The On-Orbit Performance of the Space Telescope Imaging Spectrograph

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ABSTRACT

The Space Telescope Imaging Spectrograph (STIS) is a second-generation instrument for the *Hubble Space Telescope (HST)*, designed to cover the 115-1000 nm wavelength range in a versatile array of spectroscopic and imaging modes that take advantage of the angular resolution, unobstructed wavelength coverage, and dark sky offered by the *HST*. STIS was successfully installed into *HST* in 1997 February and has since completed a year of orbital checkout, calibration, and scientific observing. In this paper, we briefly describe the STIS instrument and highlight the new capabilities that it brings to *HST*, illustrate those capabilities with examples drawn from the first year of STIS observing, and describe at a top level the on-orbit performance of the STIS hardware. We also point the reader to related papers that describe particular aspects of the STIS design, performance, or scientific usage in more detail.

Keywords: ultraviolet, visible, space instrumentation, spectrograph, HST, STIS, MAMA, CCD

1. INTRODUCTION

The Space Telescope Imaging Spectrograph is a second-generation spectrograph for the *Hubble Space Telescope (HST)*, designed to replace and greatly expand on the capabilities of two highly successful first-generation instruments, the Goddard High-Resolution Spectrograph (GHRS) and the Faint Object Spectrograph (FOS). The principal advances offered by STIS stem primarily from the use of large format, two-dimensional array detectors. Two photon-counting Multianode Microchannel Array (MAMA) detectors (each read out in a 2048 × 2048 format) record UV light, and one 1024 × 1024 pixel CCD covers the visible. Compared with the 1 × 512 linear array Digicon detectors employed by the first generation *HST* spectrographs, these two-dimensional array detectors enable STIS to provide observing modes with large spatial and/or spectral multiplexing gains.

For spectroscopic observations, STIS brings the following new capabilities to *HST*:
1. Long-slit and slitless imaging spectroscopy over the full 115-1000 nm range, at *HST* angular resolution over 25″-50″ fields of view.
2. Medium- and high-resolution echelle spectroscopy in the ultraviolet, with 20-35 times greater simultaneous wavelength coverage than in corresponding GHRS modes.
3. Higher spectral resolution in the 115-310 nm range than available with any previous space instrument.
4. Higher throughput to longer visible/near-IR wavelengths than the FOS (whose photocathode response extended to ∼700 nm).
5. Much lower dark rate per resolution element in the far-ultraviolet than the first-generation spectrographs, permitting spectroscopy of fainter sources.
6. Coronagraphic spectroscopy, utilizing the excellent image contrast of the *HST*.

All three STIS detectors can be used for imaging observations as well. Although the available filter complement is limited, STIS imaging also provides powerful new capabilities:
1. Solar-blind imaging at high sensitivity, using low-noise photon counting detectors with more than 20 times higher throughput than the Wide Field Planetary Camera 2 (WFPC2) when using its visible-blocking Woods filters.
2. Higher sensitivity broadband imaging than WFPC2, resulting from very wide bandpasses feeding a higher quantum efficiency CCD with lower read noise.
3. Superior coronagraphic capability compared with previous *HST* instruments.

2. STIS DESIGN/OBSERVING MODES

STIS was built by Ball Aerospace for the Laboratory for Astronomy and Solar Physics at NASA Goddard Space Flight Center, under the direction of the Principal Investigator, Bruce Woodgate of GSFC. In this section, we highlight the principal design features and observing modes of STIS. A much more detailed description of the design is provided by Woodgate et al.[7]

A schematic isometric of STIS, showing its optical components and principal subsystems, is presented in Figure 1. Light entering the instrument is first corrected for *HST's* spherical aberration and off-axis astigmatism by a two-mirror corrector system. A sharp image is thereby produced at the slit wheel of the spectrograph, where one of 65 small slits, long slits, or large apertures (filtered and unfiltered) can be selected. The spectrograph collimator then directs a parallel beam onto the grating wheel, where one of 21 gratings, mirrors, or a prism is selected, defining the optical mode. Order sorters are mounted in front of the gratings where required. From the grating wheel, the

Figure 1. Schematic diagram of the principal components of STIS. The components shown are mounted within a graphite epoxy enclosure of roughly 2m × 1m × 1m size. During the *HST* Second Servicing Mission (STS-82), the assembly was successfully installed in an axial instrument bay of the *HST*.

light travels to the appropriate detector either directly, or via a fold flat and camera mirror, or via an echelle grating and camera mirror. The grating wheel mechanism can also tip/tilt the optic in use to select the desired wavelength range for those modes in which the dispersed spectrum overfills the detector format.

