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The Cycle 7 Calibration Plan for STIS

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Abstract. We give a short overview of the Cycle 7 calibration plan for STIS, discussing its challenge, its general goals and philosophy, the expected calibration accuracies after Cycle 7, and the way the GO and GTOs will be informed on the progress of the calibration efforts. A list of all calibration proposals with a brief description of each is also included.

1. Introduction

As already noted by the review of Stefi Baum in this volume, the Space Telescope Imaging Spectrograph (STIS) is an extremely versatile instrument. It has three detectors on board (1 CCD, 2 MAMAs) by means of which it covers a very large wavelength range (from the far-UV to beyond 1 μm); it allows both imaging and imaging spectroscopy (including long-slit and echelle spectroscopy); there are several operational *modes* (ACQ, ACQ/PEAK, ACCUM, DOPPLER, CORONOGRAPH; there are 44 supported *apertures* (filters + slits), a total of 133 supported primary and secondary wavelength settings for the spectroscopic modes, not even mentioning the numerous available modes of STIS that are not (yet) supported.

This great versatility presents a real challenge for the STIS support group at STScI to provide all calibrations associated with both imaging and spectroscopy (e.g., dark correction, flat fielding, photometric calibrations for all settings, geometric distortions, Point Spread Functions (PSFs), Line Spread Functions (LSFs), etc.) in an accurate and timely way. In the following sections, we describe our plan on how to handle the calibration effort in cycle 7.

2. Goals and Philosophy of the Cycle 7 Calibration Program

2.1. General Goals

The general goals for the Cycle 7 calibration program of STIS are as follows:

1. The highest priority calibrations in the near term are those that will acquire missing calibration data from ground testing, or those that will likely provide a new understanding of the performance of the instrument that will be important to a significant number of observers. Most of the crucial tests and calibrations have been carried out successfully on-orbit in the *Servicing Mission Orbital Verification* (SMOV); however, there are a few still outstanding issues that are needed to support STIS Cycle 7 science. These issues are listed below:

   - The flatfielding accuracy around the "dust motes" that are present on the CCD (early results are shown in Ferguson 1997)

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- The accuracy of fringe removal for wavelengths $\geq$ 700 nm in CCD spectroscopy (gratings G750L and G750M) (early results on this issue can be found in the contributions by Goudfrooij et al. 1997 and Plait et al. 1997)
- The limiting Earth-limb avoidance angle beyond which the influence of scattered light becomes important
- The memory effect of the CCD after (heavy) saturation
- The characteristics of the red light which is scattered within the CCD substrate
- Missing dispersion solutions for some wavelength settings (mostly in the far-UV medium-dispersion modes)
- Confirmation of correctness of flight software updates for Target Acquisitions *(now confirmed)*
- Grating scatter (Red light into UV gratings, especially important in the case of the G230LB and G230MB (CCD) gratings
- Flatfielding accuracy for the MAMA's (see Kaiser et al. 1997)
- Out-of-band transmissions (red leaks) for MAMA filters
- Sensitivities of a number of medium-dispersion MAMA grating modes

2. Establish the on-orbit performance of STIS with respect to that found during Ground Calibration;

3. Monitor the on-orbit performance of STIS on a timely basis, with timescales as appropriate for a given calibration issue, both to keep track of the health & safety of the instrument and to establish the stability in time of a given calibration solution;

4. Finally, if time allows it: Commission new capabilities of STIS.

2.2. Philosophy during Cycle 7

In view of the limited amount of manpower available within the STIS support group, it is necessary to find a suitable compromise between what is ultimately needed from a calibration program and what can be reasonably observed and analyzed within the duration of Cycle 7. We therefore have to assign priorities to our calibration analysis efforts. These priorities come in two different lists. The first one shows the overall, mode independent, priorities for instrument calibration, whereas the second one shows a hierarchy of the importance of the different instrument modes (determined by the Cycle 7 usage statistics).

In broad terms we will employ the following overall calibration priorities:

1. First priority is the regular health and safety monitoring of the detectors, mechanisms, lamps, window contamination and basic operations, so that we can, at any time, attest to the acceptable performance of STIS and to its longterm stability.

2. Regular updating of reference files (e.g., biases, darks, delta flats) for use in the STIS pipeline and for a-posteriori reduction, and keeping GO updated with the latest information on our calibration experience.

