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STIS Overview; Capabilities and Basic Operations

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Abstract. This paper summarizes the basic capabilities of STIS and describes its successful early on-orbit operation for Cycle 7.

1. An Overview of STIS

STIS, the Space Telescope Imaging Spectrograph, was built by Ball Aerospace Corporation under the direction of Bruce Woodgate (GSFC), the Principal Investigator for STIS. A description of the instrument and its early on-obit performance through the Servicing Mission Orbital Verification (SMOV) period is provided by Kimble et al. (1997) and a more detailed description of the instrument and its science operation is available in the STIS Instrument Handbook and the updates to it (contact help@stsci.edu or see the STScI Web pages).

STIS is an extremely diverse instrument which can be used both for spectroscopy and imaging and which operates from the near-infrared through the ultraviolet. In order to accomplish this range of science STIS has the following components.

- A slit wheel which holds the apertures for spectroscopy and filters for imaging
- A grating wheel (called the Mode Select Mechanism, or MSM) which holds and tilts the first order gratings, the cross dispersers for use with the echelles, and the mirrors for imaging. Only specific central wavelength settings can be achieved as continuous tilt selection is not available.
- Three detectors; a CCD for use in the NIR/Optical and two MAMAs, one for use in the Near-UV to roughly 1650 Å and one for use in the Far-UV to roughly 1150 Å.
- Two calibration lamp systems - including line lamps and flat field lamps.
- A smart CPU which enables the flight software to perform onboard target acquisitions (which take roughly 5 min) that are needed for all slitted spectroscopy and coronography and peakups (which take 5-10 min) that are needed only for observations in the smallest slits (<= 0.1 arcsecond).

2. Typical Operations for STIS Spectroscopy

A typical STIS spectroscopic sequence will consist of the following:

- A target acquisition, followed by a peakup if one is observing in the smallest slits (those which are less than or equal to 0.1 arseconds) to center the target in slit. The target acquisition is performed immediately following the Guide Star Acquisition at the start of visit. Acquisitions and peakups have been shown to be quite robust and accurate for STIS (see Kraemer and Downes, this volume).
- A series of science exposures at a given grating setting or a series of grating settings.

- Automatic wavecals inserted by the ground system at 40-60 minute intervals which return zeropoint accuracies of 0.1 to 0.2 pixels or better, for most settings, to account for both the Mode Select Mechanism irrepeatability and the thermal drifts.

- For MAMA observations, only a total of 5 orbits are permitted per visit, since we have been forced to allow operation of the MAMA high voltage only in the SAA-free orbits of each day, in order to avoid upsets of the MAMA Control Electronics due to charged particles triggering the opto-isolators in the circuitry.

- For visits longer than 4 orbits, taken in a small slit, observers may wish to take a second peakup after 4 orbits, to assure that FGS drift does not cause the target to drift off center in the slit

3. Parallel Observations

STIS can be used in parallel with other instruments. The STIS MAMAs can be used only in coordinated and not in pure parallels to assure that bright object screening can be done of the observing fields. The early worries over 50CCD (clear) imaging and the impact of UV bright sources on persistence have been shown to be unfounded and today 50CCD is used regularly in the pure parallels program (see Gardner et al., this volume). STIS detectors do not operate in parallel with each other (as they share one optical path) but observations interleaving STIS detectors have no extra overhead.

4. STIS Detector Overview

STIS has three large format (1024 x 1024 pixels) detectors. The STIS/CCD (SITE) is used from the NUV through NIR with a spectral range from 2000-11000 Å, a 51x51 arcsecond field of view, 0.05 arsecond pixels, low read noise (4 electrons at a GAIN=1), low dark current (0.002 electrons/sec), good dynamic range (up to 140,000 electrons at GAIN=4), and high QE. The overhead between identical exposures is roughly 60 sec for full frame, and 20 seconds using subarrays. The performance at wavelengths longward of about 8000 Å is affected by fringing and by an extended halo on the PSF (see Kimble this volume). Small dust motes visible on flats cover a very small fraction of the detector, but can have opacities of 20%. The general performance of the STIS CCD has been excellent to date (see Kimble this volume). The CCD has shown excellent repeatability during early standard star spectroscopic sensitivity monitoring with repeatability to better than 1% (and see also Ferguson, this volume for photometric results in CCD imaging mode).

