Hubble Vision

Dr Martin Hendry
Dept of Physics and Astronomy
University of Glasgow

Hubble Vision:

The Legacy of the Hubble Space Telescope

10 meetings, beginning 12/01/08

Course Coordinator

Dr Martin Hendry, martin@astro.gla.ac.uk Tel: 0141 330 5685

Course Aims

To review the scientific legacy of the Hubble Space Telescope, investigating some of the key discoveries made by HST during the telescope's 18 years of operation.

Hubble Vision:

Course Topics

- A brief history of telescopes, and the 'case for space'
- HST and the Solar System
- HST and the lives and deaths of stars
- The search for extra-solar planets
- From Hubble the man to Hubble the telescope
- Mapping and measuring the Universe with HST
- A long time ago, in a galaxy far, far away
- Space telescopes across the E-M spectrum and beyond
- After Hubble: the James Webb Space Telescope

Hubble Vision:

Resources on the web

http://www.astro.gla.ac.uk/users/martin/teaching/hubble/

Username: space
Password: telescope

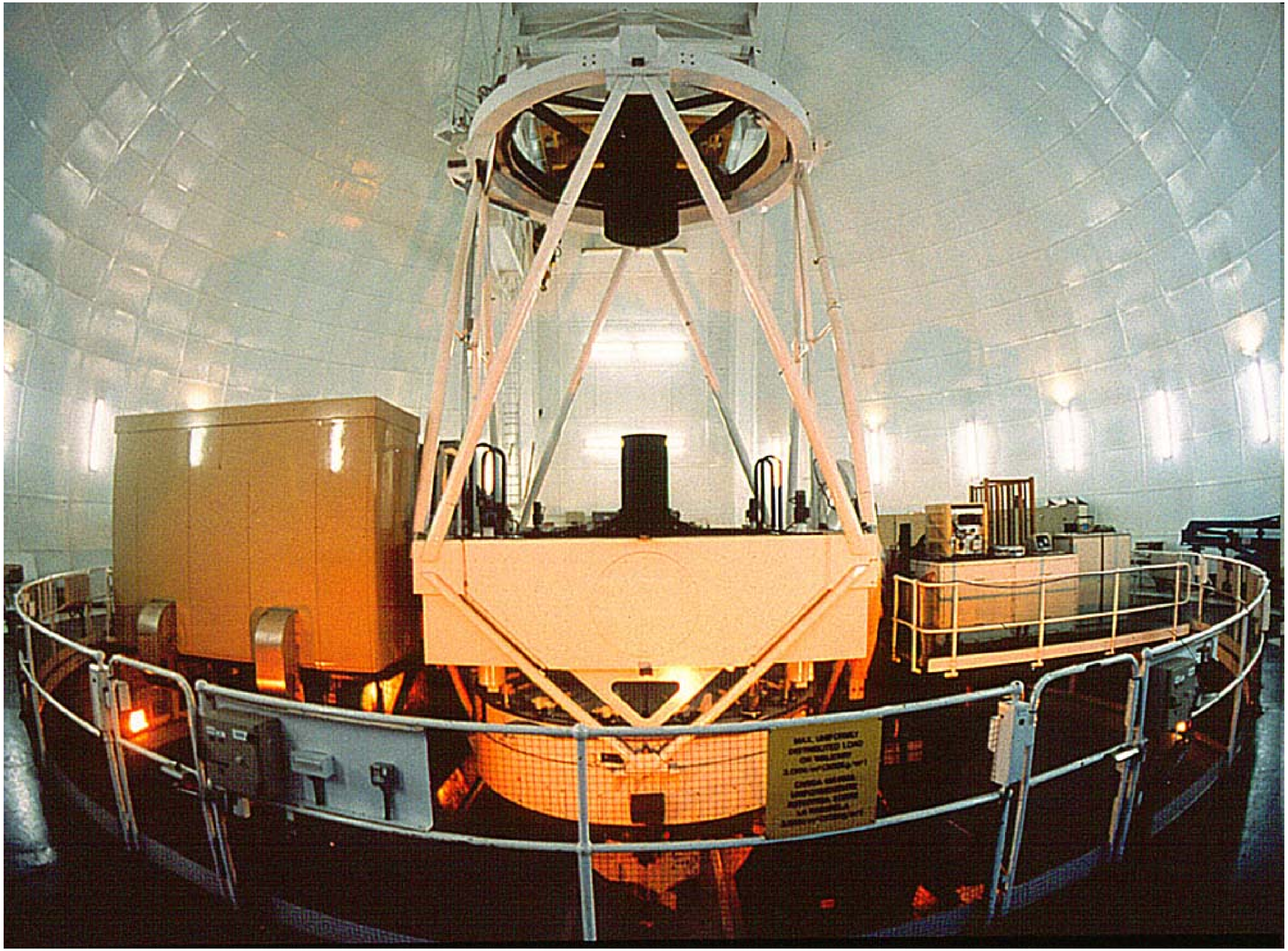
THE UNIVERSE
YOURS TO DISCOVER

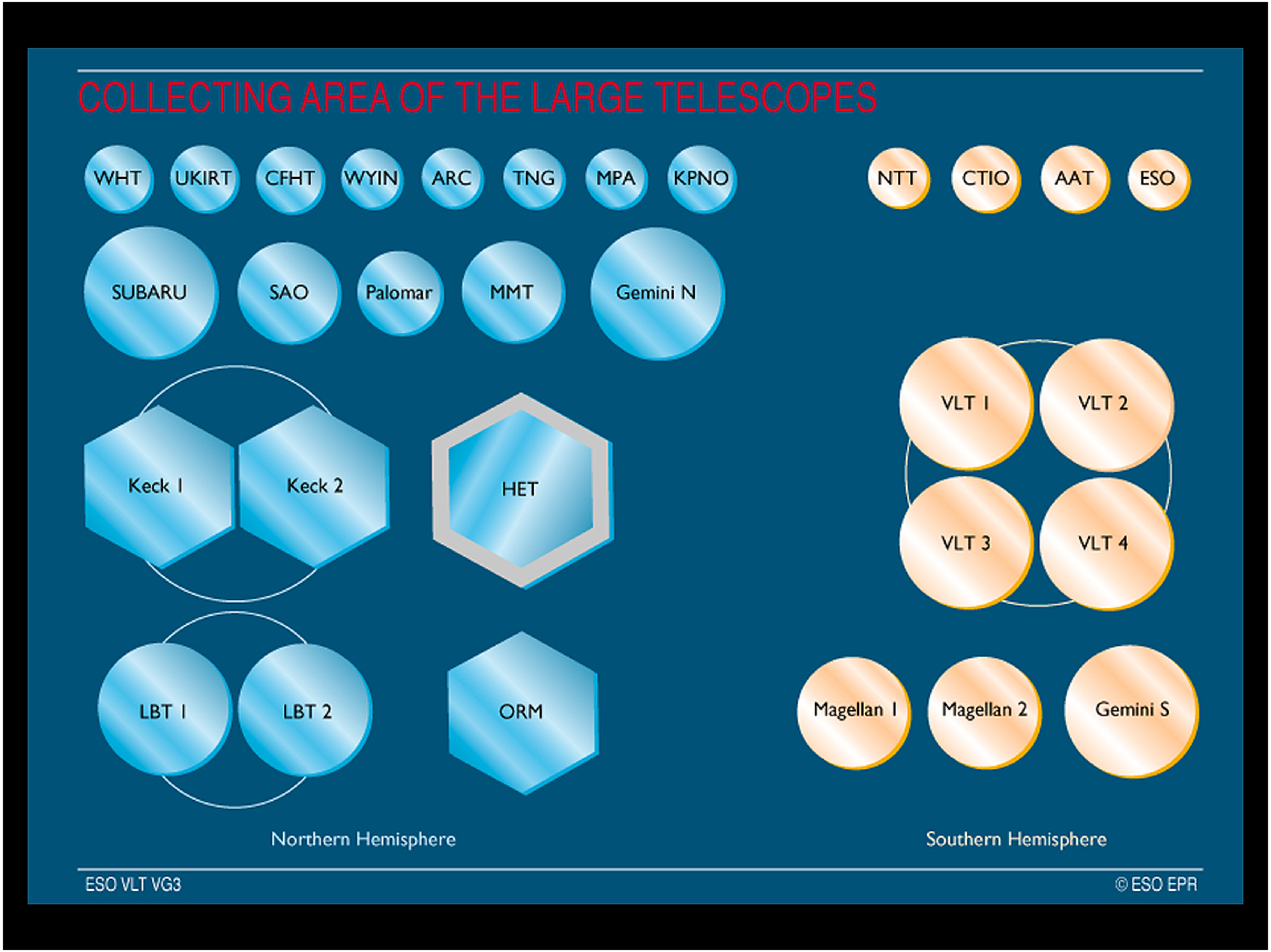
INTERNATIONAL YEAR OF
ASTRONOMY
2009

SUPA IGR University of Glasgow

DACE, January 2009

DACE, January 2009





COLLECTING AREA OF THE LARGE TELESCOPES
WHT
UKIRT
CFHT
WYIN
ARC
TNG
MPA
KPNO
NTT
CTIO
AAT
ESO
SUBARU
SAO
Palomar
MMT
Gemini N
VLT 1
VLT 2
VLT 3
VLT 4
Keck 1
Keck 2
HET
LBT 1
LBT 2
ORM
Magellan 1
Magellan 2
Gemini S
Northern Hemisphere
Southern Hemisphere
ESO VLT VG3
© ESO EPR

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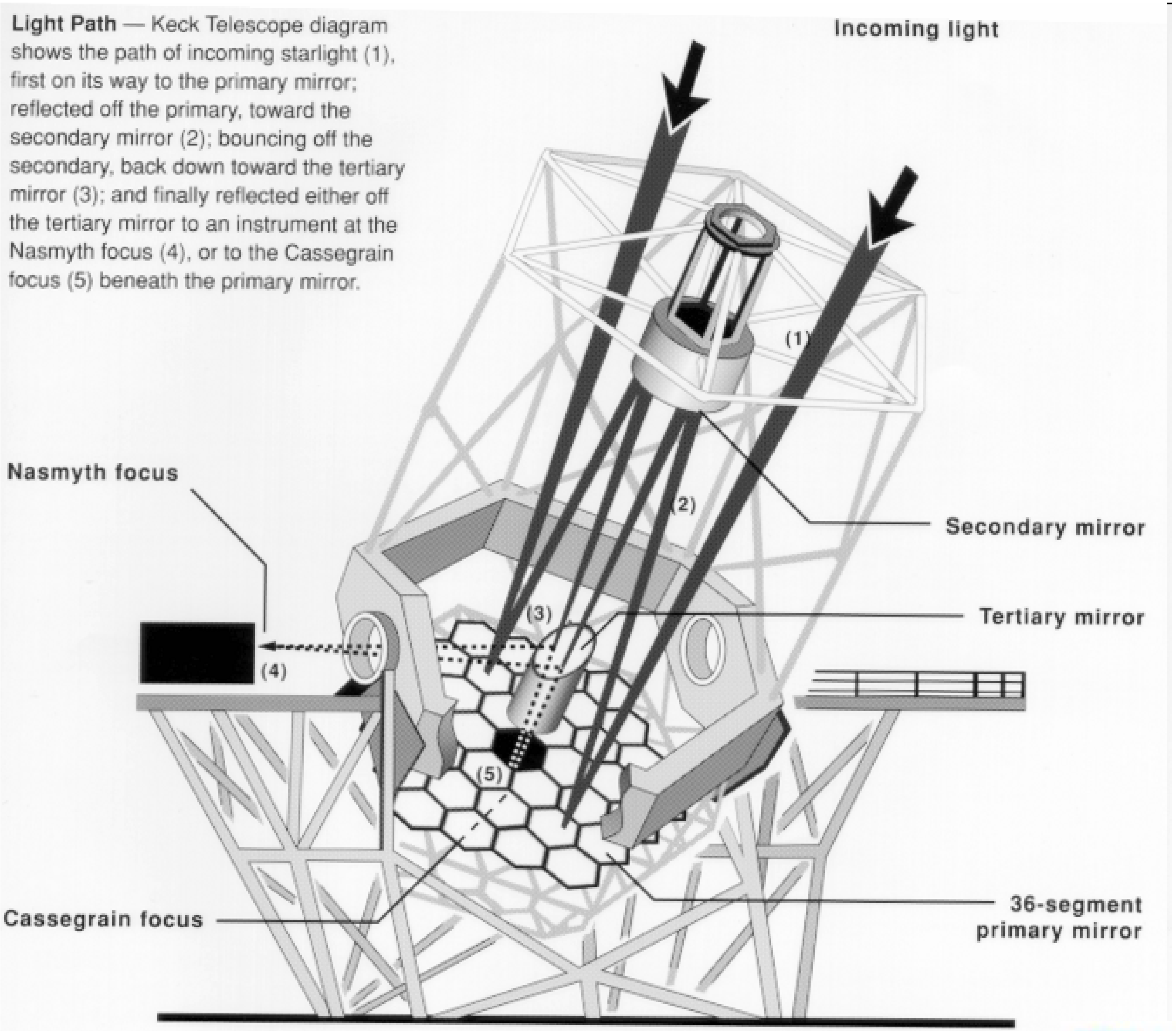
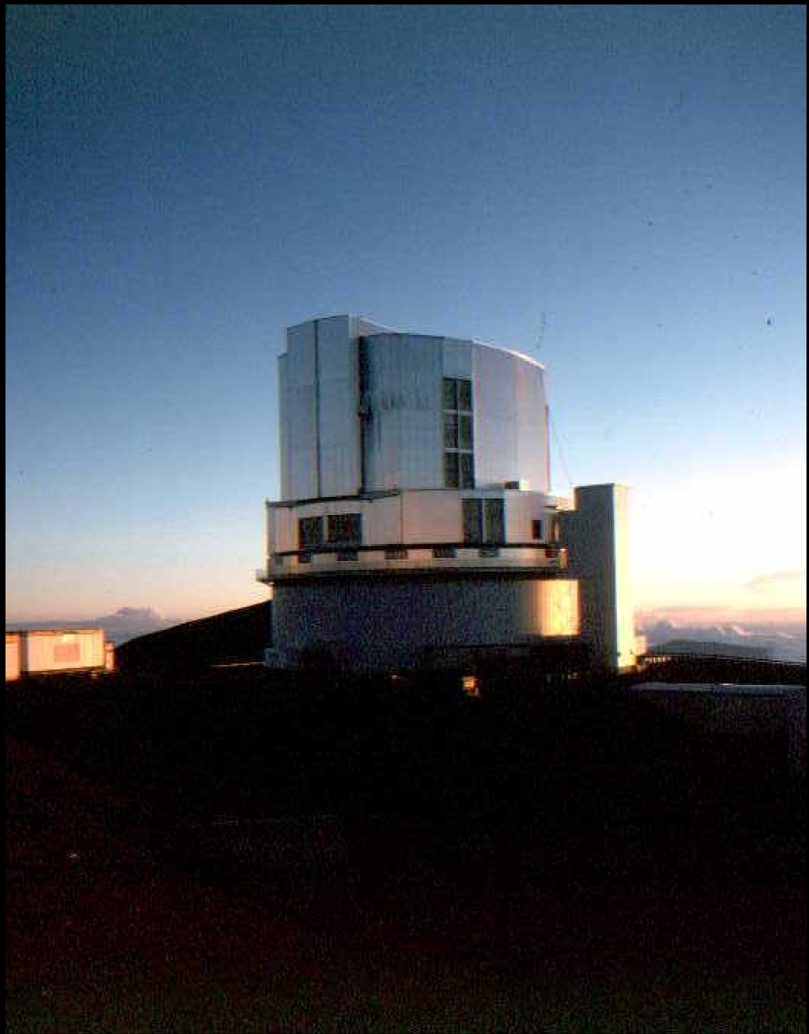
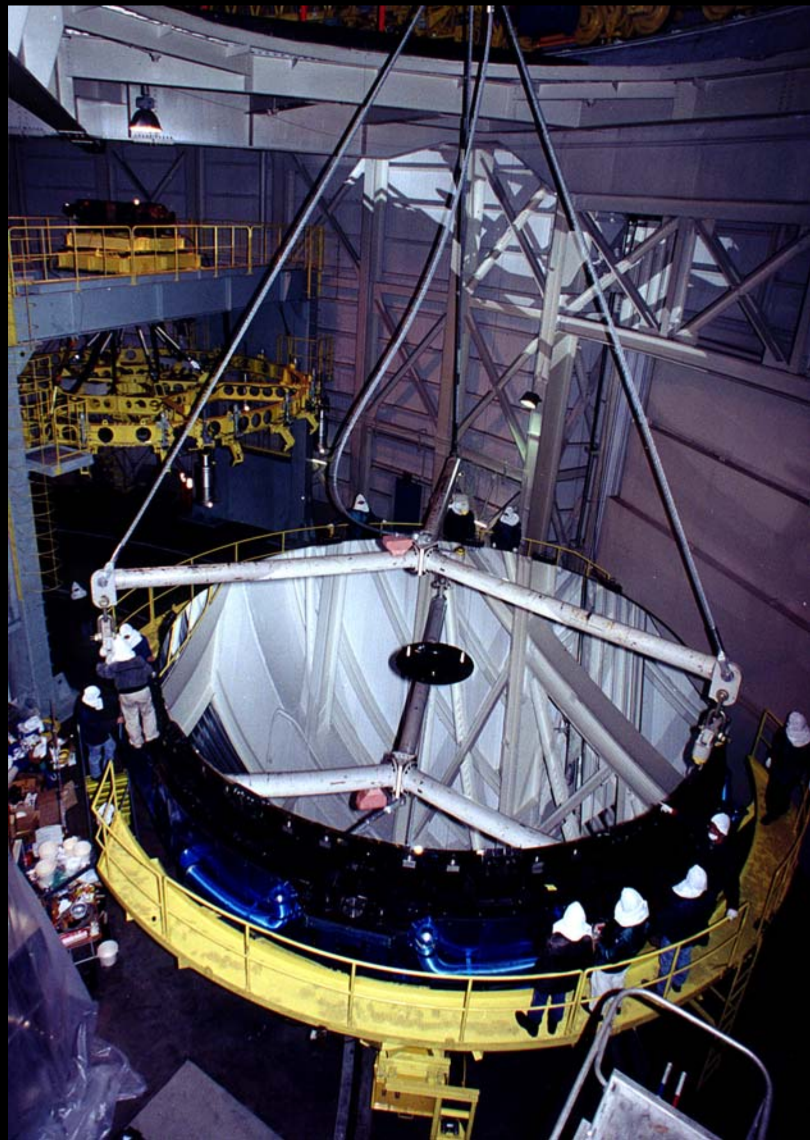
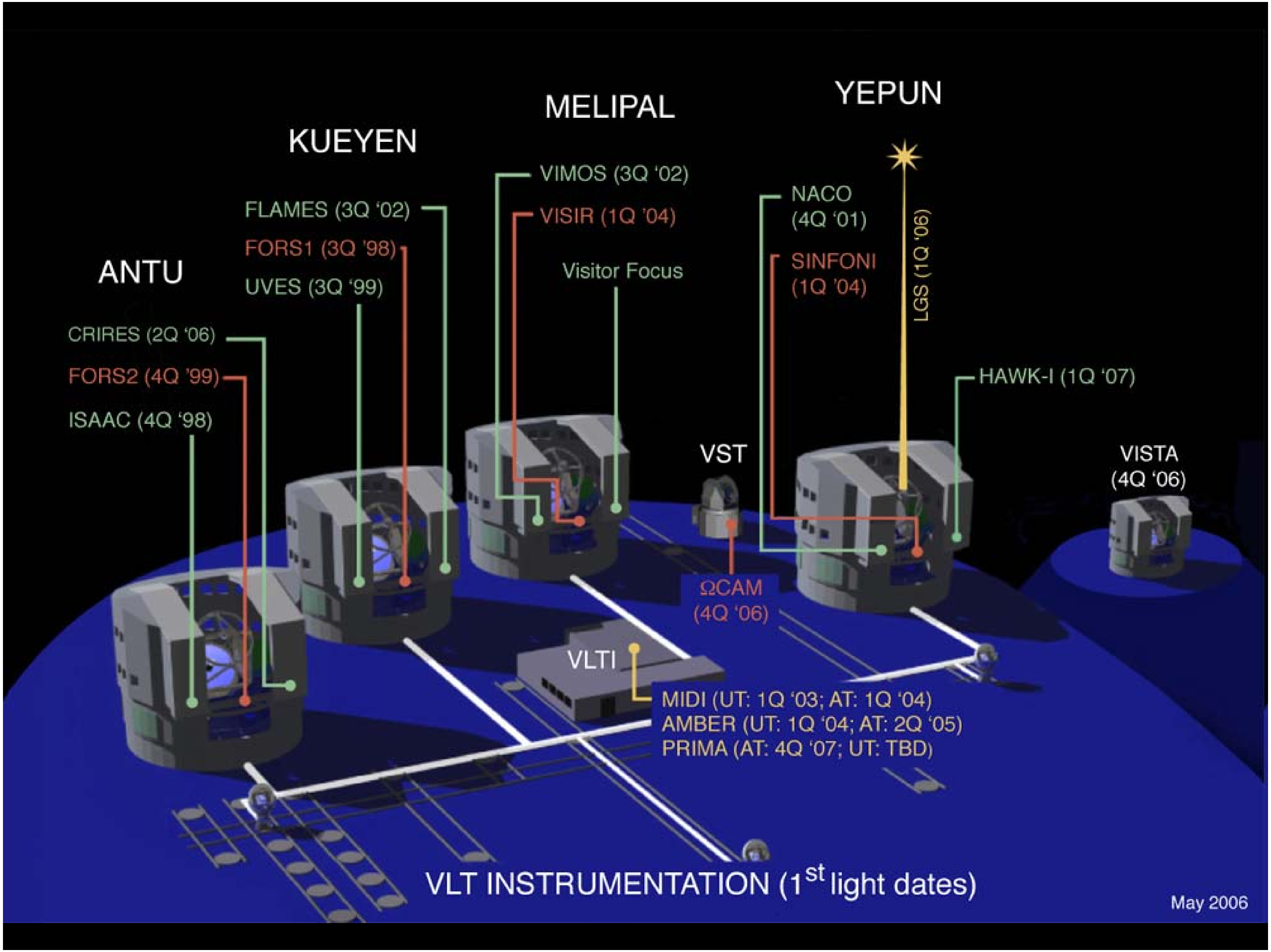


Credit: California Association for Research in Astronomy

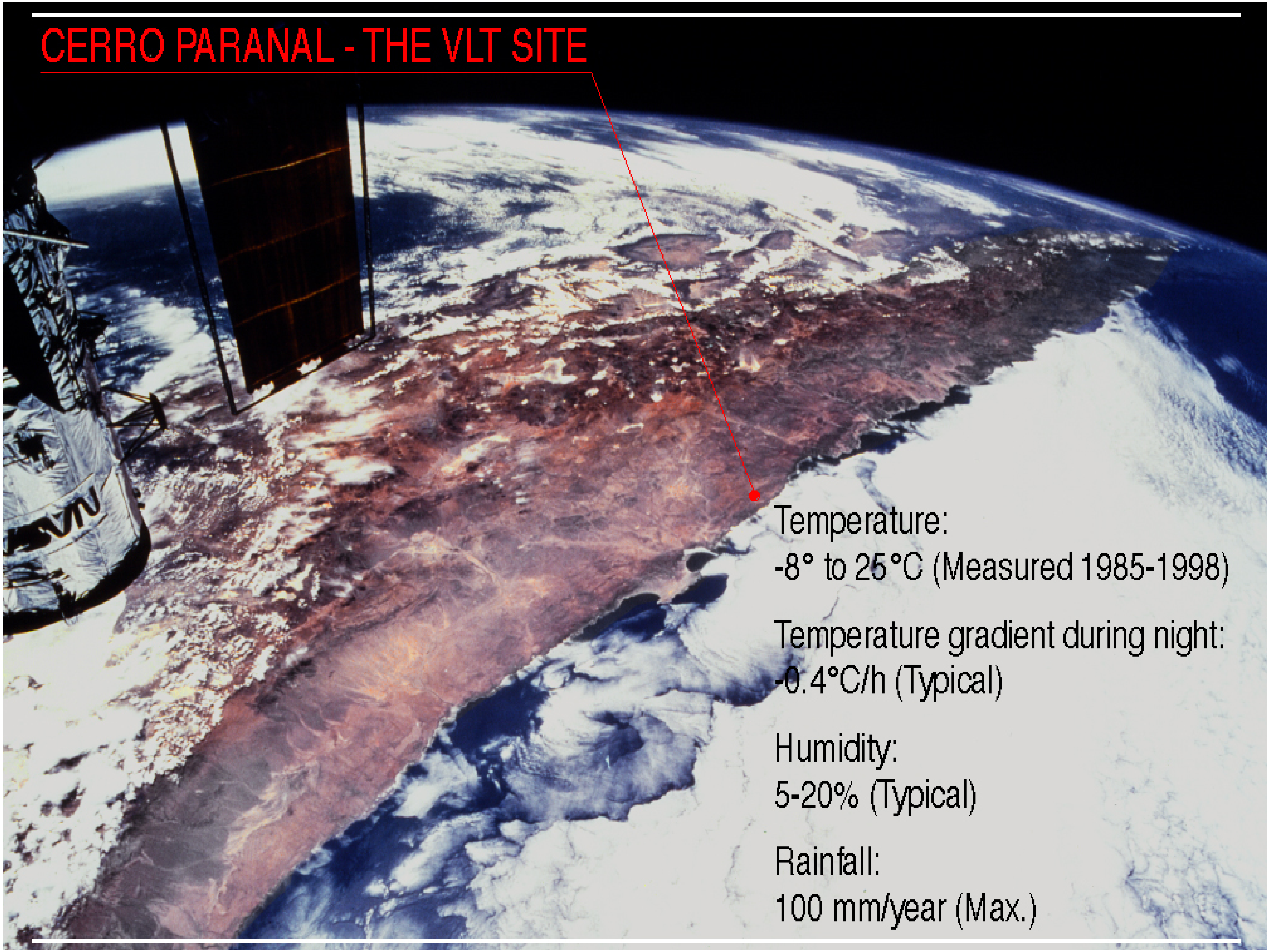






ANTU
KUEYEN
MELIPAL
YEPUN
CRIRES (2Q '06)
FORS2 (4Q '99)
ISAAC (4Q '98)
FLAMES (3Q '02)
FORS1 (3Q '98)
UVES (3Q '99)
VIMOS (3Q '02)
VISIR (1Q '04)
Visitor Focus
NACO (4Q '01)
SINFONI (1Q '04)
LGS (1Q '06)
HAWK-I (1Q '07)
VST
ΩCAM (4Q '06)
VISTA (4Q '06)
VLTI
MIDI (UT: 1Q '03; AT: 1Q '04)
AMBER (UT: 1Q '04; AT: 2Q '05)
PRIMA (AT: 4Q '07; UT: TBD)
VLT INSTRUMENTATION (1st light dates)
May 2006

CERRO PARANAL - THE VLT SITE



Temperature:
-8° to 25°C (Measured 1985-1998)

Temperature gradient during night:
-0.4°C/h (Typical)

Humidity:
5-20% (Typical)

Rainfall:
100 mm/year (Max.)

