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Instrument Science Report STIS 2018-07

STIS Bright Object Protection for Available-But-Unsupported Modes

Joleen Carlberg ¹

¹ Space Telescope Science Institute, Baltimore, MD

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ABSTRACT

In this Instrument Science Report, we describe techniques for determining the safety of proposed observations using the STIS FUV- or NUV-MAMA for spectral settings or apertures that are available, but unsupported. Such modes may not be selectable in APT using the BOT tool or in the exposure time calculator. These observations can be cleared if a supported mode can be identified that is guaranteed to estimate comparable or higher count rates than the proposed setup. Observations clearing the BOT with the related supported mode would thus be safe in the proposed unsupported mode. A practical example of the described techniques are presented for clearing a planetary nebula observation (the topic of a recent a Cycle 25 SNAP program), which also lead to the inclusion of a new planetary nebula template for the exposure time calculator.

Contents

- Introduction (page 2)
- Using the BOT (page 3)
- Using the ETC (page 5)
- Change History (page 8)
- References (page 8)
- Appendices (page 9)

1. Introduction

Two of the detectors on STIS (the FUV-MAMA and NUV-MAMA) can be damaged by over-light conditions. Multiple safety mechanisms are in place to prevent damage, including screening limits (Leitherer & Clampin 1996) and on-board monitoring of the local and global count rates that will either shutter or shut-down the instrument when rates are exceeded (Clampin 1996). To avoid the disruptive safety strategies, global and local count rates must be estimated for all proposed MAMA observations to ensure they are below the recommended safety limits. Furthermore, the field immediately surrounding the science target is screened for nearby bright objects that could illuminate the detector if it falls in the field of view in imaging mode or along the slit in spectroscopic modes. Both of these checks are expected to be completed by Principal Investigators (PIs) by the time of Phase II submission, and they are rechecked independently by a Contact Scientist (CS) on the STIS team before observations can be scheduled. The exposure time calculators (ETC, <http://etc.stsci.edu/etc/>) and bright object tool (BOT) in the Astronomer’s Proposal Tool (APT, <http://www.stsci.edu/hst/proposing/apt>) are provided to support these safety checks.

STIS has a large complement of apertures—over 100 aperture names, when including all aperture entrance sizes, filters, and offset locations. Many of these are seldom used and have not been included in the BOT or ETC. When paired with a given spectral element, each aperture may either be supported, available-but-unsupported, or forbidden to use. In Table 1, we list the subset of apertures that are available-but-unsupported for at least one first order or echelle grating but that are not a supported aperture for any grating. Comprehensive tables of the availability of all aperture and spectral element combinations can be found in Table A.2 of the STIS Instrument Handbook (Riley et al. 2018) or in the “Official STIS Aperture List” in the HST Phase II Proposal Instructions document.

The question of how to demonstrate the safety of observations using available-but-unsupported modes recently arose for the Cycle 25 SNAP proposal 15211, which obtained spectra through the 6×6 square aperture. In this work, we outline the considerations that must be addressed to verify detector safety with specific reference to how they were applied to the SNAP program. Briefly, the safety of the observation must be demonstrated with an aperture and observing strategy supported by the BOT and ETC that would yield comparable or higher count rates than the proposal observation. The SNAP program had the additional complication that the science targets (planetary nebulae) have different spectra energy distributions for the point source and extended source components, and we demonstrate the multistep ETC calculations required to attain a correct estimate of the global and local count rates through the large aperture.

This document is not intended as an exhaustive list of how to handle any given situation, but merely provides an illustration that PIs and CSs can use as a starting place to adapt to their own unique situations.

2. Using the BOT

The Bright Object Tool (BOT)¹ in the Astronomer’s Proposal Tool (APT) is designed to automatically calculate the global and local count rates of field targets within a given macroaperture buffer zone around the proposed science. This buffer zone extends 5'' beyond the edge of the aperture and is meant to account for initial pointing errors. When there are no orientation constraints and the target is centered spatially in the aperture, the circular region screened has a radius of 5'' plus half the length of the slit. If the target is off-center spatially (e.g., when using a pseudo-aperture position or for G140L/G140M observations that are offset by 4'' to avoid the repeller wire shadow), the radius of the screened area is 5'' plus the distance between the target and the farther edge of the slit.