The observing modes of STIS can be divided into four spectral bands. Band 1 (115-170 nm) is covered by a photon-counting MAMA detector, designated the FUV MAMA, with an opaque CsI photocathode deposited directly on the front of its single curved-channel microchannel plate (C-plate). Band 2 (165-310 nm) is covered by a similar detector, the NUV MAMA, utilizing a semi-transparent CsTe photocathode on the inside of the detector window. This detector provides additional coverage down to 115 nm in imaging and prism modes, and it serves as a backup to the FUV MAMA. The MAMAs were developed by Ball Aerospace and are both permanently sealed tubes with MgF_2 entrance windows. See Refs. ?,?,?,? for further details about the MAMA design and operation.

Bands 3 and 4 (305-555 nm and 550-1000 nm, respectively) are covered by a backside-thinned, UV-enhanced, multipinned-phase, 1024 × 1024 pixel CCD developed by Scientific Imaging Technologies for the STIS program. The CCD also provides backup to the NUV MAMA in the 170-305 nm range for long-slit spectroscopy (with higher throughput in fact at the longer wavelengths of that band than the primary MAMA modes). The CCD is cooled to an operating temperature of -83 C using a four-stage thermoelectric cooler (TEC). The CCD and TEC are enclosed within a sealed, evacuated housing, whose fused silica window is only slightly cooler than the rest of the instrument, minimizing the condensation of contaminants that could otherwise be deposited directly onto the much colder CCD. See Ref. ? for a more comprehensive discussion of the CCD subsystem.

The properties of the long-slit imaging spectroscopy modes provided by STIS are summarized in Table 1. Plate scales in the MAMA modes range from 0.0244″ (G140L, G230L) to 0.0290″ (G140M, G230M) per MAMA pixel in the cross-dispersion direction, yielding fields of view of 25″-30″ for ultraviolet imaging spectroscopy. In all of the CCD modes, the plate scale is 0.050″ per pixel, yielding a 50″ field of view. Using the GnnnL modes (see Table), low resolution imaging spectroscopy (R $\sim$ 500-1000) at *HST* angular resolution can be obtained over the full 115-1000 nm band in just four exposures (or just two exposures for the entire ultraviolet range). Alternatively, imaging spectroscopy at higher resolving power can be obtained over narrower wavelength intervals using the medium resolution GnnnM modes.

Table 1. Spectral resolution of the primary, long slit, science modes. Each mode is shown with the corresponding detector, nominal bandpass, bandwidth per exposure, number of exposures to cover the full bandpass, dispersion, measured resolving power and where the measurement was obtained. All measurements were with nominal, two pixel wide slits, 52″ $\times$ 0.050″ for MAMA modes and 52″ $\times$ 0.100″ for CCD modes.

Mode	Detector	Nominal Range (Å)	Å/Exposure	Exposures per Band	Å/pix	Resolving Power	Data Source
G140L	FUV MAMA	1150-1700	597	1	0.583	950-1400	Flight
G230L	NUV MAMA	1650-3100	1583	1	1.55	500-960	Flight
G230LB	CCD	1672-3077	1405	1	1.37	700-1050	Flight
G430L	CCD	3050-5500	2809	1	2.75	500-980	Flight
G750L	CCD	5500-10000	4993	1	4.88	560-760	Flight
PRISM	NUV MAMA	1150-3100	>1950	1	0.47-0.48	1200-31	Ground
G140M	FUV MAMA	1150-1700	54.3	11	0.0530	7800-19200	Flight
G230M	NUV MAMA	1650-3100	89.2	18	0.0872	8200-20600	Flight
G230MB	CCD	1650-3100	154	12	0.151	5200-11200	Flight
G430M	CCD	3050-5500	283	10	0.277	4900-10100	Flight
G750M	CCD	5500-10000	567	9	0.555	5100-10400	Flight

Table 2. Spectral resolution (low-res mode) of the primary echelle modes. Each mode is shown with the corresponding detector, nominal bandpass, bandwidth per exposure, number of exposures to cover the full bandpass, dispersion, measured resolving power and where the measurement was obtained. All measurements were with nominal, two pixel wide slits, 0.200″ $\times$ 0.060″ for the medium resolution modes and 0.200″ $\times$ 0.090″ for the high resolution modes.

