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Revised Procedures for Creating Charts to Support MAMA Moving Target Bright Object Protection

Charles Proffitt, Brian McLean, and James Davies
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ABSTRACT

We describe a revised set of procedures and software for creating finding charts and object catalogues which can be used to assess the risk to the STIS MAMA and ACS SBC detectors from bright blue objects in the vicinity of proposed planetary observations. These charts show the path of a given planet, moon or comet across the background of stars, down to the magnitude limit of the GSC2 digitized sky survey plates. Associated object catalogues and color-magnitude diagrams are also produced showing which stars may violate bright object limits for the selected instrument mode.

Introduction

Because the STIS NUV-MAMA, FUV-MAMA and the ACS SBC detectors run the risk of being over-illuminated and sustaining localized damage from UV-bright sources during exposures, procedures were devised to prevent the accidental imaging of such targets. For moving targets, the challenge is greater, as the background field changes as the moving planet or comet traces a path along the sky. In general, the exact timing of moving-target observatons is not known until shortly before the observation is scheduled. This means that the Instrument Scientist doing the bright-object protection (BOP) check has to be prepared to assess, on a short time scale, the risk to the instrument from background stars anywhere along the planet's path during a given observing window of time. The charts and object catalogues described in this document are among the tools the Instrument Scientist uses to carry out the BOP check.

This TIR describes the software used to assist these moving target bright object checks and is an update of STIS TIR 2005-01. The core of this procedure is a set of IDL routines which overlay the track of a moving target on plate images from the DSS, while also labeling stars and producing a corresponding catalog of the GSC2 J and F plate magnitudes. These routines were originally written by Mike Potter to be used on the GSC project's VAX computers. One of this papers authors (JD) made some modifications to get some of these routines to run on Solaris work stations. Another of the authors (BM) then modified these routines to access the DSS images and catalogs via a web interface, finally freeing them completely from the GSSS Vax machines. CP then made additional modifications to automate the production of HR diagrams and to improve the ability to quickly identify only those stars that need further attention for the particular mode under consideration.

Details of Procedure

Producing finding charts that show the path of the moving target superimposed on a star field with an associated object catalog for the star field involves a number of steps. The calculation of the moving target emphemerides requires the PERCY[1] program which is currently only available on STScI Solaris systems. The rest of the procedure uses a number of IDL scripts which interact with the GSSS databases and extract images from the DSS. These scripts can now be run from any computer with an IDL license and WWW access. The following is a step-by-step guide to creating the BOP charts for solar system objects. Straight cookbook walkthroughs of a couple of examples, without any added discussion, are also given in "Appendix 1: Walkthroughs for some basic examples" on page 13.

Setting up the IDL XSPAM environment

Many of the routines used to produce the charts use a IDL package developed for use with the HST Guide Star catalog. Copies of these routines are currently located on the Solaris science cluster in the directory `/data/inline1/teams/acs/xspam`. This directory also contains a shell script named `idlxspam`, which, when executed from the unix command line, will define the needed environment variables, add the xspam directories to the IDL search path, and then start the proper version of IDL using the `xspam_ini.pro` startup routine. If these routines are installed on another system, this `idlxspam` script should be modified to use the appropriate path names.

1. PERCY is described at http://www.pst.stsci.edu/moss/moss_public.shtml.

Create the ephemerides

The PERCY program in the Moving Object Support System (MOSS) software is used to create ephemerides for the target. The ephemerides give the right ascension and declination for each hour UT over the entire observing window. These RA and DEC positions as a function of time will be used to plot the path of the moving target over the star fields for given observing windows.

Generating the ephemeris requires executing a number of commands inside PERCY. These were detailed in both the PERCY documentation and in the predecessor to this document (STIS TIR 2005-1) but are not repeated here. Instead, to avoid having to hand edit a number of PERCY scripts, we have added to the idlxspam package a simple IDL procedure that will generate a set of PERCY commands that are adequate for most cases. After starting up the xspam environment as described above, simply run the command:

```
XSPAM > make_percy_file,object,begintime,endtime
```

where "**`object`**" is the name of a target that is recognized by PERCY, and "**`begintime`**" and "**`endtime`**" are string variables giving the day-month-year. There is also an optional `obsname` keyword which will append an extra text string to the output file. So to compute the ephemeris for Saturn during January 2007, the command to be typed at the xspam prompt could be:

```
XSPAM > make_percy_file,'titan','1 mar 2007','15 mar 2007',obsname='07'
```

This will produce a text file called `titan07.per` which contains the commands that need to be executed inside PERCY to produce the ephemeris. The script is designed to automatically exclude times when the target is closer than 45 degrees to the Sun, as during these times the object cannot be observed by HST.

