1997 HST Calibration Workshop
Space Telescope Science Institute, 1997
S. Casertano, et al., eds.

STIS Capabilities: Current and Future Implementation

Bruce E. Woodgate

Goddard Space Flight Center, Greenbelt, MD

Abstract. Capabilities of STIS currently supported and those going beyond the subset available at the start of Cycle 7 are described. The latter are candidates for later implementation.

1. Introduction

At the beginning of Cycle 7, many of the modes of STIS are activated, and "Available" to be used, and a large subset of those are "Supported" with pipeline calibration. Some others are not available yet for command development or other ground system reasons. Some of them are candidates for future development. I point out some capabilities we hope will become more available in the future. Table 1 shows some of these capabilities, and some which are already supported and are particularly sensitive.

General descriptions of STIS are available: the design in Woodgate et al, 1997, the in-orbit performance in Kimble et al (1997), and operational access in the STScI STIS Handbook by Baum et al (1996). Also see the STScI Web page

`http://www.stsci.edu/ftp/instrument_news/STIS/topstis.html`

and the IDT STIS Web page

`http://hires.gsfc.nasa.gov/stis/stispage.html`

2. QSO spectroscopy

The currently supported STIS capability for UV spectroscopy of faint QSOs, via the modes G140L and G230L, does not fully replace the nearest equivalent GHRS and FOS modes. The resolving powers, 415-1130, are lower than the GHRS low resolution modes. Consequently studies of QSOs too faint for the echelle modes, but with the ability to distinguish absorption lines as well as GHRS are not currently possible.

This problem can be partly alleviated by using modes X140M and X230M, with resolving powers 3500-4500, and a range of 20nm in the band 115-170nm, and 27.6nm in the band 165-310nm respectively. The sensitivity of the X140M mode is 62% of the STIS G140L mode, and 80% of the GHRS mode G140L. These modes use cross-disperser gratings, and their dispersions and slits are orthogonal to the prime modes. They were withheld from use partly because each spectral format also crossed the other MAMA detector, and checking for Bright Object Protection was more complicated. Now that the MAMA detectors must be cycled around the radiation belts, rather than being kept on all the time, the other MAMA could remain off during the use of these modes, removing the problem.

A comparison of QSO magnitudes reachable in the FUV modes is shown in Table 2, for an exposure of 10 orbits (24,000 sec) with S/N = 10 at 140 nm.

For all of these modes, for exposures longer than an orbit, effective sensitivities are enhanced compared to GHRS and FOS because of the lower background of the MAMAs compared to the digicons. This is particularly true for the FUV, but even the NUV, with its particle phosphorescence, has a factor 2.5 lower background than the digicons for point source spectra.

Table 1. Current and future STIS performance

Performance goal	Mode	Aperture	Technical feature	Supported?	Command development needed?
Spectral resolution					
R=220,000	E140H	0.1X0.03	Repeller off	N	Y - HV control
R=167,000	E230H	0.1X0.03		N	N
R=4000	X140M	Any	NUV off	N	N- ground system?
FUV background					
- imaging	MAMA/FUV	F25SRF2	BOP	Not parallel	N
- spectra	G140L	52X2	BOP	Not parallel	N
Faint spectra					
- NUV	PRISM	6X6	BOP	N	Wavecals?
- Vis line	G430L	52X2		Y	N
- NIR line	G750L	52X2		Y	N
Faint images					
- CCD	CCD	50CCD		Y	N
- NUV				Not parallel	N
- FUV				Not parallel	N
High S/N					
- R<100,000	Except E...H	0.2X0.06FP	FP-split	N	Ground system?
Timing	Any UV	Any	Time tag	Y	N
Coronography					
- Vis/NIR	Imaging	Wedge, etc	Combine rolls	Y	N
	Spectra	Bar		Off-center only	N
UV	Imaging	Wedge, etc	Local BOP, Combine	N	Screening?
	Spectra	Bar	rolls	N	Screening?

A new reason for use of the X230M mode for NUV faint sources is that very long exposures with the E230M mode are background limited because of the phosphorescence, and spectral binning to improve S/N is less effective.

As well as QSO studies, faint stellar spectroscopy can benefit from these intermediate resolving power modes, particularly for studies of time variable lines, where increasing the exposure time does not help.

Table 2. Magnitudes reachable in FUV modes, S/N=10/resel, 10 orbits

Spectral mode	Spectral resolving power	Spectral coverage (nm)	Magnitude
G140L	770-1130	55	20.0
X140M	3500-4500	20	18.0
E140M	35,000	55	14.3
GHRS:G140L	1800-2800	30	18.8

3. Very faint object spectroscopy

The prism mode, nominally in the NUV, but in fact covering both the NUV and FUV using the NUV MAMA, provides the highest spectroscopic sensitivity. This is particularly true in the NUV where the dispersion is lowest, and for detecting continuum edges. An important current use would be for detecting the Lyman continuum break in Gamma Ray Burst afterglows, in the range $0.5<z<2$, to obtain their redshifts and other properties.

