Hubble Facts

National
Aeronautics and
Space
Administration

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The Hubble Space Telescope Second Servicing Mission (SM-2)

SCIENCE OBJECTIVES:
SEEING THE HEAVENS THROUGH DIFFERENT WINDOWS USING TECHNOLOGICALLY ADVANCED INSTRUMENTS

Flying high above Earth's atmosphere, the Hubble Space Telescope offers astronomers an unobstructed view of the heavens. When astronauts install two state-of-the-art science instruments during the next servicing mission in 1997, that view will be grander for scientists interested in studying the world through a more versatile and technologically advanced set of eyeglasses.

The instruments—the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) and the Space Telescope Imaging Spectrograph (STIS)—feature technology that wasn't available when scientists designed and built the original Hubble instruments in the late 1970s. They will replace the Goddard High Resolution Spectrograph (GHRS) and the Faint Object Spectrograph (FOS).

With the new instruments, astronomers will be able to image and take spectroscopic measurements of objects that emit near infrared and ultraviolet (UV) radiation, expanding the telescope's ability to see different forms of light.

Why the Need for Expanded Views

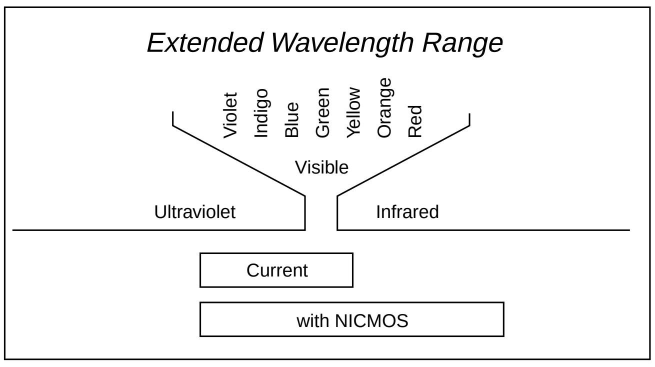
The ability to detect different colors of light is important. Ultraviolet and visible or optical light—which current Hubble instruments primarily see—are types of electromagnetic radiation which occupy a narrow band of a very wide spectrum. Equipped with instruments that discern other wavelengths, the telescope will give astronomers distinctly different windows into the cosmos.

Consequently, astronomers worldwide will get a more complete picture of supermassive black holes, brown dwarfs, star-forming regions, flare stars, ancient clusters of galaxies so far back in space and time that they appear as they did when the universe was very young, and possibly planetary systems around newly formed stars—all in an effort to better understand the origin, nature and evolution of our universe.

This understanding will be made possible by the different types of science astronomers will perform—spectroscopy and imaging.

Spectroscopy

A picture is worth a thousand words, but the light that formed the picture also has its own story to tell. Spectroscopy—a technique that separates light or radiation into its component colors or wavelengths—allows scientists to interpret the story.



Anyone can separate light by passing it through a slit and then through a glass prism; which creates a rainbow effect. The same principle is at work when a rainbow appears in the sky, revealing the component colors of sunlight spread out by water droplets in a cloud.

If a gas or some other component that strongly absorbs light is placed in front of the light path, the rainbow pattern is interrupted by a set of dark lines characteristic of the gas.

Also, tenuous hot clouds of gas in space emit distinctive patterns of bright lines. In both cases, these bright or dark spectral lines are like signatures or fingerprints: They reveal the chemical identity of the source creating the tell-tale lines.

To perform spectroscopy, scientists build scientific instruments called spectrographs or spectrometers, which spread out the light gathered by a telescope so that scientists can study the resulting spectral lines. Both STIS and NICMOS will do just that.

