The Integrated Bright Object Tool (BOT) – STIS/MAMAs

R. Downes, T. Rogers, K. Peterson
December 21, 2006

Abstract

A integrated Bright Object Tool (BOT) has replaced the old VTT-based RObust Bright Object Tool. The main engine for the tool, as well as the basic processing steps, has remained unchanged, but the source of the input data, as well as the display of the results, have been changed to provide a more complete tool. The tool will check each exposure in a program for field (and prime) objects that are either health-and-safety concerns, or may impact the scientific value of the data. The tool will utilize the GSC2 catalog to determine the brightness and (rough) spectral type of all objects in the macro-aperture, determine the count rate and total counts for each object via a lookup table, and compare these values to limits set by the STIS Group. The output products will be a table listing the results for all objects, with the status of each object (health-and-safety concern, science concern, safe, or unknown status), and an Aladin image with the object's status indicated.

The new tool utilizes information in the proposal file, and also uses the APT and Aladin interfaces for its tabular and graphical display, respectively. For Instrument Scientists, the use of the proposal file, instead of the ASSIST database, allows for the support of position changes (e.g. POS TARGs) for exposures. For GOs, the use of the proposal file allows for more than one exposure to be processed at one time, making it much easier to run the tool on the entire proposal.

Introduction

The VTT-based Robust Bright Object Tool (ROBOT) has be utilized by both GOs and Instrument Scientists since Cycle 10. One of the main deficiencies of the tool for Instrument Scientists has been the inability to handle exposures with positional changes (e.g. POS TARGs), which is due to the need to access the ASSIST database. For GOs, the need to run each exposure individually makes proposal checking extremely tedious. The new tool will utilize information in the proposal, which eliminates both problems. The tool will use information in the Phase II proposal to identify all the stars in the macro-aperture that are in the GSC2 catalog. The color information of those stars will be converted to spectral types, and count rates (and total counts) for each star will be determined via a lookup table (based on Exposure Time Calculator results). The final products will be a tabular view of analysis of each star in the field (available through the APT interface) and a graphical view (available through the Aladin interface), in which all stars with health-and-safety concerns are labelled in red, all stars with science concerns (e.g. bright targets that could bleed) are labelled in orange, all stars for which an analysis could not be performed (e.g. incomplete color information) are labelled in blue,and all stars that are safe are labelled in green. There will also be a printable and downloadable listing of the results for all targets.

It is important to note that BOT will only be useful for field stars that are in the GSC2, and for the target if it is a normal star. Since most science targets are not normal main-sequence stars, use of the ETCs to fully verify the prime targets will still be required. Extended targets will not appear in the GSC2, and will therefore need to be checked by hand. Variable targets, although in the GSC2, will only have the magnitude at the time of the GSC2 plate, and may therefore not have the "correct" magnitude for the time of observation. While most variables have small amplitudes, some objects (e.g. cataclysmic variables and symbiotics) have large amplitudes, which could pose problems (either as field objects, or as the prime target).

In this document, we describe how the tool works for the STIS/MAMAs. This tool will enhance (compared with the VTT-based ROBOT) the bright object checking performed by the Instrument Group, and can allow PIs to more easily do their own checks to assure their observations are valid from both a health-and-safety as well as scientific integrity perspective.

Assumptions

The following assumptions were made in implementing BOT processing:

- The size of the macro-aperture (search radius) is padded over the nominal size to account for possible mispointings (but still close enough for the Guide Star acquisition to be considered successful) of HST. The size of the pad – 20.9" - was determined by the Instrument Group.

- All field objects are Main Sequence stars. This is a reasonable assumption, although it will not be always correct (e.g. most prime targets are not normal stars). This is the only assumption possible due to only 1 color being available.

- All objects have no reddening. This is clearly incorrect in the plane, but is not unreasonable at high galactic latitude (where most HST observation are obtained). This is the only assumption possible due to only 1 color being available. Since reddening would decrease the ultraviolet flux, this is also the conservative assumption when doing health-and-safety checks.