The STIS MAMA (Multi-Anode Microchannel Array) detectors are used in the UV. They are photon counting detectors and have both an accumulate mode which is the typical mode of observation and a time-tag mode. In the time-tag mode each photon is time-tagged to 125 microsec. The MAMA detectors are subject to damage at high local (per pixel) and global (over the detector) count rates, therefore we have had to set brightness limits for targets to preserve the safety of the detector. While the MAMAs have 1024x1024 pixels, it is possible to use the MAMAs in the so-called ‘highres’ mode; this allows subsampling of the 1024x1024 pixels, using 3 electrodes per pixel to centroid the incident charge to roughly half-pixel accuracy, thereby producing 2048x2048 array images. This provides a 10-30% increase in resolution for unresolved features at the price of decreased signal-to-noise per pixel due to increased fixed pattern noise from the statistics of charge partition between the electrodes. All data with STIS is taken, by default, in highres mode and the raw data archived as such. However, the calibration pipeline bins the data back to nominal pixel size, so the calibrated data have the native pixel format and are 1024X1024 pixels in size.

The STIS/NUV-MAMA operates in the NUV from roughly 1650-3100 Å, covers a 25x25 arcsecond FOV, has 0.024 arcsecond pixels, no read noise, reasonably low dark current ($6x10^{-4}$ counts/pix/sec) and is solar insensitive (with a Cs_2Te photocathode).

The STIS/FUV-MAMA operates in the UV from 1150-1700 Å, also covers a 25x25 arcsecond FOV, has 0.024 arcsecond pixels, no read noise, extremely low dark current ($7x10^{-6}$ counts/pix/sec), and is solar blind (CsI photocathode).

5. What Science Does the Space Telescope Imaging Spectrograph Do?

STIS can be used to perform the following basic science.

- First Order Spectroscopy from 1150 - 11000 Å with a long slit which is 51 arcsecond long in the optical and 25 arcsecond long in the UV. The first order modes include the Low resolution ‘L’ Gratings which have a resolving power, R, of roughly 500 - 1400 (where R is defined as wavelength divided by a spectral resolution element in Å, where a resolution element is nominally taken as two detector pixels) providing roughly 500 km/sec resolution and the Medium resolution ‘M’ Gratings which have a resolving power of roughly $5000 - 17000$, corresponding to 50 km/sec resolution. Slits of varying widths (52x0.1, 52x0.2, 52x0.5, 52x2, slitless) are supported for observations in first order modes.

- Echelle Spectroscopy from 1150 - 3100 Å, optimized for point source observations using small apertures to separate orders (<= 0.2x0.2 arcseconds). The Medium Resolution Echelles (E230M, E140M) have nominal resolving powers of roughly $30,000 - 45,000$ providing roughly 10 km/sec resolution and the High Resolution Echelles (E230H, E140H) have nominal resolving powers of roughly 110,000, providing roughly 2.5 km/sec resolution.

- Objective Prism spectroscopy in the UV from 1200-3100 Å either slitless or with a long slit, providing resolving powers from 1000 at the short wavelength end to 26 at the long wavelengths.

- Imaging with the CCD, NUV-MAMA, and FUV-MAMA. There is a limited filter set. In the optical, the low readnoise, low dark current, high CCD QE, and in particular the wide band pass of the clear CCD imaging mode means STIS can get deeper faster than WFPC2, particularly when color information is not needed. In the UV, the FUV-MAMA is solar blind and much more sensitive (factor of >10) than WFPC2 with the Woods filters, opening up new science opportunities there as well.

- High Time Resolution in the UV Time-Tag mode where resolutions of 125 microseconds can be achieved in any of the spectral or imaging modes.

- Coronagraphy, either coronagraphic imaging in the optical and near IR or bar-occulted spectroscopy over the entire spectral range (1150-11000 Å) using the 52x0.2 slit with a 0.5 arcsecond bar.

The principal gains of STIS relative to FOS and GHRS are the spatial coverage provided by long slit spectroscopy and the greatly increased wavelength coverage at high spectral (echelle) resolutions enabled by the full two dimensionality of the detectors. Additionally, STIS provides greatly decreased background for point sources in UV due to the fine plate scale, appreciably higher throughput in the optical/IR due to the use of the CCD, ease and relative time-efficiency of the target acquisitions and peakups due to the smart CPU, and high time resolution spectroscopy and imaging due to the time-tag mode.