Mode	Detector	Nominal Range (Å)	Å/Exposure	Exposures per Band	Å/pix	Resolving Power	Data Source
E140M	FUV MAMA	1150-1700	587	1	λ/91700	46000	Flight
E230M	NUV MAMA	1650-3100	808	2	λ/60000	29900-32200	Flight
E140H	FUV MAMA	1150-1700	202	3	λ/228000	99300-114000	Flight
E230H	NUV MAMA	1650-3100	277	6	λ/228000	92300-110900	Flight

Echelle spectroscopy is provided at medium and high resolution in both the FUV and NUV bands (see Table 2). Cross-dispersion plate scales are 0.0290″ per pixel for all modes. Order separation in the echelle modes ranges from 0.4″-1.8″; nevertheless, longer slits can be used to good effect on extended emission-line sources. Note that the nominal resolving power of the E140H and E230H modes is ∼100,000 when observing through two-pixel wide slits. However, ground testing using the narrowest STIS slit (0.025″), the high-resolution (2048 × 2048) readout format of the MAMA detector, and a higher-resolution configuration of the FUV MAMA high voltage system ("repeller off") has demonstrated a resolving power of >200,000 for the E140H mode. This limiting-resolution configuration has not yet been tested in-flight.

As indicated above, imaging modes are also provided for all three STIS detectors, with 25″ × 25″ field of view for the MAMA detectors and 50″ × 50″ for the CCD. The filter complement available for use with the imaging modes is shown in Table 3.

Table 3. STIS bandpass and cutoff (longpass) filters. The filters available for use in STIS imaging modes are listed here, with the names used in the STScI proposal instructions, the detector(s) with which the filter is designed to be used, and the wavelength range and peak transmission of the filter.

Filter	Suitable Detector(s)	Type	Turnon or Central λ (nm)	FWHM (nm)	Peak Transmission
F25LYA	FUV MAMA	Line, Ly α	121.6	8.5	10.4%
F25SRF2	FUV MAMA NUV MAMA	Cutoff	128	N/A	90%
F25QTZ	FUV MAMA NUV MAMA	Cutoff	145	N/A	90%
F25CN182	NUV MAMA	Continuum	188	51	33%
F25C3	NUV MAMA	Line, CIII] λ1909	198	16	13%
F25CN270	NUV MAMA	Continuum	271	23	72%
F25MG2	NUV MAMA	Line, MgII λ2800	280	6.0	45%
F28X50O2	CCD	Line, [OII] λ3727	374	8	55%
F28X50O3	CCD	Line, [OIII] λ5007	500.6	0.6	74%
F28X50LP	CCD	Cutoff	525	N/A	95%

3. SCIENTIFIC DEMONSTRATIONS

In this section, we present a few sample observations of astronomical targets from the first year on-orbit, to demonstrate some of the range of capabilities that STIS provides. Most of the examples are drawn from the Early Release Observation program or the Orbital Verification program. While a number of Guest Observer (GO) and Guaranteed Time Observer (GTO) observing programs have also been carried out, the resulting data are still proprietary; numerous publications based on STIS results can be expected in the coming years.

3.1. Narrow-Slit Imaging Spectroscopy — M84 Nuclear Dynamics

Figure 2 shows the results of narrow-slit spectroscopy of the nuclear gas disk in the center of the Virgo Cluster elliptical galaxy M84. STIS observations in mode G750M (6295-6867 Å) were taken through a 0.2″ wide slit centered on the nucleus. The *HST* + STIS FWHM resolution of 0.10″ in the cross-dispersion direction corresponds to only 8 pc at the nominal distance of M84. Modelling of the strong velocity shear seen in the emission line spectra (±400 km/sec over only 0.2″ along the slit) yields a mass for the dark, compact central object (presumably a supermassive black hole) of a few × 10^9 solar masses. See Ref. ? for further details.

The presence of a gas disk makes measurements of the nuclear dynamics in this galaxy particularly straightforward. However, it should be noted that STIS will also be able to probe the stellar dynamics of nuclear regions through measurements of the velocity dispersion vs. position for composite stellar absorption lines. Several programs are currently underway to survey the demographics of galaxy nuclear black holes by this more general technique.

