solar systems out there. We suspect there are even planets like Earth, with liquid water. But... is there life?	Simulations of exoplanets and Earth-like planets. ftp://ftp.eso.org/pub/pad/broadcasting/NR-2007/VNR22/ … ANIMATIONS_BROADCAST.mov
Locating such extrasolar planets proves difficult. They are often hidden from astronomers by the intense light radiated by their mother stars. Interferometers launched into the darkness of space may provide a novel answer. Right now NASA is considering a project called the Terrestrial Planet Finder. And in Europe, scientists are designing the Darwin Array.	TPF/Darwin footage. [e-mailed Randal.K.Jackson@jpl.nasa.gov 09/08/08] OR http://www.spacetelescope.org/videos/html/heic0720e.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0720e.avi

	 http://www.spacetelescope.org/videos/html/heic0720d.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0720d.avi  http://www.spacetelescope.org/videos/html/heic0720c.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0720c.avi
Six space telescopes orbit the Sun in formation. Lasers control their mutual distances to the nearest nanometre. Together they have incredible resolving power, cancelling out the light from overbearing stars so scientists can actually see Earth-like planets around other stars.	More of the same; simulations of planet detections.
Next astronomers must study the light reflected by the planet. It carries the spectroscopic fingerprint of the planet's atmosphere.	Images of Earth-like planets. 218069main_HSTMethaneunlabeled_20080319_HI.jpg  http://www.spacetelescope.org/vid

	eos/html/hst15_exoplanet.html http://www.nasa.gov/mission_pages/hubble/science/exoplanet_transit.html
Who knows, in 15 years time we may detect the signatures of oxygen, methane and ozone. The signposts of life.	Zoom in: images of possible life forms. (**MARTIN**)
5:19 (45) **(Take 45.1.7)** **Dr. J:** The Universe is full of surprises. The sky never ceases to impress.	Night sky above horizon; silhouette figure walks outside and points telescope. (Dr. J. not in view) FAST MOTION, FAST MUSIC Slowly rotating sky. USE Bernd Proschold
No wonder that hundreds of thousands of amateur astronomers across the globe go out every clear night to marvel at the cosmos.	**USE Babak-MM2.avi (7 seconds long)** Babak-MM4.avi and Babak-MM5.avi are also good, but both are fast and a bit jumpy when slowed down (TWAN footage) (Additional: Stellafane footage. http://www.ct-astronomer.com/stellafane2006.htm  summit pan 1.jpg (Credit: Phil Harrington) 

	summit pan 3.jpg (Credit: Phil Harrington)  summit pan 4.jpg (Credit: Phil Harrington) Stellafane_panorama01.jpg (Phil Harrington) Stellafane_panorama03.jpg (Phil Harrington Webmaster@Stellafane.com) http://stellafane.org/post_conv/2005_conv/2005_conv.html)
Their telescopes are much better than the instruments used by Galileo. Their digital images even surpass the photographic images taken by professionals just a few decades ago.	Examples of amateur results. http://www.ct-astronomer.com/astrophotos.htm http://astrosurf.com/sguisard/  SGU-Cone-Rosette-STL-200mm-M-cp8.jpg  SGU-Baade_Window-STL-300mm-M-cp8.jpg  SGU-Etacar-070513-FS128-STL-H15x20m-RVB8x10m-VRGLL-L-

	cp8.jpg  SGU-LMC-300mm-V5-M-cp8.jpg SGU-rhooph-060402-fsq-50x5min-800A-S-ps-cp.jpg SGU-ic434-v2_filtered-ps2-S.jpg
Astronomers' quest for cosmic understanding, their telescopic exploration of the Universe, is only 400 years old. There's still a lot of uncharted territory out there. (6:04)	Mosaic of nice space images; more and more images are added (they become smaller and smaller), until a grid of many dozens of images is visible.
8. Postlude (00:46)	
0:00 (46) **Narrator**: We've come a long way since Galileo began charting the heavens with his telescope four centuries ago. Today we still observe the Universe with telescopes, not only from Earth but in the limitless regions of space. The seed of humanity lies in our seemingly endless supply of ingenuity and curiosity. We have just begun answering some of the greatest questions conceived. We have charted over 300 planets around other stars	 http://www.spacetelescope.org/videos/html/heic0719f.html (Credit: ESA/Hubble (M. Kornmesser & L. L. Christensen)) heic0719f.avi BUT replace Messier etc w. Lipperhey, Janssen, Galileo, Kepler, Newton etc. TWAN footage End: Visuals: Stars moving above telescopes

in our own Milky Way and located organic molecules on planets around far flung stars. These incredible discoveries may seem like the zenith of human exploration, but the best is undoubtedly yet to come... You too can join the discoverers. Look up and wonder. 00:46	SGU_Zodiacal_Light_and_Milky_Way_1280x720.wmv Bernd Proschold:   END TITLES

