PART IV:

STIS

- STIS

Chapter 19

STIS Overview

In This Chapter...

This chapter provides an overview of the capabilities and design of STIS and describes the basic instrument operations. The material presented here is excerpted from the more complete information provided in the *STIS Instrument Handbook*, and we refer you there for more complete information about the properties of STIS as an instrument.

19.1 Instrument Capabilities and Design

The Space Telescope Imaging Spectrograph (STIS) was built by Ball Aerospace Corporation for the Goddard Space Flight Center (GSFC) Laboratory for Astronomy and Solar Physics, under the direction of Bruce Woodgate (GSFC), the Principal Investigator (PI). STIS has been performing very well since its installation during the second HST servicing mission in February 1997. A basic description of the instrument, and of its on-orbit performance through the Servicing Mission Orbital Verification (SMOV) program is provided by Kimble, et al. (1997, *ApJL*, in press). We encourage all STIS users to reference this paper, and to review the related papers in this special *ApJ Letters* which describe the Early Release Observations, and demonstrate the realized scientific capabilities of STIS. Long-slit and slitless image spectroscopy of galactic nuclei and SN1987A are described in Bower et al. (1997), Hutchings et al. (1997), and Sonneborn et al. (1997); medium- and high-resolution UV echelle spectroscopy of stars and the interstellar medium are described by Heap et al. (1997), Jenkins et al. (1997), and Walborn et al. (1997); Schultz et al. (1997) describe visible and near-IR spectroscopy of a brown dwarf near a much brighter companion; Pian et al. (1997) and Sahu et al. (1997) describe deep CCD imaging of a Gamma Ray Burst transient and of gravitational lens arclets, respectively; and Gardner et al. (1997)

describes the serendipitous detection of a high-redshift galaxy in a parallel observation.

STIS is a versatile instrument providing both imaging and spectroscopic capabilities with three two-dimensional detectors operating from the ultraviolet to the near-infrared. The optics and detectors have been designed to exploit HST's high spatial resolution. STIS has first order gratings, designed for spatially resolved long-slit spectroscopy over STIS's entire spectral range, and echelle gratings, available only in the ultraviolet, that maximize the wavelength range covered in a single spectral observation of a point source. The STIS Flight Software supports on-board target acquisitions and peakups to place science targets on slits and coronagraphic bars.

STIS can be used to obtain:

- Spatially resolved, long-slit or slitless spectroscopy from 1150–11,000 Å at low to medium spectral resolution (R ~ 400–14000) in first order.
- Echelle spectroscopy at medium to high spectral resolution (R ~ 23,500–100,000), covering a broad instantaneous spectral range ($\Delta\lambda$ ~800 or 250 Å, respectively) in the ultraviolet (1150–3100 Å).

In addition to these two prime capabilities, STIS also provides:

- A modest imaging capability using: the solar-blind far ultraviolet MAMA detector (1150–1700 Å); the solar-insensitive near ultraviolet MAMA detector (1700–3100 Å); and the optical CCD (2000–11,000 Å) through a small complement of narrow- and broad-band filters.
- Objective prism spectroscopy (R ~1000–26) in the vacuum ultraviolet (1200–3100 Å).
- High time resolution ($\Delta\tau$ = 125 microseconds) imaging and spectroscopy in the ultraviolet (1150–3100 Å) and moderate time resolution ($\Delta\tau$ ~10 seconds) CCD imaging and spectroscopy in the optical and near IR (2000–11,000 Å).
- Coronagraphic imaging in the optical and near IR (2000–11,000 Å) and bar-occulted spectroscopy over the entire spectral range (1150–11,000 Å).

See Table 19.1 on page 19-6 and Table 19.2 on page 19-7 for a complete list of grating and filters, respectively.

The STIS Detectors

STIS uses three large format (1024 x 1024 pixel) detectors:

- A Scientific Image Technologies (SITe) CCD, called the `STIS/CCD`, with 0.05 arcsecond square pixels, covering a nominal 51 x 51 arcsecond square field of view (FOV), operating from ~2000 to 11,000 Å.
- A Cs_2Te Multi-Anode Microchannel Array (MAMA) detector, called the `STIS/NUV-MAMA`, with 0.024 arcsecond square pixels, and a nominal 25 x 25 arcsecond square field of view (FOV), operating in the near ultraviolet from 1650 to 3100 Å.