The World's Largest Optical Telescopes

Operational

Aperture (meters)	Name	Location	Latitude; Longitude Altitude	Comments
10.4	Gran Telescopio Canarias	La Palma, Canary Islands, Spain	28 46 N; 17 53 W 2400 m	Observatorio del Roque de los Muchachos; segmented mirror based on Keck
10.0	Keck Keck II	Mauna Kea, Hawaii	19 50 N; 155 28 W 4123 m	each mirror composed of 36 segments operated separately or in tandem as the Keck Interferometer
~10	SALT	South African Astronomical Observatory	32 23 S; 20 49 E; 1759 m	based on the HET design
9.2	Hobby-Eberly	Mt. Fowlkes, Texas	30 40 N; 104 1 W 2072 m	very inexpensive: spherical segmented mirror; fixed elevation; spectroscopy only
8.4	Large Binocular Telescope	Mt. Graham, Arizona	32 42 N; 109 53 W 3170 m	a pair of 8.4-m mirrors on one mount giving the light gathering of an 11.8m and eventually the resolution of a 23-m
8.3	Subaru	Mauna Kea, Hawaii	19 50 N; 155 28 W 4100 m	NAOJ
8.2	Antu Kueyen Melipal Yepun	Cerro Paranal, Chile	24 38 S; 70 24 W 2635m	operated separately or as units of the VLT Interferometer
8.1	Gillett	Mauna Kea, Hawaii	1950 N; 155 28 W 4100 m	aka Gemini North
	Gemini South	Cerro Pachon, Chile	30 20 S;70 59 W (approx) 2737 m	twin of Gemini North

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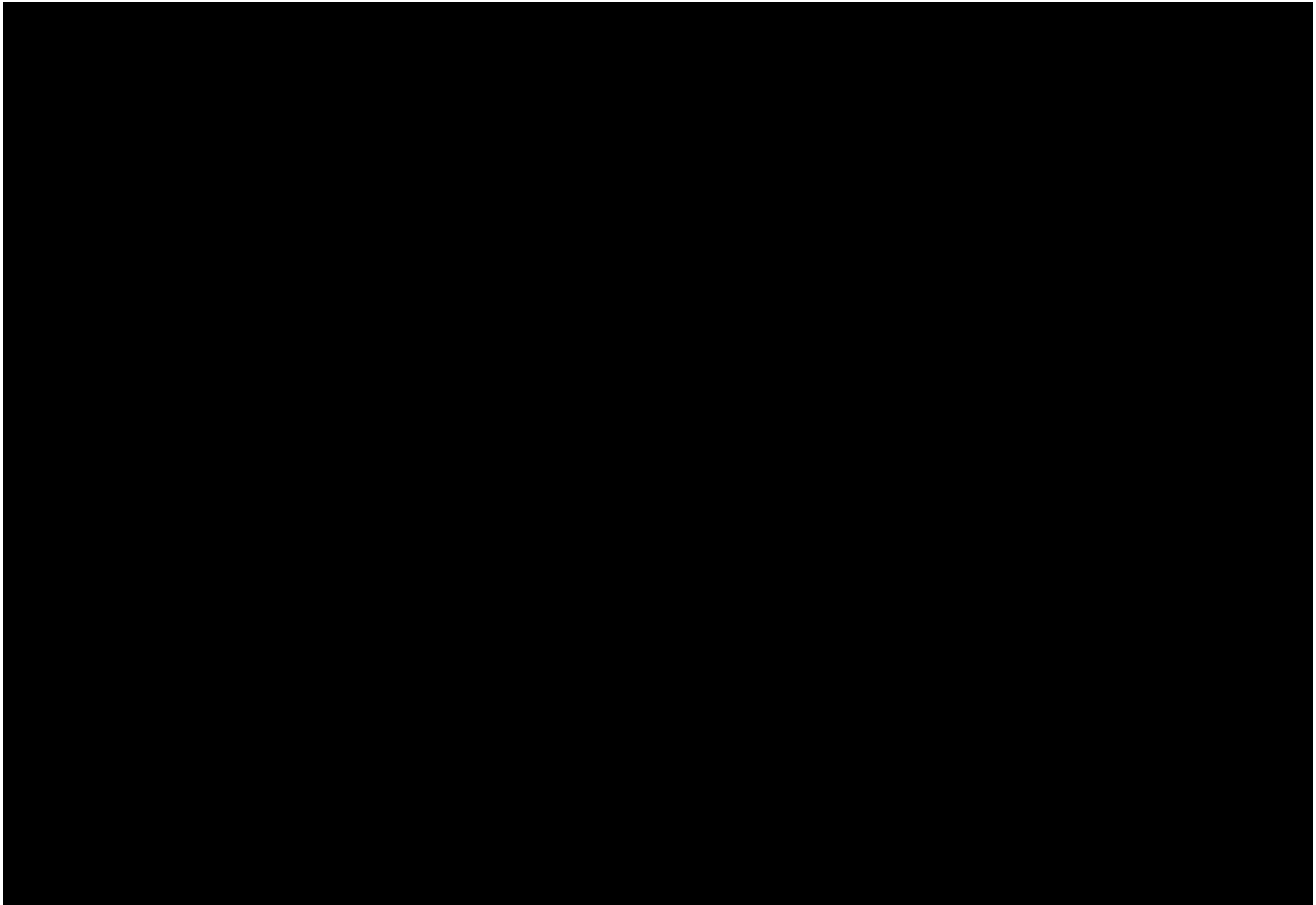
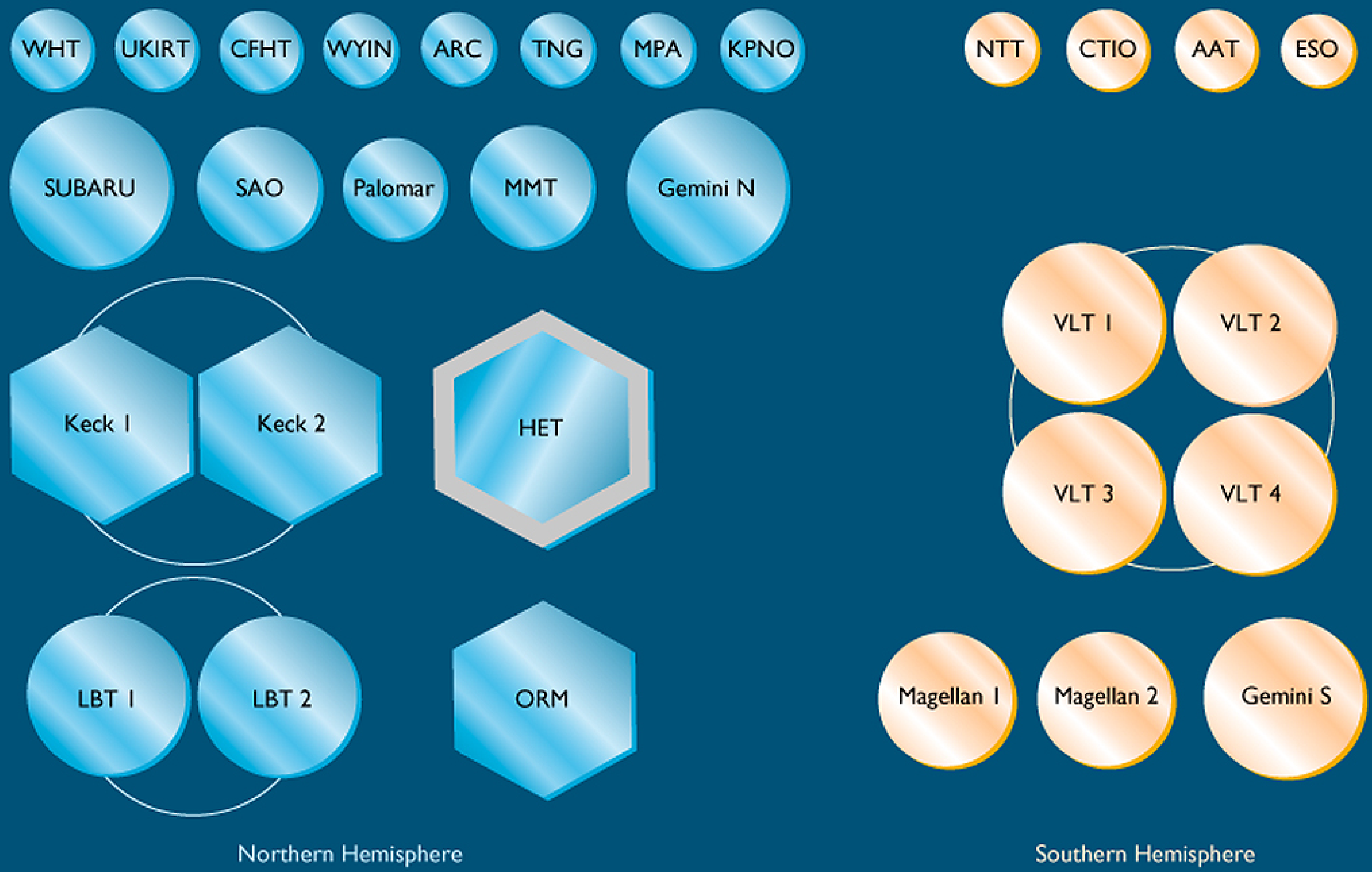
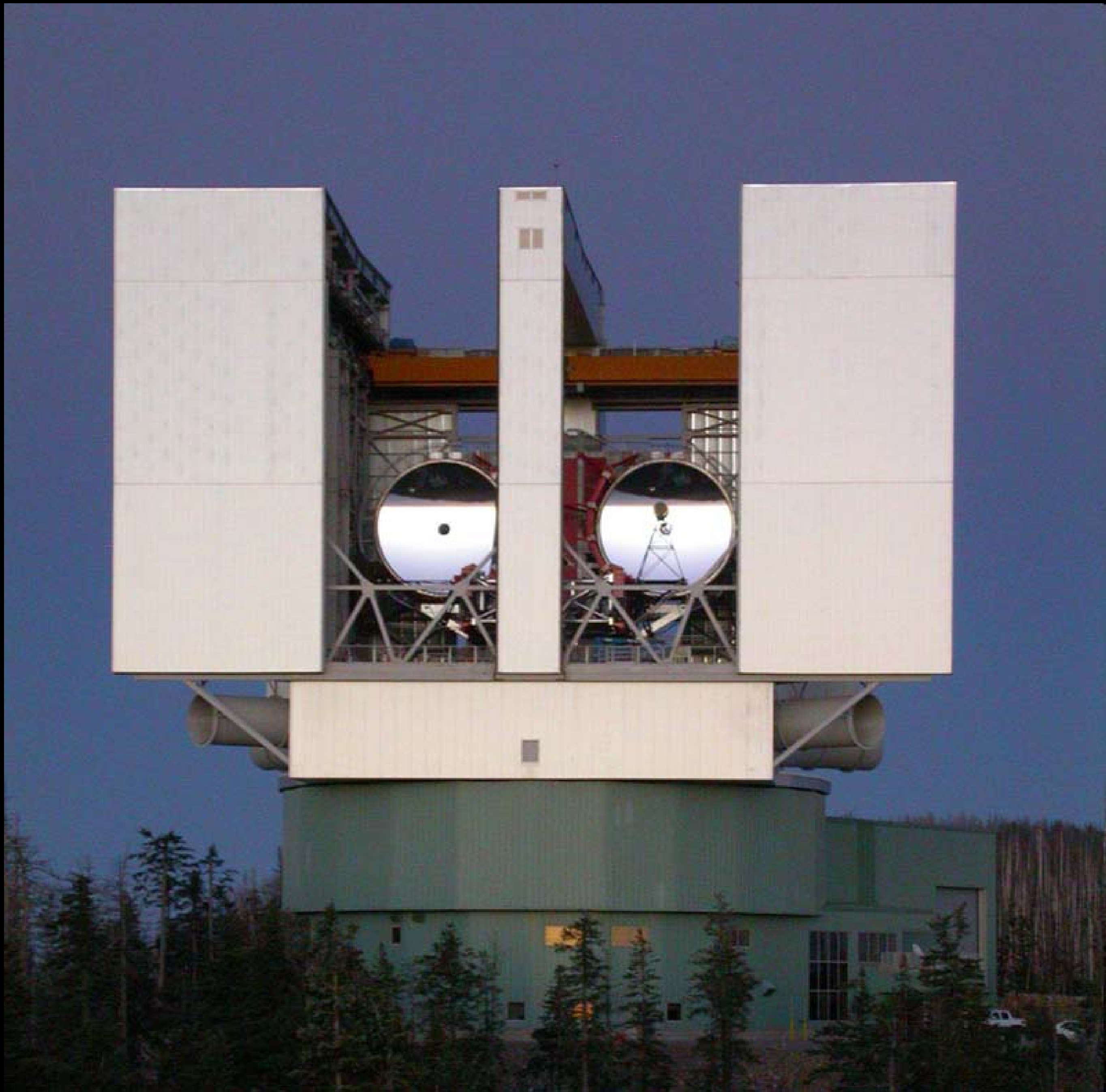
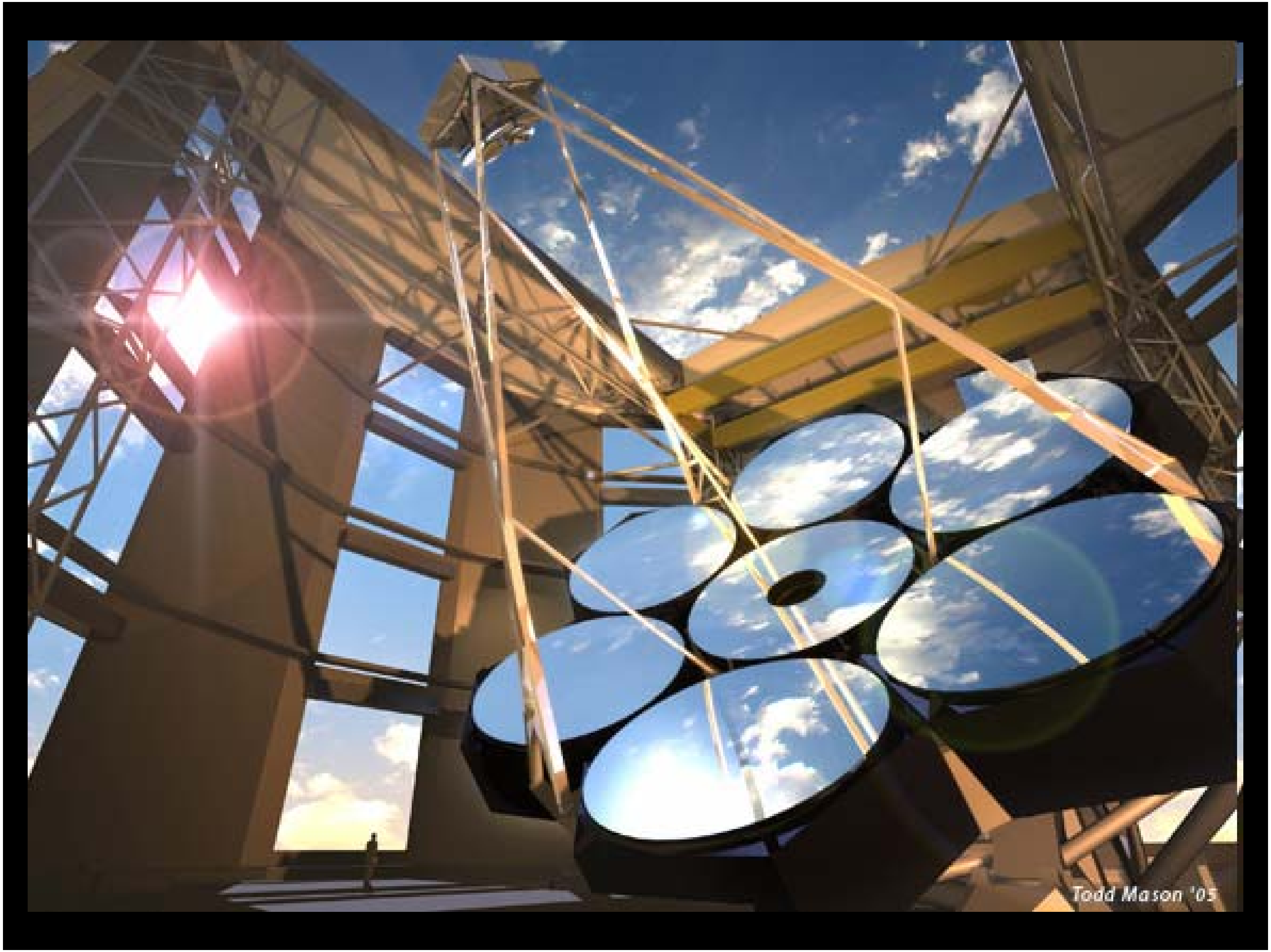