The basic strategy for clearing observations using an unsupported aperture is to select a supported aperture with a similar sized or larger slit width and ensure that the BOT is covering a macroaperture that satisfies the conditions outlined in the previous paragraph. For the many unsupported apertures of non-standard slit length, this can trivially be accomplished by running the BOT using the long-slit (52'' long) aperture of equivalent slit width. The BOT will screen a much larger macroaperture than is needed. Unknown and unsafe targets that are outside the requisite safety macroaperture for the unsupported aperture (e.g., slit length +5'') can safely be ignored. Those within must be cleared with further analysis as usual.

The strategy is more complicated for the larger square apertures, e.g., 6 × 6, for which there is no long slit aperture of equivalent width. In this case, the user can use the default echelle 0.2×0.2 square aperture and specify a POS TARG offset (a small pointing maneuver in the spacecraft reference frame) to increase the macroaperture cleared by the BOT to the desired size. The step size should be the difference in radii between the large and small apertures (see the example below). Note that since the size of the 0.2×0.2 will truncate some of the PSF, users should carefully inspect any “Safe Targets” identified by the BOT with local or global count rates larger than 50% of the limits.

Example: Consider an observation using the available-but-unsupported 6×6 aperture with a spectroscopic grating. With no constraints on the orientation of the slit, the user must clear a macroaperture of radius $3\sqrt{2} + 5''$ around the target center (e.g., a region encompassing the aperture’s diagonal plus a 5'' buffer on all sides). This can be accomplished by making a local copy of the Phase II file², selecting the supported 0.2×0.2 square aperture, and adding a POS TARG in the special requirements container

¹<http://apst.stsci.edu/apt/external/help/documentation/Running-BOT.html>

²The changes made to the selected aperture for BOT clearing should **not** be submitted to STScI since they are not intended for the actual observations

Table 1. A List of Available-But-Unsupported STIS Apertures for Spectroscopy

Aperture	Description
0.1X0.06 0.2X0.5 0.3X0.06 0.3X0.09 0.3X0.2	Echelle apertures
0.5X0.5 2X2 6X6	Square apertures
1X0.06 1X0.2 6X0.06 6X0.5	Medium slit apertures
52X0.05F1 52X0.05F2 52X0.1F1 52X0.1F2 52X0.2F2 52X0.5F1 52X0.5F2 52X2F1 52X2F2 52X0.1B0.5 52X0.1B1.0 52X0.1B3.0	Fiducial bar slits
F25CN270 F25CIII F25CN182 F25LYA	Narrow band filters
F28X50LP F28X50OII F28X50OIII	Broad band filters
36X0.05P45 36X0.05N45 36X0.6P45 36X0.6N45	Planetary apertures (rotated $\pm 45^\circ$)

for that exposure to center the 0.2×0.2 aperture on a corner of the 6×6 aperture. In this example, the value of the offset should be $(6 - 0.2)/2\sqrt{2} = 4.10''$ and can be made in either the X or Y direction. Figure 1 illustrates this example with a screen shot from APT of the 0.2×0.2 aperture offset by a POS TARG of $4.10''$ in the X-direction. The size of the 6×6 aperture centered on the target position is drawn for reference.

Warning: There is a limitation to specifying a POS TARG to increase the macroaperture cleared by the APT/BOT. When the offset exceeds $5''$, the BOT will clear an annulus around the offset position, and a small field centered around the target will not be checked by the BOT. In such cases, the user will have to make two copies of the exposure, one with and one without the offset for the BOT to clear the entire extended macroaperture region around the target.