STIS

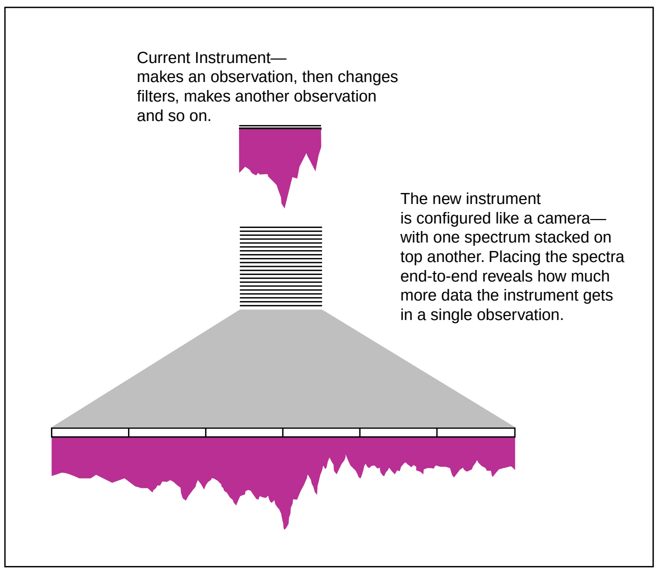
STIS separates ultraviolet and optical light into its component colors, thereby giving scientists critical diagnostic information about an object's composition, temperature, motion and other chemical and physical properties. It will perform the work now done by GHRS and FOS, but more efficiently and with better sensitivity. In addition, STIS can image objects in space.

The instrument, developed by a team led by Dr. Bruce Woodgate at the Goddard Space Flight Center's Laboratory for Astronomy and Solar Physics, employs two-dimensional detectors instead of one-dimensional detectors used on existing Hubble spectrographs. To understand the advantages of the newer two-dimensional technology, consider a camera. When you take a photograph, the resulting snapshot shows both vertical and horizontal dimensions. In other words you get a complete picture of the object you photographed. If cameras only took one-dimensional views, your photographs would be dramatically incomplete. You would see only one strip of the object you photographed. To get a complete picture you would have to take multiple exposures, each with the camera pointing in a slightly different direction - a very inefficient process. If your camera could only photograph one small point of the scene at a time, you would have to fill in both vertical and horizontal dimensions by repointing the camera and taking many exposures.

Astronomers have similar problems in using the current Hubble spectrographs. Their light sensors consist of 500 individual "photocells" arranged in a straight line. The colors of the spectrum are spread out over this one dimension. At any one time, the spectrographs can only measure a small segment of the spectrum of a single point in the sky - a single star or a small portion of a planet or a galaxy. To build up a complete spectrum of a star, the internal optics of the spectrograph have to be repointed and multiple exposures taken. To measure the spectra of many points across the center of a galaxy, for example, the entire HST has to be repointed many times and multiple long exposures taken - a very inefficient process.

With the STIS's two-dimensional light sensors, astronomers will be able, at any one time, to measure a segment of the spectrum of a star which is about 30 times wider than with the present spectrographs - eliminating the need for 30 separate exposures. When studying the chemical composition and physical conditions in a star, astronomers take a spectrum and then identify and measure various dark absorption lines or bright emission lines in the spectrum. With the much wider piece of the spectrum obtained with STIS, they will be able to detect many more spectral lines in a single observation.

Also, the STIS can, at one moment, measure up to 500 separate points in space, along a slit placed across an extended object such as a planet or a galaxy, eliminating the need to repoint the HST 500 separate times and to make 500 separate measurements. This



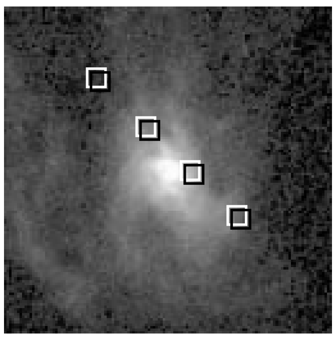
will allow astronomers to measure very efficiently how rapidly stars and gas are moving around the center of a galaxy, making STIS the world's most powerful black-hole hunter.