This mode is currently supported when used with 25x25 arcsec apertures with various filters, most usefully SrF_2 with a cutoff at 125 nm (T = 1%) to exclude the Lyman alpha geocorona, and with the 2x2 arcsec aperture. Use of the 6x6 arcsec aperture would allow rejection of other sky lines for much of the spectrum, such as the 247 nm line, while allowing point and shoot operations without prior HST image analysis if the position is known to +/- 3 arcsec from ground observations. This enables spectroscopic observations with HST of the GRB afterglow much sooner after its discovery, while it is still bright enough.

A S/N of 5 per 2 nm band could be obtained in 10,000s for V=23 at 180 nm and V=24 for 270 nm.

A narrow compact Lyman alpha emission line of $5\text{x}10^{-17}$ erg cm^{-2} s^{-1} at 250 nm (z=1) would be detected at S/N=5 in the same time. This is 6 times fainter than the faintest of a group of 3 Lyman alpha galaxies at z=2.4 that we have found.

4. Compact emission line galaxies

Very high redshift galaxies may be detected spectroscopically if they are compact and have emission lines. Their redshifts may be measured. Line ratios can indicate whether they are formed by star formation or AGNs. Line broadening and extended emission may indicate dynamics.

The low resolution modes of any of the 4 bands may be used, depending on the redshifts searched for. Lyman alpha may be searched for between redshifts zero to 7. For the NUV band, either the MAMA (G230L) mode or the CCD (G230LB) mode may be used, depending whether sensitivity above or below 250 nm is emphasized. For specific known objects, a slit may be used, but to search a suspect cluster or a random field, a slitless mode may be used. Slitless observing requires a small proportion of the time be spent in direct imaging to act as a position reference to determine the wavelength scale.

The current initial GO pure parallel program uses slitless G750L to measure compact galaxy redshifts. Several emission line galaxies have been found (see Gardner et al. poster in this volume). For objects in the center of the field, the wavelength range is 550-1000 nm. A compact emission line at 700 nm, for example Lyman alpha at z=4.7, with a flux of $4\text{x}10^{-17}$ erg cm^{-2} s^{-1} would be detected at S/N=5 in one orbit. This would correspond to a dust free star formation rate of 3-12 M_0 yr^{-1}(H_0=65 km s^{-1} Mpc^{-1}, Q_0=0.02).

5. High resolution spectroscopy

The highest spectral resolution measured with STIS in test is R=220,000. This was obtained in Mode E140H using the 0.1x0.03 arcsec slit, the FUV MAMA repeller off, hi-res (2048x2048) data analysis, and illuminating with a mono-isotopic Pt lamp to avoid hyperfine structure broadening. The 2048x2048 data mode is the normal raw data mode from the spacecraft, the 0.1x0.03 arcsec slit is an Available Mode requiring special justification, but the Repeller-off requires command development not yet available.

The same measurement with the normal Repeller-on would yield R= 190,000, and with also the 0.2x0.09 arcsec slit, to return to the nearest Supported mode, would yield R= 114,000

The NUV MAMA does not have a repeller. The highest resolution NUV mode, E230H, using the 0.1x0.03 arcsec slit would provide R= 167,000.

Results using STIS for ISM spectroscopy with the supported 0.09 arcsec wide slit are found in Jenkins et al (1997), and results illustrating the need for the highest resolving powers obtainable, showing ISM b-values less than 0.5 km/s, are found in Welty et al (1996).

These capabilities are summarized in Table 3.

Table 3. Highest spectral resolving powers

Spectral mode	Slit width (arcsec)	Repeller	Resolving power ($\lambda/\partial\lambda$)
E140H	0.03	OFF	220,000
E140H	0.03	ON	190,000
E140H	0.09	ON	115,000
E230H	0.03	N/A	167,000

6. Special capabilities

Several other forefront capabilities of STIS that should be mentioned, are being covered at this meeting.

The ability to do high S/N spectroscopy above S/N= 100 is being explored and is reported on by Kaiser. For modes other than the high resolution echelle modes (E140H and E230H), for which Doppler smoothing will permit very high S/N, the use of the FP-split slits will extend the S/N capability.

Timing of photon arrival times using the time-tag readout has been demonstrated using the Crab pulsar, and a timing accuracy of at least 1 in 10^6 shown, limited by the current calibration of the spacecraft clock. See the poster by Lindler et al. in this volume.

A reduction in stray light from stellar images may be obtained by using the coronagraph stops (Cornett et al. poster in this volume). This is mostly due to preventing the light from the image core reaching the CCD and scattering within the CCD backing and reflecting from the CCD window. This is initially being used for the detection of protoplanetary disks around nearby stars with the CCD. Spectroscopic use of the coronagraphic bars in the UV, when permitted, will allow the detection of faint extended emission, particularly in emission lines, around bright objects without getting swamped by the haloes produced in the detectors by the bright objects, and without saturating the detectors. Applications include material around galaxy nuclei and stellar winds.

Direct imaging with STIS is very sensitive, particularly when broad or no filters are used. CCD imaging with no filter can go 3 to 6 times fainter than WFPC2, largely because it covers 200 to 1000 nm, but it also has somewhat higher DQE and lower noise. NUV imaging with the Quartz filter covers 150 - 310 nm. FUV imaging with the SrF_2 filter covers 130 to 170 nm, avoiding the Lyman alpha geocorona.

References

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