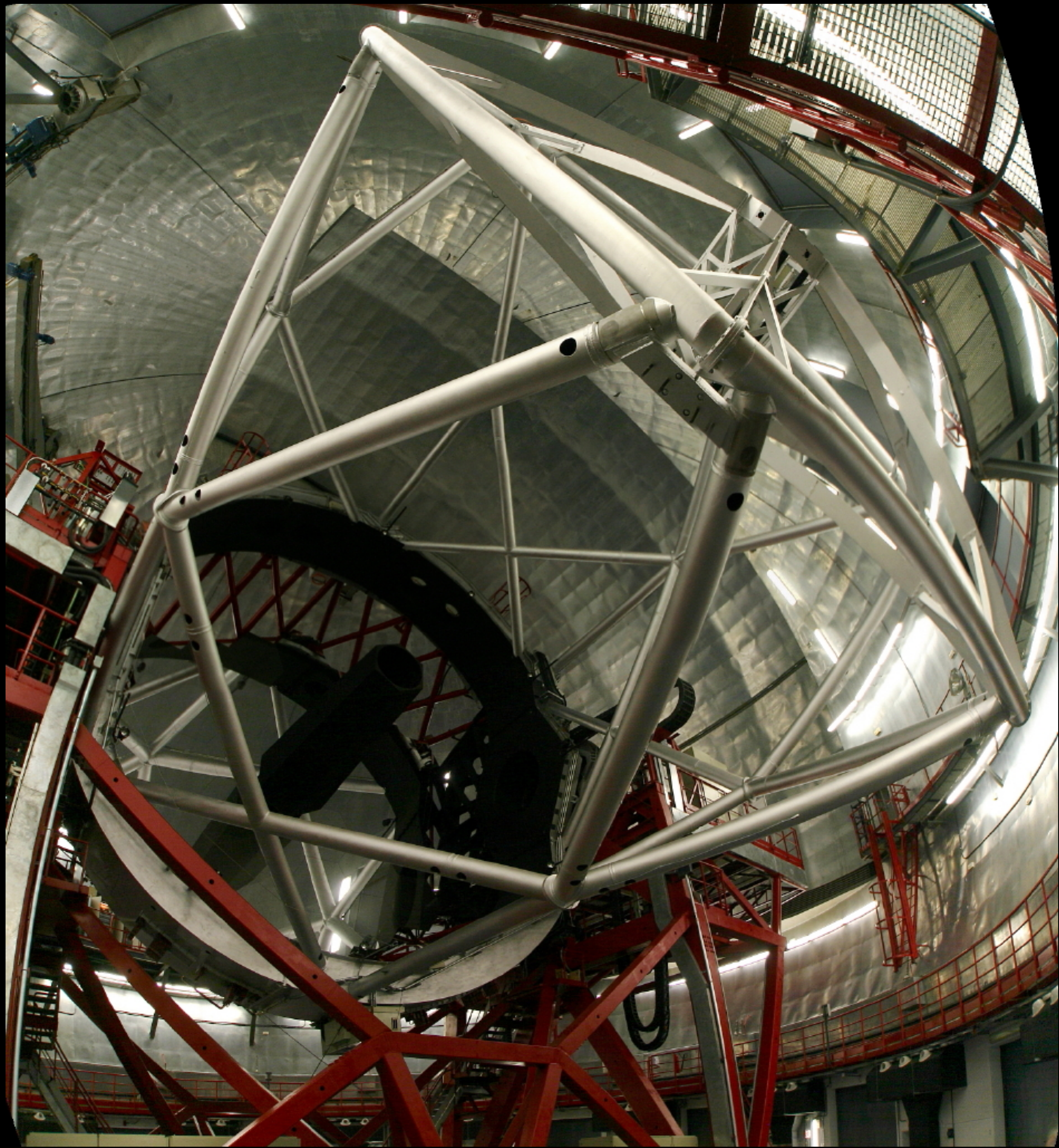
Hobby-Eberley telescope

COLLECTING AREA OF THE LARGE TELESCOPES

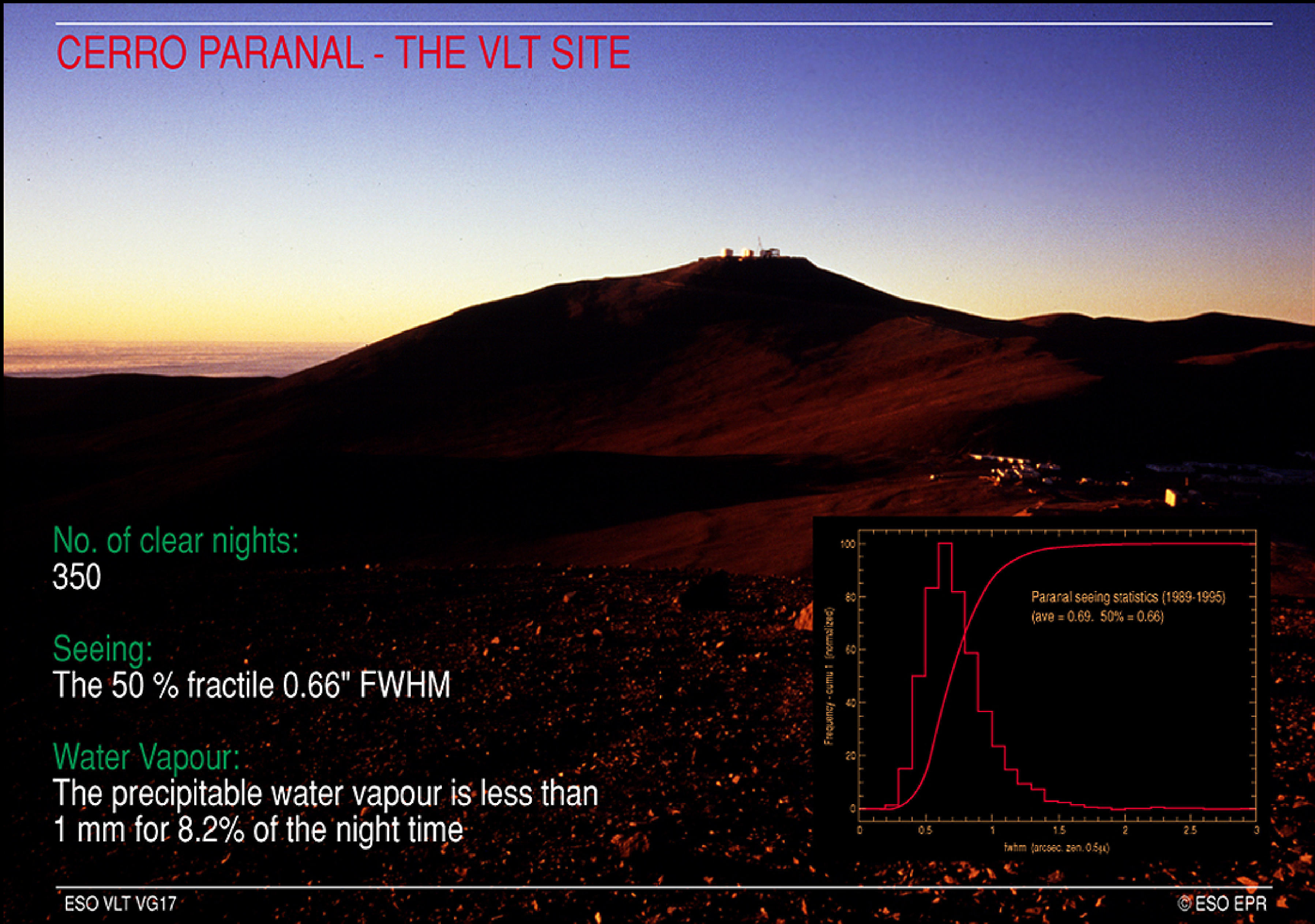





Todd Mason '05



The Earth at night from space


CERRO PARANAL - THE VLT SITE
No. of clear nights:
350
Seeing:
The 50 % fractile 0.66" FWHM
Water Vapour:
The precipitable water vapour is less than
1 mm for 8.2% of the night time
Pararal seeing statistics (1989-1995)
(ave = 0.69. 50% = 0.66)
Frequency - cumu 1 (normalized)
fwhm (arcsec. zen. 0.5μ)
0
0.5
1
1.5
2
2.5
3
20
40
60
80
100
ESO VLT VG17
© ESO EPR

Absorption

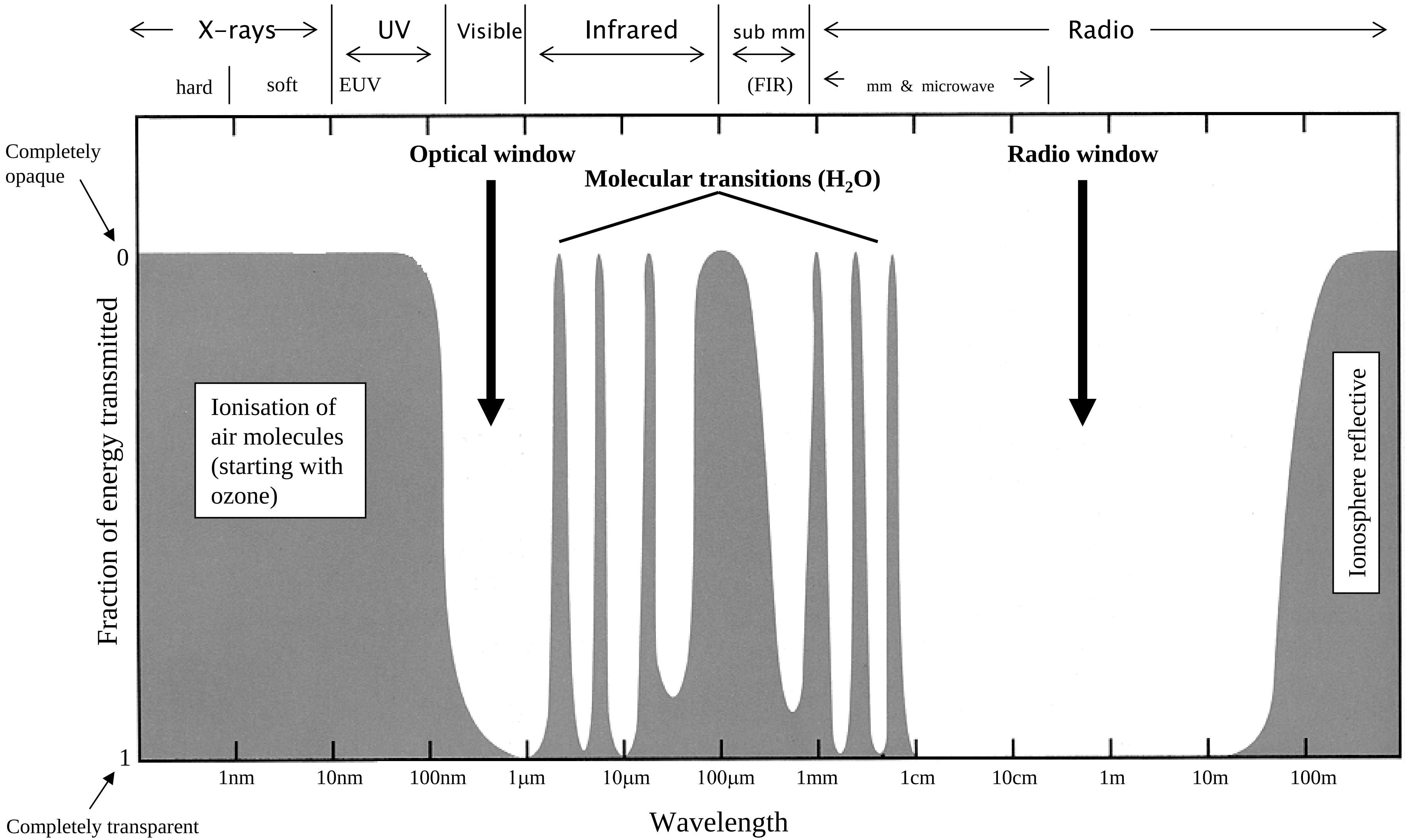
Between the optical and radio windows (i.e. in the infra-red) there are numerous absorption bands due to **molecular transitions** (mainly of water)

The world's best observatories (e.g. La Palma, Hawaii, La Silla, Paranal) are all at altitudes which place them above inversion layers.

DACE, January 2009

Absorption

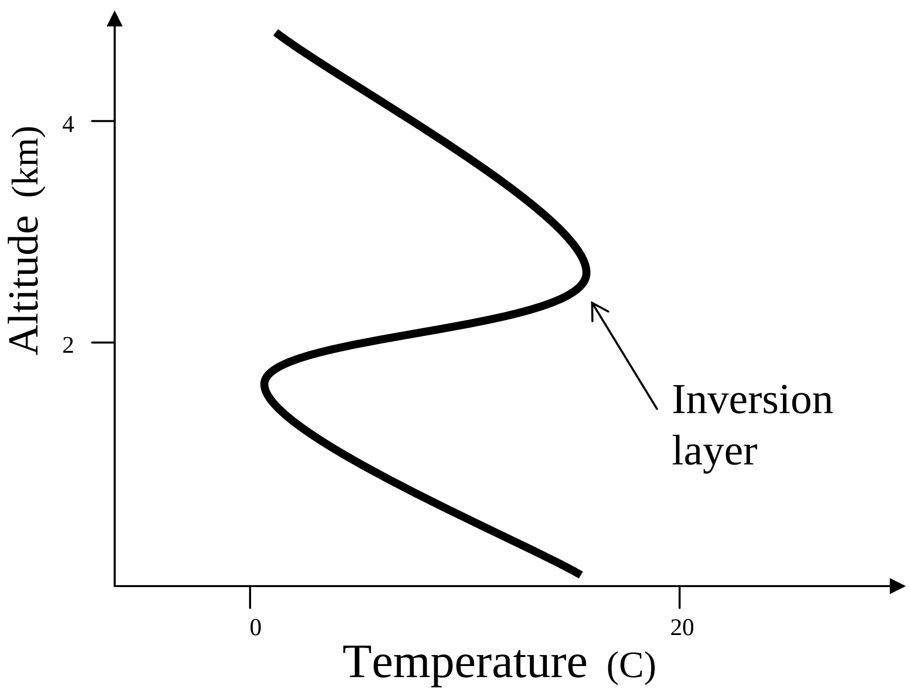
The Earth's atmosphere is opaque to E-M radiation, apart from two windows: in the **optical** and **radio** regions of the E-M spectrum.

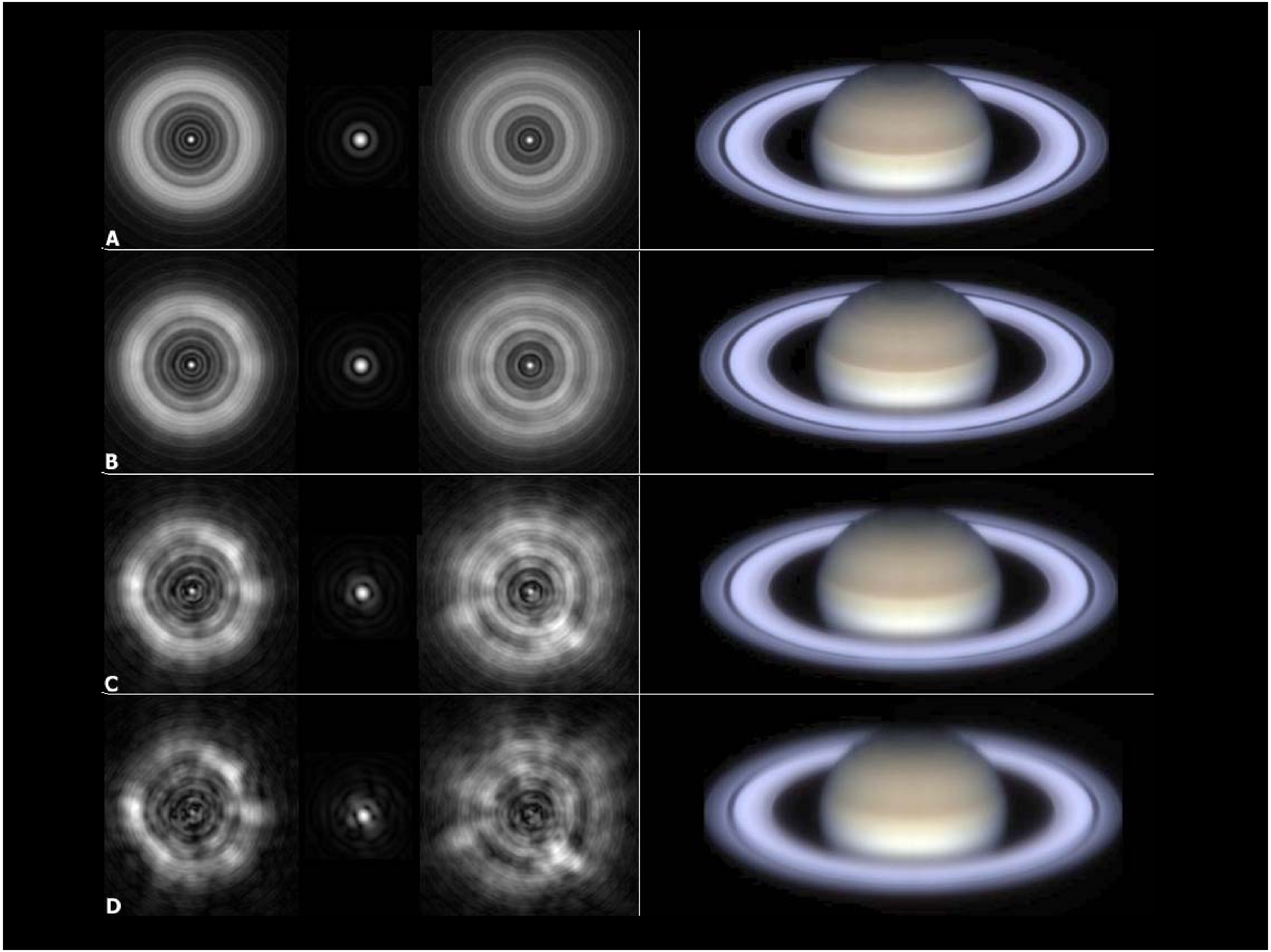


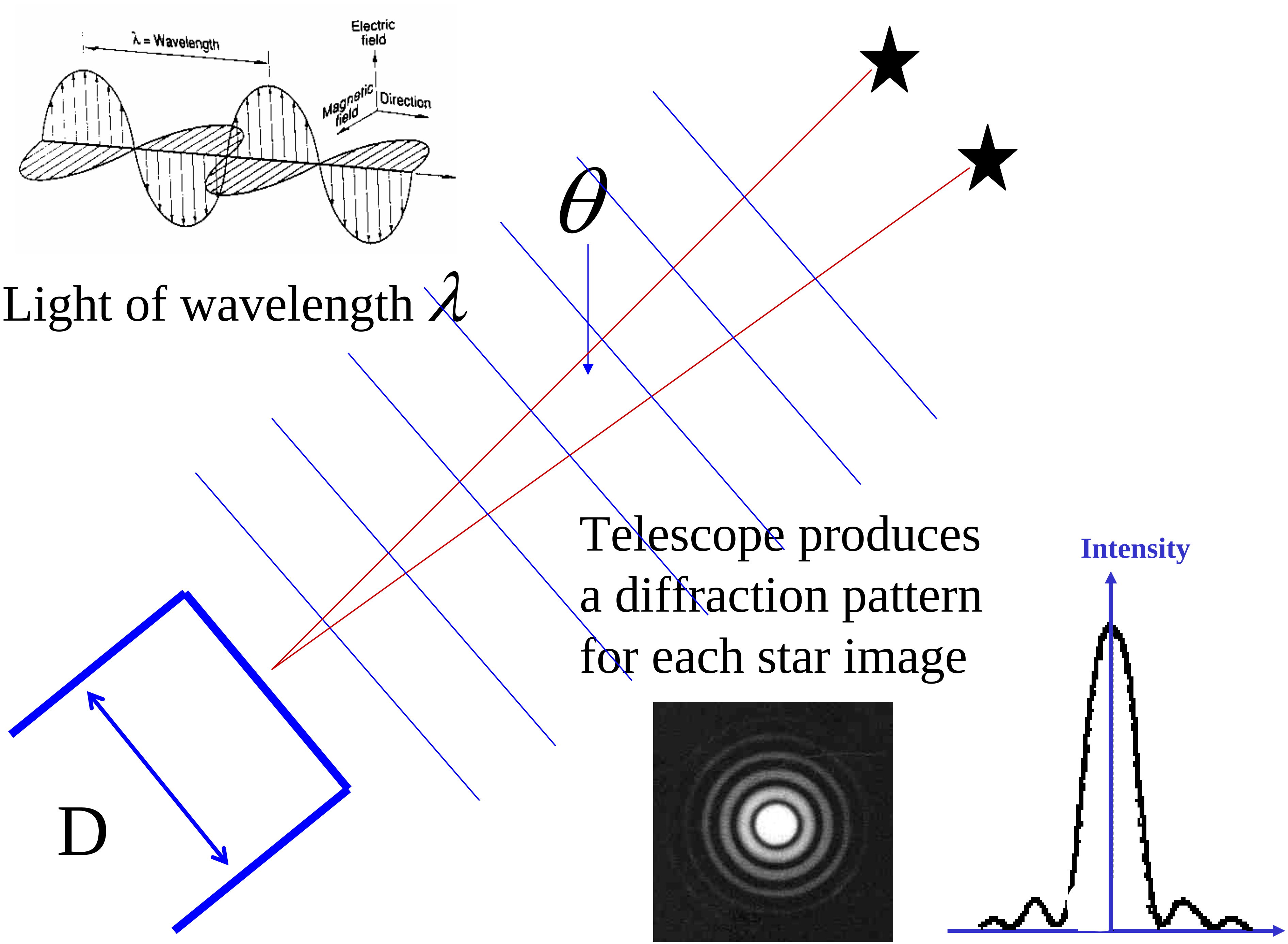
Absorption

Between the optical and radio windows (i.e. in the infra-red) there are numerous absorption bands due to **molecular transitions** (mainly of water)

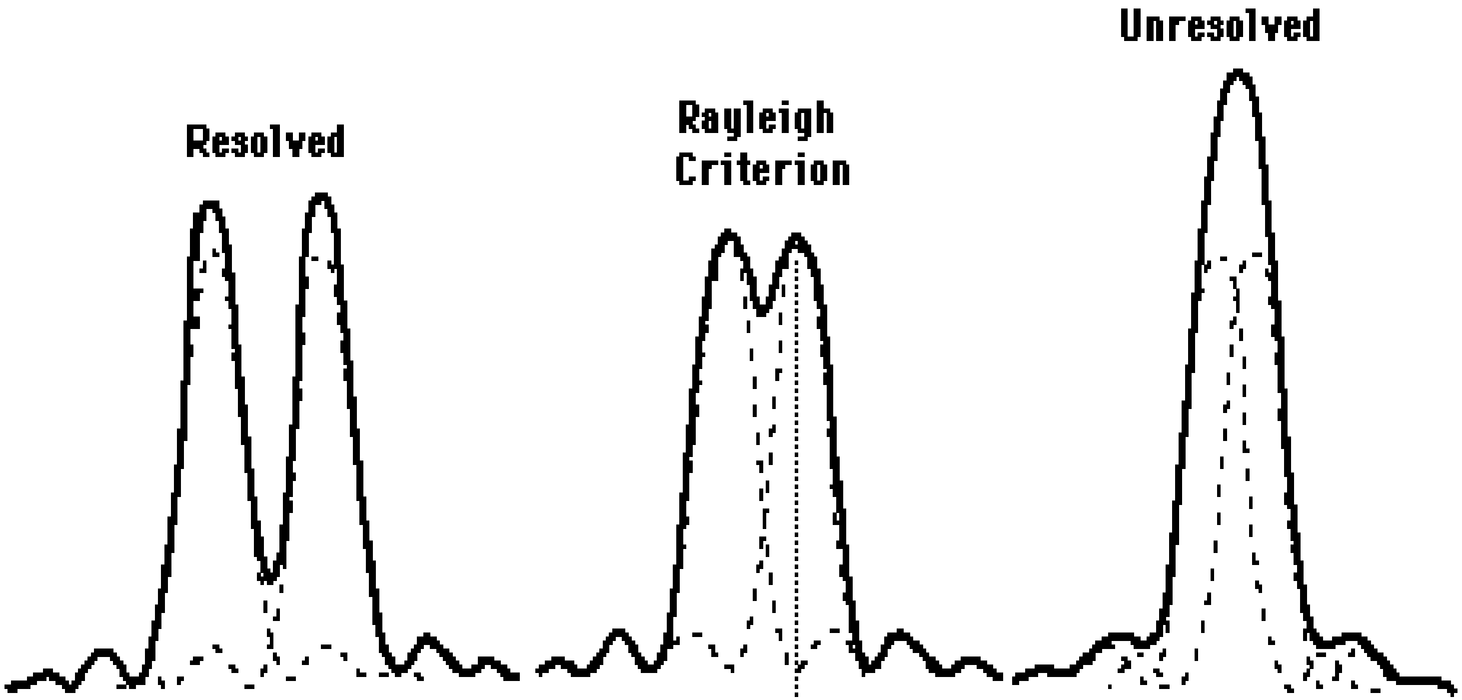
It is possible to get *above* the clouds containing this water vapour because of the **temperature structure** of the atmosphere. Above about 2km there is a thin **inversion layer**, where the temperature *increases* with height. Clouds form at the *base* of the inversion layer, leaving generally clear, dry air above.