STIS affords astronomers the opportunity to gather more data in less time. It will enable many new scientific discoveries that were hopeless to pursue because the process was so time consuming.

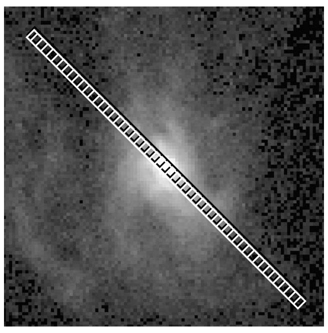
Supermassive Black Holes and Other Space Exotica

Some of the greatest advantages to using STIS are in the study of supermassive black holes, cosmology, solar flares and the distribution of matter in the universe.

- **Massive Black Holes**. These exotic objects are so massive, and their gravitational forces so strong, that nothing—not even light—can escape. To verify whether an object truly classifies as a massive black hole, astronomers need to determine how quickly stars and other debris orbit around the center of these objects. These measurements, which need to be taken at 10 different adjacent locations within a relatively small area, help determine how much mass is concentrated in the center. If there is more mass than can be accounted for by stars alone, the mass must be locked away in something very compact—a black hole. Given STIS's dramatically enhanced data-gathering capabilities, scientists will be able not only to locate supermassive black holes, but begin to discern differences in their characteristics.



Black hole detection took multiple observations with current instrument.



New instrument can sample the area suspected of harboring a black hole in a single observation

- **Stellar Flares**. Flares are powerful explosions on the surfaces of many stars. When our own Sun flares, the episodes frequently disrupt communications, create power line surges and threaten space travelers. Astronomers don't understand the physics behind such violent eruptions, but by studying the events on other stars, they will begin to unlock some of their physical secrets.

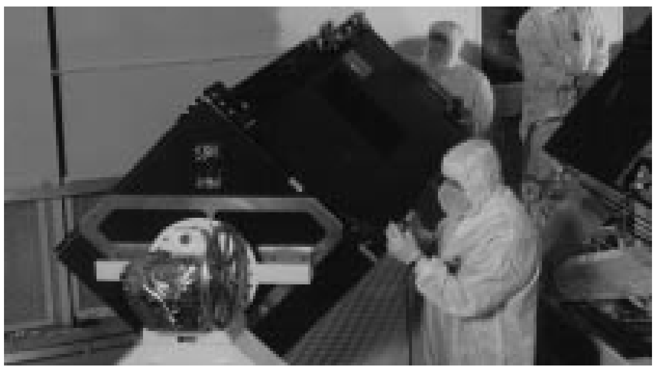
- **Evolution of the universe.** By taking spectral measurements of deuterium (heavy hydrogen) and ordinary hydrogen in intergalactic clouds of gas, astronomers will be able to determine how the ratio of abundances of deuterium to ordinary hydrogen has changed from the time of the big bang to the present. This information indicates how much mass the universe contains. Knowing the mass of the universe will help astronomers determine whether the universe will continue to expand forever or will ultimately stop expanding and begin to collapse.

- **Distribution of Matter.** Emitting the energy of more than a trillion Suns, quasars can be used to probe the universe. As their light streams toward Earth, the radiation encounters intergalactic clouds and other matter. These encounters show up in the spectral lines, giving astronomers an idea of what exists in the vast expense of space separating us from the very distant quasar.

NICMOS and the Infrared

NICMOS, developed by University of Arizona Professor Rodger Thompson and a 16-member science team, will see the universe at near infrared wavelengths more sensitively and in sharper detail than any other existing or planned telescope. It, too, takes "photographs" and spectroscopic measurements.

Infrared light, which falls between visible and radio waves on the electromagnetic spectrum, isn't absorbed like visual light by the clouds of dust found abundantly in the universe. Although infrared radiation can



be seen from ground-based telescopes, Hubble's position high above Earth's atmosphere gives astronomers superior image quality.