- A solar blind CsI MAMA, the `STIS/FUV-MAMA`, with 0.024 arcsec pixels, and a nominal 25 x 25 arcsecond square FOV, operating in the ultraviolet from 1150–1700 Å.

The basic observational parameters of these detectors are summarized in Table 19.1 on page 19-6 and Table 19.2 on page 19-7.

The CCD provides high quantum efficiency and good dynamic range in the near-ultraviolet through near-infrared, and it produces a time integrated image in the so-called `ACCUM` data taking mode. As with all CCDs, there is noise (*read noise*) and time (*read time*) associated with reading out the detector. Time resolved work with this detector is done by taking a series of multiple short exposures. The minimum exposure time is 0.1 sec, and the minimum time between successive identical exposures is 37 seconds for full-frame readouts and 11 seconds for subarray readouts. CCD detectors are capable of high dynamic range observations, which are limited for a single exposure by the depth of the CCD full well, roughly ~120,000 to 170,000 e^{-} for the STIS CCD. This number is the maximum amount of charge (or counts) that can accumulate in any one pixel during any one exposure, without saturation. Cosmic rays affect all CCD exposures, and observers will generally want to CR-SPLIT their observations to allow cosmic ray removal in post-observation data processing.

The two MAMA detectors are *photon counting* detectors which provide a two-dimensional ultraviolet imaging capability. They can be operated either in `ACCUM` mode, to produce a time-integrated image, or in `TIMETAG` mode to produce an event stream with fast (125 µsec) time resolution. Doppler correction for the spacecraft motion is applied automatically on-board for data taken in `ACCUM` high spectral resolution modes.

The STIS MAMA detectors are subject to both *scientific* and *absolute* brightness limits. At high local (>50 count sec^{-1} $pixel^{-1}$) and global (>250,000 counts sec^{-1}) illumination rates, counting becomes nonlinear in a way that is not correctable. At only slightly higher illumination rates, the MAMA detectors are subject to damage.

STIS Physical Configuration

The STIS optical design includes corrective optics to compensate for HST's spherical aberration, a focal plane slit wheel assembly, collimating optics, a grating selection mechanism, fixed optics, and focal plane detectors. An independent calibration lamp assembly can illuminate the focal plane with a range of continuum and emission line lamps.

The *slit wheel* contains apertures and slits for spectroscopic use and the clear, filtered, and coronagraphic apertures for imaging. The slit wheel positioning is repeatable to very high precision: +/– 7.5 and 2.5 milli-arcseconds in the spatial and spectral directions, respectively.

The *grating wheel*, or Mode Selection Mechanism (MSM), contains the first-order gratings, the cross-disperser gratings used with the echelles, the prism, and the mirrors used for imaging. The MSM is a nutating wheel that can orient optical elements in three dimensions. It permits the selection of one of its 21 optical elements as well as adjustment of the tip and tilt angles of the selected grating or mirror. The grating wheel exhibits non-repeatability which is corrected in post-observation data processing using contemporaneously obtained comparison lamp exposures (i.e., wavecals).

For some gratings, only a portion of the spectral range of the grating falls on the detector in any one exposure. These gratings can be scanned (tilted by the MSM) so that different segments of the spectral format are moved onto the detector for different exposures. For these gratings a set of pre-specified central wavelengths, corresponding to specific MSM positions, i.e., grating tilts, have been defined.

STIS has two independent calibration subsystems, the HITM (Hole in the Mirror) system and the Insert Mechanism (IM) system. The HITM system contains two Pt-Cr/Ne line lamps, used to obtain wavelength comparison exposures and to illuminate the slit during target acquisitions. Light from the HITM lamps is projected through a hole in the second correction mirror (CM2), so light from the external sky still falls on the detector when the HITM lamps are used. The IM system contains flatfielding lamps and a single Pt-Cr/Ne line comparison lamp. When the IM lamps are used, the Calibration Insert Mechanism (CIM) is inserted into the light path, blocking all external light. Observers will be relieved to know that the ground system will *automatically* choose the right subsystem and provide the necessary calibration exposures.