A
B
C
D



λ = Wavelength
Electric field
Magnetic field
Direction
Light of wavelength λ
θ
D
Telescope produces a diffraction pattern for each star image
Intensity

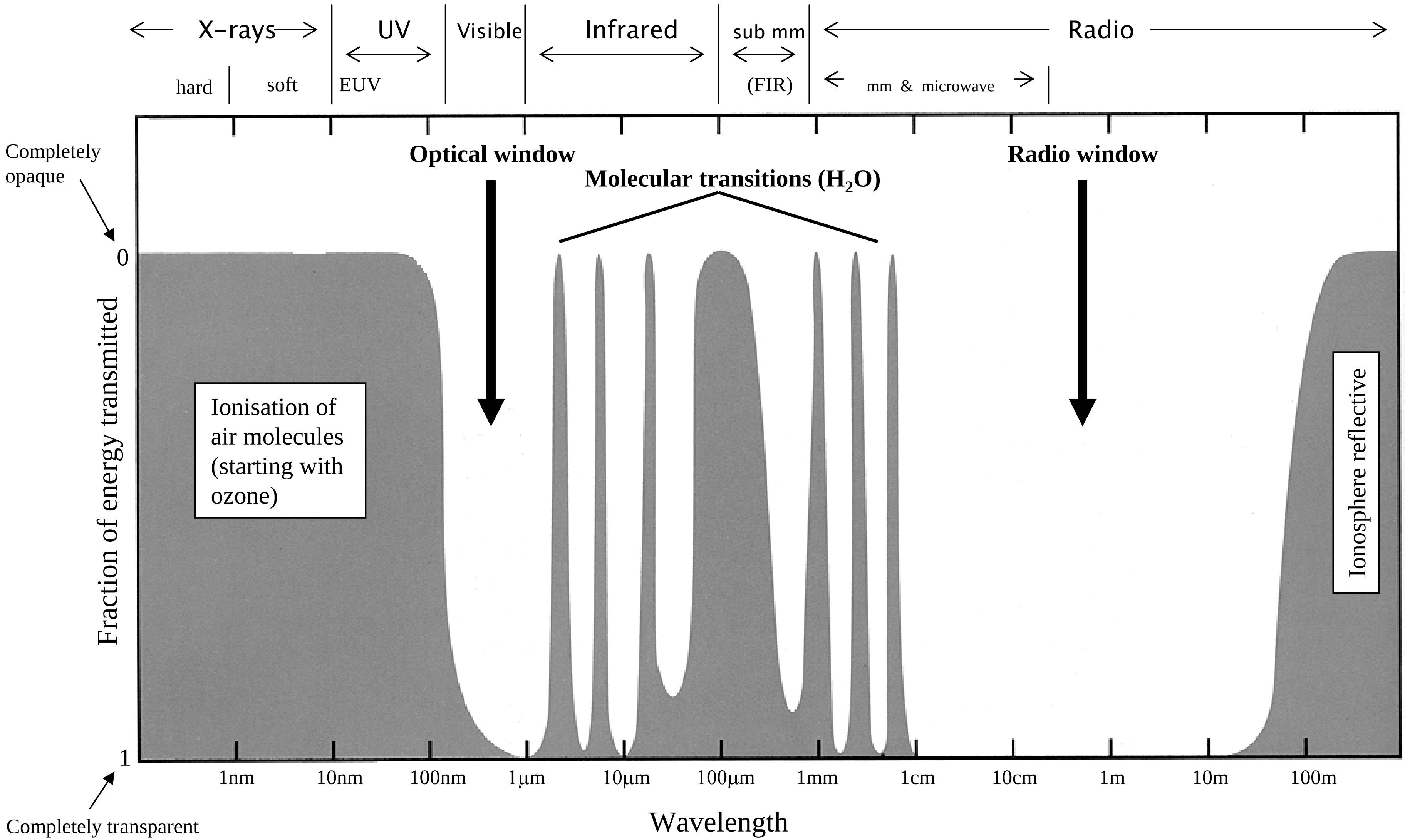


Rayleigh criterion for the minimum resolvable detail:

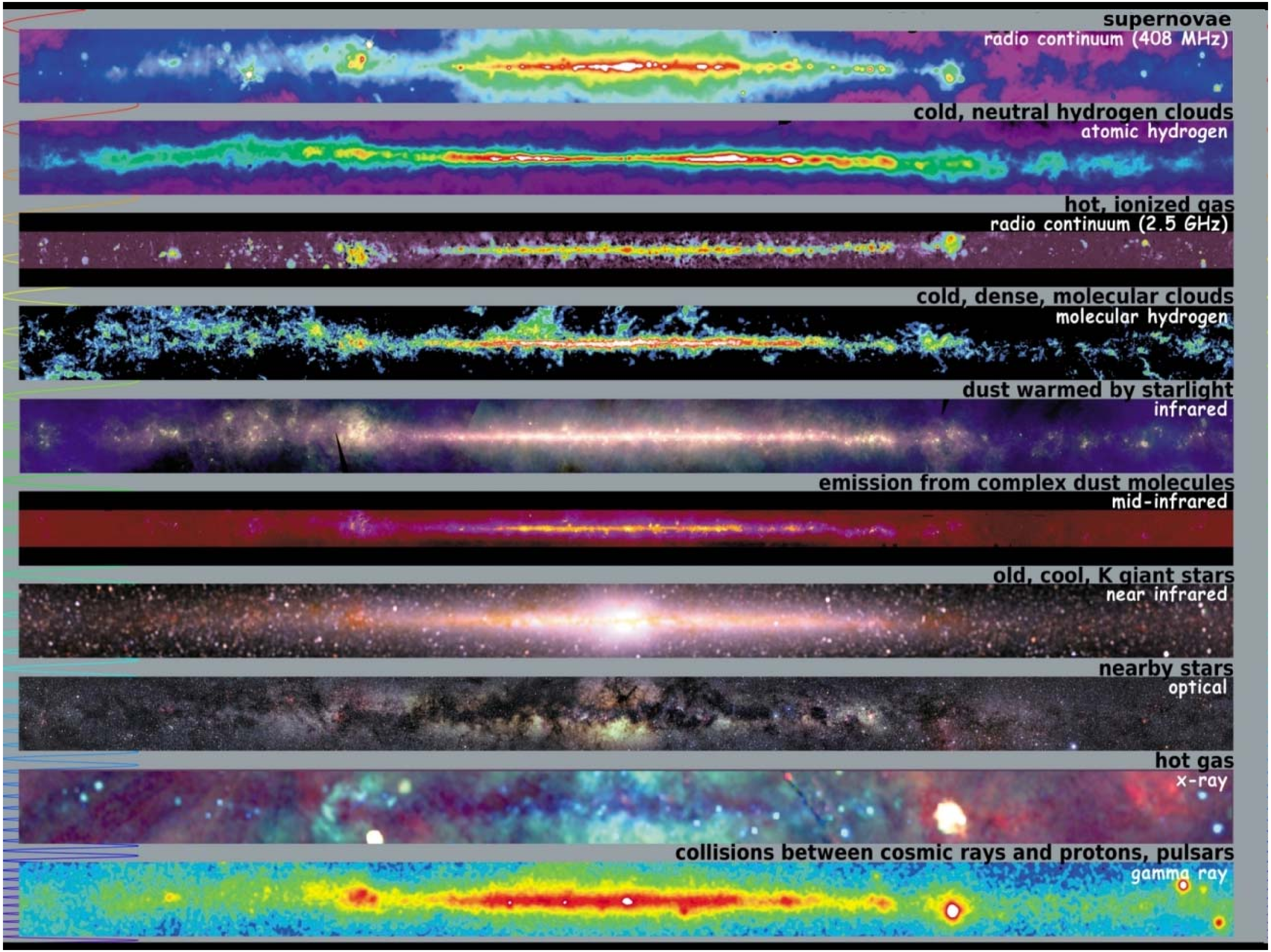
$$\boxed{\theta = \frac{1.22\lambda}{D}}$$

Absorption

The Earth's atmosphere is opaque to E-M radiation, apart from two windows: in the **optical** and **radio** regions of the E-M spectrum.



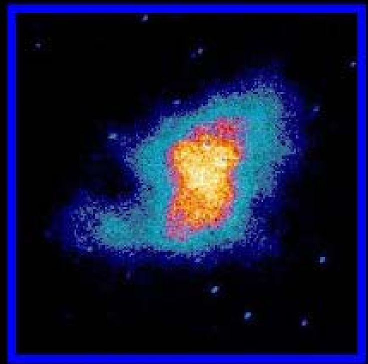

© 2000, Axel Mellinger


supernovae
radio continuum (408 MHz)
cold, neutral hydrogen clouds
atomic hydrogen
hot, ionized gas
radio continuum (2.5 GHz)
cold, dense, molecular clouds
molecular hydrogen
dust warmed by starlight
infrared
emission from complex dust molecules
mid-infrared
old, cool, K giant stars
near infrared
nearby stars
optical
hot gas
x-ray
collisions between cosmic rays and protons, pulsars
gamma ray

M1 – The Crab Nebula

Distance: 6300 light-years (1.9 kpc) | Image Size = 6.5 x 6.5 arcmin | Visual Magnitude = 8.4

X-Ray: Chandra

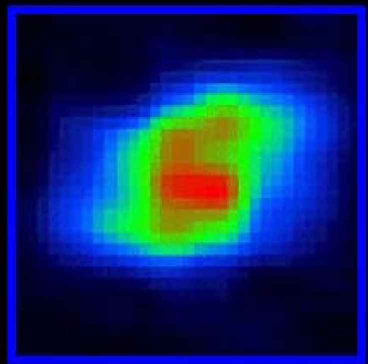


Ultraviolet: ASTRO-1

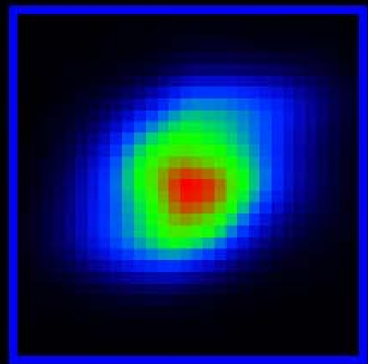
Visible: DSS

Visible: Color VLT

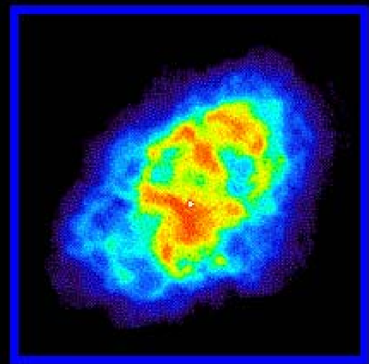
Near-Infrared: 2MASS



Mid-Infrared: IRAS



Far-Infrared: IRAS



Radio: NRAO

Distance: 37,000,000 light-years (11 kpc) Image Size = 11 x 13.5 arcmin Visual Magnitude = 8.4

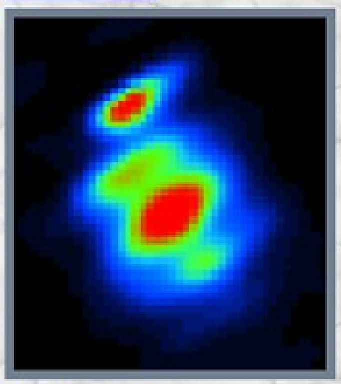

Visible: DSS


Visible: T. & D. Hallas


Visible: TIE

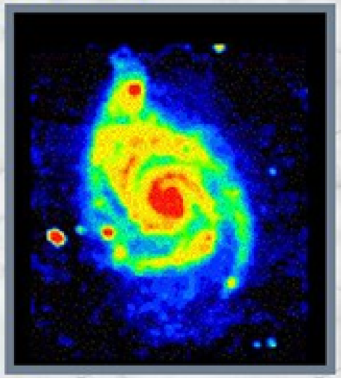

Near-Infrared: 2MASS


Mid-Infrared: ISO


Far-Infrared: IRAS

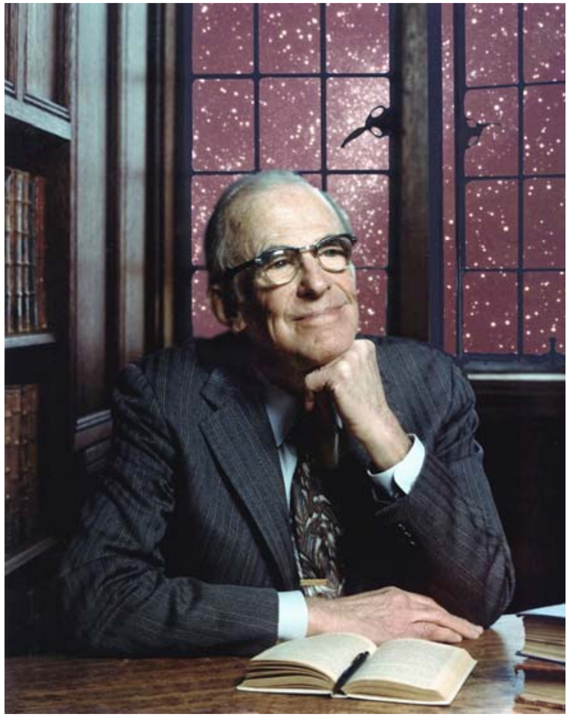

X-Ray: Chandra

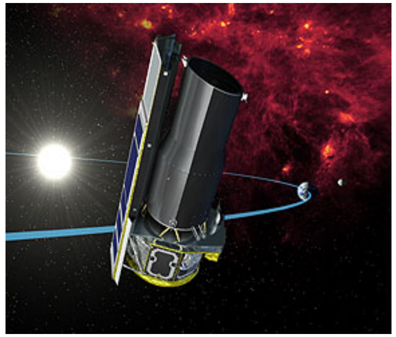

Ultraviolet: FOCA/CNRS


Radio: VLA

The Case for Space

- Atmospheric absorption
- Atmospheric scattering





NASA's 4 "Great Observatories"

Compton GRO
Chandra XRT
Hubble Space Telescope
Spitzer IRST

Timeline

1946 Spitzer paper: "Astronomical advantages of an extra-terrestrial observatory“

1966 US launches the Orbiting Astronomical Observatory

1968 US launches OAO-2, takes UV observations until 1972.
NASA proposes plans for a Large Orbiting Space Telescope.

1974 Budget cuts end the Large Orbiting Telescope project.

1978 Design begins for a rejuvenated Space Telescope project.
The goal is for a 1983 launch.

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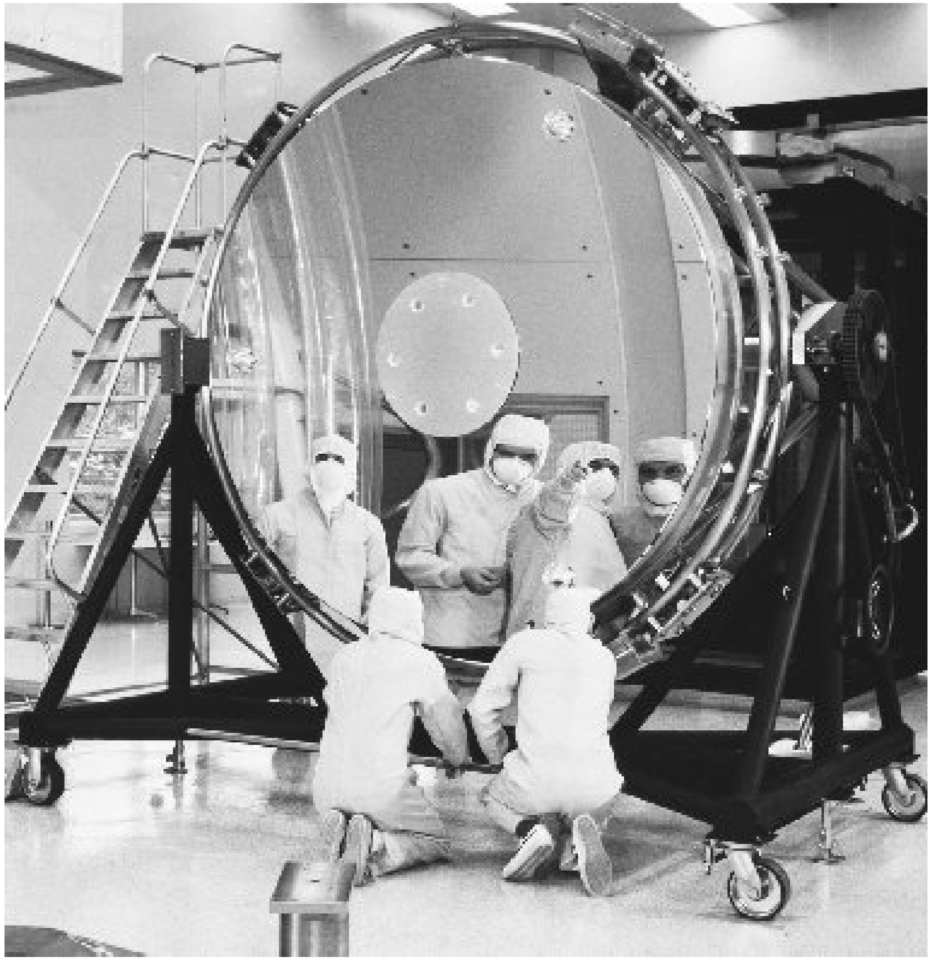
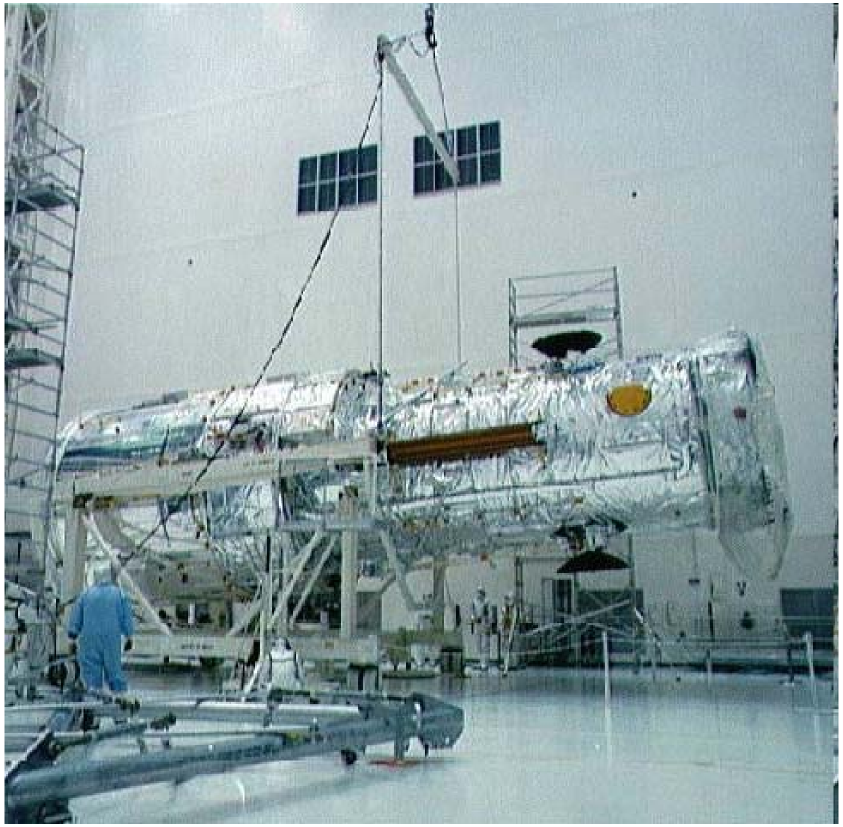
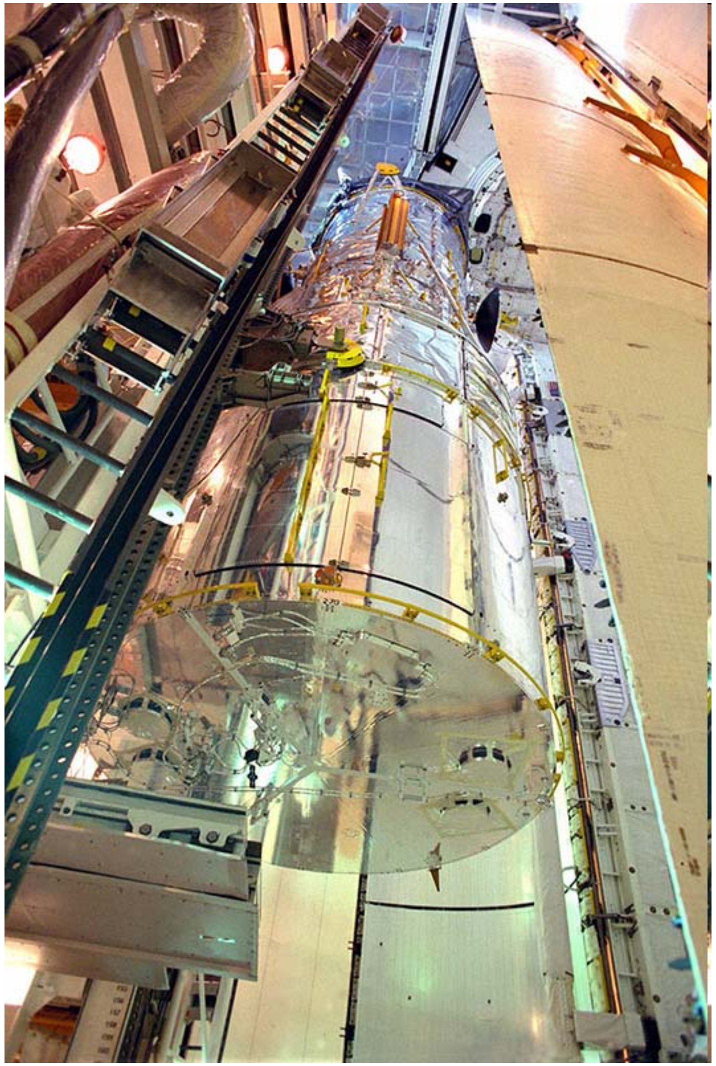
1978	Design begins for a rejuvenated Space Telescope project. The goal is for a 1983 launch.
1980s	Optics company Perkin-Elmer begins construction of primary mirror. management and technical problems postpone launch until 1985.
1983	The Space Telescope Science Institute (STScI) is founded, located at Johns Hopkins University. STScI takes over science management from NASA.
1985	Construction of HST is completed, including 5 original science instruments.

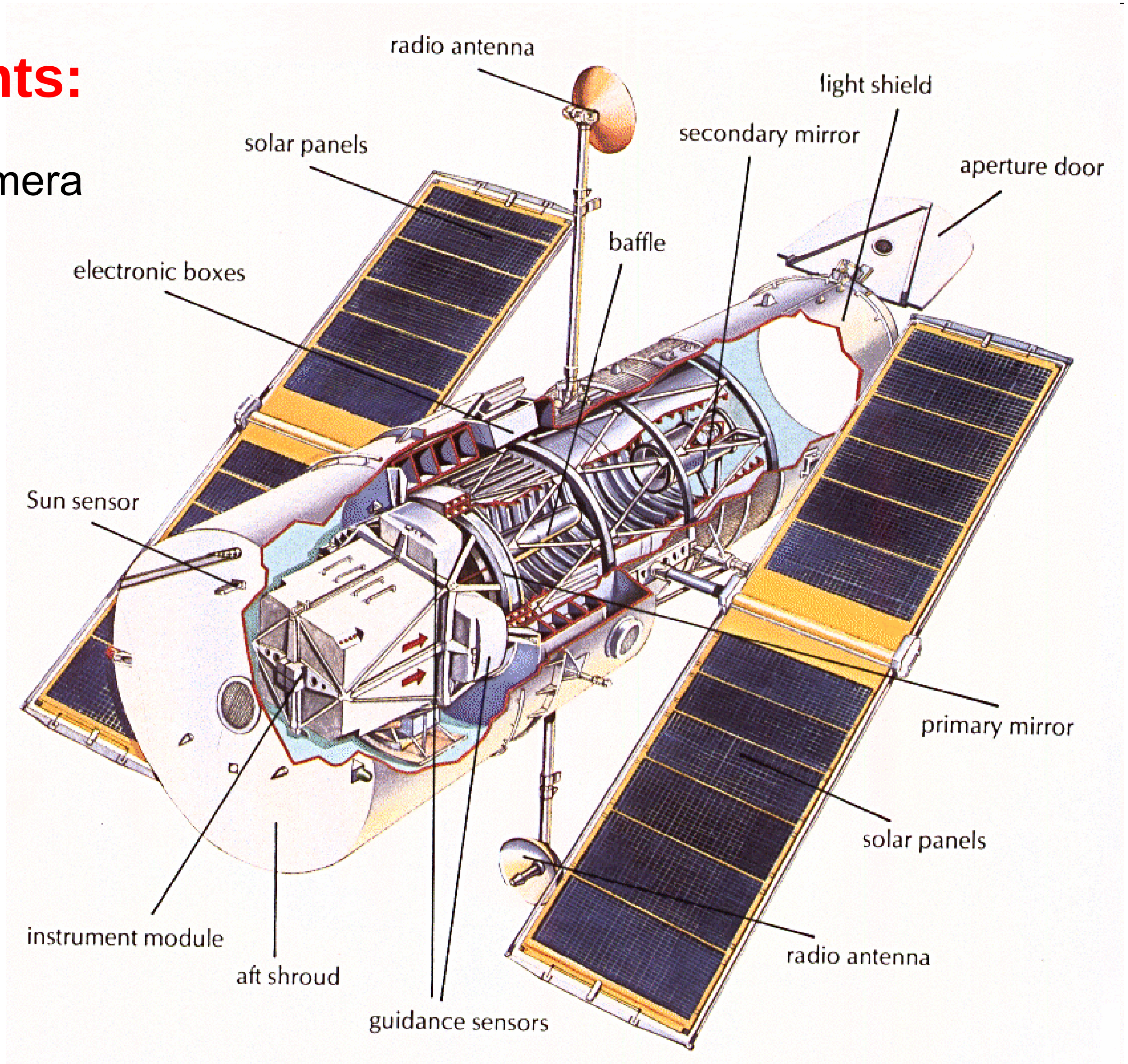




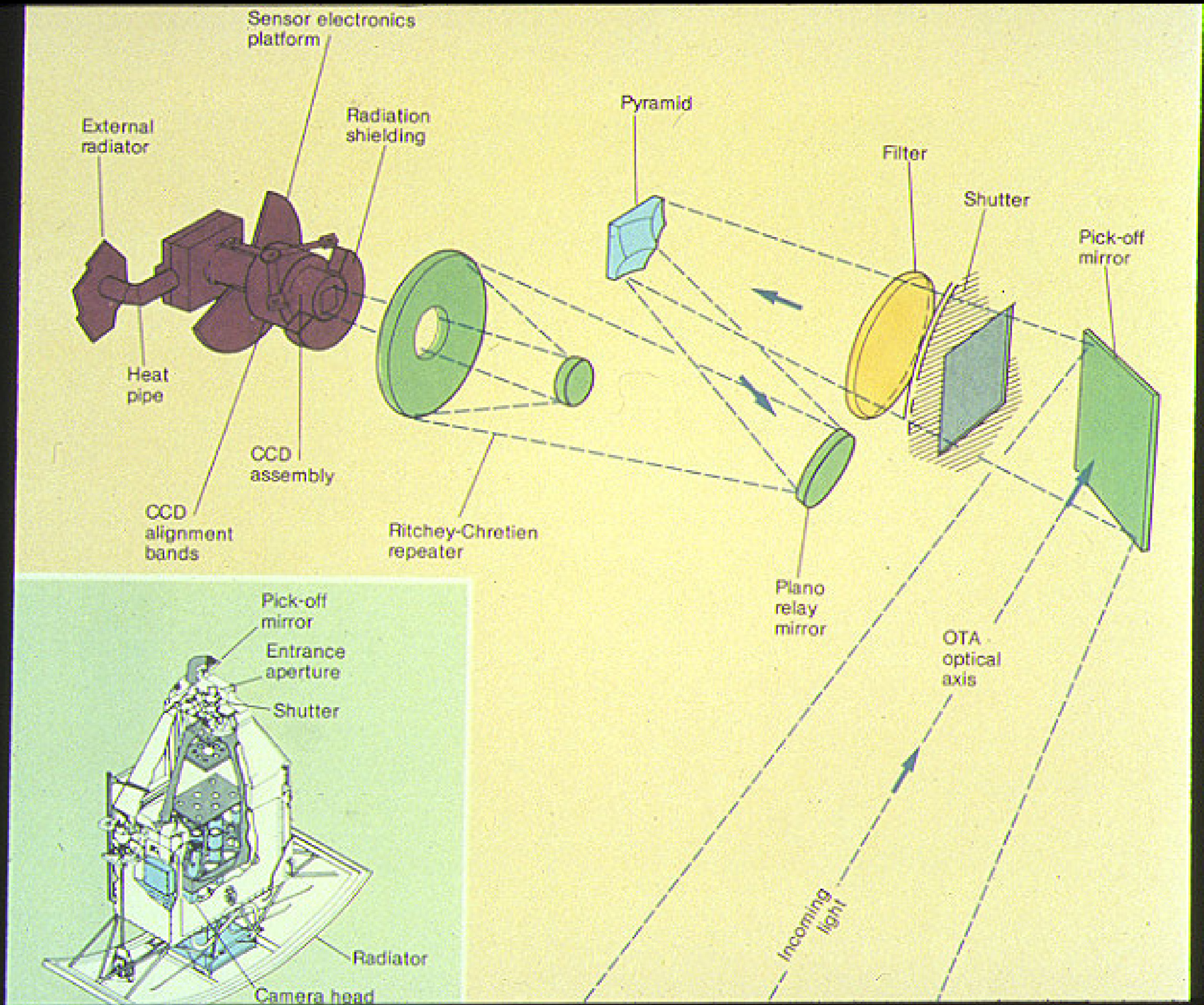


5 original instruments:

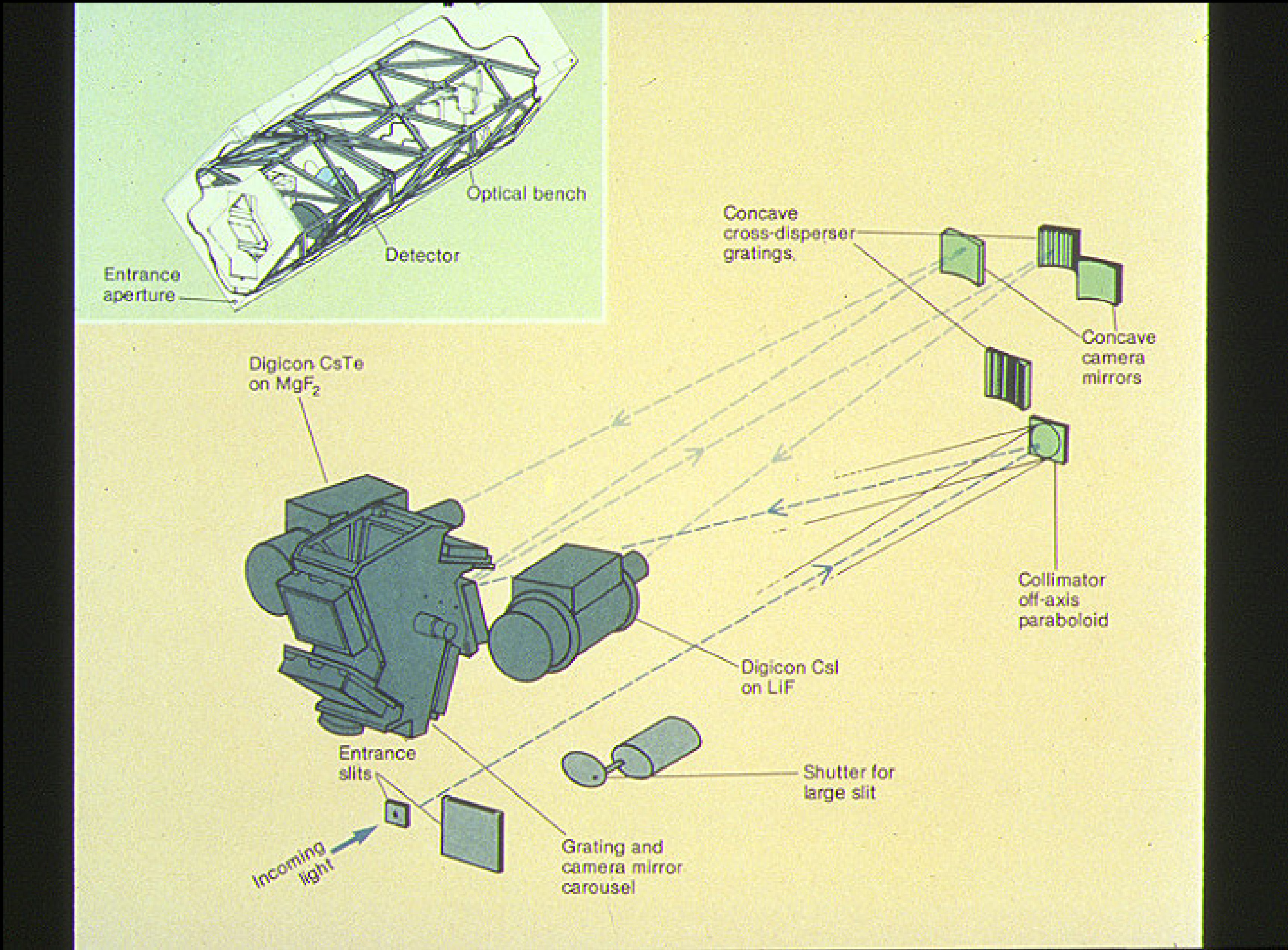
- Wide field & Planetary camera
- High-res spectrograph
- Faint object camera
- Faint object spectrograph
- High speed photometer



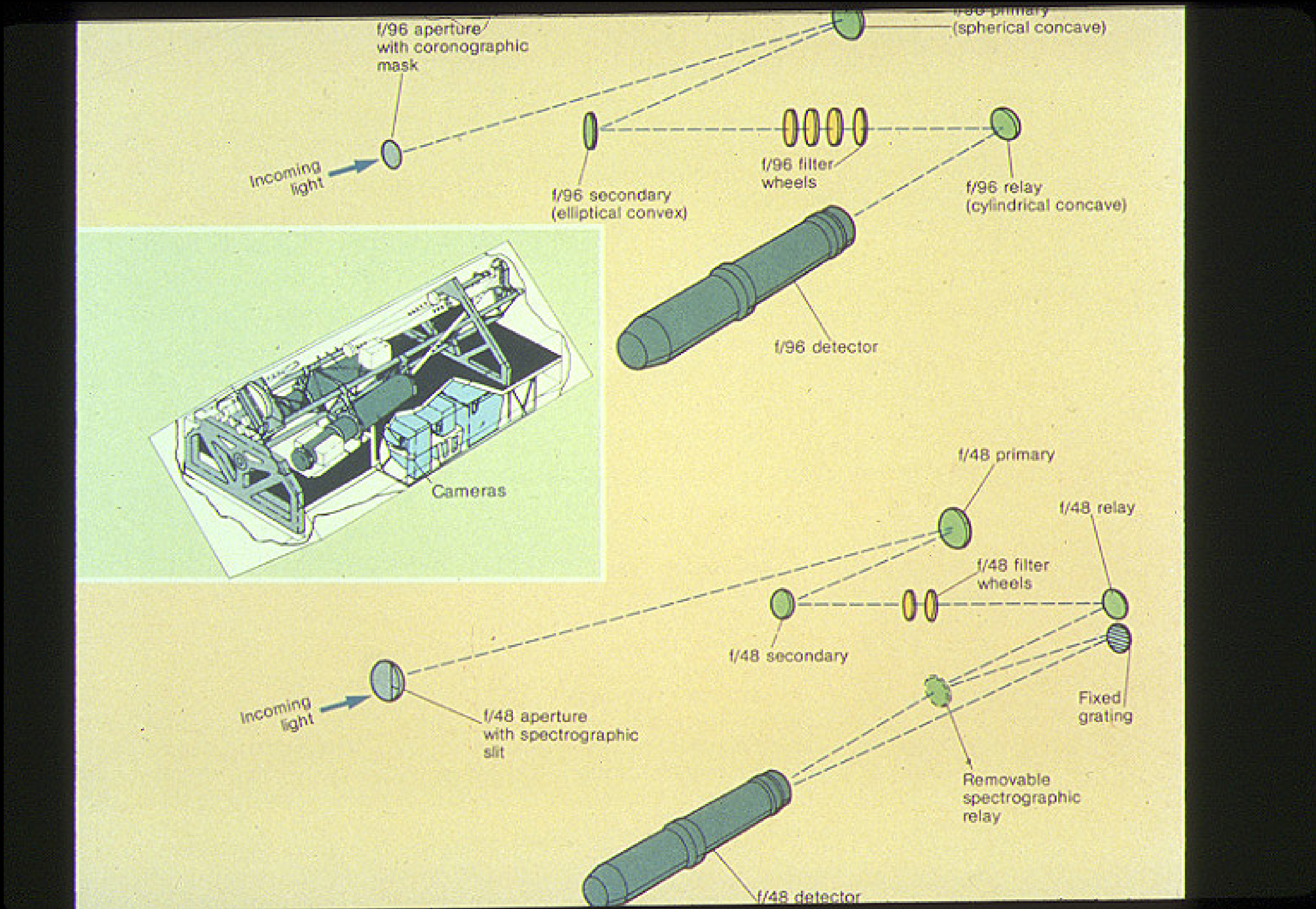
Wide field and planetary camera



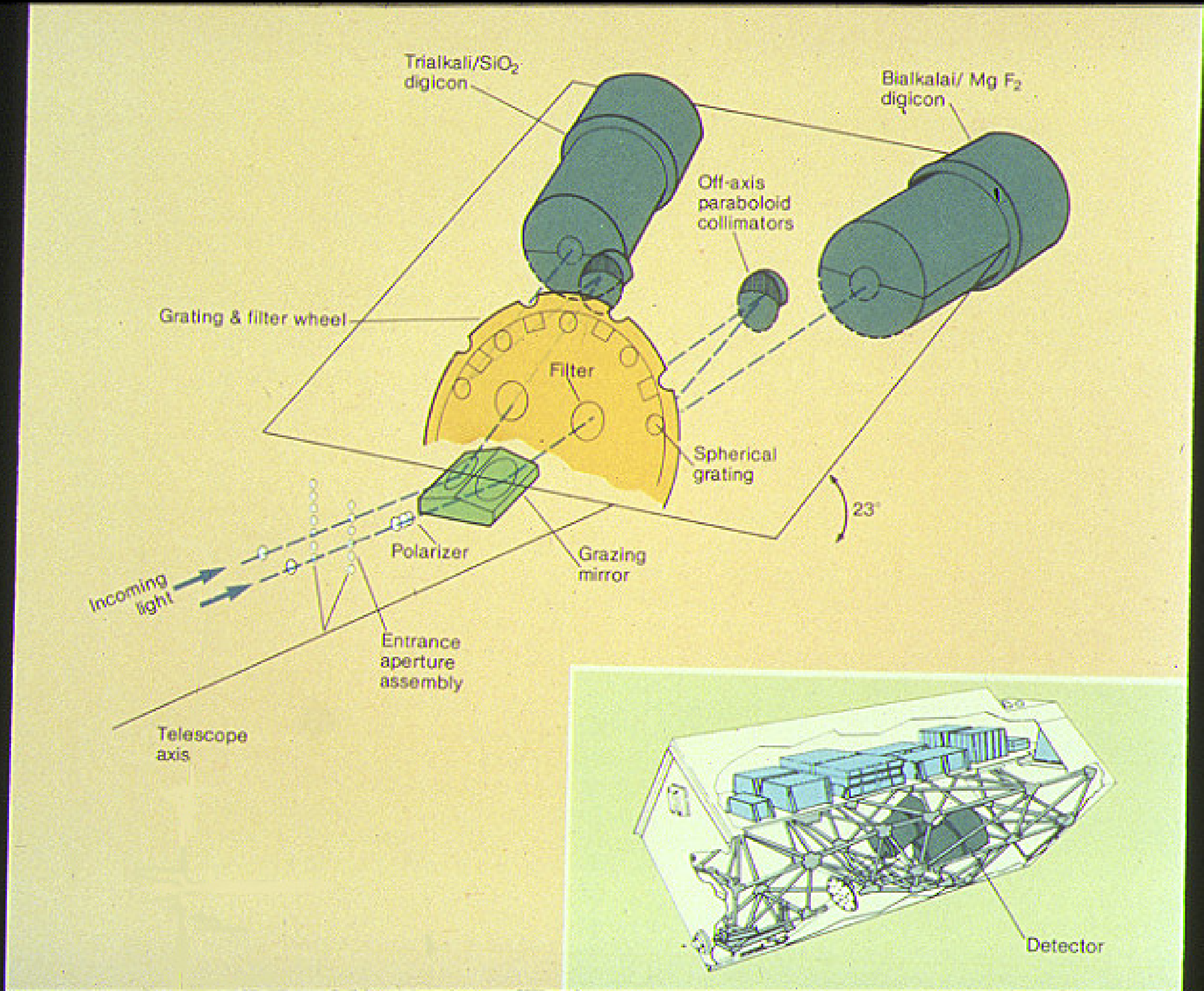
High resolution spectrograph



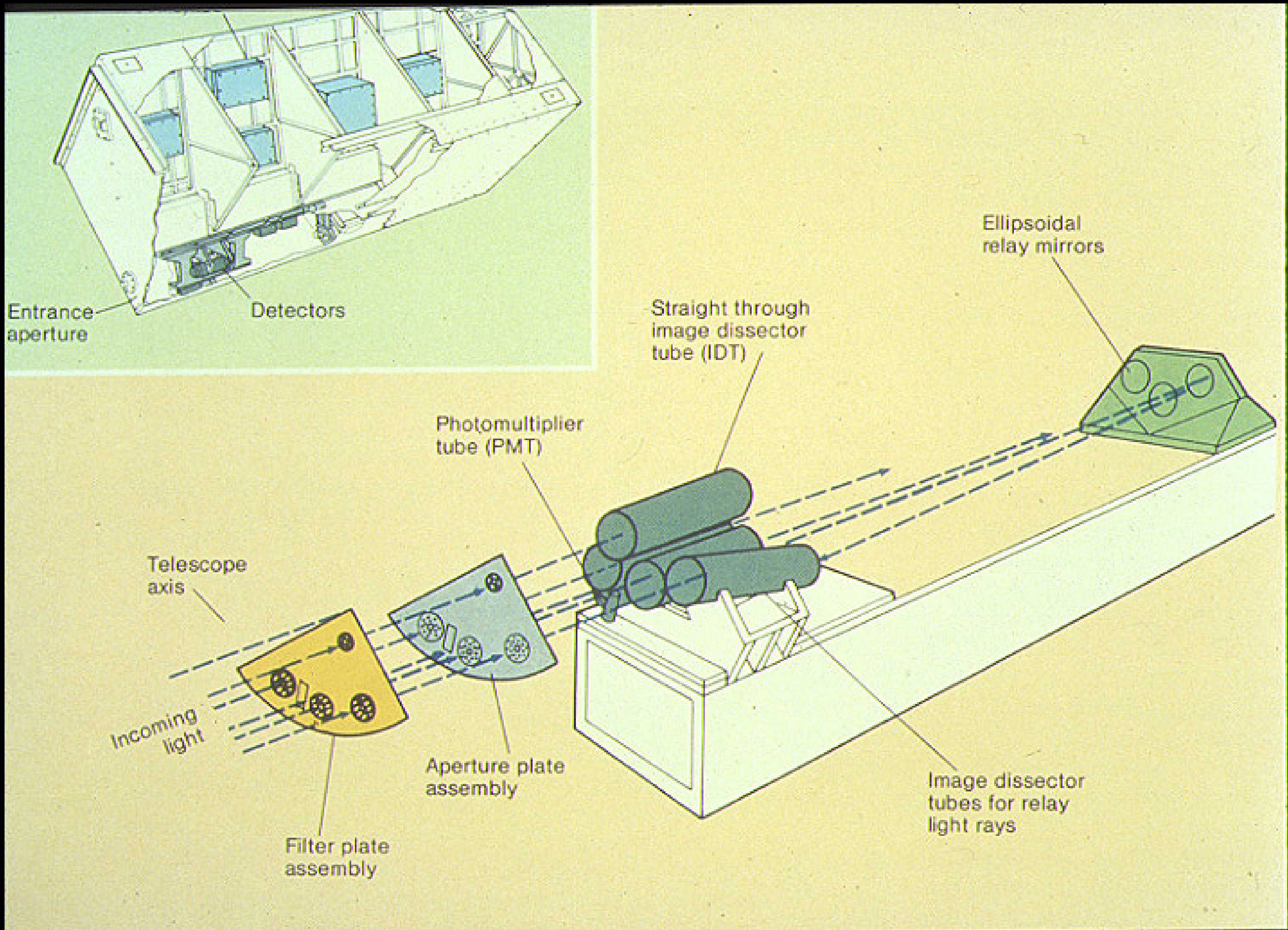
Faint object camera



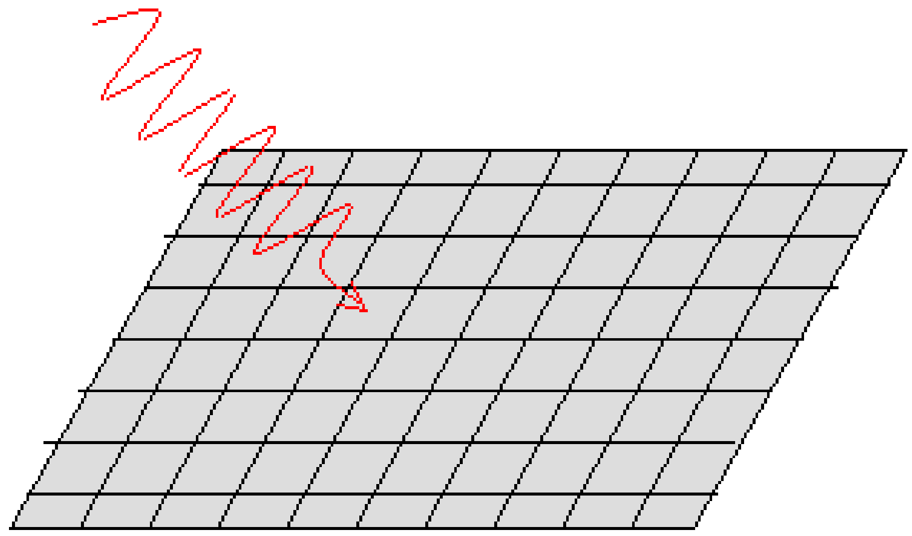
Faint object spectrograph



High speed photometer



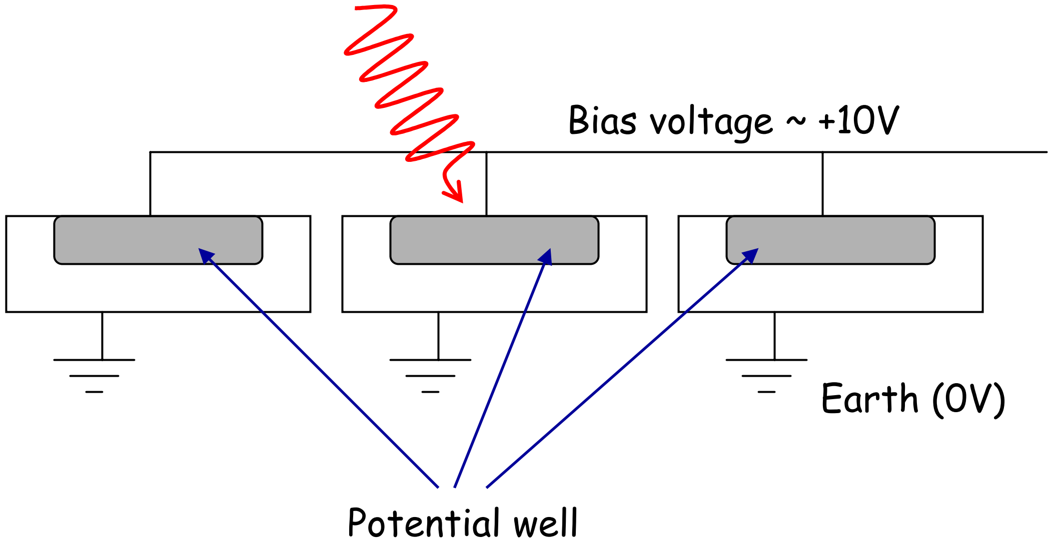
Charge Coupled Device (CCD)



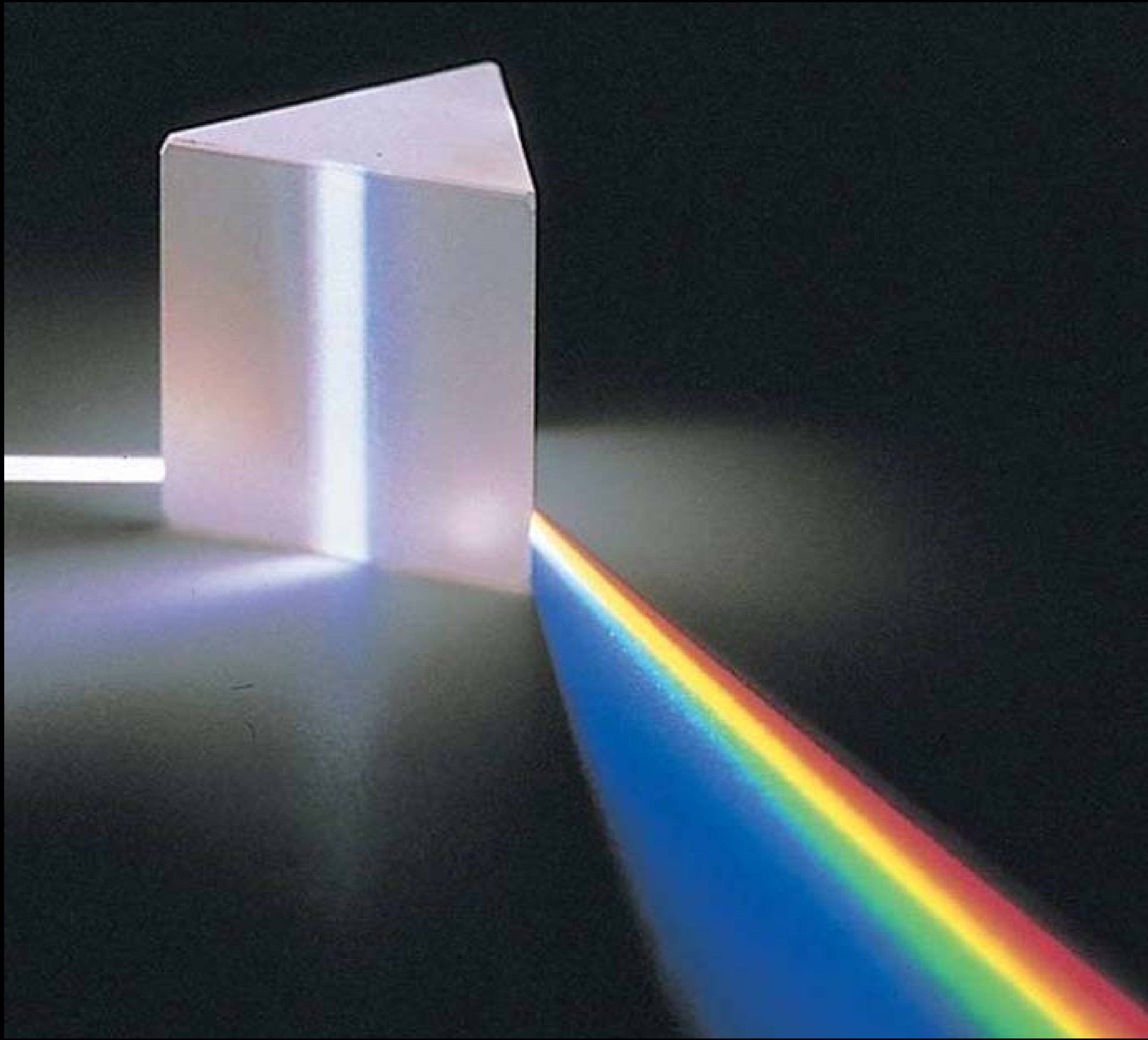
A CCD is a semiconductor array of light-sensitive pixels – typically about 20 μm across.