Another major advantage for Hubble is the fact that Earth's atmosphere emits infrared radiation, creating a glow that interferes with ground-based observations of sources emitting in this wavelength band. The new instrument overcomes that challenge.

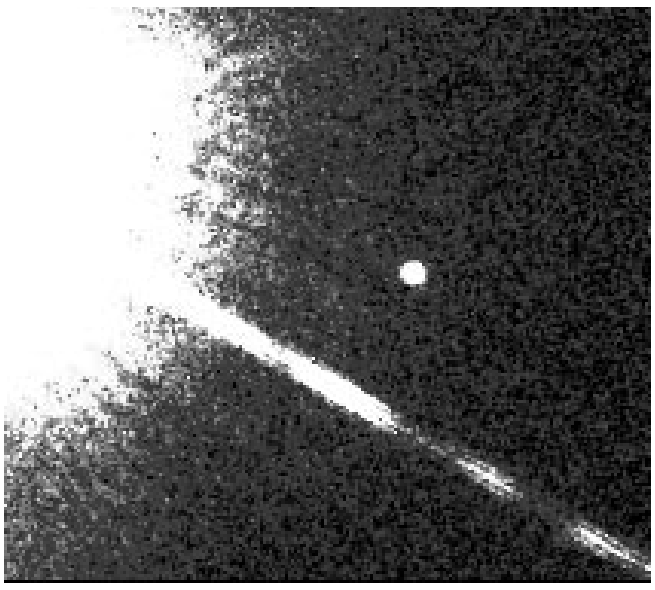
The instrument is a system of three cameras. To make sure the instrument doesn't emit its own infrared heat, which would interfere with observations, engineers have designed it so that it operates at very cold temperatures—58 degrees Kelvin or 355 degrees below zero Fahrenheit. To stay cool, the detectors are housed inside a cryogenic dewar containing frozen nitrogen ice. This container will keep the detectors cool for up to five years, much longer than any previous space experiment.

The detectors, which operate independently yet simultaneously but with different fields of view, perform a thousand times better than previous detectors. With this expanded view into the infrared, coupled with the instrument's vastly improved detectors, astronomers will be able to address how galaxies, stars and planetary systems form. A sampling of the questions it will tackle include:

- **How do stars form**? With its infrared eyes, the instrument will be able to see through the dust clouds that enshroud newly forming stars. The images will reveal the structure and form of the disks around these stars and the spectra will tell about the gas temperatures, velocities and magnetic fields that control the star-forming dynamics.

- **How many stars have planetary systems?** Perhaps one of the most intriguing questions in astronomy today, the telescope will be able to detect and image the dust particles around stars that give birth to planetary systems, such as our own solar system. Hubble images of the Orion Nebula have given astronomers tantalizing clues, but the enhanced capabilities will provide even more information.

- **What are brown dwarfs?** Although astronomers have gazed at the heavens for centuries, only recently have they detected an example of a brown dwarf. Falling somewhere between a star and a planet, a brown dwarf probably began its life as a newly forming star, but for some reason, it didn't collect enough mass to ignite the internal nuclear reaction needed to power it as a star. NICMOS, with its sensitivity to infrared light, will be able to search the heavens for brown dwarfs and explore that gap between stars and actual planets.



Brown Dwarf Gliese 229B

- **How do galaxies form and evolve?** Objects at the very horizon of the observable universe, which formed shortly after the Big Bang, sometimes can't be seen in visible light because the light they emit loses some of its energy as it travels across space. This phenomenon is called a red shift. By training NICMOS on these very distant objects, scientists will be able to learn more about how galaxies formed during the early universe and answer questions about the shape, size and structure of the universe.

- **What powers active galaxies and quasars?** These objects emit more energy than a trillion Suns. Since their discovery, scientists have grappled with the question of what powers them. With NICMOS, astronomers will be able to study the galactic centers, seeing through the dust and gas that resides at these centers to get a better look.

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