3.2. Medium-Slit Imaging Spectroscopy — SN1987A

For low velocity-width emission line objects, fine angular resolution can be preserved even when observing through a wider slit that accepts more of the astronomical target. Observations of the inner ring of the SN1987A system provide a striking demonstration of this capability.[?] In this case, the dispersions of the G430M and G750M modes (Figure 3) and the G140L mode (Figure 4) nicely separate the principal emissions of the roughly 1.7″ diameter fossil circumstellar ring. Morphology, density, and temperature of the ring can be deduced from the various spectral features. In the visible spectrum, blue-shifted emission of the Hα and [OII] lines at the 2 o'clock position of the ring provides an indication of the first stages of its interaction with the supernova blast wave. In the ultraviolet spectrum, high velocity Lyα emission ($\pm$15,000 km/sec at least) is interpreted[?,?] as arising from a reverse shock propagating back into the supernova debris.

3.3. Slitless Imaging Spectroscopy — Parallel Observing of High-Z Galaxies

A great deal of STIS data will be taken in parallel with prime operations of the WFPC2 and NICMOS instruments. While the pointing direction is not selectable in this case (being determined by the primary observing program), STIS can make effective use of the observing time by taking spectra of many objects at once, using the 50″ × 50″ aperture with a low resolution grating mode (combined with a direct image to provide a wavelength reference). We are currently using the G750L mode for most parallel observing, primarily to capture compact emission-line galaxies which should show up as near point-like sources in the spectra. Given that strong galaxy emission might arise from [OII] λ3727, [OIII] $\lambda\lambda$4959,5007, Hα, and Lyα, the STIS observations provide a sensitive search for such objects over a wide range of redshifts.

Figure 5 shows an example of the discovery of a compact emission-line galaxy at a redshift of 0.804, with the [OIII] lines redshifted to an observed wavelength of >9000 Å.[?] The upper right panel shows the direct image, the lower panel shows a spectrum of the same region with the G750L grating, and the upper left panel is a close-up of the [OIII] emission lines from the compact galaxy.

3.4. Ultraviolet Echelle Spectroscopy at High S/N — BD+28°4211

Figure 6 presents an E140M echelle mode spectrum of the hot sub-dwarf star BD+28°4211, taken during the STIS Orbital Verification period. Though the numerous spectral features detected have not yet been interpreted scientifically, the observation represents a very important technical demonstration of STIS capabilities. First, the multiplexing advantage offered by the large-format MAMA detector is vividly demonstrated by the echellogram, which covers simultaneously 587 Å in the FUV at a FWHM resolving power of 46,000. With the GHRS, an observer could have chosen either a spectral range of ~30 Å at a resolving power of 20,000–30,000 or a wavelength range of only 6–9 Å at a resolving power of 90,000 for high resolution observations in the FUV. (Note that STIS E140H mode observations cover 202 Å at a resolving power of >100,000).

Equally important is the demonstration (Figure 7) that the MAMA detector can also provide high S/N, a critical issue for the effective interpretation of high resolution spectra. As discussed further in Section 4 and in greater detail in Refs. ?,?, the use of F–P split techniques (as developed for the GHRS and FOS) yielded a S/N of at least 280 for this observation, in regions where the count statistics permitted.

3.5. Solar-Blind Ultraviolet Imaging — Jupiter and Saturn

The photon-counting MAMA detectors in STIS are insensitive to visible light and so can select out the faint FUV emission from the aurorae of planets from the much brighter reflected solar light in the visible. The improved UV sensitivity and higher spatial resolution of STIS enables planetary aurorae to be seen without rotational blurring and with more detail than before, and enables variations with time to be followed.

Figure 8 shows STIS FUV images of Jupiter's polar regions superimposed on a WFPC2 visible light image of the disk.[?] The high latitude rings are aurorae from particles originally generated in volcanoes on the satellite Io, falling down Jupiter's magnetic field lines. The slightly lower latitude streaks are due to particles directly from Io, which is magnetically connected to the surface of Jupiter at these latitudes. The emission in each case is from the Lyα line of hydrogen. The structures rotate with Jupiter, since the magnetic axis is offset from the rotational axis.

Figure 9 shows the auroral rings formed above the surface of Saturn.[?] In this FUV composite, Lyα emissions (color-coded red) are concentrated in the auroral zones, while molecular hydrogen emissions (isolated from Lyα

through use of the SrF_2 cutoff filter "F25SRF2") are seen over the full disk of the planet as well as in tightly confined regions of the aurora.