3. Using the ETC

For users interested in using available-but-unsupported apertures with a specific spectral element, the ETC calculation must be accomplished in a way that mimics how counts will accumulate with the unsupported aperture. Multiple ETC calculations may be required. In general, an ETC run with a slit of equivalent slit width or larger is needed to assess the expected global count rate from the source and the local count rate. Additionally, the global count rate contribution from the sky background and from spatially extended sources must be considered, which requires ETC calculations covering equivalent spatial areas. There are a few caveats to bear in mind to accomplish this:

- The size of the MAMA detector is *smaller* than the long slit, so the effective area of, e.g., the $52 \times 2''$ slit is only $25.19 \times 2 = 50.38 \text{ arcsec}^2$, not 104.
- A scaling factor may need to be applied to ETC calculations for extended objects if the science target is larger than the aperture in one or both dimensions.
- The ETC reports the background contribution as the combined sky and dark contributions, whereas only the sky contribution scales with the area of the aperture.

Example: Consider an FUV/G140L observation of a planetary nebula (PN) using the 6×6 aperture. Assume that the PN has the following characteristics:

- Diameter is $7.2''$
- Nebular emission surface flux at H_β is $3 \times 10^{-13} \text{ erg sec}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1} \text{ arcsec}^{-2}$
- Central star $T_{\text{eff}} = 50,000 \text{ K}$
- Central star $V = 13$
- $E(B - V) = 0.5$, for $R_V = 3.1$

