Hubble Space Telescope Servicing Mission 4 Cosmic Origins Spectrograph

After its installation during SM4, the Cosmic Origins Spectrograph (COS) will restore spectroscopy to Hubble's scientific arsenal, and at the same time provide unique new capabilities that will take the telescope into exciting, uncharted waters. With the other new Hubble instrument—the Wide Field Camera 3 (WFC3)—COS will lead the way on an 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 how galaxies, stars and planets formed and evolved, and it will help determine how elements needed for life such as carbon and iron first formed.

As a spectrograph, COS won't 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.

A primary science objective for COS is to measure the structure and composition of the ordinary matter that is concentrated in what scientists call the "cosmic web"—long, narrow filaments of galaxies and intergalactic gas separated by huge voids. COS will use scores of faint distant quasars as "cosmic flashlights," whose beams of light have passed through the cosmic web. Absorption of this light by material in the web will reveal

the characteristic spectral fingerprints of that material. This will allow Hubble observers to deduce its composition and its specific location in space. Observations like this, covering vast distances across space and back in time, will illuminate both the large-scale structure of the universe and the progressive changes in chemical composition of matter, as the universe has grown older.

The Instrument

COS has two channels, the Far Ultraviolet (FUV) channel covering wavelengths from 115 to 177 nm, and the Near Ultraviolet (NUV) channel, covering 175-300 nm. Ultraviolet light, the type of radiation that causes sunburn, is more energetic than visible, optical light; and "near" UV refers to the part of the UV spectrum closer to the visible, just beyond the color violet.

The light-sensing detectors of both channels are designed around micro-channel plates. These are thin plates comprising thousands of tiny curved glass tubes, all aligned in the same direction. Simply described, incoming photons of light ultimately induce showers of electrons to be emitted from the walls of these tubes. The electron showers are accelerated, captured, and counted in electronic circuitry immediately behind the micro-channel plates.

A key feature of COS—the one which makes it unique among Hubble spectrographs—is its maximized efficiency, or "throughput." Each bounce of a light beam off an optical surface within an instrument takes some of the light away from the beam, reducing the throughput. This is a problem that is especially acute in the UV, and the COS FUV channel was designed specifically to minimize the number of light bounces. The incoming FUV beam makes one bounce off a selectable light-dispersing grating, and goes directly to the detector. An additional advantage within COS is the very low level of scattered light produced by its light-dispersing gratings.

The COS and the Space Telescope Imaging Spectrograph (STIS), currently aboard Hubble, are highly complementary in their capabilities. The STIS, installed in 1997 during Servicing Mission 2, is a highly versatile, "all purpose" spectrograph. It suffered an electronics failure in 2004 and is scheduled for a repair attempt during SM4. By design, the COS does not duplicate all of STIS's capabilities, but by having more than 30 times the sensitivity of STIS for FUV observations of faint objects such as distant quasars, COS will enable key scientific programs which would not be possible with STIS. If STIS repair is successful, the two spectrographs working together will provide a full set of spectroscopic tools for astrophysical research.

COS will be installed in the instrument bay currently occupied by "COSTAR," the set of corrector mirrors on deployable arms that provided corrected light beams to the first generation of Hubble instruments. COSTAR is no longer used on the telescope.

Mission Science Goals

The Origin of Large-Scale Structure — This goal employs the COS' superior throughput to obtain absorption line spectra from the faint light of distant quasars as it passes through the nebulous intergalactic medium. The spectra will reveal the structure that is filtering the quasar light, and this will enable scientists to understand the hierarchal structure of the universe at its largest scales. Theories predict (and observations support) the notion of a cosmic web of structure.

The COS will help determine the structure and composition of the ordinary baryonic matter that is concentrated in the cosmic web. Baryonic matter is made up of protons and neutrons, like the atoms in our body. The distribution of baryonic matter over cosmic time can best be detected, ironically, not by how much it glows (in stars and galaxies) but by how much light it blocks.

The Formation, Evolution and Ages of Galaxies — This goal will also utilize quasar sightline observations. The light serves as a probe of galactic haloes it passes through, sampling their contents. By sampling galaxies near and far, scientists will constrain galaxy evolution models and measure the production of heavy elements over cosmic time.

The Origin of Stellar and Planetary Systems — As an ultraviolet-detecting instrument, the COS can detect young, hot stars (hotter than our sun) embedded in the thick dust clouds that gave rise to their birth, clarifying the phenomenon of star formation. The COS will also be used to study the atmospheres of the outer planets in our solar system.

COS characteristic	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 (pixels)	32768 x 1024	1024 x 1024
Pixel size (microns)	6 x 24	25 x 25
Gratings	3	4
Enhancement factor over previous spectrograph	Detection of objects more than 30x fainter than with STIS	Detection of objects more than 2x fainter than with STIS

The COS Team. The 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.

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Hubble Facts
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