3.6. Coronagraphic Imaging — β Pictoris Disk

Planetary systems are thought to be formed from equatorial gas and dusk disks, themselves produced as the forming star condenses from interstellar clouds. The best studied protoplanetary disk, that around the star β Pictoris, was observed by STIS in its visible light coronagraphic imaging mode (Figure 10), which removes most of the light from the star, alowing the much fainter reflected light from the disk to be seen. This allowed the disk to be seen closer to the star than in previous observations (Figure 11),[?] in to a distance equivalent to that of Neptune from the Sun. The warp may be due to planets that have already formed within the disk.

4. HARDWARE PERFORMANCE OVERVIEW

Having presented a sample of scientific demonstrations of STIS capabilities, in this section we briefly describe the on-orbit performance of STIS from a more hardware-oriented perspective. Our treatment here will be at a very top level. More detailed, quantitative discussions can be found in companion papers in this volume: Bowers et al.[?] — optical design and performance; Kaiser et al.[?] — detector design and performance; Gull et al.[?] — sensitivity, thermal stability, and time-tag observing; Argabright et al.[?] — MAMA detector photometric stability; Becker et al.[?] — target acquisition software design and performance. Baum et al.[?] in this volume review STIS's first year on-orbit from more of an operations and calibration perspective. An overall in-flight performance summary is given also by Kimble et al.,[?] and a variety of STIS-related papers can be found in the proceedings of the 1997 HST Calibration Workshop.[?]

Most importantly, as of this writing (13 months after launch), all STIS hardware is fully functional. While the STIS design incorporates a significant amount of redundancy, at this time the instrument is operating fully on its primary systems. All backup systems that have been checked also operate properly.

Optical performance has been excellent overall.[?] All modes meet their resolution requirements. The instrument throughput specifications (admittedly somewhat conservative) have been comfortably exceeded for all modes; more significantly, in-flight sensitivities are in close agreement (typically $\pm$20%) with pre-launch predictions and calibrations. Over most of the STIS wavelength range, stability has also been excellent (<1% change over the first year). The one exception is the extremely contamination-sensitive FUV wavelength range. Here, sensitivity monitoring in mode G140L does indicate a decline in throughput, with a slope ranging from 2%–7% per year over most of the band, with as much as 16% per year loss at the very shortest STIS wavelengths (1175 Å).[?] As the source of the contamination is currently unknown, it is not known whether this decline will continue over the long term. Fortunately, the critical Lyα range shows only a 2% decline at this time.

Detector performance has been completely nominal in resolution and sensitivity, as inferred from end-to-end measurements. The only surprises have been a radiation issue with the detector control electronics and an unexpectedly high NUV MAMA dark rate.[?] The control electronics issue involves unwanted response of the detector reset circuitry for both the MAMAs and the CCD to radiation-induced transients produced in optical-isolator components in the electronics chain. Because of this sensitivity, energetic particles (encountered mostly in the South Atlantic Anomaly [SAA]) can cause a partial reset of the detector electronics (abruptly shutting down the high voltage for the MAMA detectors). For the CCD, reconfiguration of the detector control voltages (all <35 V) at each SAA exit is a sufficient and benign approach to dealing with this issue. For the MAMAs, which operate at >2 kV, it is preferable neither to cycle the high voltage rapidly around each SAA crossing, nor to leave the high voltage on and suffer abrupt shutdowns daily. Instead, the MAMAs are operated in the following manner. Each MAMA's high voltage is ramped up and down at the nominal slow rate just once per day in the block of contiguous non-SAA-crossing orbits, if the MAMA is scheduled for use that day. This regimen restricts MAMA availability to ~40% of *HST* orbits, adequate for scheduling the planned MAMA science.

The high dark level in the NUV MAMA detector (600–1800 counts/second) is an unfortunate consequence of long time-constant phosphorescence in the detector's MgF_2 window after excitation of metastable states during SAA crossings. While this potential concern was well known to the STIS team before launch, an error in the screening of this particular MgF_2 ingot allowed a window with a high concentration of phosphorescent impurities to be used. The per-pixel dark rate is still quite modest, however ($\sim 10^{-3}$ counts/pixel/second). Hence, in short exposure-time observing programs, only very low S/N observations are significantly affected. However, observations which are long or substantially binned in the analysis are compromised by the higher background.