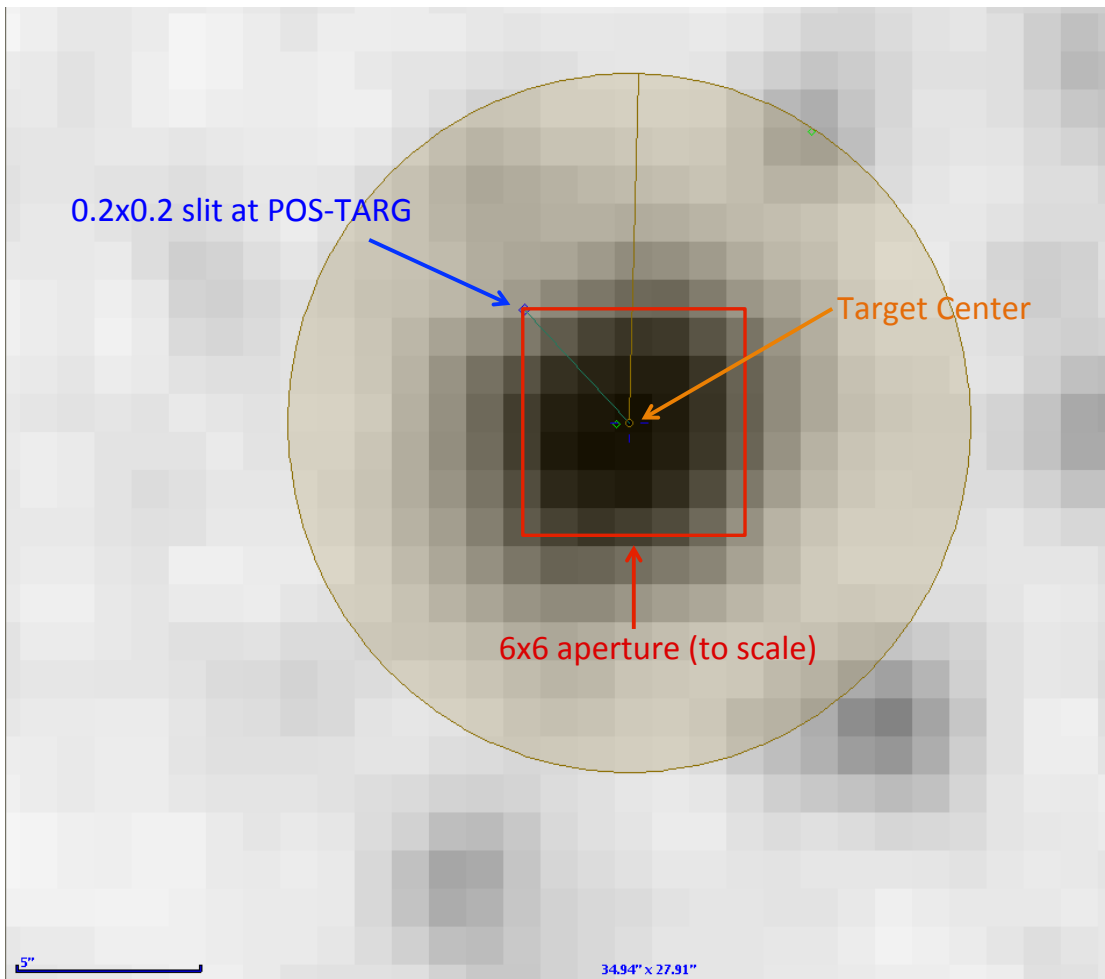


Figure 1. Screenshot of the APT/BOT illustrating the macroaperture cleared for a 0.2×0.2 aperture offset by $4.10''$ from the target center. For reference, the screenshot is annotated with the 6×6 aperture centered on the target to illustrate how this setup effectively clears the larger aperture with a $5''$ buffer.

The ETC does not support this aperture, and two ETC calculations are needed to obtain accurate global count rates from both the science target and the background sources. Two ETC calculations are also required to accurately represent the two components of the science target since the aperture has a relatively large spatial extent.

ETC Calculation #1 (STIS.sp.1294756): The first ETC calculation will capture the count rates due to the background and the central star of the PN. The unsupported science aperture subtends $36''$ square arcsec on the sky. The standard 52×2 slit subtends ~ 50.4 square arcsec of the sky that falls on the detector (the MAMAs are shorter than $52''$). Therefore, the ETC calculation can be run using the 52×2 slit with a point source science target. The following selections in the ETC should be made:

- Grating: G140L
- Slit: 52×2
- Wavelength: (any value from 1150–1736 Å)
- Source type: Point Source/Use default region
- Spectral distribution: a Black-body with temperature $T = 50,000$ K
- $E(B - V)$: 0.5 ($R_V = 3.1$)
- Normalization: 13.0 Vega Magnitude/Johnson V bandpass

The brightest pixel in this calculation is 1.8 ct/s/pix. The global count rate due to the point source is 3,780 ct/s. The global count rate from the background is 1287 ct/s, which can be scaled down by a factor of $36/50.4$ to account for the smaller sky area of the 6×6 aperture.

ETC Calculation #2 (STIS.sp.1294757): The second ETC calculation will capture the global and local count rates due to the extended source and can be accomplished by selecting the clear aperture. The following selections in ETC should be made:

- Grating: G140L
- Slit: MAMA Clear (slitless)
- Wavelength: (any value from 1150–1736 Å)
- Source type: Extended Source/ Diameter is $7.2''$
- Spectral distribution: Non-Stellar Objects/Planetary Nebula Extended Emission (see Appendix A).
- $E(B - V)$: 0.5 ($R_V = 3.1$)
- Normalization: 3×10^{-13} erg sec $^{-1}$ cm $^{-2}$ Å $^{-1}$ arcsec $^{-2}$ at 4861.0 Å.

The brightest pixel in the extended source calculation has a count rate of only 0.02 ct/s/pixel. The global count rate calculated for the extended source is 875 ct/s; however, in the real observation, some of the source's light will be lost since the nebula is larger than the aperture. Assuming a constant surface brightness, the scale factor is simply the ratio of the area of the aperture to the area of the nebula. Because the ETC presumes that the full detector (635 arcsec²) will be on sky in this calculation, the background alone triggers a warning from the ETC about exceeding the bright limit for irregularly variable sources. However, this background is a gross overestimate and can be safely ignored.

The final local count rate is the sum of the local count rates from the two different calculations: $1.8 + 0.02 = 1.82$ ct/s/pix. The global count rate is the sum of the point source and scaled background contributions from the first calculation plus the scaled extended source contribution from the second calculation: $3780 + 1287(36/50.4) + (36/(\pi(7.2/2)^2)) * 875 = 5472$ ct/s.

4. Conclusions

This document is meant to lay down guidelines for verifying the safety of proposed observations that cannot be directly modeled with the ETC and/or BOT tools currently in place. Users with questions on how to apply these guidelines to their unique situation may contact the STIS team via the HelpDesk at <http://hsthhelp.stsci.edu>.