- For objects that have only an F magnitude, an extended search is performed around the position and assume the J magnitude of the object is equal to the faintest J magnitude detected. Since the object was not detected, and since we can detected objects at this limit, the object cannot be brighter than this limit. This conservative assumption allows us to process and clear many objects that would otherwise require "manual" processing.

- All objects with B-V<+0.1 are assumed to be O5V stars. This assumption is necessary due to the near degeneracy in the spectral type-color relation at the blue end.

- All objects above a Vcrit value (spectral element dependent) are assumed to be O5V stars. This assumption is necessary due to the lack of reddening information.

- The GSC2 flag indicating the object is not a star is ignored for all faint (V > 17) objects. This is due to the fact that the reason most of these objects have the flag set due to the poor S/N in the PSF. While is issue is important in determining the object can be used as a guide star, it is not relevant for bright object checking. Failure to do this resulted in a large number of "unknown" objects appearing in many fields, which then needed to be "manually" cleared.

Processing Steps

1. The user loads their Phase II APT file, and selects their desired exposure(s) to process.
2. The user clicks on the BOT button to bring up the tool, and clicks on the Update Display button to begin processing.
3. The GSC2 is searched for all objects (even those flagged as not usable as guide stars) within the macro-aperture. The macro-aperture is a circle centered on the fiducial point of the aperture (i.e. where the prime target will be placed) that encompasses the entire aperture with a pad to account for pointing errors.

Detector	**Shape**	**Radius**	**Radius in ROBOT**	**Radius in BOT**
STIS/MAMA	quad	17.9”	35.4”	38.8”

Note that this definition of the macro-aperture is not always consistent with the values in the SIAF files. All area targets are ignored. The information returned is the object name, coordinates, and magnitudes (**F** and **J**). If either the F or J magnitude is undefined, convert the default value of “-99.9” to “unknown”. Note that Tycho entries in the GSC2 will have **V** and **B-V**, and these must be corrected to get them on the standard system via:

V(corrected) = **V**(Tycho) - 0.09***B-V**(Tycho)

B-V(corrected) = 0.85***B-V**(Tycho)

4. The **F** and **J** magnitudes are converted to **V** and **B-V** via the following conversions:
   - for the northern hemisphere (determined by the coordinates of the stars)

     $\mathbf{V} = \mathbf{F} + 0.03 + 0.44*(\mathbf{J}-\mathbf{F}) - 0.03*(\mathbf{J}-\mathbf{F})^2 + 0.02*(\mathbf{J}-\mathbf{F})^3$

     $\mathbf{B}\text{-}\mathbf{V} = -0.04 + 0.69*(\mathbf{J}-\mathbf{F})$
   - for the southern hemisphere

     $\mathbf{V} = \mathbf{F} + 0.03 + 0.43*(\mathbf{J}-\mathbf{F}) - 0.02*(\mathbf{J}-\mathbf{F})^2 + 0.02*(\mathbf{J}-\mathbf{F})^3$

     $\mathbf{B}\text{-}\mathbf{V} = -0.03 + 0.73*(\mathbf{J}-\mathbf{F})$

5. Some objects in the GSC2 do not have both and F and J magnitudes, while other objects are not considered stars. The treatment of these objects depends on the detector selected, and is described below.

Detector	**no F and no J**	**F and no J**
STIS/MAMA	list F, J, V, B-V, and rea son as "unknown", spec tral type as "no color info"	For objects with F fainter than 17.0, do a second query of the GSC2 using a 10 arcminute radius centered on the target coordinates. From the targets detected in this query, select the J magnitude of the faintest object, and add (make brighter) 0.2 magnitudes. Use this value as the J magnitude of the target and process normally. For objects brighter than F=17.0, list J, V, B-V, and reason as "unknown", F as GSC2 value, spectral type as "no color info"

Detector	**no F and J**	**F and J, not a star**
STIS/MAMA	list F, V, B-V, and reason as "unknown", J as GSC2 value, spectral type as "no color info"	Compute the V magnitude as though the object were a star. If the V magnitude is fainter than a cutoff value (which is the V of an O5 star in the "worst" filter reddened by E(B-V)=0.6 which is just safe; if the object were reddened less, the object would be treated by the tool as an O5 star), then treat the object as a star. The cutoff values are FUV (25MAMA)= 15.8 and NUV (25MAMA)= 16.5

6. After the **V** and **B-V** is derived, a sanity check should be performed. If the **V** magnitude is fainter than 24 or brighter than -2.0, or if the **B-V** color is redder than 3.0 or bluer than -0.5, the photometry is faulty and should not be used. The **V**, **B-V**, and spectral type should be listed as “unknown”.