To run PERCY, one needs an account on the Unix science cluster, and the setup script needs to be run by typing the following at the unix command line:

```
unix> source /data/moss/moss_setup
```

This statement can also be put into the unix `.setenv` file or another startup file which is executed during login, but if the disk **`/data/moss`** is unavailable, this could prevent the login procedure from completing, and make it difficult to log into your account!

Percy can then be started by typing `percy` on the unix command line. Starting PERCY will take a while. Once the **`Percy->`** prompt appears, type the line given below to execute the commands in the file created by the `make_percy_file` IDL routine. The

";" is required after each command in PERCY; long commands can be entered over several lines and will not be executed until a line terminated with a ";" is entered.

```
Percy-> start titan07.per;
```

This will execute the script that was generated by the `make_percy_file` procedure, calculating the position of Titan between the specified begin and end times, at one hour intervals, as seen from the center of the Earth (note that 606 and 399 are the internal indices that Percy uses to refer to Titan and the Earth). A look at the resulting ephemerides file `titan07.eph1` shows:

```
         UT   --- TIME FORMAT YYYY-MON-DD HR:MN:SC ::RND
         RA   --- J2000 RIGHT ASCENSION OF 606 FROM 399 FORMAT
                  XXX.XXXXXXX UNITS DEGREES
         DEC  --- J2000 DECLINATION OF 606 FROM 399 FORMAT XXX.XXXXXXX
                  UNITS DEGREES
         DIST --- DISTANCE OF 606 FROM 399 FORMAT XX.XXX UNITS AU

         Light-time correction is applied.


2007-MAR-01 00:00:00  142.9457270   16.0262224    8.261
2007-MAR-01 01:00:00  142.9436367   16.0273355    8.262
2007-MAR-01 02:00:00  142.9415461   16.0284514    8.262
2007-MAR-01 03:00:00  142.9394552   16.0295702    8.262
2007-MAR-01 04:00:00  142.9373637   16.0306917    8.262
2007-MAR-01 05:00:00  142.9352712   16.0318160    8.262
2007-MAR-01 06:00:00  142.9331777   16.0329430    8.263
2007-MAR-01 07:00:00  142.9310829   16.0340728    8.263
2007-MAR-01 08:00:00  142.9289865   16.0352052    8.263
2007-MAR-01 09:00:00  142.9268884   16.0363403    8.263
...
```

Standard, predefined objects in PERCY currently include the nine "classical" planets and most of their named moons. To produce a set of ephemerides for another object, such as a comet or asteroid, the target will first have to be defined and its orbital elements specified. Sample commands to do this are given below for the comet NEAT-2001Q4. The commands for specifying the orbits of asteroids and new planetary satellites are very similar; see the PERCY documentation for more details. These commands can either be typed at the Percy prompt or put into a run file.

```
define neat-2001q4 10001;
make comet neat-2001q4 using elements
   distance of periapse 0.9620902173959869 au
   eccentricity 1.000704343327172
   inclination 99.62258884399483 degrees
   longitude of node 210.2505442849937 degrees
   argument of periapse 1.19540159595864 degrees
   time of passage tdb 15-may-2004:11:15:26.0
   epoch of elements tdb 04-nov-2002
   beginning jan 1 2004
```

```
ending jan 1 2006
frame ecliptic
equinox j2000
maximum relative error 0.001 arcseconds
maximum absolute error 10 kilometers
insert into new "neat-2001q4.bsp";
```

Obviously the dates, object and file names, and the orbital elements will be different for any given object. The orbital elements are usually given in the observer's Phase-II proposal, although for comets these are likely to change significantly due to non-gravitational effects on the comet's orbit. More accurate elements may only be available shortly before the observation executes, and the IS should consult with the PI and the PC to ensure that the field screened for bright objects is large enough to cover the range of possible positions.

Once the object has been defined in PERCY, the user can proceed as above by using the newly defined object name, (`"neat-2001q4"` in this case), in place of a standard object's name.

PERCY and APT support a wide variety of ways to designate targets that point HST somewhere other than the center of the moving object being observed. While any offset could be taken into account by simply expanding the bright object search radius, this can make clearing observations in crowded fields much more difficult. When possible it is better to simply use the ephemeris for the position actually targeted.

As a practical matter, for moving target SBC programs, the most common way of specifying such an offset is by giving a position angle in degrees from celestial north and a radius in arc-seconds from the target's center. In the phase 2 files, this will appear in the LEVEL 2 or LEVEL 3 moving target specification as "**`TYPE=POS_ANGLE, RAD=20.0, ANG=90.0, REF=NORTH`**". To support this we have added an option to the "make_percy_file.pro" IDL script that will include the necessary PERCY commands in the **`.per`** file. Simply include the option npa=[PA,radius] with PA in units of degrees east of celestial north and the radius given in arcseconds, when running the IDL procedure, e.g.:

```
XSPAM>make_percy_file,'jupiter','01-feb-2007','02-mar-2007',npa=[90.,20.]
```

Use of the IDL XSPAM scripts to produce star catalogues and charts.