19.2 Basic Instrument Operations

Target Acquisitions and Peakups

Once the telescope acquires its guide stars, your target will be within ~1–2 arcseconds of the aperture center. For science observations taken through slits less than three arcseconds in either dimension, and for science observations involving the coronagraphic bars, a target acquisition exposure is taken to center the target in your chosen science aperture and is followed by one or more peakup exposures to refine the target centering of point or point-like sources. Acquisition exposures always use the CCD, one of the filtered or unfiltered apertures for CCD imaging, and a mirror as the optical element in the grating wheel. Peakup exposures use a science slit or coronagraphic aperture, the CCD, and either a mirror or a spectroscopic element in the grating wheel.

Routine Wavecals

Each time the MSM is moved to select a new optical element or to tilt a grating, the resulting spectrum is projected onto the detector with an error (lack of repeatability) of roughly plus or minus 1 to 10 pixels (better for some modes and worse for others). In addition, thermal effects cause the spectrum to drift slowly with time (typical drifts are 0.1 pixels per orbit, extreme cases in the case of forced large temperature swings registered as high as 0.35 pixels per orbit). An internal calibration lamp observation (`WAVECAL`) is automatically taken following each use of a new grating element or new scan position (grating tilt) and every 40 minutes thereafter, in order to allow calibration of the zero point of the wavelength (dispersion) and spatial (cross dispersion) axes in the spectroscopic science data during post observation data processing. These routine, automatically-occurring, wavecal observations are expected to provide sufficient wavelength zeropoint accuracy for the large majority of GO science.

Data Storage and Transfer

At the conclusion of each exposure, the science data are read out from the detector in use and placed in STIS's internal buffer memory, where they are stored until they can be transferred to the HST data recorder (and thereafter to the ground). This design makes for more efficient use of the instrument, as up to seven CCD or four MAMA full frame images can be stored in the internal buffer at any time. The frames can be transferred out of the internal buffer to the data recorder during subsequent exposures, as long as those exposures are longer than three minutes.

STIS's internal buffer stores the data in a 16-bit per pixel format. This format imposes a maximum of 65,536 data numbers per pixel. For the MAMA detectors this number is equivalent to a limit on the total number of *photons* per pixel which can be accumulated in a single exposure. The CCD full well (and not the 16-bit buffer format) limits the photons per pixel that can accumulate without saturating in a single exposure, for both GAIN=1 and GAIN=4 observations.

Parallel Operations

STIS's three detectors do *not* operate in parallel—only one detector can be used at any time. Exposures with different STIS detectors can, however, be freely interleaved in an observing sequence, and there is no extra setup time or overhead in moving from one detector to another. The three detectors, sharing the bulk of their optical paths, also share a common field of view of the sky. STIS *can* be used in parallel with any of the other three science instruments on HST; however, use of the MAMA detectors in parallel is restricted.

Table 19.1: STIS Spectroscopic Capabilities

	Spectral Range (Å)		Spectral Resolution				
Grating	**Complete**	**Per Tilt**	**Scale Δλ (Å per pixel)**	**Resolving Power (λ/2Δλ)**	**# Prime Tilts[a]**	**Detector**	**Slits (apertures)[b, c, d, e]**
CCD First Order Spectroscopy							
`G750L`	5240-11490	5030	4.92	535-1170	2	CCD	52X0.1 52X0.2 52X0.5 52X2 52X0.2F1
`G750M`	5450-11150	570	0.56	4870-9950	11	CCD	
`G430L`	2900-5700	2900	2.73	530-1040	1	CCD	
`G430M`	3025-5615	286	0.28	5330-10270	10	CCD	
`G230LB`	1685-3065	1380	1.35	615-1135	1	CCD	
`G230MB`	1635-3190	155	0.15	5550-10335	11	CCD	
MAMA First Order Spectroscopy							
`G230L`	1570-3180	1610	1.58	600-1150	1	NUV-MAMA	
`G230M`	1640-3175	90	0.09	9110-17500	19	NUV-MAMA	
`G140L`	1150-1736	610	0.60	935-1440	1	FUV-MAMA	
`G140M`	1145-1740	55	0.05	11500-17400	12	FUV-MAMA	
MAMA Echelle Spectroscopy							
`E230M`	1575-3110	800	λ/60,000	30000	2	NUV-MAMA	0.2X0.2, 0.2X0.06
`E230H`	1625-3150	267	λ/228,000	114000	6	NUV-MAMA	0.1X0.2, 0.1X0.09
`E140M`	1150-1735	620	λ/91,700	45800	1	FUV-MAMA	0.2X0.2, 0.2X0.06
`E140H`	1150-1700	210	λ/228,000	114000	3	FUV-MAMA	0.2X0.2, 0.2X0.09
MAMA Prism Spectroscopy							
`PRISM`	1150-3100	1950	1.2-120	1000-26	2	NUV-MAMA	25MAMA (clear)