Credits

An ESA/Hubble-IAU-ESO production
Celebrating the International Year of Astronomy 2009

www.eyesontheskies.org • *www.spacetelescope.org* • *www.astronomy2009.org* •
www.eso.org • www.iau.org

Direction & Executive Producer
Lars Lindberg Christensen, ESA/ESO

Art Director / Production Designer
Martin Kornmesser, ESA/ESO

Written by
Govert Schilling
Lars Lindberg Christensen, ESA/ESO

3D Animations
Martin Kornmesser, ESA/ESO
Luis Calçada, ESO

DVD Authoring
Andre Roquette, ESA/ESO

Lee Pullen, ESA/ESO

Research
Laura Simurda, ESA/ESO

Editing
Martin Kornmesser, ESA/ESO

Cinematographer & Narration Mastering
Peter Rixner

Soundtrack & Sound Effects
movetwo - Axel Kornmesser & Markus Löffler

Lead Scientist
Dr. J (Dr. Joe Liske, ESO)

Technical Support
Lars Holm Nielsen (ESA/ESO)
Raquel Yumi Shida (IAU/ESA-ESO)
Dirk Essl (ESO)

IYA2009 Coordination
Pedro Russo & Mariana Barrosa (IAU/ESA-ESO)

Proof reading
Anne Rhodes

English Narration
Howard Cooper

German Narration
Thomas Höricht

Chinese (mandarin) Narration
Prof. Wei-Hsin Sun (NTU/CAST)
Shiu-Sheng Chen

Translations

БЪЛГАРСКИ
Daniela Kirilova
Radoslav Zamanov
Nevyana Markova
Vassil Popov
Galin Borissov
Lyuba Slavtcheva-Mihova
Valentin Koptchev
Mariya Lyubenova (Astronomical Association, Sofia)

BOSNIAN
Muhamed Muminović i Marko Bačanović

ČESKÝ
Jan Veselý, Hvězdárna a planetárium v Hradci Králové,
Jiří Dušek, Hvězdárna a planetárium Mikuláše Koperníka v Brně

CHINESE
Sze-leung Cheung
Prof. Wei-Hsin Sun (NTU/CAST)
Taipei Astronomical Museum

DEUTSCH
Prof. Dr. Susanne Hüttemeister
Dr. Thomas Langbein
Dr. Thomas Posch
Dipl.-Ing. Herbert Raab
Mag. Daniela Schobesberger
Dr. Gabriele Schönherr
Dr. Björn Voss

ΕΛΛΗΝΙΚΑ
Manolis Zoulias (Academy of Athens, Greece)

ENGLISH
Lee Pullen
Andre Roquette

ESPAÑOL
Tania Penuela
Carolina Nunez
Bruno Sanchez-Andrade Nuño

עִבְרִית
רקוצ יש ר"ד :תירבעל םגרת

ÍSLENSKA
Snæbjörn Guðmundsson
Sverrir Guðmundsson
Sævar Helgi Bragason

FRANÇAIS
Julie Bolduc-Duval
Anny-Chantal Levasseur-Regourd

ITALIANO
Ufficio Comunicazione INAF:
Caterina Boccato
Valeria Cappelli
Chiara Di Benedetto
Elena Lazzaretto

LATVIEŠU VALODA
Mârtiòð Gills
Kristîne Adgere
Andrejs Alksnis
Kârlis Bçrziòð
Mâris Krastiòð
Agnese Zalcmane

MAGYAR
Csák Balázs
Dr. Hegedüs Tibor
Molnár Péter

Szalai Tamás

NEDERLANDS
Eddy Echternach

PORTUGUÊS
Nelma Alas Silva (CAUP)
Ricardo Reis (CAUP)
Mariana Barrosa (IAU & ESA- ESO)

PORTUGUÊS (BRAZIL)
Augusto Damineli

SLOVAK
Marian Vidovenec

SLOVENSKI JEZIK
Andreja Gomboc in Bojan Kambič

SUOMI
Leena Tähtinen

KISWAHILI
Dr Noorali Jiwaji
Mr Nathaniel Mbaga
Prof. Tigiti Sengo
Ms. Hadija Jilala
Mr. Richard Mtambi
Ms Sabra Ahmed
Ms Consolata Mushi