Be sure to first be in the desired working directory with a copy of the eph1 file produced by the Percy procedures discussed above. Then execute the `idlxspam` shell script described above, and this will start up IDL and load the xspam environment.

The `mtwebprocess` procedure takes the .eph1 file produced above and creates the `.plt2` file which contains a list of the best plate for each position. For instance, if our ephemeris file is called '`titan07.eph1`', the following command should be entered:

```
XSPAM > mtwebprocess,'titan07',targetname='Titan',targetdiam=0.86
```

This task is set by default to use the blue or "J" emulsion plate from the DSS. If a different emulsion is desired, the routine can be used with the optional flag `platecolor='F'` or `platecolor='N'` to use the red or infrared plates instead. The `mtwebprocess` task can also take an optional flag (`/MARS, /JUPITER, /SATURN, /URANUS, /NEPTUNE,` or `/PLUTO),` which will set the size and name of the planet automatically. Otherwise, the user will have to enter this information using the `targetname` and `targetdiam` keywords or when prompted. Note that using the `targetdiam` keyword fixes the angular size of the target in arcseconds, while the other options will adjust the angular size as the distance between the Earth and the target varies.

The `mtwebchartlist` routine is then used to create the `.plt3` file (list of moving target positions, the `.cdf` file (with information about the charts), and `.fits` files containing the extracted pieces of the DSS images, one for each chart to be made.

```
XSPAM > mtwebchartlist,'titan07'
```

The names of the .cdf and .fiits files are created from the first six characters of the ephemeris name, plus the chart number. So in our Titan case, the first `.cdf` file is `titan0_0001.cdf`, and the first fits file is `titan0_0001.fits`. So at the end of this step, there should be one `.plt3` file and a number of `.cdf` and `.fits` files in the working directory, each corresponding to a single chart. In this Titan example, there are 7 charts.

Finally, the charts and catalog files are created by the `MTCHARTS_SBC` task:

```
XSPAM > mtcharts_sbc,'titan07','Titan',/acs,insmode='F115LP'
```

This task takes the rootname of the `.plt3` file as its first argument, the name that will appear on the charts as its second argument, and then either `/ACS` or `/STIS` depending on the instrument to be used. For ACS, the particular instrument mode may also be specified. This option is not yet implemented for STIS modes. Specifying the instrument will determine the size of the track plotted. STIS MAMA imaging modes typically used a 25x25 arcsecond FOV which taken diagonally gives a maximum size 35 arcsecond-width track (solid line in Figure 1), and the ACS SBC requires a 70" diameter macro-aperture to cover all possible rotations. The dotted lines show an extra 5" buffer. If the optional parameter `QYN='Y'` was used in the `mtwebchartlist` routine, the position of the dotted lines will be increased by the radius of the target.; this allows the delimited region to cover centering the target on any location of the planet's disk. These routines do not contain any provision for adding an arbitrary increase to the size of the area marked, such as might be required to support POS TARGS.

Depending on the shape of the track, the software will pick the optimum number of plots per page. In our example, the seven charts are plotted on three pages (with rootnames `titan0_p0001, titan0_p0002, and titan0_p0003`). By default two versions of each of these postscript pages are produced; a third version is produced if the `insmode` option is specified. Note that the first part of the postscript file names are truncated to 6 characters in length.

- `titan0_p000*.ps1` - charts show the GSC2 image with path of the moving target over plotted.
- `titan0_p000*.ps2` - same as `.ps1`, but with stars labelled. Each label corresponds to an entry in that chart's `.cat` file.
- `titan0_p000*.ps3` - same as the `.ps2` file, but only those stars that are within 1 sigma of the screening limits or are brighter than the screening limits for the instrument mode, are labeled. Stars in the catalog with no colors are also labeled. These files are only produced if the `insmode` is specified.

In crowded fields, so many stars may be labeled that the `.ps2` file becomes unreadable. The number of stars labeled can be limited by specifying a magnitude range in the call to `mtcharts_sbc`, by using the optional keywords `j_lim` or `f_lim.` For example, to label only those stars with J plate magnitudes between 17 and 0, use `j_lim = [0,17]`. There is also a `jf_lim` keyword which can be used to set limits on the J-F colors of labeled stars. These limits are not applied to the labeling of the `.ps3` file.

Evaluating the Outputs

A section of a BOP chart (the .ps2 file) for Titan is shown in Figure 1. The path of the moon is plotted over the star field, and the labelled stars correspond to entries in the catalog file.