Arrays of 10^7 pixels standard.

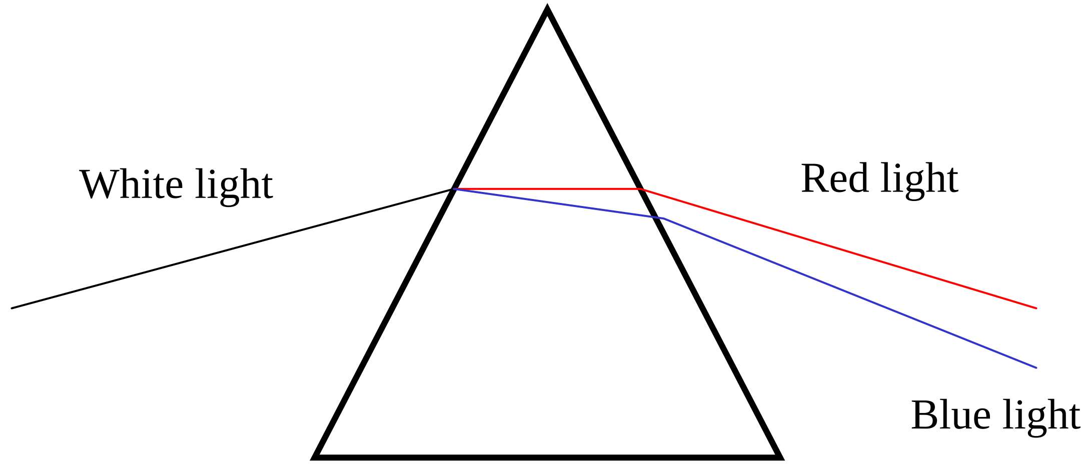
'State of the Art' – mosaics of CCDs, of 10^9 pixels in total

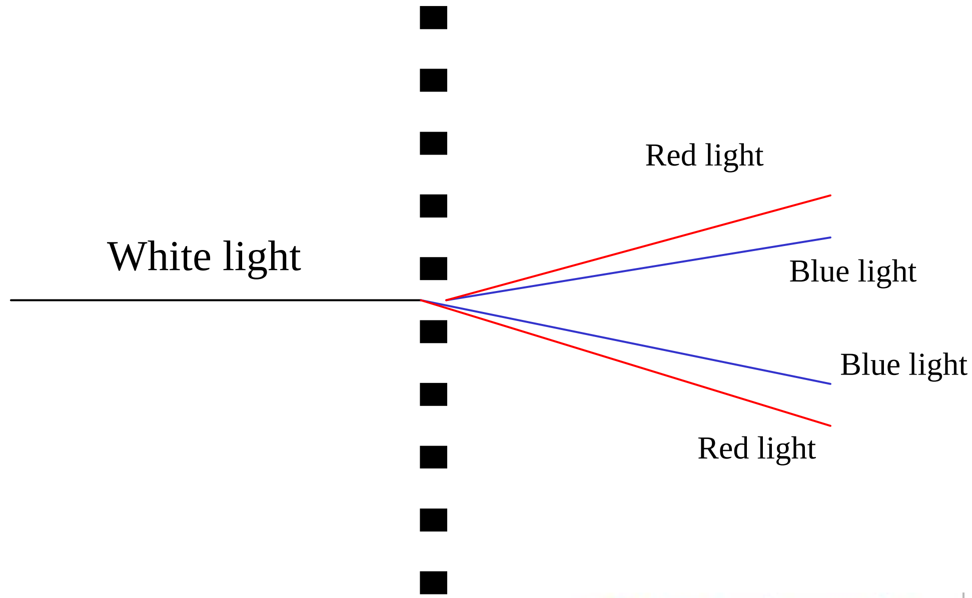


- Electron released when photon strikes semiconductor
- Bias voltage draws electron into potential well; stored there during exposure



Much higher spectral resolution can be achieved using a **DIFFRACTION GRATING**

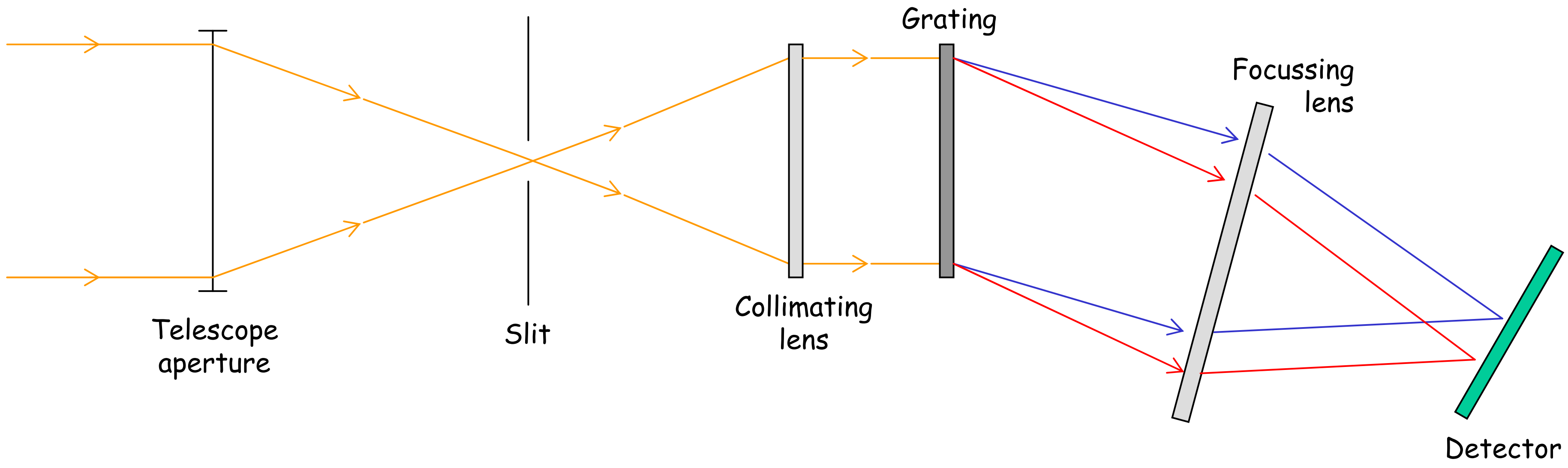




Note that a prism disperses blue light more strongly than red light, while for a diffraction grating red light is dispersed more strongly than blue light.

Design of a Slit Spectrometer

Key features of the design are summarised in the following diagram



Choose focal length of focussing lens so that width of diffraction peak at the detector $\geq$ width of pixel on detector.

i.e. the diffraction maxima cover several pixels

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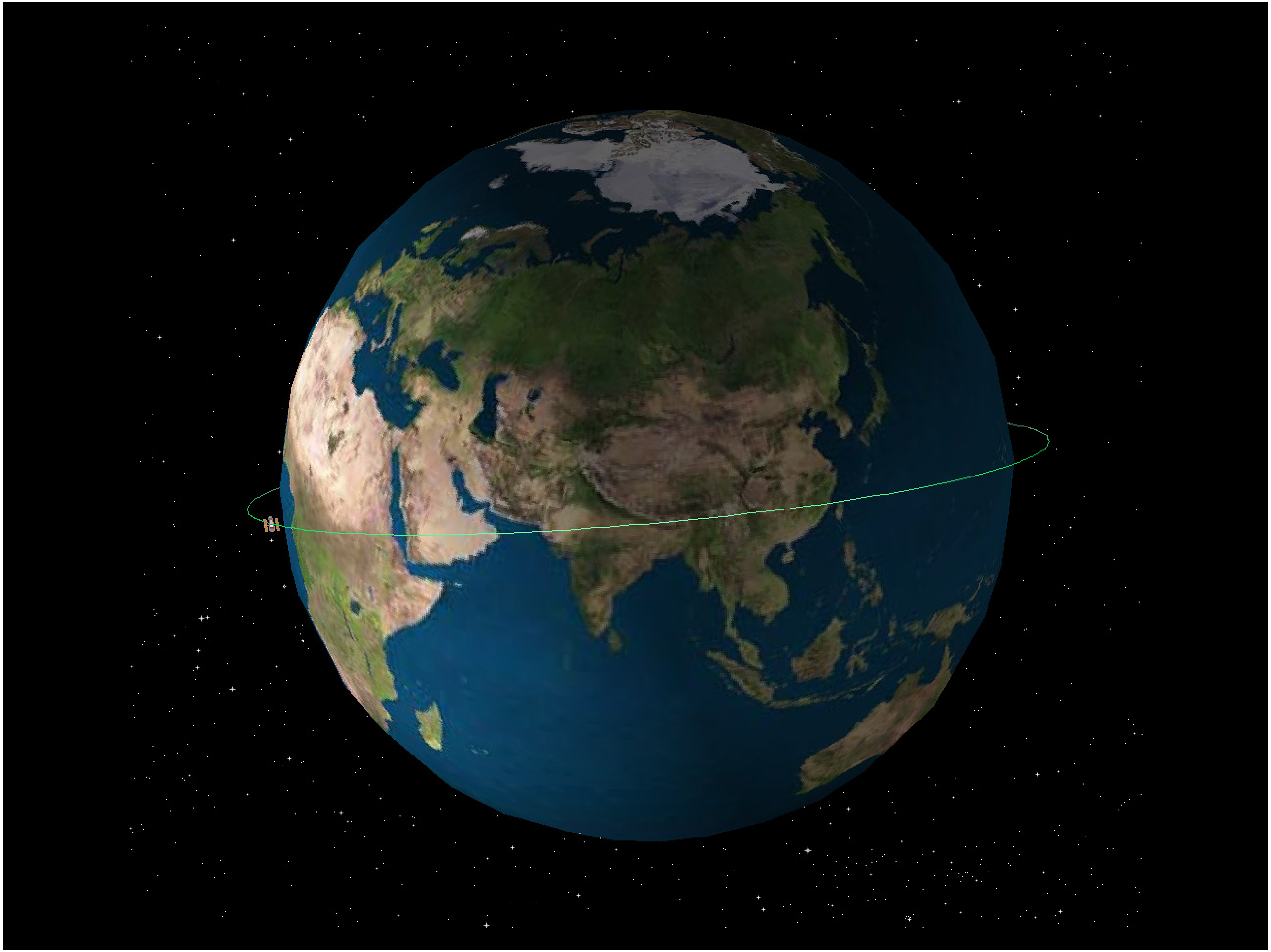
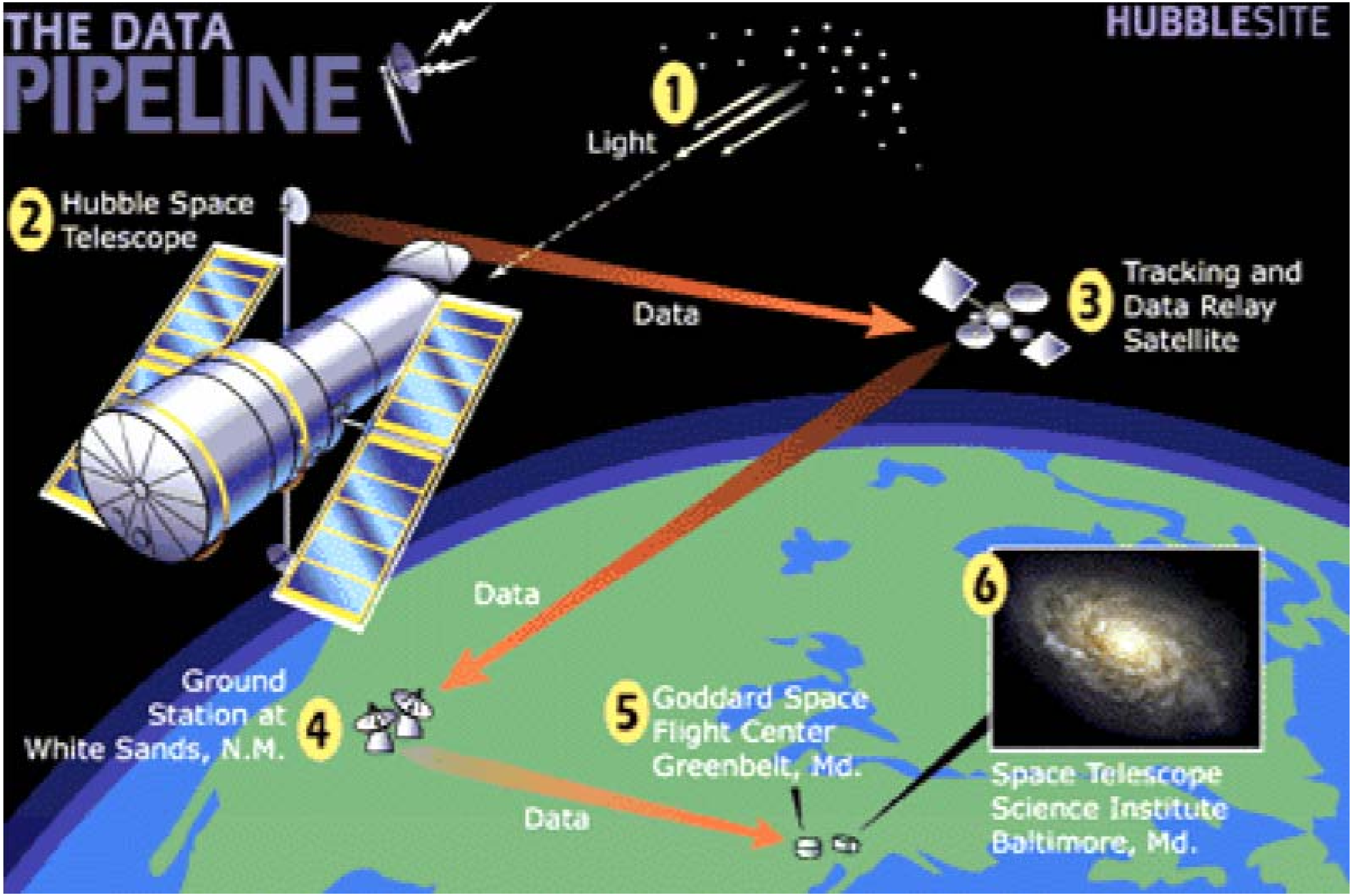
1986 The space shuttle Challenger explodes upon liftoff. The disaster forces delays in all programs, including Hubble.

Timeline

1990 April 24th

STS-31: Discovery lifts off, carries HST to low orbit.




THE DATA PIPELINE
HUBBLESITE
1 Light
2 Hubble Space Telescope
Data
3 Tracking and Data Relay Satellite
Data
Ground Station at White Sands, N.M. 4
5 Goddard Space Flight Center Greenbelt, Md.
Data
6
Space Telescope Science Institute Baltimore, Md.

Timeline

1990 April 24th

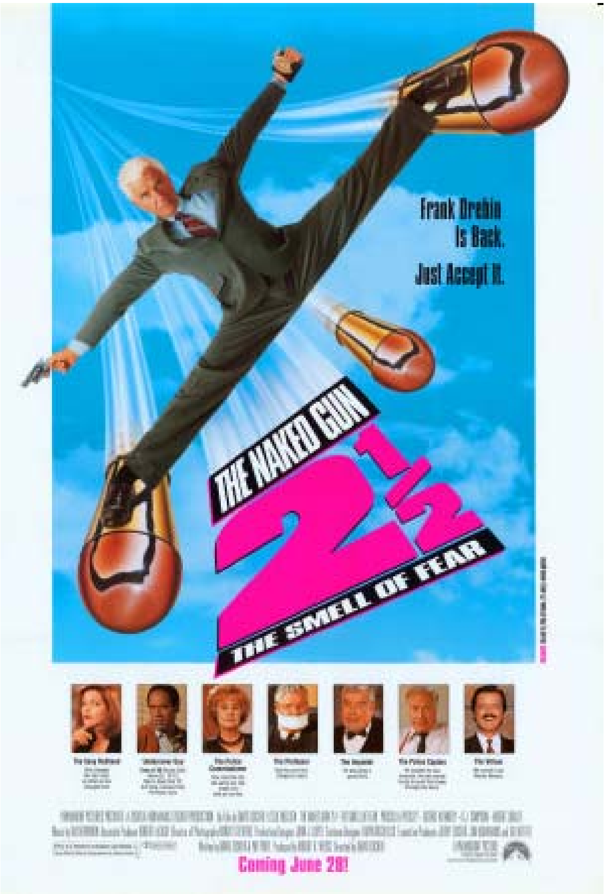
STS-31: Discovery lifts off, carries HST to low orbit.

April 27th

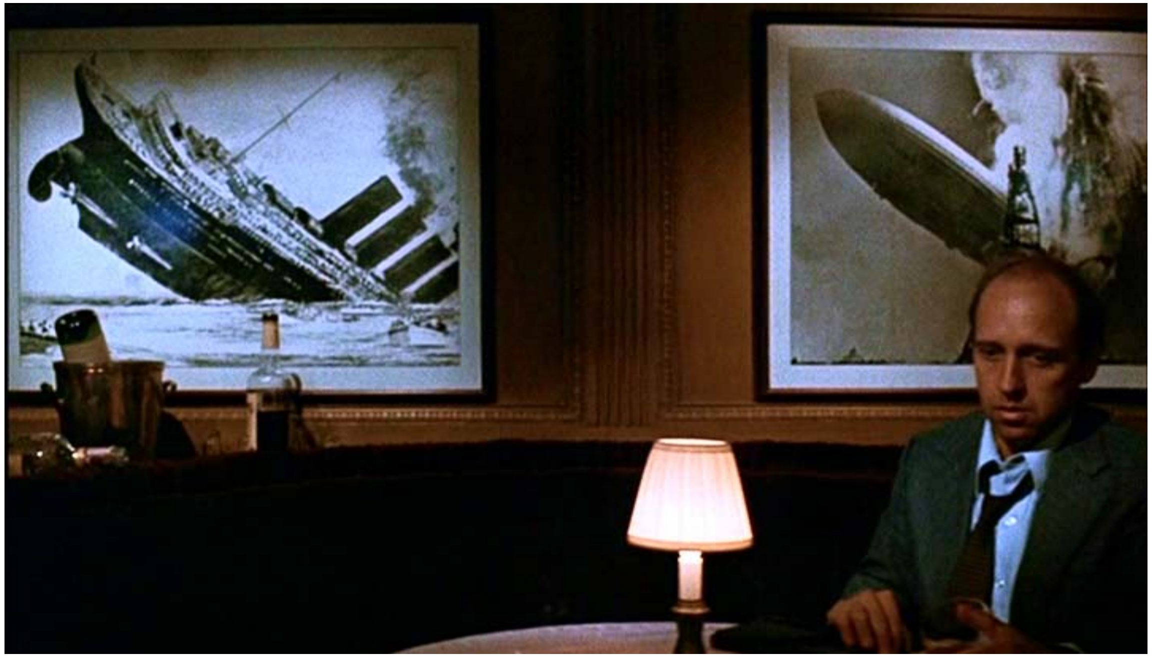
HST deployed from shuttle. Flaw in mirror design quickly becomes apparent:

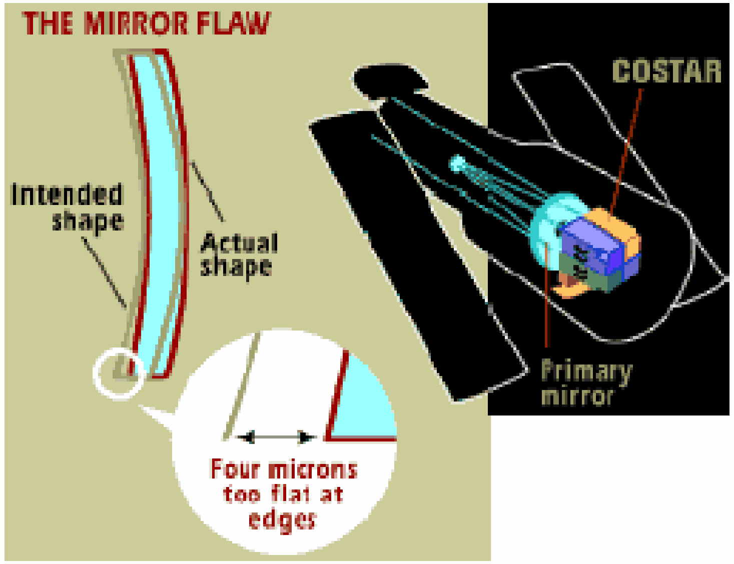
Images blurred due to **spherical aberration**.