POLSKI
Leszek Błaszkiewicz
Ewa Janaszak
Bogusław Kulesza
Jacek Szubiakowski
(Olsztyńskie Planetarium i Obserwatorium Astronomiczne)
Anna Raiter (ESO)

Contributing photographers
Jean-Charles Cuillandre
Babak Tafreshi/The World At Night
Bernd Pröschold/The World At Night
Kirk Pu'uohau-Pummill (Gemini Observatory)
Stéphane Guisard (ESO)
Thad V'Soske/The World At Night
Serge Brunier/The World At Night
Yuri Beletsky/ESO

Thanks to

CELESTRON

A. Fujii

Aaron Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
Adam Block
Alain Riazuelo
ALMA
American Institute of Physics/Emilio Segrè Visual Archives
Andrew Dunn
Association of Universities for Research in Astronomy
AUI
Bill Miller
C.R. O'Dell/Rice University
Calvin Hamilton
Canada-France-Hawaii Telescope/Coelum
CFHT/Jean-Charles Cuillandre
D.Clowe
Dan Schechter/Science Photo Library
Davide de Martin
De Vero Telescopii Inventore by Pierre Borel
Digitized Sky Survey 2
Dirk Bernhardt-Walther
Effelsberg Telescope/MPI für Radioastronomie
Eran Laor Cartographic Collection and The Hebrew University of Jerusalem, Dept. of Geography
ESA
ESA/Hubble
ESO
Frank Summers (NASA/STScI)
Gemini Observatory
George Willis Ritchey
GMT/Carnegie Observatories
Guy Plante (Laval)
H. Weaver (JHU/APL), A. Stern (SwRI), and the HST Pluto Companion Search Team
Hale Observatories/Science Photo Library
Historic Cities Project
History of Science Collections, University of Oklahoma Libraries
Huntington Library
IceCube
J. Bally (University of Colorado) and H. Throop (SWRI)
J. Stauffer (SSC, Caltech)
J. Westphal (Caltech)
James Cook University (Graeme L. White & Glen Cozens)
jcookfisher
Jeff Hapeman
K. Noll (STScI)
Keck Observatory
Klaus Dolag (MPA, Garching)
L. Cieza (Univ. of Texas at Austin)
Large Binocular Telescope Observatory/Marc-Andre Besel
Large Binocular Telescope Observatory/Ray Bertram
Lars Bachmann (SDC)
LOFAR/ASTRON
M. Markevitch,
M. McCraughean
M. Robberto (STScI)
MAGIC Telescope
Mark Hanna
Michael Pierce

Michael Richmond
Museum Boerhaave
NASA
NASA/Chandra X-ray Observatory Center
NASA/Goddard Space Flight Center Conceptual Image Lab
NASA/Johnson Space Center
NASA/JPL-Caltech
NASA/NCSA University of Illinois
NASA/Space Telescope Science Institute
NASA/Spitzer Science Centre
NASA/University of Chicago and Adler Planetarium and Astronomy Museum
NASA/Voyager 2
Nigel Sharp
NOAO
NRAO
NSF
Palomar observatory
Panther Observatory
Paul Hickson (UBC)
Pedro Ré and Lewis Morris Rutherfurd
Peter Rixner
Phil James (Univ. Toledo), Todd Clancy (Space Science Inst., Boulder, CO), Steve Lee (Univ. Colorado)
Pierre Auger Observatory
R. Thompson (Univ. Arizona)
Richard Dreiser
Rob van Gent
Robert Berrington (Indiana University)
Robert Gendler
Robert Hurt (NASA/SSC)
Royal Astronomical Society/Science Photo Library
S. Carey (SSC/Caltech)
Science Photo Library
Scott Kardel
Shapell Family Digitization Project
Sheila Terry/Science Photo Library
SKA Program Development Office/Xilostudios
SOHO (ESA & NASA)
Special Astrophysical Observatory
Stellafane/ Phil Harrington
Steve Cannistra
T. Megeath (University of Toledo)
The Board of Regents of the University of Oklahoma
The Franklin Institute
The Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration
The Jewish National & University Library
The Nationaal Archief
The TMT Observatory Corporation
The University of Arizona's Steward Observatory Mirror Laboratory
The University of Chicago
Todd Mason, Mason Productions/LSST Corporation
Tom Jarrett
Univ. of Maryland/A.S. Wilson et al.
VISTA
W. M. Keck Observatory/Rick Peterson
Whipple Observatory
Wiphu Rujopakarn/John Hill/Aaron Ceranski

WIYN

This movie is dedicated to:
the users of the amazing telescope
in the past, present and future...
&
Oliver Patkós Christensen (production child)