7. The **B**-**V** color is converted to a spectral type (assumed main sequence) via the table below . The tool will adjust the color by the difference between the nominal error and the actual error (i.e. make the color bluer by [error - 0.28^m]); for objects with inferred J magnitudes (see Step 5), do not correct for errors. To determine the error, use the square root of the sum of the squares of the **F** and **J** errors. Note that for the health-and-safety checks, we will treat all stars with **B**-**V** colors less than or equal to +0.1, and all stars brighter than or equal to a critical V (V_{crit}) magnitude (filter/ grating dependent), as O5 stars; the V_{crit} values are listed in **Appendix 1 – Vcrit values**. While this may result in false positives, analysis has shown that the rate is acceptably low. To interpolate, always take the bluest color (e.g. if the star has B-V=0.85, select K0).

Color to Spectral Type conversion

B-V	**Spectral Type**	**B-V**	**Spectral Type**
-0.32	O5	-0.30	B0
-0.24	B1	-0.14	B5
0.00	A0	+0.03	A1
+0.14	A5	+0.31	F0
+0.43	F5	+0.59	G0
+0.63	G2	+0.66	G5
+0.82	K0	+1.15	K4
+1.41	M0	+1.49	M2
+1.61	M4		

8. The exposure information is derived from the proposal file, and the relevant parameters are given below.

Exposure Parameters

Detector	**Parameters**
STIS/MAMA	spectral element, central wavelength, exposure time, aperture

9. Based on the magnitudes, apertures, and exposure information, determine the count rate and total counts for each star via a lookup table (see **Appendix 2 - STIS Sample Lookup table**). The table contains the count rate for all (see **Appendix 3 – Number**

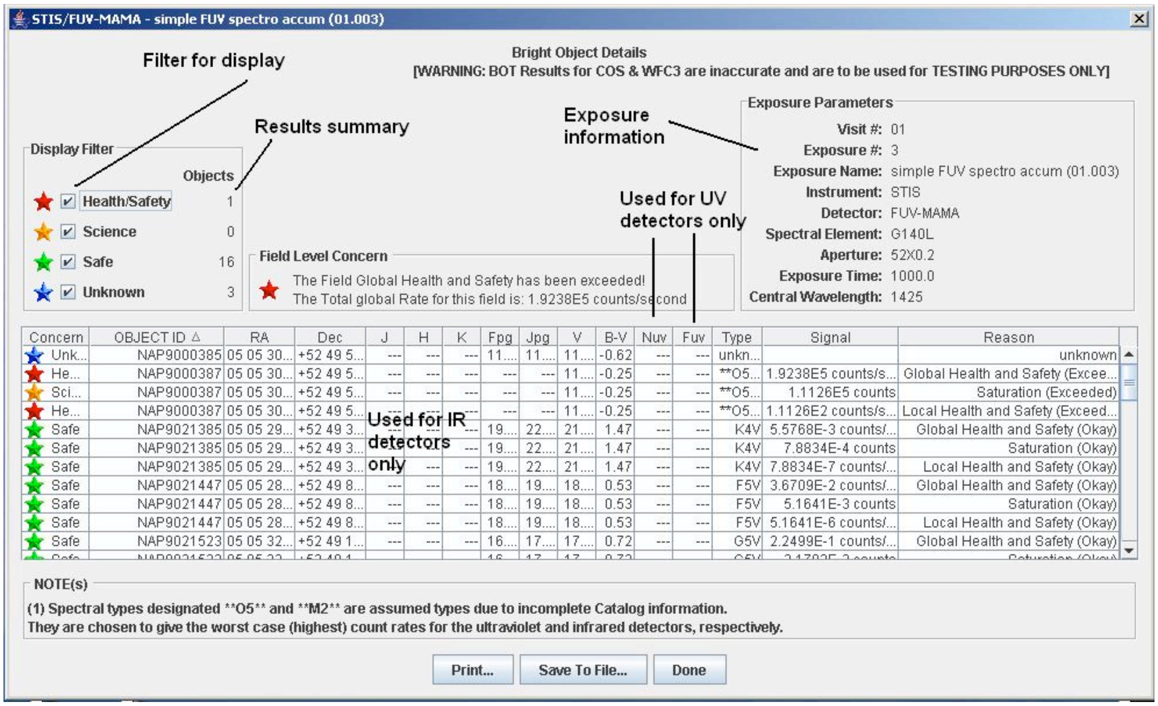
of Instrument Configurations) instrument configurations for a **V** = **V_o** object. To scale for the true **V** magnitude of a star, multiply the table value by $10^{(0.4*[V_o - V_{obj}])}$. To determine the total counts, multiply the corrected count rate by the exposure time. For the STIS/MAMA imaging observations (spectral element not starting with G, E, or P), a slightly more complicated procedure is needed. The lookup table values have had the sky background contribution removed. After scaling the counts for the V magnitude, the sky contribution (see **Appendix 4 - MAMA Imaging Sky Background Values**) needs to be added back in. Also, a "field check" should be performed by summing the count rates for all the objects in the field and forming a "pseudo-object"; note that the count rates should be summed before adding in the (single) sky value.

