National Aeronautics and Space Administration

NASA facts

Hubble Space Telescope Servicing Mission 4 Cosmic Origins Spectrograph

Installing the Cosmic Origins Spectrograph (COS) during SM4 will effectively restore spectroscopy to Hubble's scientific arsenal, and at the same time provide the telescope with unique capabilities. Together with the other new Hubble instrument—the Wide Field Camera 3 (WFC3)—COS will journey toward more ground-breaking scientific discoveries.

Instrument Overview

COS is designed to study the large-scale structure of the universe and how galaxies, stars and planets formed and evolved. It will help determine how elements needed for life such as carbon and iron first formed and how their abundances have increased over the lifetime of the universe.

As a spectrograph, COS won't capture the majestic visual images that Hubble is known for, but 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. The cosmic web is shaped by the gravity of the mysterious, underlying cold dark matter, while ordinary matter serves as a luminous tracery of the filaments. 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 thin micro-channel 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.

If astronauts are able to complete the on-orbit repair of the Space Telescope Imaging Spectrograph (STIS) aboard Hubble, it will highly complement the COS. The "all purpose" STIS, installed in 1997 during Servicing Mission 2, suffered an electronics failure in 2004 and is currently in safe hold. By design, the COS does not duplicate all of STIS's capabilities. Possessing 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 using STIS. On the other hand, COS is best suited to observing point sources of light such as stars and quasars, while STIS has the unique ability to observe the spectrum of light across spatially extended objects such as galaxies and nebulae. Should STIS be repaired, the two spectrographs working in tandem will provide astronomers with 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 after SM1 in 1993. Astronauts will store the no longer needed COSTAR instrument aboard the shuttle for its return to Earth.

Mission Science Goals

<u>*The Origin of Large-Scale Structure*</u> — This goal uses 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.

<u>*The Formation, Evolution and Ages of Galaxies*</u> — This goal will also use 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.

<u>*The Origin of Stellar and Planetary Systems*</u> — 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	cross-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

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