Significant amelioration of the NUV MAMA dark rate may become possible with the installation of the Aft Shroud Cooling System (ASCS), currently scheduled for deployment on *HST* during the 1999 Third Servicing Mission. The primary purpose of the ASCS is to maintain the STIS and Advanced Camera for Surveys detectors in their nominal temperature range despite general warming of the *HST* aft shroud. However, modelling of the temperature dependence of the NUV MAMA dark rate indicates that cooling of the NUV MAMA tube could reduce the steady-state dark rate by roughly a factor of 2 and could periodically reduce the dark rate by a factor of 10 over a roughly five day period in an active cooling campaign mode. Such reductions will be extremely beneficial for some key STIS observing programs, particularly in extra-galactic astronomy.

The FUV MAMA experiences no such dark rate difficulties. The global dark rate is 6–10 counts/second, corresponding to $< 10^{-5}$ counts/pixel/second. Extraordinarily long FUV MAMA observations can be carried out with negligible background levels.

In another critical area, high S/N capability, both MAMA detectors have already demonstrated outstanding performance. One of the key drivers in selecting the MAMA technology (in addition to the stable, high spatial resolution format) is the relatively low gain required from the microchannel plate. The low (but well-saturated) gain of the STIS C-plates yields high local dynamic range as well as the ability to process a large number of counts per unit area before significantly affecting the local gain and hence the pixel-to-pixel flat field, and thus the S/N capability of the detector. These benefits have in fact been realized. The flat-field response of both MAMA detectors has been found to be extremely stable.

In-flight evaluation of the MAMA high S/N capability is addressed at length in this volume by Kaiser et al.[?] We can briefly summarize as follows. The formal STIS S/N specification is that the instrument shall deliver a S/N capability of >100 per 2 × 2 pixel resolution element, count statistics permitting. In-flight tests demonstrate that single, low resolution spectra can be rectified to this level or better, for both detectors, using composite flats constructed from ground-based calibration data. Orbital Verification tests have yielded S/N ∼130 for the FUV MAMA and ∼150 for the NUV MAMA for spectra reduced in this way.[?,?] Flat fields constructed from in-flight data acquired with the onboard calibration system should improve the rectification of MAMA spectra further.

In the higher resolution echelle modes, Doppler shifting of the spectrum over the detector smooths the detector response and improves the flat-fielding of the data even more. Combining the Doppler smoothing with spectral offsetting techniques analogous to the F-P split methodology employed by the GHRS and the FOS, STIS has demonstrated S/N capability of 280 (FUV MAMA; see Figure 7) and 340 (NUV MAMA) in echelle mode observing.[?,?] These results are extremely encouraging.

The CCD detector is also performing quite well. The demanding 4 e rms read noise specification has been met in flight. The only significant change from ground performance is the higher level of cosmic rays and the gradual accumulation of radiation-induced hot pixels. Cosmic rays are most effectively dealt with by splitting observations into at least two exposures to permit vetoing of the cosmic ray events; observations particularly sensitive to the presence of hot pixels can benefit by also dithering the pointing slightly between exposures to permit removal of the fixed hot pixels as well.

The most challenging data analysis issue for CCD observations is the problem of fringing in the spectroscopic modes at long wavelengths (>750 nm), where the CCD silicon is starting to become transparent. Substantial modulation of the input spectrum (as much as 35% peak-to-peak) is produced by the interference of multiply reflected beams within the CCD. However, in-flight tests demonstrate that the acquisition of contemporaneous flats using the onboard tungsten continuum lamps permits rectification of long wavelength CCD spectra to better than 100:1 S/N over most of the wavelength range as well.[?]

Such flats of course are insufficient for de-fringing slitless spectra (such as those acquired in the parallel spectroscopy program), as the wavelength map onto the detector shifts with the position of the individual sources. A semi-empirical fringing model (involving construction of a detailed map of the CCD thickness and reflection amplitudes) is currently under development at Goddard by Eliot Malumuth; though at an early stage of development, the model shows great promise for attacking even this more difficult problem.

5. SUMMARY

The Space Telescope Imaging Spectrograph, a versatile spectrograph and imager, has been operating successfully as part of the *HST* complement of focal plane instruments for over a year. All of the STIS hardware is functioning well. In its first year of operation, it has demonstrated a wide variety of new scientific capabilities, which will be exploited in attacking a wide range of astrophysical problems in the coming years.

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