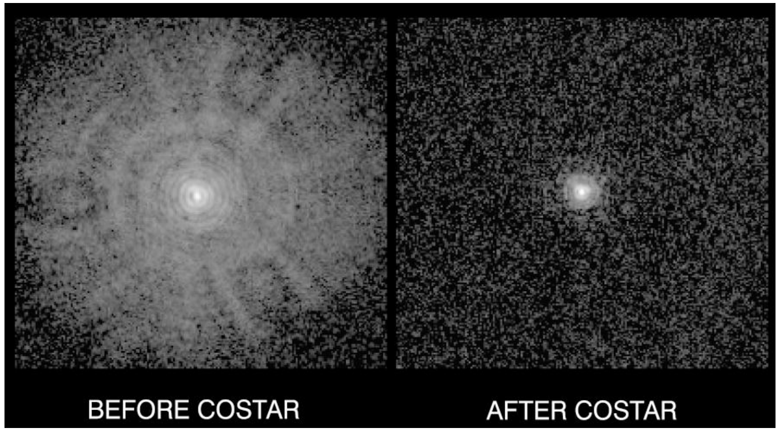

Prof. Jeff Hoffman
Astronaut



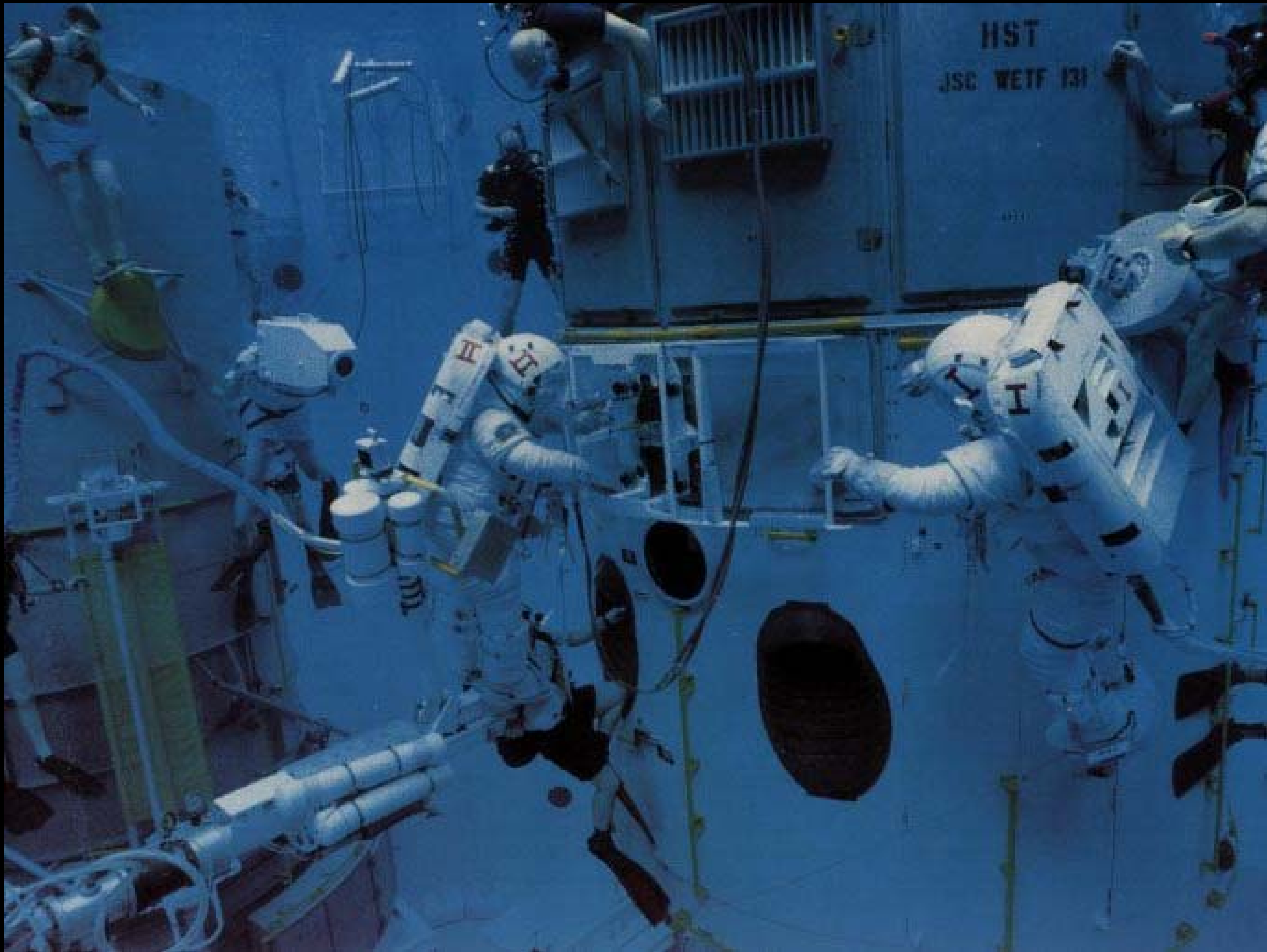
Released 1991

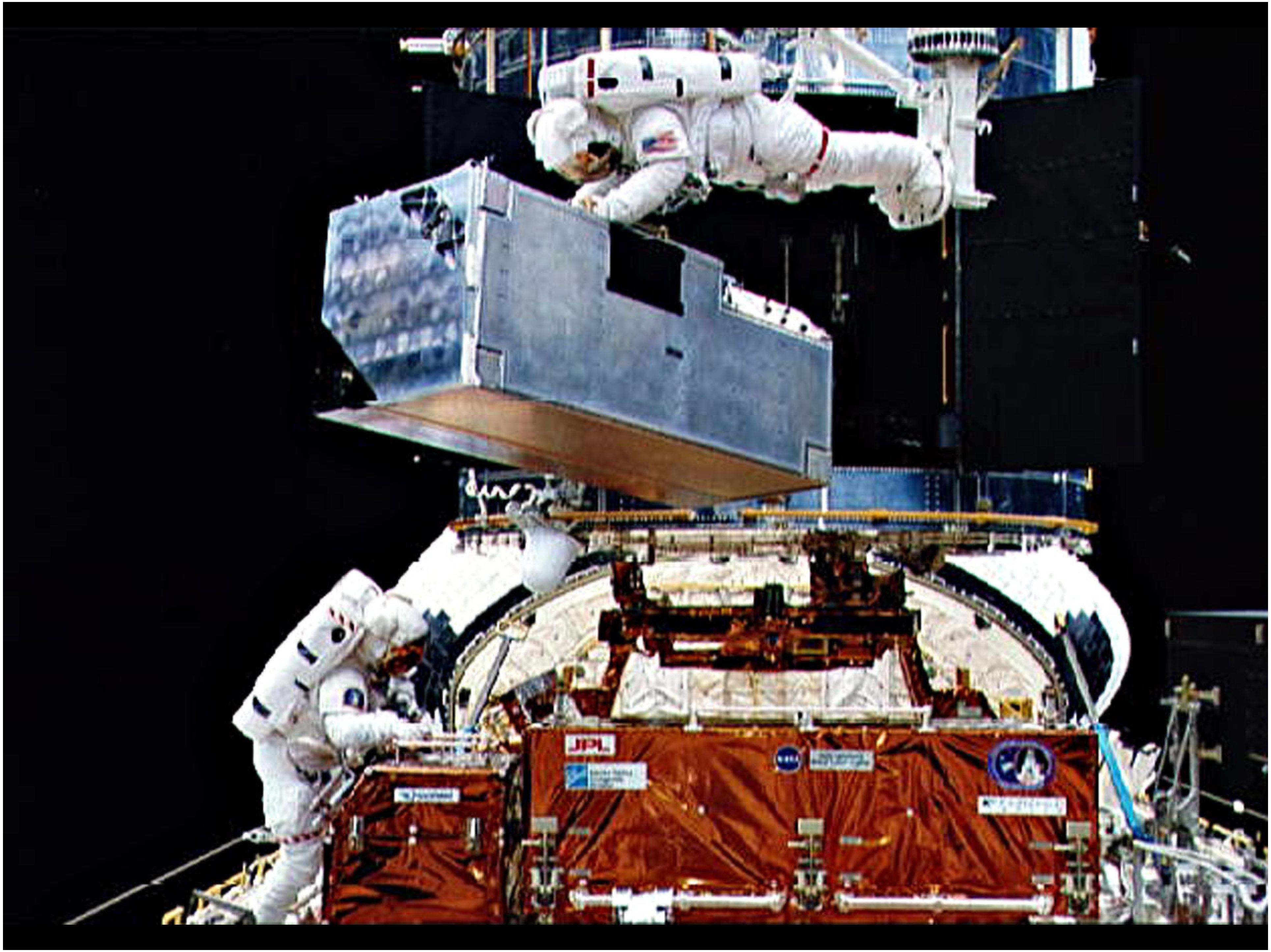


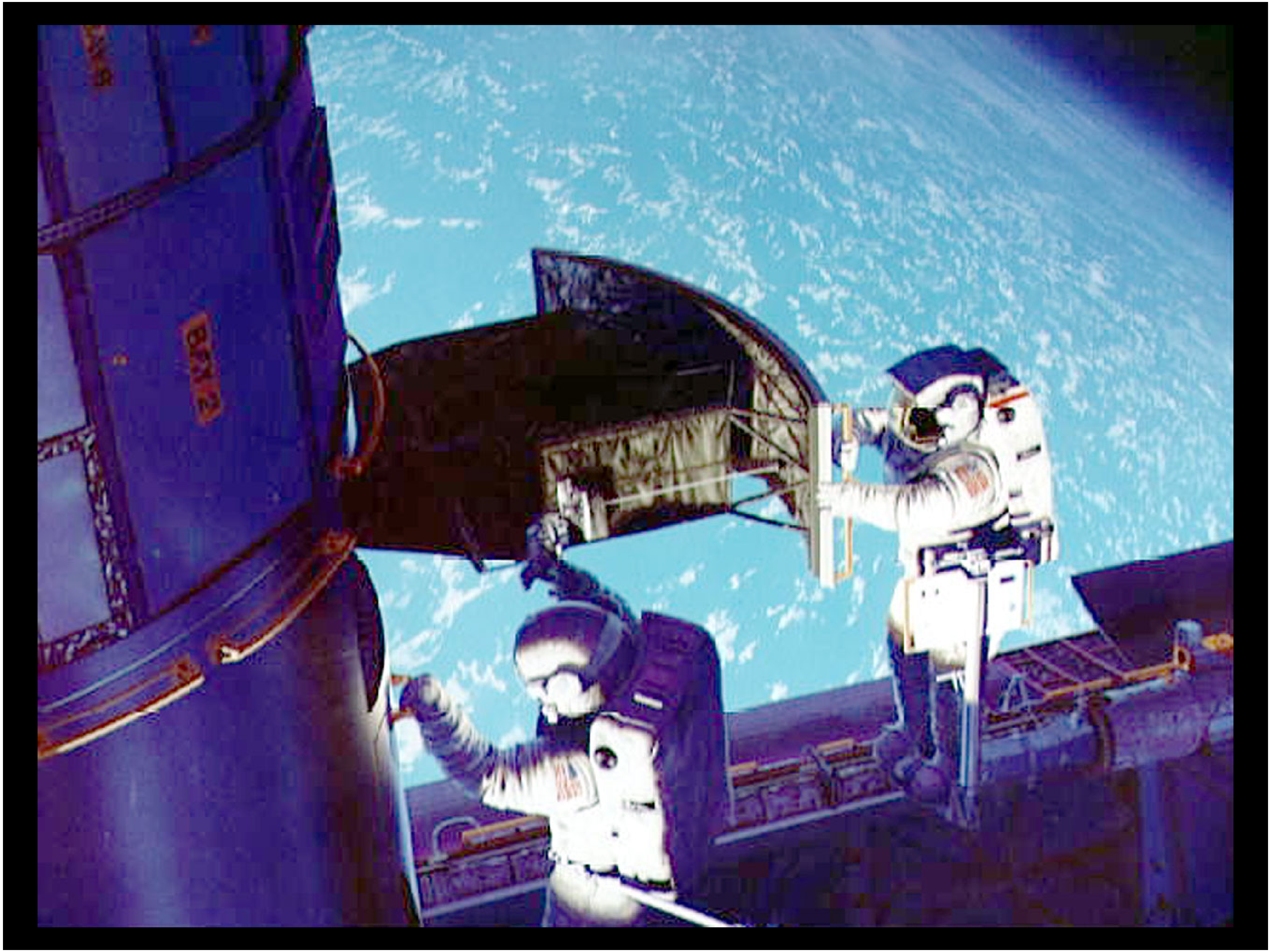


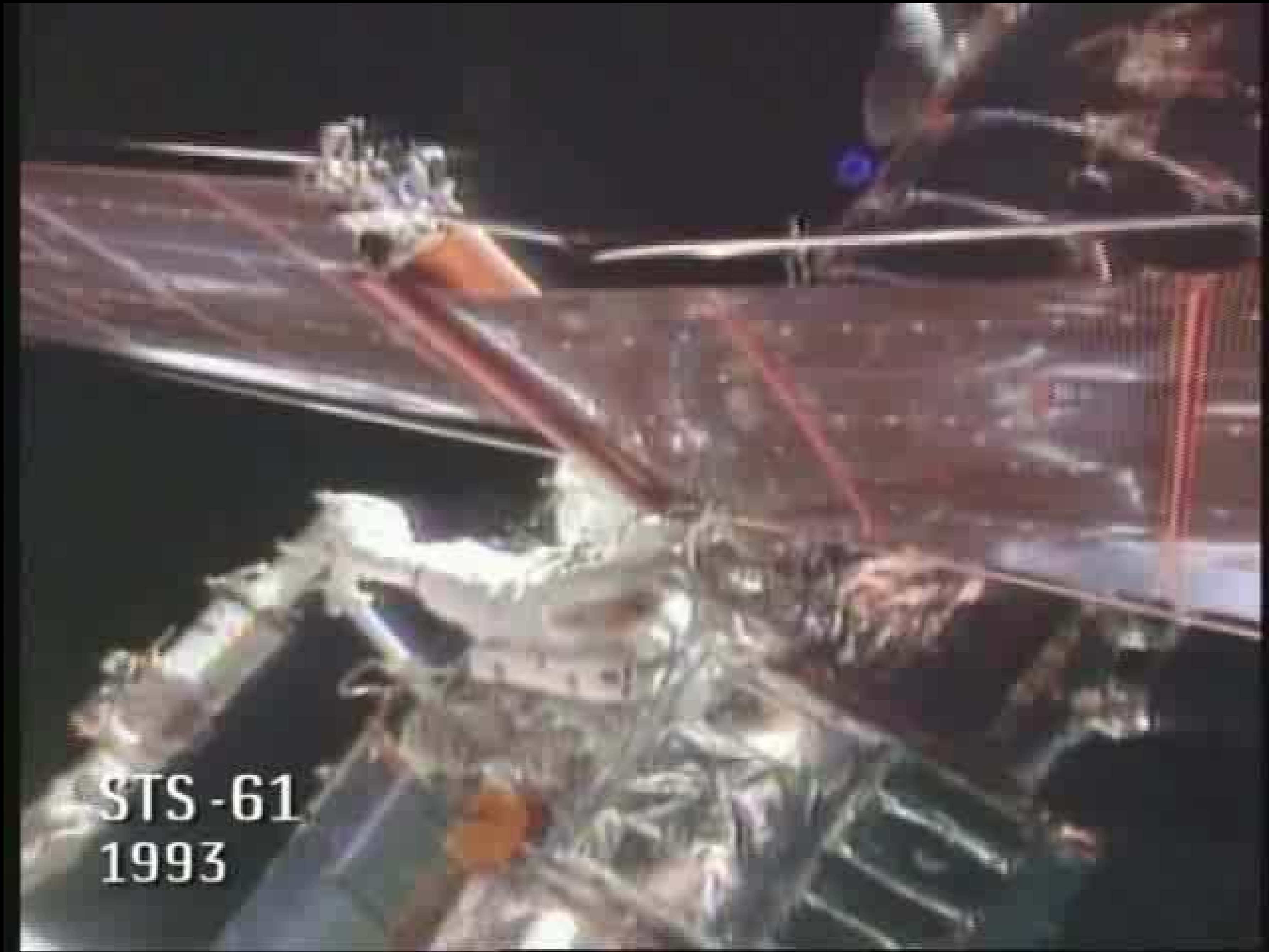


Flt	STS No.	Astronaut	HH	MM	Hubble Space Telescope EVAs in Detail
N/A	STS-31 0 EVAs	Bruce McCandle Kathryn Sullivan	00	00	**04/24/90: HST Launch** McCandless and Sullivan were suited up for an EVA when one of Hubble's solar arrays failed to unfurl as expected. Controllers later coaxed it open without needing a spacewalk.
29* 27	STS-61 5 (*29th US flight with an EVA; STS EVAs = 27)	Story Musgrave Jeffrey Hoffman Thomas Akers Kathy Thornton **STS-61 TOTAL**	07 06 07 06 06 **35**	53 47 21 35 50 **26**	**12/02/93: HST Servicing Mission 1** First mision with five spacewalks; astronauts installed the WFPC-2, COSTAR, four gyroscopes, gyro electronics and two new solar arrays. All mission objectives were accomplished, correcting HST's flawed optics.
35 38	STS-82 5	Mark Lee Steven Smith Gregory Harbau Joseph Tanner **STS-82 TOTAL**	06 07 05 07 06 **33**	42 11 17 27 34 **11**	**02/11/97: HST Servicing Mission 2** Four EVAs originally planned; fifth EVA added to repair peeling and flaking insulation. Objectives included installation of STIS, NICMOS, a fine guidance sensor, a solid-state recorder and a reaction wheel assembly (RWA-1). All objectives accomplished.
40 48	STS-103 3	Steven Smith* John Grunsfeld Michael Foale Claude Nicollier **STS-103 TOTAL**	08 08 08 **24**	15 08 15 **38**	**12/19/99: HST Servicing Mission 3A** Servicing Mission 3 was broken into two missions, SM-3A and SM-3B, because of multiple gyroscope failures. Objectives of SM-3A included installation of a new computer, another solid-state recorder, a fine guidance sensor and six gyroscopes. All objectives accomplished.
51 74	STS-109 5	John Grunsfeld* Richard Linneha James Newman Michael Massim **STS-109 TOTAL**	07 06 07 07 07 **35**	01 48 20 16 30 **55**	**03/01/02: HST Servicing Mission 3B** Objectives included installation of two new solar arrays, diode boxes, a reaction wheel assembly, power control unit, the Advanced Camera for Surveys and an experimental cooler to revive the NICMOS instrument. All objectives accomplished. **STS SINGLE FLIGHT RECORD**


HST
JSC WETF 131



JPL




STS -61
1993

COMPARISON of HUBBLE SPACE TELESCOPE FAINT OBJECT CAMERA IMAGES

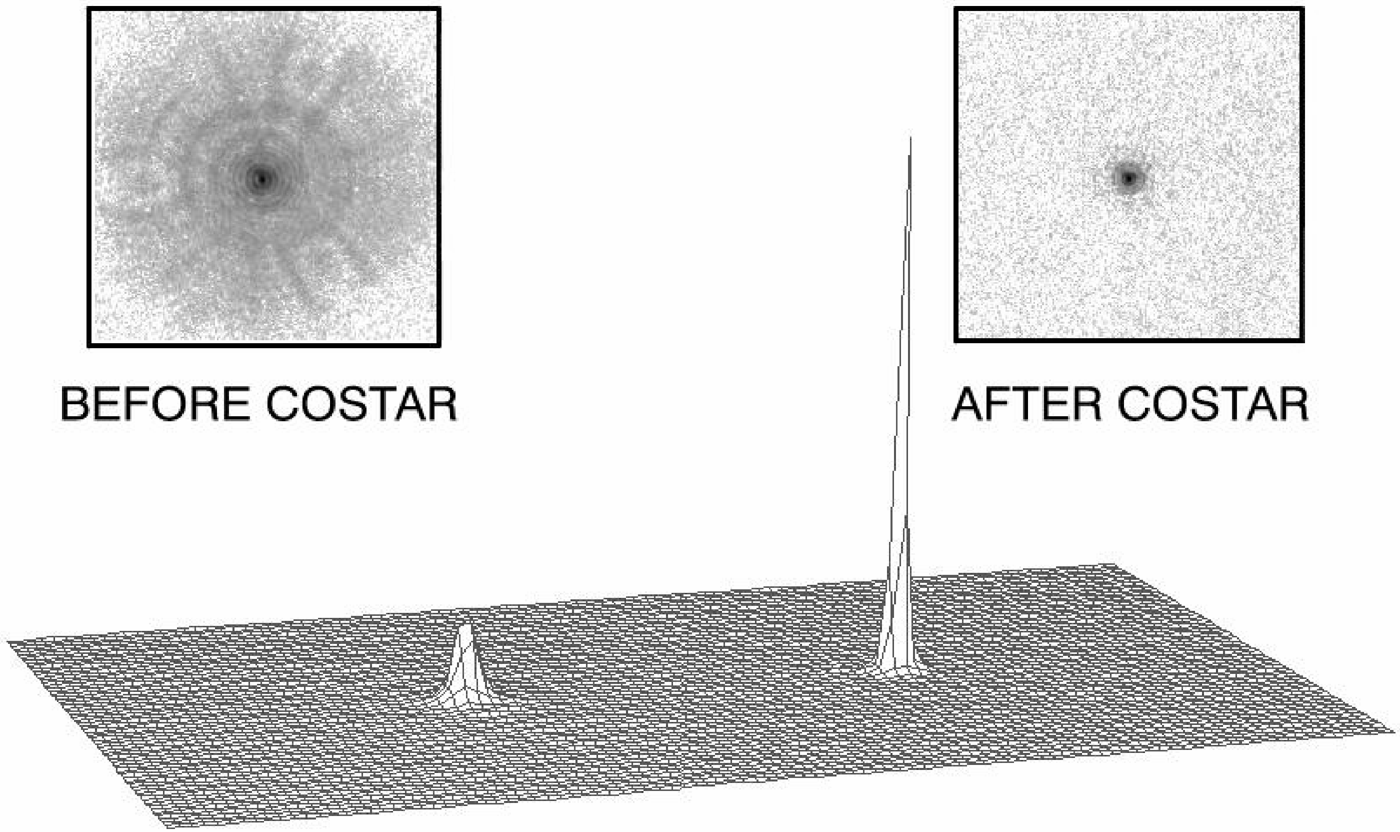
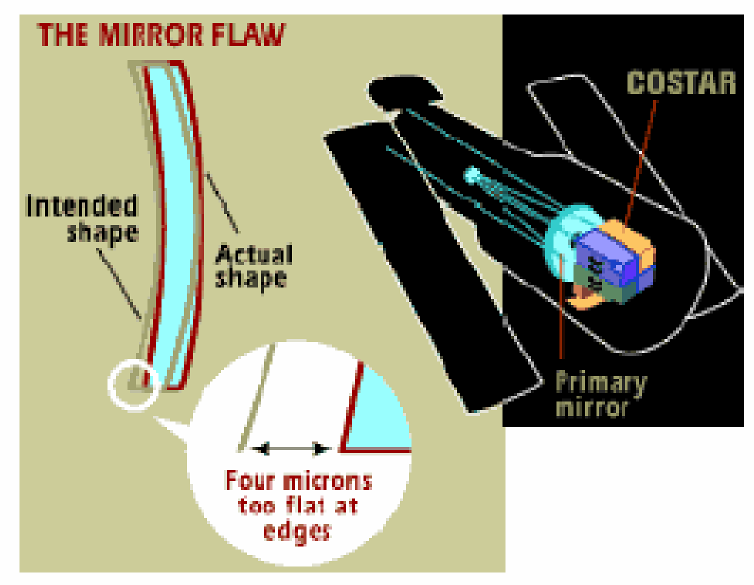
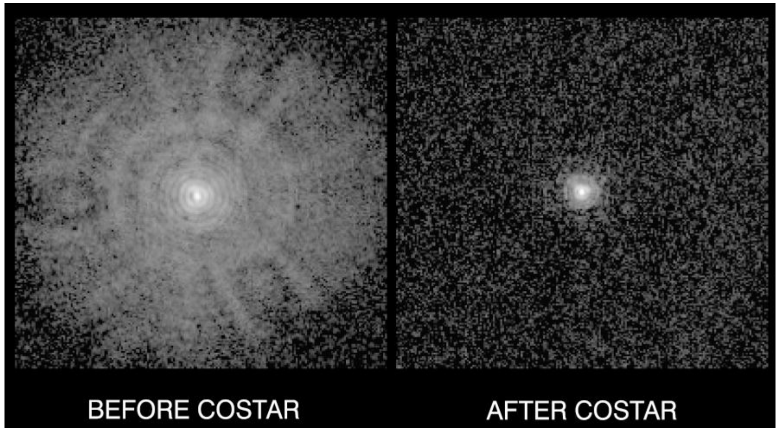


Image Sharpness Before and After COSTAR





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HST SM-1: 02/12/93

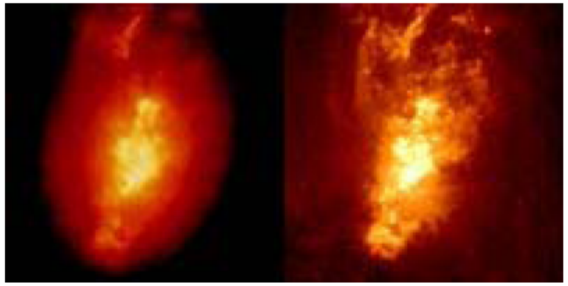
Hubble's Instruments: COSTAR - Corrective Optics Space Telescope Axial Replacement

COSTAR is not really a science instrument; it is a corrective optics package that displaced the High Speed Photometer (HSP) during the first servicing mission. COSTAR is designed to optically correct the effects of the primary mirror's aberration on the Faint Object Camera (FOC). All the other instruments, installed since HST's initial deployment, were designed with their own corrective optics. When the FOC is replaced by the Advanced Camera for Surveys (ACS) during Servicing Mission 3B, COSTAR will no longer be needed.

