

# 11 TELESCOPE and X-RAY

## SYNOPSIS

### **TELESCOPE – New Eyes on the Cosmos**

For well over 15 years, free from the distortions of Earth's atmosphere, the Hubble Space Telescope has collected breathtaking images of the cosmos with remarkable clarity. Now, ground-based telescopes are fighting back. They are combining the sight of several instruments and correcting atmospheric shimmer. The Very Large Telescope in Chile is already out-doing Hubble. When OWL, the Overwhelmingly Large Telescope, comes on stream, it will image planets around other stars.

### **X-RAY – Invisible Astronomy**

Much of the cosmos cannot be seen through optical telescopes. But it can be detected in wavelengths of the electromagnetic spectrum ranging from gamma-rays, through X-rays and ultra-violet to infra-red and radio. They reveal cauldrons of starbirth, exploding stars, neutron stars and black holes. Most exciting are Gamma-ray Bursters - cosmic flashes as bright as a million trillion Suns. On average, a Gamma-ray Burster occurs somewhere in the sky every day.

## BACKGROUND

Telescopes are our eyes on the Universe and telescopes work by imitating our eyes. We see an object when light from that object passes through a lens at the front of the eye and is brought to a focus at the back – on the retina. The image then travels to the brain for processing.

With a telescope, light from the cosmos is collected by a large primary mirror at the rear of the instrument, bounced to a secondary mirror, then returned, usually through a hole in the primary mirror, to a focal point behind. That point is the so-called prime focus. If the focal point is at the side of the telescope, it is called the Nasmyth focus. The focal point is like the retina. Where the telescope processes the images is like the brain.

The best locations for telescopes are on arid sites high above the clouds. The Canary and Hawaiian islands are good because oceans steady the atmosphere. The less the shimmer, the sharper the image. The other vital factor is the darkest possible skies – the reason why observatories are built well away from the light and dust pollution of cities.

In orbit 600 kilometres above Earth, the Hubble Space Telescope has no such problems. Freedom from atmospheric distortion more than compensates for Hubble's modest 2.4-metre mirror. Its images are second to none. Launched by Space Shuttle in 1990, subsequent missions have regularly serviced and repaired Hubble and boosted its orbit.

Hubble gathers images with instruments behind its primary mirror – like ACS, the Advanced Camera for Surveys, and NICMOS, the Near Infrared Camera and Multi-Object Spectrometer. Individually or in unison, the cameras have gleaned thousands of superb images of objects in the Solar System, our Galaxy and the cosmos beyond. But, as Hubble nears the end of its life, ground-based astronomy is fighting back.

On a desert mountaintop in the Chilean Andes, the Very Large Telescope (VLT) is four telescopes in one. Each instrument has a main mirror which is 8.2 metres wide, 17 centimetres thick and ground and polished to an accuracy of ten nanometres. To keep their precise curvature, each mirror has 150 supports – tiny computerised actuators that maintain the optimum shape of the reflecting surface.

As each mirror slews when tracking the sky, the intelligent mirror-supporters compensate for shifting weight. The technique is called “active optics”. The VLT overcomes atmospheric turbulence with actuators beneath each secondary mirror. They sense distorted incoming light and deform the mirror surface to compensate. Wavy beams are straightened as if the air above the telescopes were perfectly still – a trick called “adaptive optics”.

The VLT is a giant eye on the sky and out-performing Hubble. To light already gathered by its four big instruments, the VLT is marrying that of four smaller telescopes. Together they have the grasp of a mirror over 16 metres across. Even so, when the Overwhelmingly Large Telescope (OWL) comes on stream, its incredible light grasp and ability to resolve the minutest details will be equivalent to a mirror 100 metres across. Still in the planning stage, OWL will see the earliest galaxies and planets around other stars.

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Conventional astronomy reveals only part of the cosmos. Even the most powerful optical telescope leaves much of the Universe invisible. That is because optical light, split into the seven colours of the rainbow, is just the visible sliver in a band of invisible radiation called the electromagnetic spectrum.