6. Outstanding Technical Considerations as of Launch and Status

There were a number of outstanding technical considerations as of launch, all of which have been favorably resolved. These are described below.

- Concern existed about the ability to get signal to noise greater than 30 per resolution element in the Near-IR, longward of roughly 8000 Å where fringing and the long wavelength PSF halo set it. It has now been shown that relatively high signal to noise (100 to 1 for point or fully diffuse sources) can be achieved by the taking of contemporaneous flats which can be used to rectify the data in post-observation data processing (see Goudfrooij and Plait, this volume). However, issues do still remain, particularly the long wavelength halo which in conjunction with the fringing, and for complicated source structures, can still make it difficult to remove the fringes (see also Kimble, this volume).
- Concern existed about the ability to get high signal-to-noise observations with the MAMA detectors. This area is still under work as well, but the signs are extremely encouraging with signal-to-noise greater than 150 per resolution element over a point source extraction box having been achieved on sensitivity calibration stars (see Kaiser, this volume) and early results from the test of the FPSPLIT slits showing the ability to achieve signal-to-noise considerable higher than even this (look for ISRs on the WWW in the future). The quoted signal-to-noises refer to the ability to detect faint lines on a continuum; the fidelity of line shapes will depend critically on other factors as well, such as background subtraction and scattered light.
- At launch there remained a flight software problem which prevented taking of data using onboard Doppler correction for the MAMA echelle modes. This was corrected by the GSFC FSW Group (who took over responsibility for the STIS FSW at launch), and uploaded to STIS in early August, along with the target acquisition fixes (see below) and successfully tested on orbit immediately thereafter.

The principal 'discrepancies' uncovered on orbit include the opto-isolator resets which affect the operation of the MAMAs, the rate of hot pixel growth on the CCDs, and the elevated NUV-MAMA dark rate (see Kimble, this volume for details on these three). During the commissioning of target acquisitions it became clear that the FSW could be further optimized to make the acquisitions and peakups more robust and accurate; those FSW fixes were implemented and uplinked in August and demonstrated to work most effectively (see Kraemer and Downes, this volume). Lastly, there exist mostly small, but some important, differences in predicted versus realized sensitivities (see Bowers, this volume).

7. STIS Science Examples

The scientific use of STIS science is just starting to pick up for Cycle 7 as of the writing of this contribution. However, excellent STIS science examples exist in the archive and are publically available. They come from the EROs, SMOV and Cycle 7 Calibration Activities, and some early planetary GO science. The full range of STIS science capabilities have now been demonstrated: including the echelles, which have been used for interstellar medium absorption studies and stellar absorption studies, the long slit and slitless first order optical and UV capability - which have been used on black hole studies in a nearby galaxies (see this volume Bowers), emission line regions around active galactic nuclei, SN1987A, comets, and for the pure parallels observations (see Gardner, this volume). Coronagraphic imaging and spectroscopy has been used to observe Beta Pic and a putative brown dwarf, respectively. The remarkable depth of CCD clear imaging (achieving a depth within a magnitude of the deepest single filter observations of the Hubble Deep Field in only two orbits!), has been demonstrated through observations of a Gamma Ray Burster (see Fruchter, STScI newsletter, July 1997) and high time resolution timetag observations have been taken of the Crab (see Lindler et al., this volume). Many of these data are now public, and others will become public shortly. The EROs and early science results will be featured in a special, January, issue of the ApJ Letters.

Remember all SMOV data, all Cycle 7 Calibration data (some data good for science there!), all of the archival pure parallel data (slitless G750L, 50CCD and longpass filter imaging) as well as the ERO data is public.

8. Summary

SMOV is complete, finishing off a successful collaborative effort to commission STIS by STScI and the STIS IDT. All Cycle 7 science is now fully commissioned - and STIS is off and running. The on-orbit performance of STIS has generally been exceptional - very close to ground predictions; while a few things are not as good as predicted, the bulk are right on and others substantially better. For future updates to the STIS on-orbit performance we refer you to the STIS Instrument Page off the Observing with HST Page of STScI. With STIS GOs and GTOs using the broad range of STIS capabilities and STIS performing as well as it is, we look forward eagerly to an exciting cycle full of new astronomical discoveries.

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References

Baum S. et al., 1996, *STIS Instrument Handbook*, (Baltimore:STScI)

Kimble R. et al., 1997, ApJ Letters, in press