3. Basic sensitivity calibration of all spectroscopic modes, and monitoring its stability in time as well as that of the flat field calibrations.

4. Optical performance (e.g., PSFs, LSFs, Geometric distortion, etc.)

5. Characterization of miscellaneous specific peculiarities (e.g., detector non-linearity, Charge Transfer Efficiency (CTE), long-wavelength halo, fringing and scattered light).

Within each of these priority groups, our calibration priority will be in the following order of observing modes:

1. First-order low-resolution *prime* grating modes (G140L, G230L, G430L, G750L).
2. Echelle spectroscopy.
3. First-order medium-dispersion grating modes.
4. CCD imaging (broad-band first, then narrow-band).
5. MAMA imaging (broad-band first, then narrow-band).
6. First-order low-resolution *backup* grating modes (G230LB, G230MB), including the analysis of its grating scatter.

In addition to this, on-axis calibrations have higher priority than do off-axis calibrations. I.e., we will first establish the calibrations at the *center* of the field or slits and expand the calibration to two dimensions thereafter.

In view of these analysis priorities, it is unavoidable that not all data taken by GOs will have the available calibration data fully analyzed yet by the time their observations are taken, especially if it concerns data taken in a mode that has a low "analysis priority". In any case, we would like to stress that *all calibration data in the archive is immediately non-proprietary upon archival*, and can thus be retrieved by the GO to perform his/her own calibration at any time.

2.3. Expected Calibration Accuracies

Tables 1 and 2 summarize the calibration accuracies we aim to achieve by the end of cycle 7 for the different spectroscopic and imaging attributes, respectively.

Table 1. Spectroscopic Accuracies to be reached in Cycle 7

Attribute	**Accuracy: CCD**	**Accuracy: MAMA**	**Limiting Factor(s)**
Relative wavelengths (within exposure)	$0.1 - 0.25$ pixels	$0.25 - 0.5$ pixels	Optical & geometric distortion
Absolute wavelengths (across exposures)	≤ 1.0 pixel	≤ 1.0 pixel	Thermal stability; Internal vs. external illumination; wavecal zeropoint
Absolute photometry	10%	15%	Instrument stability; photometric calibration
Relative photometry (within exposure)	5%	$5 - 10$%	Instrument stability; photometric calibration

Table 2. Imaging Accuracies to be reached in Cycle 7

Attribute	**Accuracy: CCD**	**Accuracy: MAMA**	**Limiting Factor(s)**
Relative astrometry (within image)	0.1 pixels	0.25 pixels	Stability of optical distortion
Absolute photometry	$5 - 10$%	15%	Instrument stability; photometric calibration
Relative photometry (within image)	5%	10%	Flat fields; external illumination

Some of the indicated accuracies are already reached (e.g., relative imaging photometry for the CCD), while others will still take a while to be reached (e.g., far-UV MAMA flatfielding).

3. Specifics on the Calibration Programs

In this Section, we inform the reader with specific, but brief, information about the individual STIS calibration programs that are being executed in Cycle 7. Different goals of the calibration program are individually listed in subsections.

3.1. Monitoring for Health and Safety

Our approach to monitoring for health and safety issues is to start off with fairly intense monitoring for about 6 months, after which it will be less frequently as dictated by the first 6 months worth of data.

In the following we denote the different Cycle 7 calibration program designations in sans serif font, followed by a short description.

7600: CCD Performance Monitor
Measures the baseline performance and commandability of the CCD. Measurements of bias structure, dark current, flat field structure, and CTE.

7659: Daily Darks for ACQ Hot Pixels
For updating hot pixel list for Target Acquisitions.

7635: Hot Pixel Annealing
Anneal out CCD hot pixels, and test for window contamination.

7604: MAMA Dark Monitor
Monitoring of dark noise which is the primary means of checking the health of the MAMA detectors.

7643: MAMA Fold Distribution
Basic monitor of performance of MAMA microchannel plates.

3.2. Monitoring for Calibration Stability

7601: CCD Dark and Bias Monitor
Weekly monitor of CCD darks and biases to update reference files, including hot pixel lists

7634: CCD Flat Fielding Monitor
Monitor appearance of flat field (as well as the intensity of the tungsten lamp)

7672: CCD Sensitivity Monitor at Field Center
Monitor sensitivity of all supported low-resolution settings of the CCD gratings (wide-slit spectra of a HST spectrophotometric standard)

7639: CCD Sensitivity over full field
Take CCD images of photometric standard star field in ω Cen every few months to monitor throughput as well as measure the CTE (and the PSF)

7638: CCD PSF Monitor
Monitor PSF in different filter passbands *(deferred to 1998)*

7711: CCD Fringe Flats
Build library of CCD fringe flats in the G750L and G750M settings at central wavelengths $\geq$ 700 nm for different slits.