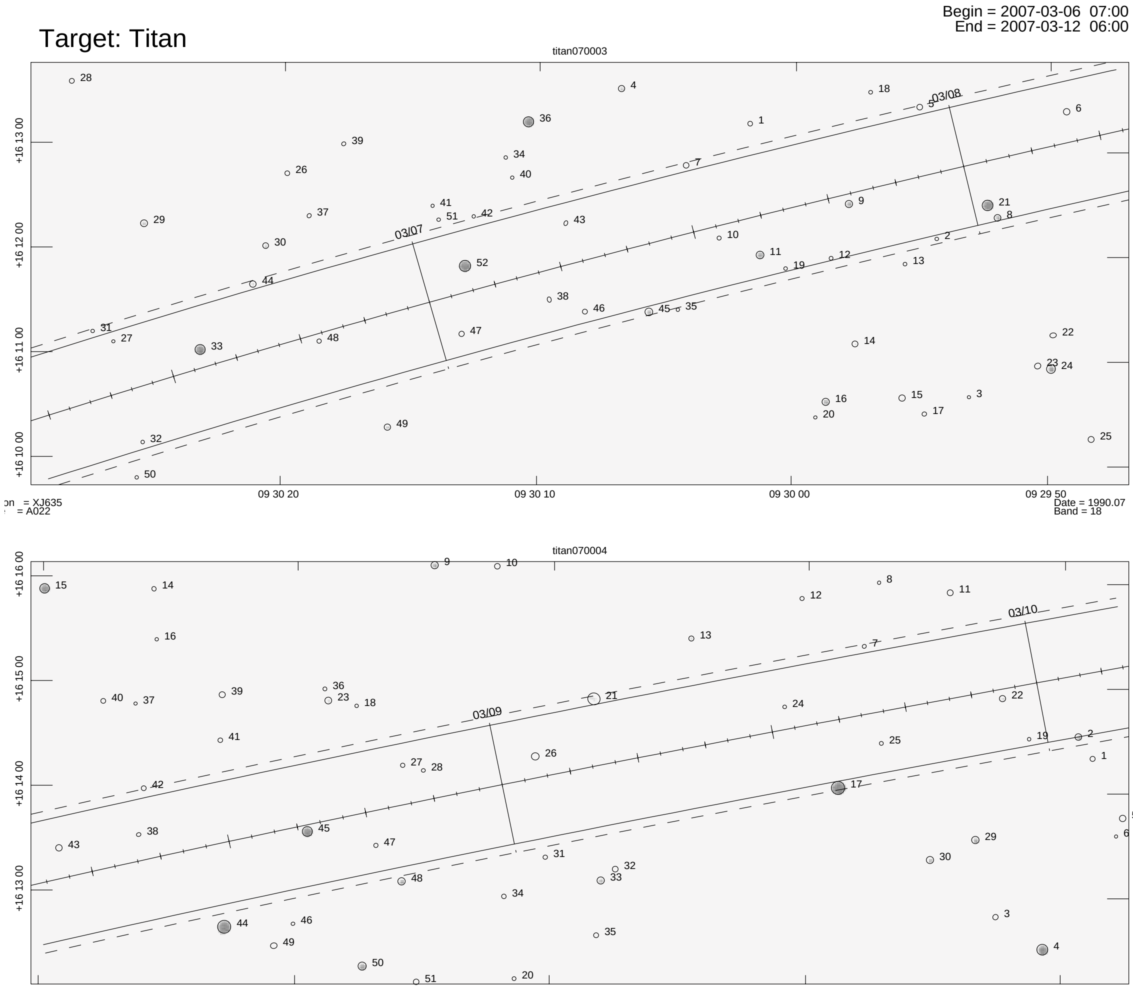

Figure 1: A section of a BOP chart (the .ps2 file) for Titan. The path of this satellite of Saturn is plotted over the star field, and the labelled stars correspond to entries in the catalog file.

In addition to the postscript pages, `.cat` files are produced for each chart, and these files list all cataloged stars on the `.ps2` postscript pages' charts. Since there may be multiple charts per page, the numbering of the `.cat` files will differ from that of the `.ps*` files.The beginning of the `titan070003.cat` file for our Titan example looks like the following:

```
==============================================================================
 =============================================================================
   Object Catalogue For Plot titan070003

    Object              RA            Dec        J     F     Cl  Status
   #      ID         hh mm ss.ss  ddd mm ss.s   Mag   Mag
------------------------------------------------------------------------------
    1    N8Z1008564   9 30  1.72  +16 13 16.7  21.13 99.90  3       1000
    2    N8Z1008537   9 29 54.35  +16 12 11.2  21.57 99.90  3       1000
    3    N8Z1008522   9 29 53.03  +16 10 40.1  21.54 99.90  0       1000
    4    N8Z1004979   9 30  6.78  +16 13 36.3  18.64 17.32  0        111
....
```

Missing magnitudes are listed with a value of 99.90. Unfortunately the catalog does not give the reason for the missing magnitude or estimate upper limits. So a star too faint to be seen on that plate gets the same value as a star that is too bright to measure. Of course this can be easily resolved by looking at the image.