Beyond violet in the visible spectrum, wavelengths shorten through ultra-violet, X-rays and gamma-rays - the shortest of all. In the other direction, beyond red, wavelengths lengthen through infra-red to the longest wavelengths of radio. The human eye detects only visible light – a tiny fraction of all electromagnetic radiation. But today non-optical telescopes let us see the invisible.

The main problem with non-optical astronomy is that most of its wavelengths are blocked by scattering in the dust and moisture of the atmosphere. Only visible light and radio waves reach the ground. As a consequence, radio was the earliest non-optical astronomy – an offspring of radar developed in World War II.

Radio waves are caught in great steerable dishes – either a big single dish or a network of smaller dishes like the Very Large Array (VLA) in New Mexico, USA. Each dish contributes to a collective focus – so-called aperture synthesis. Such detectors have unveiled radio galaxies with vast jets that indicate a supermassive black hole at the heart of each system.

With the exception of near-infra-red, which can be detected in moisture-free observatories at the south pole and on arid mountaintops, non optical astronomy is conducted from space. For instance, Spitzer is an infra-red space telescope that detects dense clouds of dust and the cooler cosmos – invisible optically. Cauldrons of star-birth are revealed.

The spacecraft SOHO works partly in ultra-violet. It unveils the seething outer atmosphere of the Sun, the corona. Another craft, GALEX, sees the Universe in ultra-violet. It detects stellar nurseries and great emissions from hot young stars – otherwise invisible. Also working in space, the Chandra Observatory collects elusive X-rays by funnelling them to a focus on an electronic detector.

After the death of a star as a supernova, Chandra excels at imaging waves of expanding gas. In X-ray they glow brightly. In visible light the famous Antennae colliding galaxies show a firestorm of starbirth. But in X-ray Chandra sees more – a maelstrom of exploding stars, neutron stars, black holes and gas at 100 million degrees.

Gamma-ray astronomy has unmasked the most powerful explosions in the cosmos - Gamma-Ray Bursters. Hypernovae are thought to be the cause. An immensely massive supergiant runs out of fuel. The core collapses to a black hole. Powerful jets spew from the surrounding disk and blast through the stellar surface. The resulting flash is as bright as a million trillion Suns – and only detected in gamma-rays.

### **Weblinks for TELESCOPE – New Eyes on the Cosmos**

<http://www.astronomy-for-kids-online.com/howdotelescopeswork.html> - From “Astronomy for Kids Online”, a simple guide to how telescopes work.

<http://www.nmm.ac.uk/server/show/conWebDoc.411> - From the National Maritime Museum in Greenwich, England, a guide to how telescopes work.

<http://www.eso.org/projects/vlt/> and <http://www.eso.org/paranal/> - Home pages for the European Southern Observatory’s Very Large Telescope (VLT) and for the Cerro Paranal Observatory where it is located, including the layout of the observatory, the unit telescopes and future developments.

<http://www.gemini.edu/> - Home page for the Gemini Observatory, comprising the two telescopes Gemini North and Gemini South, with links to an image gallery, education and outreach, newsletters and press releases.

<http://www.ifa.hawaii.edu/mko/> - From the University of Hawaii’s Institute of Astronomy, a comprehensive guide to the telescopes and other facilities of the Mauna Kea Observatories.

<http://www.iac.es/en/en.htm> - Gateway to the European Northern Observatory, which comprises the Instituto de Astrofísica de Canarias (IAC) and its two main

observatories – the Observatorio de Teide, on Tenerife, and the Observatorio del Roque de los Muchachos, on La Palma – with links to the two observatory sites. In English and Spanish.

<http://www.keckobservatory.org/> - Home page for the W.M. Keck Observatory atop Mauna Kea in Hawaii, with links to an image gallery, education and outreach and press releases.

<http://medusa.as.arizona.edu/lbto/> - Home page for the Large Binocular Telescope Observatory atop Mount Graham in Arizona, an amazing project to construct a binocular telescope consisting of two 8.4-meter mirrors on a common mount – equivalent in light-gathering power to a single 11.8 meter instrument.