10. Based on the count rates and total counts, perform the health-and-safety and science checks as described in the table below. For the “pseudo-objects”, compare the count rate with the appropriate value in the table for the GLOBAL check only.

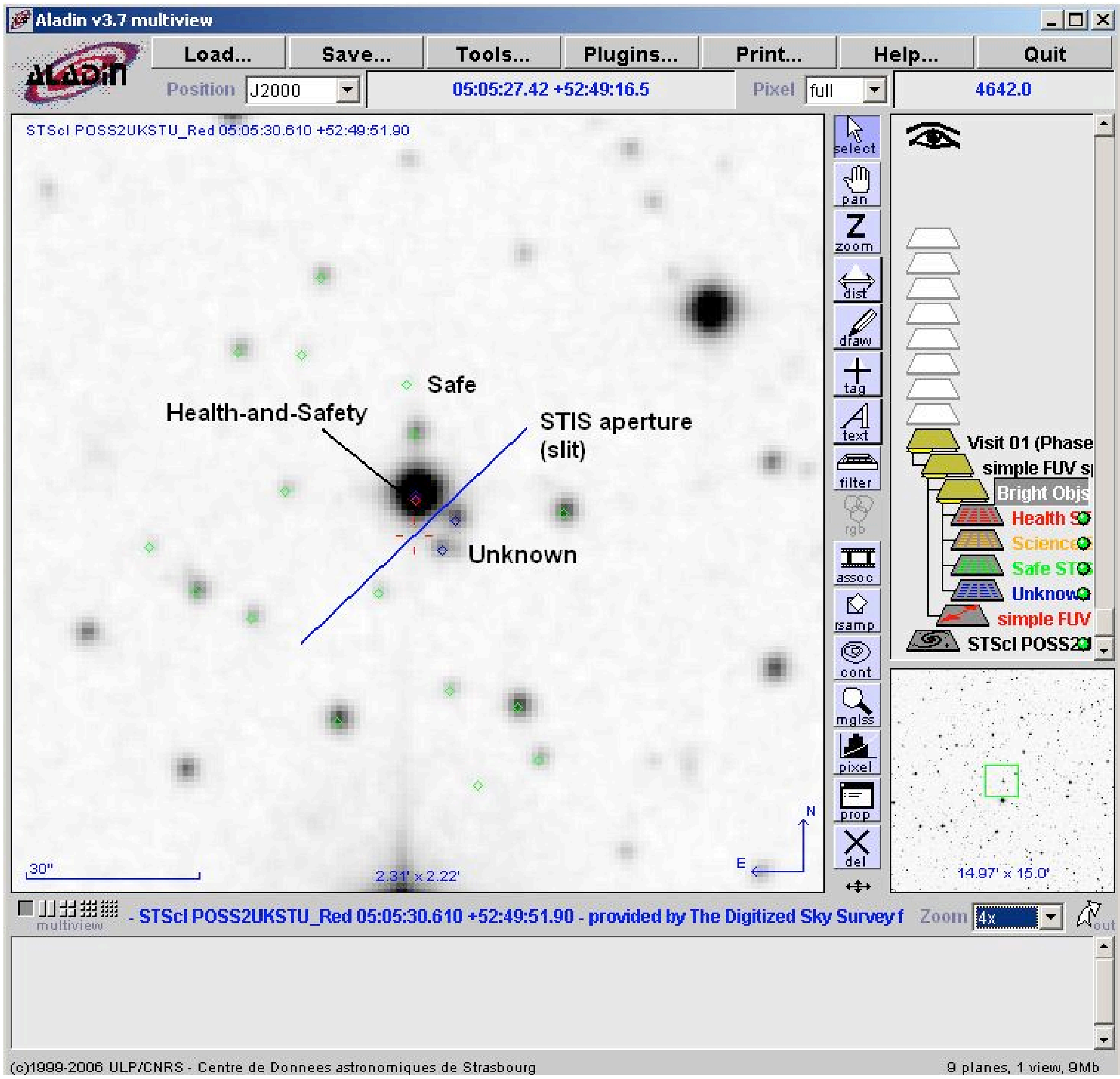
Checks Performed by BOT

Detector	**Health-and-Safety (counts/second)**	**Saturation (electrons)**
STIS/FUV- MAMA	Global: 200,000 (Imaging, E) Global 30,000 (1st order) Local 100 (imaging) Local 75 (spectroscopy)	65536
STIS/NUV- MAMA	Global: 200,000 (Imaging, E) Global 30,000 (1st order) Local 100 (imaging) Local 75 (spectroscopy)	65536

11. For all objects, produce a table giving the guide star name, coordinates, F and J magnitudes, converted V and B-V magnitudes, spectral type, signal (count rate and total counts), and an indication of the status of the object; a summary table should also be produced. For assumed spectral types (i.e. O5), make clear that the type is assumed and not derived from the B-V color. Note that this table is printable and downloaded to be a file.



12. For all objects, produce an overlay for Aladin which marks objects that are health-and-safety concerns in red, science concerns in orange, unknown concerns in blue, and safe objects in green.