Each object ID in the `.cat` file corresponds to a star in the corresponding chart in a `.ps2` file. Stars not labeled because they fall outside the magnitude limits set by the `*_lim` keywords are still included in the `.cat` file.

When the `INSMODE` is specified, a postscript plot of the color-magnitude diagram for each field is also produced in a file with the extension `.hrps` (see Figure 2). The estimated V magnitudes and *B*– *V* colors of all stars, (see “Appendix 2: Estimating V and B – V from GSC2 colors” on page 13), are plotted together with the IHB handbook limits for the mode specified. A `.cat3` file is also produced which includes the IR N plate magnitudes and the estimated *V* and *B*– *V* values:

```
================================================================================
   Object Catalogue For Plot titan070003

    Object              RA           Dec         J     F     N      V    B-V   col
   #      ID        hh mm ss.ss  ddd mm ss.s   Mag   Mag   Mag    (est. GSC2) use
--------------------------------------------------------------------------------
    1    N8Z1008564   9 30  1.72  +16 13 16.7   21.13 99.90 99.90  21.44 -0.40   J
    2    N8Z1008537   9 29 54.35  +16 12 11.2   21.57 99.90 99.90  21.88 -0.40   J
    3    N8Z1008522   9 29 53.03  +16 10 40.1   21.54 99.90 99.90  21.85 -0.40   J
    4    N8Z1004979   9 30  6.78  +16 13 36.3   18.64 17.32 16.99  17.93  0.90  JF
    5    N8Z1004968   9 29 55.07  +16 13 27.2   20.87 18.36 16.88  19.64  1.75  JF
    6    N8Z1004966   9 29 49.30  +16 13 25.2   19.60 17.49 16.06  18.51  1.46  JF
    7    N8Z1004943   9 30  4.22  +16 12 52.4   20.53 18.35 17.63  19.42  1.51  JF
    8    N8Z1004921   9 29 51.97  +16 12 23.7   17.79 17.07 16.89  17.41  0.48  JF
    9    N8Z1004920   9 29 57.81  +16 12 30.9   17.37 16.62 16.68  16.97  0.50  JF
...
```

These values are compared to handbook limits for each mode and only those stars within 1 σ of the limits or which are clearly brighter than those limits are labeled in the `.ps3` file. Currently the software is set up to label in the `.ps3` file those stars that might be above the reddened O-star screening limit (the slanted dashed line in Figure 2).

The final output is a chart directory file called `titan_chart_catalogue.txt` in our Titan example. It gives the beginning and end times for each page, and it lists the corresponding catalog files for each page. It looks like the following:

```
------------------------------------------------------------------------------
             Date & Time                          CDF Files          PostScript
       Begin              End                   Begin      End          File Name
------------------------------------------------------------------------------
 2007-03-01  00:00  2007-03-06  07:00   titan070001  titan070002  titan0_p0001
 2007-03-06  07:00  2007-03-12  06:00   titan070003  titan070005  titan0_p0002
 2007-03-12  06:00  2007-03-15  00:00   titan070006  titan070006  titan0_p0003
...
```

From this file we can see that the first postscript file of each type contains two charts, the second three charts, and the last only one. In all, about 35 files were produced while running this example