<http://hubblesite.org/> - Main site for the Hubble Space Telescope, with links to the extensive image gallery, the news center, all the latest discoveries and details of the telescope's design and construction.

<http://heritage.stsci.edu/> - A glorious selection of specially chosen images from the Hubble Space Telescope, enhanced and explained by experts in order to educate and inspire.

[http://en.wikipedia.org/wiki/Active\\_optics](http://en.wikipedia.org/wiki/Active_optics)

and

[http://en.wikipedia.org/wiki/Adaptive\\_optics](http://en.wikipedia.org/wiki/Adaptive_optics) - From Wikipedia, the free encyclopedia, two useful introductions to active and adaptive optics.

<http://www.eso.org/projects/owl/> - An introduction to the ESO 100-meter OverWhemingly Large (OWL) telescope concept, including science with OWL, the telescope design, an image gallery, frequently asked questions and links.

### **Weblinks for X-RAY – Invisible Astronomy**

[http://imagine.gsfc.nasa.gov/docs/science/known\\_11/emspectrum.html](http://imagine.gsfc.nasa.gov/docs/science/known_11/emspectrum.html) - From NASA's Goddard Space Flight Center, an introduction to the electromagnetic spectrum.

[http://en.wikipedia.org/wiki/Electromagnetic\\_spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum) - From Wikipedia, the free encyclopedia, an overview of the electromagnetic spectrum.

<http://www.darksky.org/VisionSeries/vs2.html> - From the International Dark-Sky Association, a useful description of how the human eye works.

[http://en.wikipedia.org/wiki/Radio\\_astronomy](http://en.wikipedia.org/wiki/Radio_astronomy)

and

[http://en.wikipedia.org/wiki/Submillimetre\\_astronomy](http://en.wikipedia.org/wiki/Submillimetre_astronomy)

and

[http://en.wikipedia.org/wiki/Infrared\\_astronomy](http://en.wikipedia.org/wiki/Infrared_astronomy)

and

[http://en.wikipedia.org/wiki/UV\\_astronomy](http://en.wikipedia.org/wiki/UV_astronomy)

and

[http://en.wikipedia.org/wiki/X-ray\\_astronomy](http://en.wikipedia.org/wiki/X-ray_astronomy)

and

[http://en.wikipedia.org/wiki/Gamma-ray\\_astronomy](http://en.wikipedia.org/wiki/Gamma-ray_astronomy) - A selection of entries from Wikipedia, the free encyclopedia, describing astronomical observations across the electromagnetic spectrum.

<http://www.astron.nl/wsr/WSRTgen/Howworks.html> - How a radio telescope works from the scientists at Westerbork's Synthesis Radio Telescope.

<http://www.nrao.edu/> - Main website of the National Radio Astronomy Observatory (NRAO) with an image gallery and press releases, and links to the various NRAO sites and telescopes.

<http://www.spitzer.caltech.edu/spitzer/index.shtml> - Home page for the Spitzer Space Telescope, with images, newsroom, features and explanations of what infra-red astronomy can tell us about the Universe.

<http://sohowww.nascom.nasa.gov/> - The Solar and Heliospheric Observatory (SOHO) web pages provide general information about the Sun and solar activity with links to the very best and latest SOHO images.

<http://www.galex.caltech.edu/> - Public home page for Caltech's Galaxy Evolution Explorer spacecraft.

<http://sci.esa.int/science-e/www/area/index.cfm?fareaid=23> - Home page for the European Space Agency's XMM-Newton mission.

<http://chandra.harvard.edu/> - The Chandra X-ray Observatory's excellent website for public information and education.

[http://imagine.gsfc.nasa.gov/docs/science/know\\_11/bursts.html](http://imagine.gsfc.nasa.gov/docs/science/know_11/bursts.html) - From NASA's Goddard Space Flight Center, a useful introduction to the mystery of Gamma-Ray Bursts.

<http://swift.gsfc.nasa.gov/docs/swift/> - Home page for NASA's Swift Gamma-Ray Burst Mission.