a. Number of exposures at distinct tilts needed to cover spectral range of grating, with 10% overlap between spectra.

b. Naming convention gives dimensions in arcseconds of slit. For example `52X0.1` indicates the slit is 52 arcsec long in the cross-dispersion direction and 0.1 arcsec wide in dispersion. The `F` (e.g., in `52X0.2F1)` indicates that it is the fiducial on the bar which is specified for coronographic spectroscopy.

c. For the MAMA first order modes, only ~ 25 arcseconds of the long slit projects on the detector.

d. Full aperture clear (`50CCD` or `25MAMA`), longpass filtered (`F25QTZ` or `F25SRF2` in UV), and neutral density filtered slitless spectroscopy is also supported with the first order and echelle gratings. F25MGII is supported with E230H and E230M.

e. A 6 arcsec long slit (`6X0.2`) is also supported for use with the echelle gratings, but with order overlap.

Table 19.2: STIS Imaging Capabilities

Aperture Name	Filter	Central Wavelength (λ_c in Å)	FWHM ($\Delta\lambda$ in Å)	Field of View (arcsec)	Detector
Visible - plate scale ~0.05 arcseconds per pixel					
`50CCD`	clear	---	---	51x51	`STIS/CCD`
`F28X50LP`	optical longpass	λ>5500 Å		28x51	`STIS/CCD`
`F28X50OIII`	[OIII]	5007	5	28x51	`STIS/CCD`
`F28X50OII`	[OII]	3740	80	28x51	`STIS/CCD`
`50CORON`	clear + coronagraphic fingers	---	---	51x51	`CCD`
Ultraviolet - plate scale ~0.024 arcseconds per pixel					
`25MAMA`	clear	~1750-3100 Å ~1150-1700 Å		25x25	`STIS/NUV-MAMA` `STIS/FUV-MAMA`
`F25QTZ`	UV near longpass	λ > 1450 Å		25x25	`STIS/NUV-MAMA` `STIS/FUV-MAMA`
`F25SRF2`	UV far longpass	λ > 1280 Å		25x25	`STIS/NUV-MAMA` `STIS/FUV-MAMA`
`F25MGII`	MgII	2800	70	25x25	`STIS/NUV-MAMA`
`F25CN270`	continuum near 2700Å	2700	350	25x25	`STIS/NUV-MAMA`
`F25CIII`	CIII]	1909	70	25x25	`STIS/NUV-MAMA`
`F25CN182`	continuum near 1800Å	1820	350	25x25	`STIS/NUV-MAMA`
`F25LYA`	Lyman alpha	1216	85	25x25	`STIS/FUV-MAMA`
Neutral Density Filtered Imaging					
`F25NDQ1`	neutral density filter, ND=10^{-1}	1150-11000 Å		12x12	`CCD`, `NUV-MAMA`, `FUV-MAMA`
`F25NDQ2`	neutral density filter, ND=10^{-2}			12x12	
`F25NDQ3`	neutral density filter, ND=10^{-3}			12x12	
`F25NDQ4`	neutral density filter, ND=10^{-4}			12x12	
`F25ND5`	neutral density filter, ND=10^{-5}	1150-11000 Å		25x25	
`F25ND6`	neutral density filter, ND=10^{-6}	1150-11000 Å		25x25	