Appendix 1 – V_{crit} values

Given the degeneracy of B-V (and V-R) for the bluest stars, we want to be conservative and say that all stars with B-V less than some value should be considered O stars. Also, since we only have 1 color in the GSC, we have to worry about reddened O stars looking like later-type objects. To determine the appropriate color cutoff, I selected a cutoff (B-V=+0.1), and determined what V magnitude (V_{crit}) would make an O5 star (B-V=-0.3, so E(B-V)=0.4) safe. The checking rule would then be that all stars brighter than V_{crit} and all stars with B-V<+0.1 are assumed to be O5, while the remaining objects have the spectral types set by their observed color. See the ROBOT document for more detailed analysis on the number of false positives.

Instrument	Detector	Spectral Element	Central Wavelength	V_{crit}
STIS	FUV	F25ND5		4.5
		F25ND3		9.5
		F25LYA		12.6
		F25QTZ		15.0
		25MAMA		17.0
		F25SRF2		16.5
		G140L	1425	12.0
		G140M	1420	9.0
		E140M	1425	8.0
		E140H	1416	7.5
	NUV	F25ND5		4.8
		F25ND3		9.8
		F25MGII		13.2
		F25CIII		12.8
		F25CN182		15.0
		F25CN270		15.0
		25MAMA		17.3
		F25QTZ		17.3
		F25SRF2		17.4
		G230M	2338	8.5
		G230L	2376	12.0
		E230M	1978	7.5
		E230H	2263	6.6