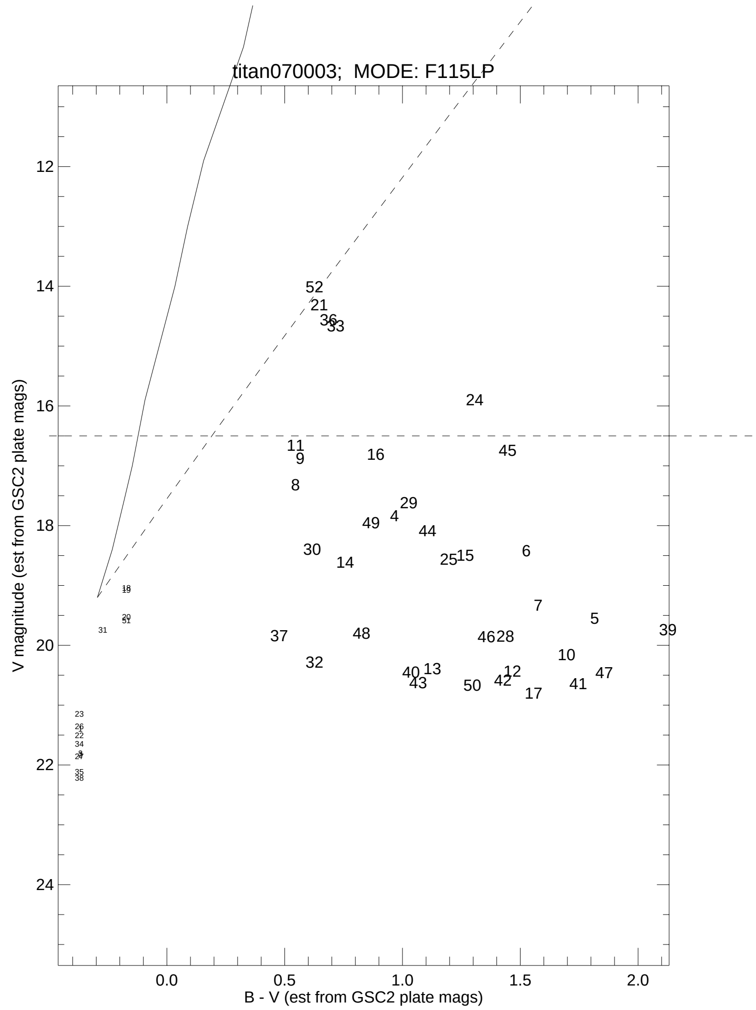

Figure 2: This shows the estimated V magnitude and B-V color for each of the stars in the upper panel of Figure 1. The numbers plotted correspond to the labels used in the catalog files and postscript images. The solid line gives the bright limit V band magnitude as listed in table 7.4 of the ACS instrument handbook for the particular mode under consideration; in this case the F115LP. This limit assumes the targets are all unreddened main-sequence stars. The horizontal dashed line, gives the “Double” limit for that mode as also specified in table 7.4 of the ACS IHB. The slanted dashed line gives the bright object limit for a sequence of increasingly reddened O5 stars. Stars listed in the catalog with only one color are labeled here in a smaller type. Stars with only “J” plate magnitudes are plotted with B-V = -0.4, those with only “F” plate magnitudes use B-V=-0.2, and those with only “N” plate colors use B-V=-0.1

Figure 1 shows a section of a chart for our Titan example. The solid line of the planetary track indicates the corner-to-corner dimension of the detector (or planet diameter plus

HST parallax if that quantity is larger). The outer, dotted line shows a +/- 5 arcsecond pointing error pad.

Added Procedures and Parameters for Very Crowded Fields

The original design of the moving target software was done under the assumption that, at the beginning of each cycle, a series of charts would be made covering all targets and times that might be needed. Once a particular window was identified as a scheduling opportunity, the IS could find the appropriate chart, and evaluate the stars that fell between the dotted lines on the `.ps2` file and decide if any presented a bright object concern. This procedure worked well enough to evaluate a few windows in sparse fields, but proved very labor intensive when working on a large number of windows or when working on extremely crowded fields. The addition of the HR diagram plots, and .ps3 files helps considerably, but very crowded fields still require considerable manual attention to identify each window on the chart and ascertain exactly which stars are close enough to the target to be inside the screening area. This not only takes a great deal of time, but also significantly increases the chances of error.

During February and March 2007, program 10862 requested a large number of ACS SBC visits to observe the Jovian aurora. Because Jupiter at this time is near the Galactic center, the fields are extremely crowded, and it was necessary to modify the procedures to better select only those stars of concern for each window. To aid in this we wrote a new IDL routine, `calcboxlim`, that defines the limits of a rectangular region that circumscribes the areas that need to be checked for a given visit, and which also trims the ephemeris file to a few hours around the times specified for that visit. The rectangular region is then passed to the `mtcharts_sbc` routine and only cataloged stars within this box are considered.

```
XSPAM> calcboxlim,ephname,tstart,tend,boxw,newroot=newroot,boxlim=boxlim
XSPAM> mtcharts_sbc,newroot,targlabel,boxlim=boxlim,/acs,insmode=insmode
```

Here `boxw` gives the half width of the box in arc-seconds. The new ephemeris file name is given by `newroot` and this is passed to the `mtcharts_sbc` routine. If our current ephemeris file is named ‘j.eph1’, and we want to flag stars that are within 35” of the target between 10:20 and 11:10 on 15 February, 2007, then we would type:

```
xspam> calcboxlim,’j’,’15-feb-2007 10:20’,’15-feb-2007 11:10’,35.0, $
newroot=newroot,boxlim=boxlim
xspam> mtcharts_sbc,newroot,’JupN’,boxlim=boxlim,/acs,insmode=’F115LP’
```

The `calcboxlim` routine has some additional parameters which allow for offsets from the ephemeris and drawing circles around the desired begin and end points to make it easier to discern which stars are actually close enough to worry about. However, these options need some revisions and so are not fully documented here.