7644: NUV-MAMA Monitoring flats
Monitor NUV-MAMA flat field to construct bi-monthly delta flats

7728: FUV-MAMA Monitoring flats
Monitor FUV-MAMA flat field to construct delta flats for every three months

7673: MAMA Sensitivity Monitor
Monitor sensitivity of all supported low-resolution settings of the MAMA gratings (wide-slit spectra of a HST spectrophotometric standard)

7720: MAMA Sensitivity over full field
Take MAMA images of photometric standard star field in NGC 6681 every few months to monitor throughput (as well as the PSF)

3.3. Major Calibration Programs

A. Flat Fielding

7636: Spectroscopic CCD Flatfielding
Build up a library of flats for all CCD grating settings during the course of cycle 7

7664: CCD External Flats, Earth Streak
Take Earth-streak flats to build up a high signal-to-noise external flat field, to be used as intermediate-order illumination correction to the internal flats

7658: CCD External Flats, Sky
Take images of the sky, to be merged together later on to form low-order illumination correction to the flat field. These exposures will be taken in parallel with an equivalent NICMOS calibration program

7645: MAMA FUV Flats
Build up a library of flats for all MAMA FUV grating settings during the course of cycle 7

7647: MAMA NUV Flats
Build up a library of flats for all MAMA NUV grating settings during the course of cycle 7

B. Sensitivities

7656: Spectroscopic and Imaging Sensitivity, CCD
Basic sensitivity meaurement for all supported CCD imaging and spectroscopic modes; running once a year

7657: Spectroscopic and Imaging Sensitivity, MAMA
Basic sensitivity measurement for all supported MAMA imaging and spectroscopic modes; running once a year

C. Dispersion Solutions

7650: Dispersion Solution Monitor, CCD
Wavelength dispersion solutions will be determined for each CCD grating on a yearly basis as part of a long-term monitoring program. Only central and extreme wavelength settings are observed

7651: Dispersion Solution Monitor, MAMA
Wavelength dispersion solutions will be determined for each MAMA grating on a yearly basis as part of a long-term monitoring program. Only central and extreme wavelength settings are observed

3.4. Special CCD Calibrations

7603: Optimizing Removal of NIR Fringing

Test accuracy of using contemporaneous spectral flats in G750L and G750M settings with $\lambda \geq 700$ nm to correct for fringes *(Already finished; see first results in Goudfrooij, Walsh & Baum 1997)*

7605: Target Acquisition Workout

Test Flight Software Changes that were linked up in August 1997 *(Already finished)*

7637: Residual Images after Overillumination

Overexpose the CCD by taking a slitless spectrum of a bright star. Take dark frames afterwards to study the residual effect over time. Repeat the experiment, now taking bias frames instead of dark frames to study the effect of read-outs. Do this whole procedure using three different gratings, one in the UV (G230LB), one in the blue (G430L) and one in the red (G750L) to check for any dependence on color.

7641: CCD External Flats, Stellar

Take images of dense stellar field and step across the field with small offsets to map out the throughput at the dust "motes". Also a test for the accuracy of relative photometry within exposures. *(Already finished)*

7642: Red Halo of Light Scattered within CCD Substrate

Observe red star through [OIII] filter (which has a red leak at $\lambda > 1\mu$m) to characterize the red halo. Repeat observation with long-pass 28X50LP filter, and take spectrum with G750L grating to characterize wavelength dependence of the halo

7646: Scattered Light near Earth Limb

Measure the scattered light from the Earth background at low limb angle with the CCD, both during bright and dark Earth conditions, to determine its effect to the background intensity.