Appendix 2 - STIS Sample Lookup table

The following items are used in creating the lookup table;

- Exposure time = 1
- V=10 (point source) for spectra, V=8 (point source) for imaging, E(B-V) = 0.0
- Zodiacal light/Bright Earth = average

Spectral Type	Detector	Spectral Element	Central Wavelength	Aperture	Countrate Local/Global
B5	NUV-MAMA	G230L	2376	52X2	TBD/TBD
B5	NUV-MAMA	G230M	1687	52X2	TBD/TBD
B5	NUV-MAMA	G230M	2419	52X2	TBD/TBD
B5	NUV-MAMA	G230M	3055	52X2	TBD/TBD
B5	FUV-MAMA	G140L	1425	52X2	TBD/TBD
B5	FUV-MAMA	G140M	1173	52X2	TBD/TBD
B5	FUV-MAMA	G140M	1420	52X2	TBD/TBD
B5	FUV-MAMA	G140M	1714	52X2	TBD/TBD
B5	FUV-MAMA	PRISM	1200	52X2[a]	TBD/TBD
B5	NUV-MAMA	E230M	1978	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230M	2707	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	1763	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	2263	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	2513	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	2762	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	2013	0.2X0.2	TBD/TBD
B5	NUV-MAMA	E230H	3012	0.2X0.2	TBD/TBD
B5	FUV-MAMA	E140M	1425	0.2X0.2	TBD/TBD
B5	FUV-MAMA	E140H	1234	0.2X0.2	TBD/TBD
B5	FUV-MAMA	E140H	1416	0.2X0.2	TBD/TBD
B5	FUV-MAMA	E140H	1598	0.2X0.2	TBD/TBD
B5	NUV-MAMA	25MAMA			TBD/TBD
B5	NUV-MAMA	F25ND3			TBD/TBD
B5	NUV-MAMA	F25ND5			TBD/TBD
B5	NUV-MAMA	F25QTZ			TBD/TBD
B5	NUV-MAMA	F25SRF2			TBD/TBD
B5	NUV-MAMA	F25MGII			TBD/TBD
B5	NUV-MAMA	F25CN270			TBD/TBD
B5	NUV-MAMA	F25CIII			TBD/TBD

B5	NUV-MAMA	F25CN182			TBD/TBD
B5	FUV-MAMA	25MAMA			TBD/TBD
B5	FUV-MAMA	F25ND3			TBD/TBD
B5	FUV-MAMA	F25ND5			TBD/TBD
B5	FUV-MAMA	F25QTZ			TBD/TBD
B5	FUV-MAMA	F25SRF2			TBD/TBD
B5	FUV-MAMA	F25LYA			TBD/TBD

Appendix 3 – Number of Instrument Configurations

To keep the lookup table manageable, we will make several simplifying assumptions. For ACS/SBC, no such assumptions were necessary.

Based on the above assumptions, the following table estimates the number of entries in the lookup table for each instrument..

Instrument Configurations

Instrument	Parameters	Configurations	Spectral Types	Total
STIS	FUV-MAMA spectra 8 cenwaves, 14 aperture	112	13	1456
	FUV-MAMA imaging 6 filters	6	13	78
	NUV-MAMA spectra 7 cenwaves, 14 aperture	98	13	1274
	NUV-MAMA imaging 9 filters	9	13	117

Appendix 4 - MAMA Imaging Sky Background Values

Detector	Detector	Filter	Global Background	Local Background
STIS	NUV	25MAMA	4774	
		F25SRF2	2098	
		F25QTZ	1634	
		F25MGII	1470	
		F25CN270	1472	
		F25CIII	1470	
		F25CN182	1547	
		F25ND3	1471	
		F25ND5	1468	
	FUV	25MAMA	19430	
		F25SRF2	1915	
		F25QTZ	7	
		F25LYA	7985	
		F25ND3	26	
		F25ND5	7	