Things that Should be Improved

- Some of the recent changes made by CP are not fully documented in the code. This should be done and the revised files should be delivered back to BM so that the versions of the xspam routines used by INS are the same as those maintained by ASB.
- Some of the current routines do not work properly if the ephemeris name is too long.
- Sometime prior to SM4, the `insmode` option should be fully implemented for STIS and COS.
- The script discussed in "Appendix 3: A Sample IDL Script for Checking Many Windows" on page 15, should be generalized so that it need not be rewritten for each specific situation.
- A script that took a list of target names and fixed RA and Dec values and produced similar charts, catalogues and diagrams might be very useful for fixed target BOP work. This would allow batch mode production of the BOP review products, and this might be considerably faster than opening each proposal in APT and running the BOP tools there. This could easily be done with the current routines by producing a fake ephemeris with a few arcseconds of movement (the routines need at least 3 hours in the ephemeris, and enough motion to avoid dividing by zero at certain places in the code), and then modifying `mtcharts_sbc.pro` so that the track can be omitted from the plots. More elegant solutions should also be possible with some additional work by ASB.

Summary

We have described a revised set of procedures and software for creating finding charts and object catalogues which can be used to assess the risk to the Space Telescope Imaging Spectrograph or the ACS SBC from bright objects in the vicinity of proposed moving target observations. These charts show the path of a given planet, moon or comet across the background of stars, shown to the magnitude limit of the digitized sky survey plates, and provide diagrams that allow the safety of individual stars to be quickly assessed by the Instrument Scientist.

Acknowledgements

Many thanks to Mike Potter who wrote the original IDL versions of these scripts and procedures, and was a useful reference during the writing of an earlier version of this ISR.

References

STIS TIR 2005-01 “Revised Procedures for Creating Charts to Support MAMA Moving Target Bright Object Protection”, by James Davies.

Appendix 1: Walkthroughs for some basic examples

These examples assume that the percy setup script has been run (source /data/moss/moss_setup), and that the idlxspam setup script is in the user’s search path. The idlxspam script can be found at `/data/inline1/teams/acs/xspam/idlxspam.`

Example 1: Observations centered on Saturn’s moon Titan

```
unix> idlxspam
XSPAM > make_percy_file,’titan’,’1 mar 2007’,’15 mar 2007’,obsname=’07’
XSPAM > exit
unix> percy
Percy-> start titan07.per;
Percy-> exit;
unix> idlxspam
XSPAM > mtwebprocess,’titan07’,targetname=’Titan’,targetdiam=0.86
XSPAM > mtwebchartlist,’titan07’
XSPAM > mtcharts_sbc,’titan07’,’Titan’,/acs,insmode=’F115LP’
XSPAM > exit
unix>
```

Example 2: Offset from Jupiter’s center by 20” at a PA 6° E of celestial N.

```
unix> idlxspam
XSPAM > make_percy_file,’jupiter’,’1 may 2008’,’30 may 2008’,npa=[6,20]
XSPAM > exit
unix> percy
Percy-> start jupiter_off.per;
Percy-> exit;
unix> mv jupiter_off.eph1 joff.eph1
unix> idlxspam
XSPAM > mtwebprocess,’joff’,/jupiter
XSPAM > mtwebchartlist,’joff’
XSPAM > mtcharts_sbc,’joff’,’Jupiter’,/acs,insmode=’F125LP’
XSPAM > exit
unix>
```

Appendix 2: Estimating V and B – V from GSC2 colors

The handbook screening limits are expressed using Johnson *V* and *B* magnitudes, however the GSC2 catalogue gives magnitudes tabulated in a different system. In Figure 3 the GSC2 photographic bandpasses are compared with the Johnson *B* and *V* and the Cousins *R* and *I* bandpasses. The current bright object checking routines in the APT use slightly different formula for the northern and southern surveys when converting between the J and F plate magnitudes and Johnson B and V. However, these differences are small, and so for our purposes we adopt the average of these relations:

$$V = F_{pg} + 0.03 + 0.435(J_{pg} - F_{pg}) - 0.025(J_{pg} - F_{pg})^2 + 0.02(J_{pg} - F_{pg})^3 \text{ and}$$

$$B - V = -0.035 + 0.71(J_{pg} - F_{pg}).$$

The color estimated from the F and J plates will be used if possible; however, for some stars, both these magnitudes may not be available. For example, very red stars may appear on both the F and N plates, but be too faint in the blue to have a listed J plate magnitude. When it is necessary to substitute the N plate IR magnitude for either the F or J plate value, we will then adopt either

$$V = F_{pg} + 0.064 + 1.057(F_{pg} - N_{pg}) + 0.815(F_{pg} - N_{pg})^2 - 0.947(F_{pg} - N_{pg})^3 \text{ and}$$

$$B - V = -0.022 + 1.299(F_{pg} - N_{pg}),$$

or

$$V = J_{pg} + 0.012 - 0.338(J_{pg} - N_{pg}) + 0.010(J_{pg} - N_{pg})^2 + 0.003(J_{pg} - N_{pg})^3 \text{ and}$$

$$B - V = -0.030 + 0.502(J_{pg} - N_{pg}).$$

These latter relations were derived from fits to synphot calculations using Kurucz (1993) model spectral energy distributions. The linear color transformations are fit using only stars with $B - V < 0$, and the zero-point offsets were arbitrarily adjusted to be consistent with the relation used in APT. Better transformations could probably be derived without too much effort, but the ones presented here should be adequate for our purposes.