COSTAR Facts

"Instrument" type	Corrective optics

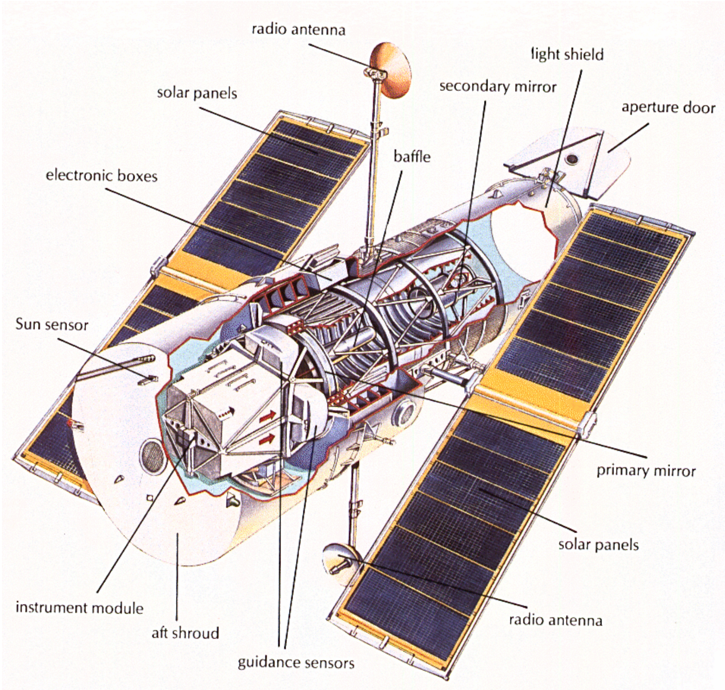
COSTAR being inserted into Hubble during First Servicing Misson.



Two images taken of the same region before and after the correction of Hubble's aberration with COSTAR.

‘2nd generation’ instruments: 1997

- Wide field & Planetary camera → WFPC2
- High-res spectrograph → STIS
- Faint object spectrograph → STIS
- High speed photometer → COSTAR



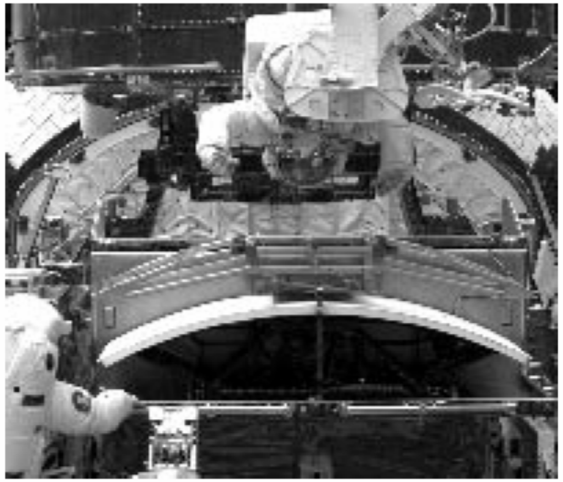
‘3rd generation’ instrument: 2002

- Faint object camera → ACS

HST SM-1: 02/12/93

Hubble's Instruments: WFPC2 - Wide Field Planetary Camera 2

The Wide Field and Planetary Camera 2 (WFPC2) was Hubble's workhorse camera for many years. It records images through a selection of 48 colour filters covering a spectral range from far-ultraviolet to visible and near-infrared wavelengths. The 'heart' of WFPC2 consists of an L-shaped trio of wide-field sensors and a smaller, high resolution (Planetary) Camera placed at the square's remaining corner.



WFPC2 is being readied for insertion into Hubble during the First Servicing Mission.

WFPC2 has produced most of the stunning images that have been released as public outreach images over the years. Its resolution and excellent quality are some of the reasons that WFPC2 has been the most used instrument in the first 13 years of Hubble's life.

WFPC2 will be replaced by WFC3 during Servicing Mission 4 in 2008.

WFPC2 Facts

Instrument type	Camera
Weight	281 kg
Dimensions	0,8 m x 2.2 m x 2,0 m
Field of view	2.7 arcminutes
Wavelength range	120 to 1000 nm


Wide Field
Camera 2
Planetary Camera
Camera 1
Wide Field
Camera 3
Wide Field
Camera 4
Hubble Deep Field
HST WFPC2
ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

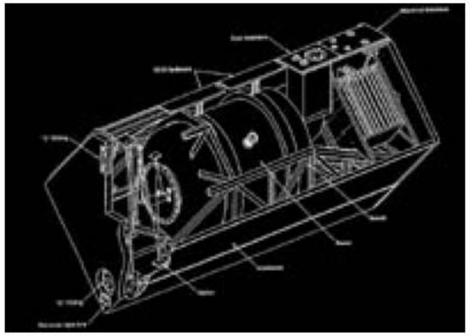
HST SM-2: 11/02/97

Hubble's Instruments: NICMOS - Near Infrared Camera and Multi-Object Spectrometer

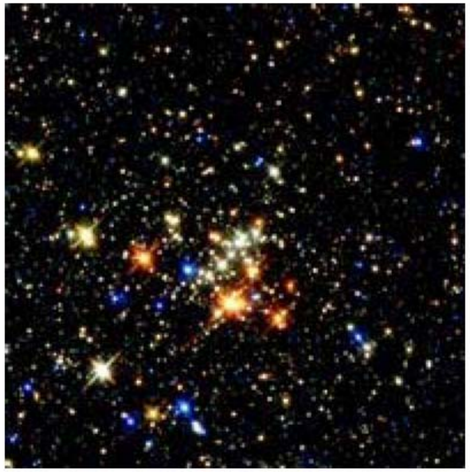
The Near Infrared Camera and Multi-Object Spectrometer (NICMOS) is an instrument providing the capability for infrared imaging and spectroscopic observations of astronomical targets. NICMOS detects light with wavelengths between 8000 to 25000 Ångstroms. These wavelengths are infrared and thus invisible to our human eyes.

NICMOS was revived by an electrical cooler installed during Servicing Mission 3B and is now again producing world class science results.

NICMOS' infrared capabilities will largely be superseded by the WFC3.



The NICMOS instrument onboard Hubble.



Typical image taken with NICMOS. It shows a gigantic star cluster in the center of our milky way. NICMOS is the only Hubble instrument which - due to its infrared capabilities - is able to look through the heavy clouds of dust and gas in these central regions.

NICMOS Facts

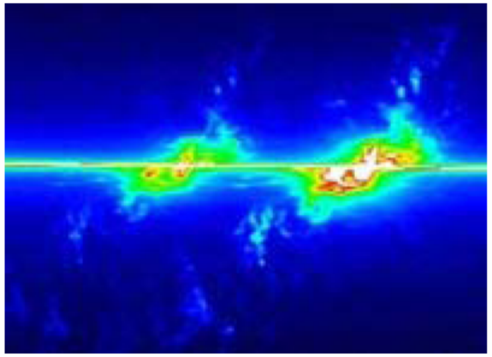
Instrument type	Camera and Spectrograph
Weight	370 kg
Dimension	2.2 m x 0.89 m x 0.89 m
Field of view	Low resolution 51.5 x 51.5 arcseconds Medium resolution 17.5 x 17.5 arcsec High resolution 11.0 x 11.0 arcsec
Wavelength range	800 to 2500 nm

HST SM-2: 11/02/97

Hubble's Instruments: STIS - Space Telescope Imaging Spectrograph

The Space Telescope Imaging Spectrograph (STIS) is a versatile "combi-instrument" taking advantage of modern technologies. It combines a camera with a spectrograph, and covers a wide range of wavelengths from the near-infrared region into the ultraviolet. A spectrograph spreads out the light gathered by a telescope so that it can be analyzed to determine such properties of celestial objects as chemical composition and abundances, temperature, radial velocity, rotational velocity, and magnetic fields. Its spectrograph can be switched between two different modes of usage: 1.So-called "long slit spectroscopy" where spectra of many different points across an object are obtained simultaneously. 2.So-called "echelle spectroscopy" where the spectrum of one object is spread over the detector giving better wavelength resolution in a single exposure. STIS also has a so-called coronograph which can block light from bright objects, and in this way enables investigations of nearby fainter objects.

The Space Telescope Imaging Spectrograph (STIS).



A STIS spectrum of the galaxy NGC 4151 revealing that gas is flowing out of a black hole in its center.

STIS Facts

Instrument type	Camera and Spectrograph
Weight	318 kg
Dimensions	2.2 x 0.9 x 0.9 m
Field of view	MAMA - 25 x 25 arcseconds CCD - 50 x 50 arcseconds
Wavelength range	115 to 1000 nm

HST SM-3B: 01/03/02

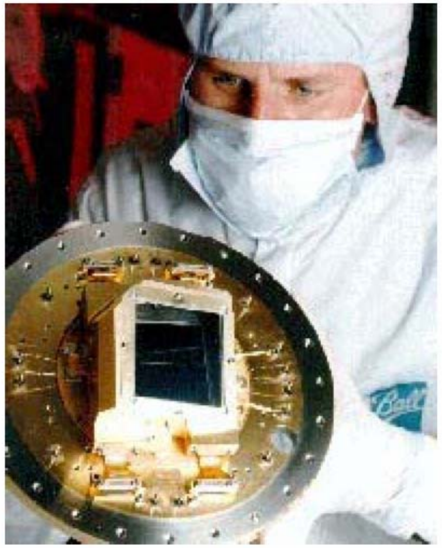
ACS - A new digital camera to extend Hubble's vision

The Advanced Camera for Surveys (ACS) replaced Hubble's Faint Object Camera during SM3B. Its wavelength range extends from the ultraviolet, through the visible and out to the near-infrared. ACS is a so-called third generation Hubble instrument. Its wide field of view is nearly twice that of Hubble's former workhorse camera, WFPC2, and with its superb image quality and high sensitivity, ACS has increased Hubble's potential for new discoveries by a factor of ten. The name, Advanced Camera for Surveys, comes from its particular ability to map large areas of the sky in great detail. ACS can also perform spectroscopy with a special optical tool called a 'grism'.

ACS - Hubble's newest scientific instrument on display in a clean-room before launch.

Three sub-instruments make up ACS

The Wide Field Camera is a high efficiency, wide field, optical and near-infrared camera. This space eye is optimised to hunt for galaxies and galaxy clusters in the remote and ancient Universe, at a time when our Cosmos was very young. The distribution in space of these distant objects will enable scientists to investigate just how the Universe evolved.

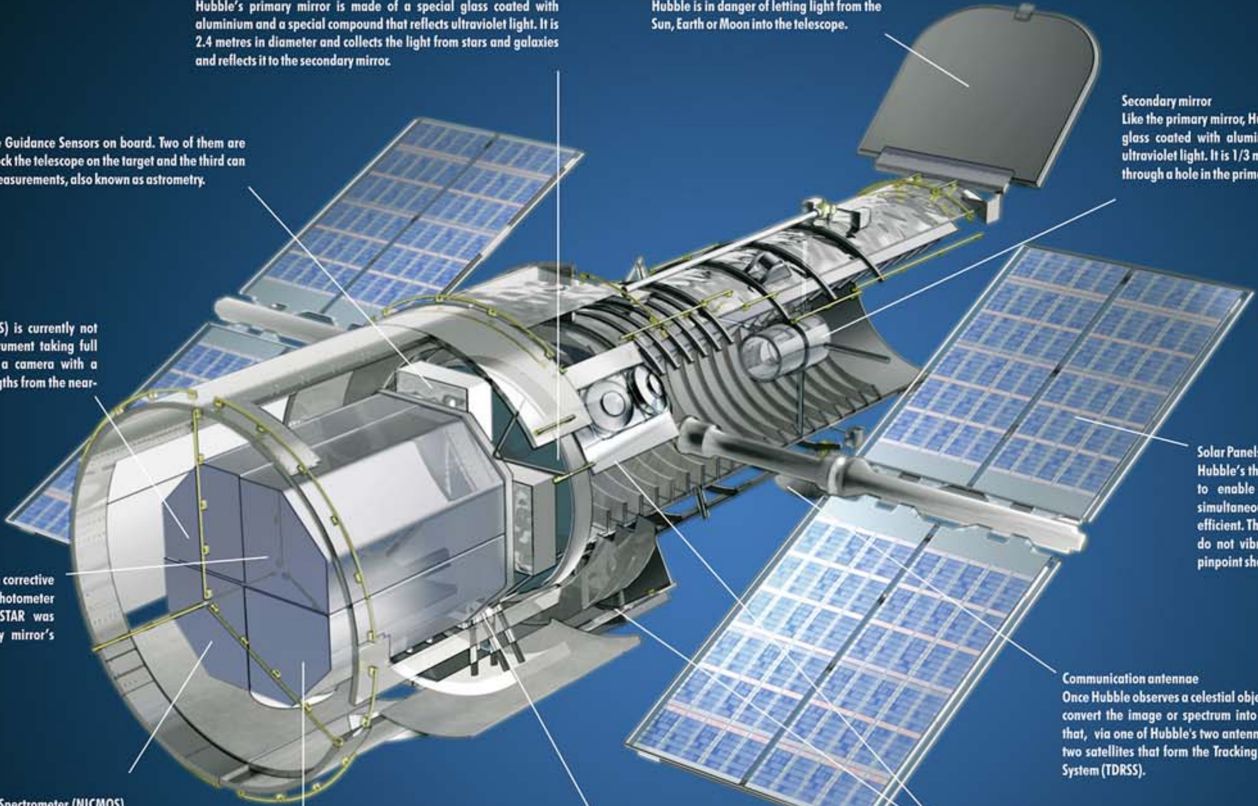


A look into one of ACS's most delicate and crucial parts - the CCD camera.

Another important sub-instrument is the High Resolution Camera. This camera is designed to take extremely detailed pictures (high resolution) of the light from the centres of galaxies with massive black holes, as well as of ordinary galaxies, star clusters and gaseous nebulae, where extraterrestrial planetary systems may be hidden. The instrument includes a coronograph, capable of improving Hubble's contrast near bright objects by about a factor of 10.

Finally, the Solar Blind Camerablocks visible light to allow faint ultraviolet radiation to be discerned. Among other things, it will be used to study weather patterns on other planets and aurorae on Jupiter.

HUBBLE'S INSTRUMENTS AND SYSTEMS



Primary mirror
Hubble's primary mirror is made of a special glass coated with aluminium and a special compound that reflects ultraviolet light. It is 2.4 metres in diameter and collects the light from stars and galaxies and reflects it to the secondary mirror.

Aperture door
Hubble's aperture door can be closed if Hubble is in danger of letting light from the Sun, Earth or Moon into the telescope.

Secondary mirror
Like the primary mirror, Hubble's secondary mirror is made of special glass coated with aluminium and a special compound to reflect ultraviolet light. It is 1/3 metre in diameter and reflects the light back through a hole in the primary mirror and into the instruments.

FGS
Hubble has three Fine Guidance Sensors on board. Two of them are needed to point and lock the telescope on the target and the third can be used for position measurements, also known as astrometry.

STIS
The Space Telescope Imaging Spectrograph (STIS) is currently not operating, but is a versatile multi-purpose instrument taking full advantage of modern technology. It combines a camera with a spectrograph and covers a wide range of wavelengths from the near-infrared region into the ultraviolet.

Solar Panels
Hubble's third set of solar arrays produce enough power to enable all the science instruments to operate simultaneously, thereby making Hubble even more efficient. The panels are rigid and unlike earlier versions, do not vibrate, making it possible to perform stable, pinpoint sharp observations.

COSTAR
COSTAR is not really a science instrument: it is the corrective optics package that replaced the High Speed Photometer (HSP) during the first servicing mission. COSTAR was designed to correct the effects of the primary mirror's aberration.

Communication antennae
Once Hubble observes a celestial object, its onboard computers convert the image or spectrum into long strings of numbers that, via one of Hubble's two antennae, are sent to one of the two satellites that form the Tracking and Data Relay Satellite System (TDRSS).

NICMOS
The Near Infrared Camera and Multi-Object Spectrometer (NICMOS) is an instrument for near-infrared imaging and spectroscopic observations of astronomical targets. NICMOS detects light with wavelengths between 800 to 2500 nanometres.

Support systems
Containing essential support systems such as computers, batteries, gyroscopes, reaction wheels and electronics.

ACS
ACS is a so-called third generation Hubble instrument. Its wide field of view is nearly twice that of Hubble's previous workhorse camera, WFPC2. The name, Advanced Camera for Surveys, comes from its particular ability to map relatively large areas of the sky in great detail.

WFPC2
WFPC2 was Hubble's workhorse camera until the installation of ACS. It records excellent quality images through a selection of 48 colour filters covering a spectral range from far-ultraviolet to visible and near-infrared wavelengths. WFPC2 has produced most of the stunning pictures that have been released as public outreach images over the years.

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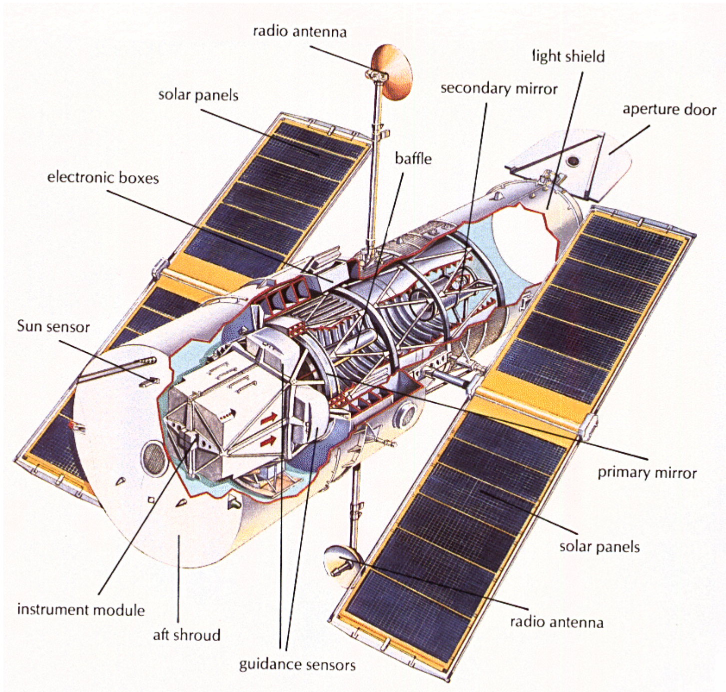


‘3rd generation’ instrument: 2002

- Faint object camera → ACS

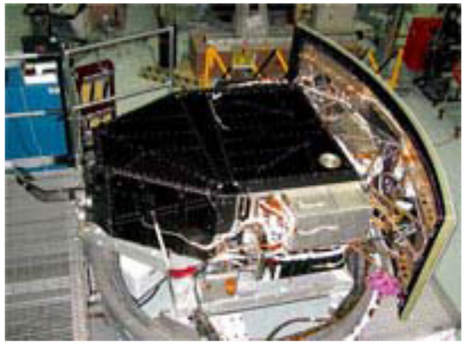
‘4th generation’ instruments: 2009?

- WFPC2 → WFC3
- COSTAR → COS

HST SM-4: 2009?

Hubble's Instruments: WFC3 - Wide Field Camera 3

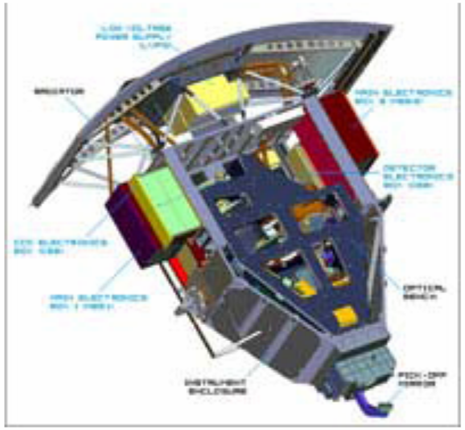
The installation of the new Wide Field Camera 3 (WFC3) during Servicing Mission 4 will foster the pioneering tradition of previous Hubble cameras while incorporating critical improvements, clearing the way for a new voyage of discovery. Together with the new Cosmic Origins Spectrograph (COS), WFC3 will lead the way to many more exciting scientific discoveries.



WFC3 Undergoing Test
Credit: NASA/GSFC

Overview

WFC3 will greatly enhance the observational capabilities of Hubble. Compared to its predecessor, it offers improved resolution over a wider field of view. In terms of overall performance, it will offer comparable performance to the ACS instrument, but over a wider range of wavelengths. The combination of these two elements – enhanced field of view and broader waveband – makes for a powerful instrument.



Schematic of WFC3
Credit: NASA/GSFC

Technology

The instrument has two channels one for ultraviolet and visible light (UVIS) and the other for near infrared (NIR). In both cases, the detectors are the solid-state devices. For the UVIS channel a silicon based CCD, similar to those found in digital cameras, is used. The similarities end there, however, as the CCD on WFC3 is a 16 megapixel, high sensitivity, low noise array. These high performance chips are made by e2V, a Uk based company, who specialise in the fabrication of large, high-performance, detector arrays for use in space. For the NIR channel, a 1 megapixel array made from the exotic material of mercuric cadmium telluride (HgCdTe) is used. The combination of these two technologies gives WFC3 its performance over an broad range of wavelengths. The table below reveals some of the key parameters for the instrument.

HST SM-4: 2009?

Parameter	UVIS Channel	NIR Channel
Spectral range (nm)	200-1000	850-1700
Detector type	Si	HgCdTe
Detector array size (pixels)	4096 x 4096	1024 x 1024
Field of view (arcseconds)	160 x 160	123 x 137
Pixel size (arcsec)	0.04	0.13
Filter complement	62	15

Science Goals

Observations in the ultraviolet and visible range will aim to address:

1. Stellar Archaeology
2. The distribution of galaxies at high redshift

Observations in the infrared range will aim to address:

1. The highest redshift galaxies
2. Water and ice on Mars and planetary moons

Panchromatic

1. Galactic Evolution
2. Star Birth, Death and Interstellar Medium

HST SM-4: 2009?

Hubble's Instruments: COS - Cosmic Origins Spectrograph

COS being prepared at the Ball Aerospace labs.
Credit: Ball Aerospace

After its installation during Servicing Mission 4, the Cosmic Origins Spectrograph (COS) will restore spectroscopy to Hubble's scientific arsenal, while providing unique new capabilities that will take the telescope into exciting and uncharted waters. With the installation of COS and the Wide Field Camera 3, Hubble will become a space observatory outfitted with a full suite of ground-breaking scientific instruments for the first time in fifteen years. It should be quite a journey.

Overview

COS will study the large-scale structure of the Universe and the formation and evolution of galaxies, stars and planets. It will also help determine the formation of elements considered essential for life, such as carbon and iron. As a spectrograph, COS does not capture the kinds of images that have made Hubble famous. Rather it will perform spectroscopy, the science of breaking up light into its individual components. Any object that absorbs or emits light can be studied with a spectrograph to determine its temperature, density, chemical composition and velocity.

Technology

COS has two channels, the Far Ultraviolet (FUV) channel covering wavelengths from 115 to 177 nanometres and the Near Ultraviolet (NUV) channel covering wavelengths from 175 to 300 nanometres. The light-sensing detectors of both channels use micro-channel plates to amplify the incoming signal prior to detection. A key feature of COS is it maximised efficiency or throughput. Every bounce of a light beam along its path leads to a loss in signal strength. COS has a single bounce when the beam is fed into the appropriate channel. The table below reveals some of the key parameters for the instrument.

HST SM-4: 2009?

Parameter	FUV Channel	NUV Channel
Spectral range (nm)	115-205	170-320
Spectral Resolution	16000-24000 med. 2000-3000 low	16000-24000 med. 2000-3000 low
Detector Type	X-delay line	NUV MAMA
Detector array size (pixels)	32768 x 1024	1024 x 1024
Gratings	3	4
Discovery factor over previous HST instruments	30x over STIS	2x over STIS

Science Goals

The aims of the instrument are organized into three broad categories, united by the theme of cosmic origins:

1. Origin of large-scale structure and the Intergalactic Medium (IGM)
2. Formation, evolution, and ages of galaxies
3. Origins of stellar and planetary systems

Development

COS was built at the Center for Astrophysics and Space Astronomy at the University of Colorado; the team is led by James Green. The prime contractor for the design and manufacture of COS was Ball Aerospace & Technologies Corporation in Boulder, CO. Development of the FUV detector was at the University of California-Berkeley.