Acknowledgements

Special thanks are due to Charles Proffitt who devised the POS TARG strategy described above and especially to the late Nolan Walborn who devoted considerable time and energy devising the overall safety strategies specifically described in this work as well as devoting many years overseeing the safe and successful use of STIS for observations.

Change History for STIS ISR 2018-07

Version 1: December 10, 2018- Original Document

References

- Clampin, 1996, STIS Instrument Science Report 1996-31
- Leitherer & Clampin, 1996, STIS Instrument Science Report 1996-24
- Riley, A., et al. 2018, "STIS Instrument Handbook", Version 17.0, (Baltimore: STScI)

Appendix A

The original PN template supplied with the ETC (*pn_smooth*) is a model of NGC 7009 built from a variety of sources. It contains emission line fluxes across the UV, optical, and IR compiled from the literature as well as a calculated nebular continuum and a calculated blackbody continuum for the central star. This template would be an inappropriate choice for the second ETC calculation in Section 3 above because it includes the central source contribution. An extended object ETC calculation with this template would, in effect, treat the central star as also being extended and would lead to erroneously large global count rate estimates. A modified PN template that *only* includes the nebular component was delivered for the release of ETC 26.1. This template was created by subtracting out the flux of a $T_{\text{eff}} = 80000$ K blackbody normalized to $V = 12.6$ from the original template.

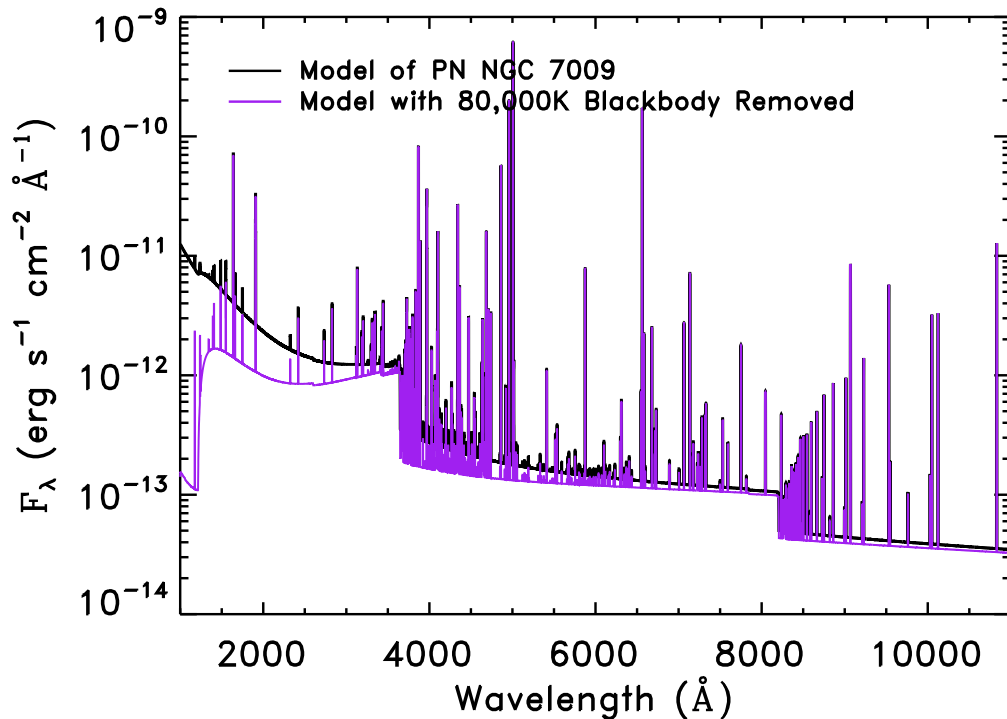


Figure 2. A comparison of the the planetary nebula template spectra now in place in the ETC. The original template (black) contains flux contributions from both the central point source and the extended nebula, whereas the modified template (purple) contains only nebular flux.