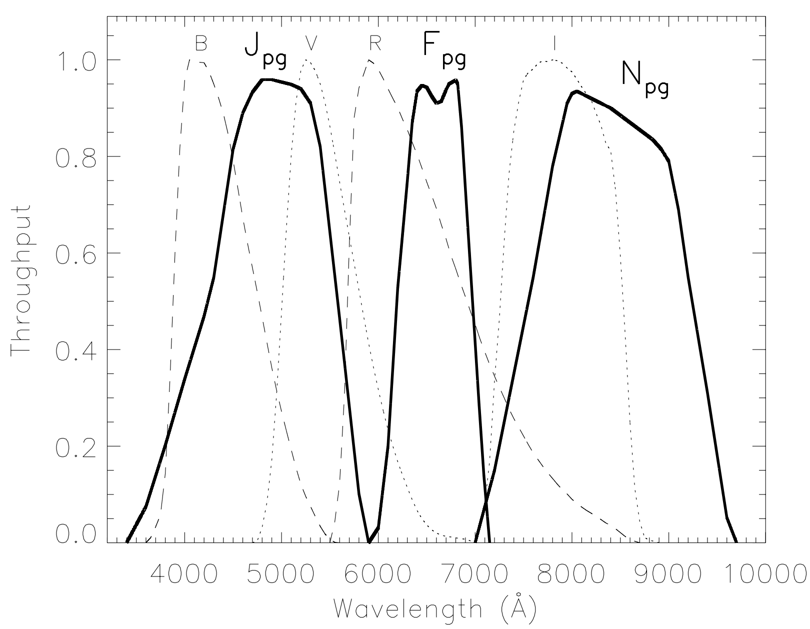

Figure 3: The GSC2 photographic bandpasses for the J (IIIaJ), F (IIIaF), and N (IVN) plates (heavy solid lines), are compared to the Johnson/Cousins *BVRI* bandpasses.

Appendix 3: A Sample IDL Script for Checking Many Windows

The following IDL routine was used to produce charts for a large number of isolated observing windows along the ephemeris specified by the file `‘j.eph1’`. The windows were contained in a file named ‘`ab.windows`’ with lines formatted like:

```
10862A0   2007.041:20:25:19   2007.041:21:16:58   00:51:39
10862A0   2007.041:22:01:13   2007.041:22:52:52   00:51:39
10862A1   2007.042:15:36:08   2007.042:16:27:47   00:51:39
10862A2   2007.044:12:21:16   2007.044:13:12:55   00:51:39
```

This matches the format usually delivered by the PC to specify the windows that need to be checked. Cutting and pasting this information directly from the E-mail from the PC to the input file reduces the chances of transcription errors. The following script could then be run using this input file by just typing:

```
xspam > loop_jup_swindows,'ab'
```

This produces a full set of charts for each window, with only the dangerous stars near the search area labeled in the `.ps3` file. Note that this routine uses some features of the `calcboxlim` routine that were not discussed above.

```
pro loop_jup_swindows,visit,platecolor=platecolor
; use SC catalog with J plate

if(not keyword_set(platecolor)) then platecolor='J'

; winfile is list of windows supplied by PC in .usb file format
; but without any header lines or blank lines
winfile=visit+'.windows'

openr,uwin,winfile,/get_lun
line=''

iwin=0
ephname='j'

while (not eof(uwin)) do begin

 readf,uwin,line
 sline=strsplit(line,' ',/extract)
 tstart=sline[1]
 tend=sline[2]

 siwin=strtrim(string(iwin),2)
 if(strlen(siwin) lt 2) then siwin='0'+siwin
 vwin=visit+siwin
```

```
 paoff=[[22.,5.]]

 calcboxlim,ephname,tstart,tend,35.0,boxlim,visit=vwin,newroot=newroot,$
           raextra=0.0,decextra=0.0,circles=circles,/jupiter,paoff=paoff

 mtwebprocess,newroot,/jupiter,platecolor=platecolor
 mtwebchartlist,newroot,qyn='n'
 mtcharts_sbc,newroot,newroot,/acs,insmode='F115LP',cat='sc', $
              boxlim=boxlim,circles=circles,j_lim=[0,17]

 iwin=iwin+1
endwhile

free_lun,uwin
end
```