7648: Missed Dispersion Solutions, CCD

Take arc lamp spectra in the CCD grating settings which were missing from Ground and SMOV calibrations

7652: LSF Measure, CCD

Measure LSF of emission lines of young Planetary Nebula (of which the FHWM of the lines is ~ 8 km s^{-1}) as a function of λ and compare with LSF of arc lines

7654: Slitless Spectroscopy, CCD

Determine dispersion solution as a function of position on the CCD by taking slitless spectra of a star with known radial velocity and numerous narrow absorption lines, and moving it around on the CCD

7660: STIS to FGS Alignment Check

Re-verify the STIS aperture and slit locations, and check the transformation of the STIS CCD detector reference frame to the FGS reference frame, after the FGS-FGS update

7665: Geometric Distortion, CCD

Step star along wide slit and step along slit to map out the geometric distortion in three residual CCD grating settings that were missed in Ground Calibration

7666: CCD Linearity and Shutter Stability Test

Use Tungsten and relatively bright star to test linearity at high and low intensities, as well as the stability of shutter delay time for CCD

7668: Missing Incidence Angle Corrections, CCD
Measure corrections to dispersion solutions for non-concentric slits with respect to the reference slit (up to first order)

7723: Red Scattered Light with CCD UV Gratings
Determine influence of red scattered light to spectra taken with the G230LB and G230MB CCD gratings by comparing spectra of a red star with those taken with the equivalent MAMA gratings (G230L and G230M).

3.5. Special MAMA Calibrations

7649: Missed Dispersion Solutions, MAMA
Take arc lamp spectra in the MAMA grating settings which were missing from Ground and SMOV calibrations

7653: LSF Measure, MAMA
Measure LSF of emission lines of young Planetary Nebula (of which the FHWM of the lines is ~ 8 km s^{-1}) as a function of λ and compare with LSF of arc lines *(deferred)*

7655: Slitless Spectroscopy, MAMA
Determine dispersion solution as a function of position on the MAMA by taking slitless spectra of a star with known radial velocity and numerous narrow absorption lines, and moving it around on the MAMA

7661: MAMA Filter Red Leak Measurement
Measure out-of-band throughput for MAMA filters with the CCD

7667: MAMA Geometric Distortion
Step star along wide slit and step along slit to map out the geometric distortion in the MAMA grating settings that were missed in Ground Calibration

7669: Missing Incidence Angle Corrections, MAMA
Measure corrections to dispersion solutions for non-concentric slits with respect to the reference slit (up to first order)

7671: External to Internal Wavelength Scale Corrections
Observe emission-line object with known radial velocity to check dispersion solution from arc lamp *(deferred)*

7721: Slit Throughputs
Measure relative slit throughputs for a variety of commonly used slits as a function of wavelength (using one and the same star)

7774: High S/N PSF Measurement
Deep images of isolated point sources are taken in MAMA imaging modes (NUV and FUV) using selected narrow-band filters to establish a (central) PSF with S/N = 100 in the near wings

7724: Doppler Checkout
Check automatic Doppler correction for MAMA ACCUM measurements *(deferred)*

3.6. Total Orbit Summary

The total amount of orbits needed for execution of the full Cycle 7 calibration plan for STIS is shown in Table 3, subdivided into the different goals of the program.
The total number of external orbits needed for STIS calibrations is about 10% of the total STIS (external) observing time, both for the CCD and the MAMA.

Table 3. Orbit Summary for Cycle 7 STIS Calibrations

	External Orbits		**Internal Orbits**
	Prime	**Parallel**	
CCD, Total	84	154	1334
Monitoring	22	4	1149
Major	25	150	124
Special	37	0	61
MAMA, Total	167	0	1401
Monitoring	115	0	1374
Special	52	0	17

4. Keeping the GO/GTO Community Informed

The status of the STIS Calibrations in Cycle 7 is kept up to date on the World Wide Web through the "calibration resources" WWW page that can be accessed through the STIS home page (`http://www.stsci.edu/ftp/instrument_news/STIS/topstis.html`). On the "STIS Calibration Resources" are

1. Pages on the Cycle 7 Calibration Program: A table of all programs (sorted by either topic or execution date) with links to their phase I and phase II proposal texts. If you have comments or suggestions on the calibration plan, please email them to `help@stsci.edu` with a clear title, such as "Comments on STIS cycle-7 calibration plan." We will certainly welcome your input.

2. A page on the STIS On-Orbit Performance, containing various summaries and examples of the on-orbit performance of STIS, obtained from analysis of data from SMOV and early Cycle 7 calibration proposals.

3. Under construction: Page on calibration accuracies reached to date in the different observing modes of STIS (this page will be available by November 1, 1997, and regularly updated thereafter).

References

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