

A Throughput Tool for WFC3

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ABSTRACT

We have written an IDL program, called `wfc3tp.pro`, for estimating the count rate on the Wide Field Camera 3 (WFC3) detectors given an input flux. The input flux can either be astronomical (in which case the HST Optical Telescope Assembly is included in the system throughput) or the optical stimulus used in ground testing (in which case the input flux is assumed to be in photons at the WFC3 pickoff mirror). Besides the obvious selectable parameters (filter and channel), the user can also specify the chip in UV channel, the quadrant in the IR channel, the filter temperature in the IR channel, the quantum yield correction (creation of more than one electron for UV photon), and the band width for the optical stimulus beam. The program was written to assist with ground testing, but it is useful for calculating the signal-to-noise in astronomical observations with WFC3.

Introduction

We have written an IDL routine, called `wfc3tp.pro`, that will provide the end-to-end throughput of the Wide Field Camera 3 (WFC3), assuming the latest measurements of component throughputs. The routine simply takes these various component measurements, interpolates them to a common wavelength scale, and multiplies them together. Thus, `wfc3tp.pro` is just a convenient wrapper for combining the throughputs appropriate to a specified observing mode. These throughputs are the latest available measurements for each component as of this writing. The throughputs for the optics (window transmissions and mirror reflectivities) come from Joe Sullivan at Ball Aerospace; the quantum efficiencies come from the Detector Characterization Lab at Goddard Space Flight Center (GSFC); the IR filter transmissions come from Ray Boucarut at GSFC; the UV filter transmissions come from John Trauger at the Jet Propulsion Lab.

Installation

The routine is very straightforward to install and use. `wfc3tp.pro` is the program, and `datafiles.tar.gz` is a UNIX tar file containing all of the throughput measurements. To install the package in a dedicated directory on a UNIX system, copy `wfc3tp.pro` and `datafiles.tar.gz` to that directory, and unpack the data files (`gunzip datafile.tar.gz; tar -xvf datafiles.tar`). By default the program assumes that all of the data files reside in a subdirectory called `datafiles`, but the “`path`” variable in the program can be set to another location.

Using the program

Here we describe the use of `wfc3tp` (version 1.2). If the user simply types “`wfc3tp`” at the IDL prompt, a brief synopsis of the program usage is given. Typing “`wfc3tp,/help`” gives a longer help summarizing the information in this ISR. The program has 3 required input parameters: `wave`, `flux`, and `filter`. There is one optional output parameter, `cps`, giving the rate in electrons/second on the detector; if it is not specified, that rate is printed to the screen upon program completion. All of the parameters are described below.

- `wave` = input wavelength (required), in Angstroms. If doing ground testing, this is a scalar value specifying the selected wavelength of the optical stimulus. If calculating count rate for an astronomical source, this is a vector.
- `flux` = input flux (required). For ground testing, this is a scalar specifying the rate of photons hitting the pickoff mirror at the wavelength specified; units are photons/sec. For an astronomical source, this is a vector with units of $\text{erg/s/cm}^2/\text{Angstrom}$.
- `filter` = input filter (required). This is a string (given in quotes) specifying the filter. The specification must be unique but it need not be complete. E.g., to specify the F555W filter, one can say “F555W” or “555” but “5” will not work. The user can also specify “CLEAR” in either channel, although observing without a filter will not be available to observers.
- `cps` = output count rate (optional). This is the count rate on the detector, in e^-/sec . If not specified, the count rate will be printed on the screen.

Other optional input parameters are:

- `astro` = 0 (default) or 1. If set (by specifying `astro=1` or `/astro` on the command line), `wave` and `flux` are assumed to be vectors specifying flux from an astronomical source, and the HST Optical Telescope Assembly (OTA) is included in the end-to-end throughput. If set to 0 (the default), the OTA is not included, and `wave` and `flux` are assumed to be scalars specifying the photon rate hitting the WFC3 pickoff mirror.

- chip = 1 (default) or 2. The UVIS detector is split into two chips, referred to as #178 and #18 in the current flight package. As with the Advanced Camera for Surveys, the notation is a little confusing. Images from chip 1, corresponding to #178, have “CCD-CHIP=1” in the science header, but reside in the fourth extension of the fits file, which is also the second science extension (SCI,2). Images from chip 2, corresponding to #18, have “CCDCHIP=2” in the science header, but reside in the first extension of the fits file, which is also the first science extension (SCI,1). Chip 2 performs better at the shortest wavelengths (near 2000 Angstroms), while chip 1 performs better near 8000 Angstroms.
- quad = 1 (default) through 4. The quadrant of the IR detector.
- ir = 0 (default) or 1. If set, the IR channel is used.
- uv = 0 or 1 (default). If set, the UVIS channel is used.
- qyield = 0 (default) or 1. If set, the quantum efficiency on the UVIS detector is reduced to correct for the quantum yield. At wavelengths shorter than 3396.8 Angstroms, there is a finite chance that a single photon will produce two electrons on the detector. The correction is about 1.7 at 2000 Angstroms. By default, the raw (uncorrected) quantum efficiency is used, so that the actual rate on the detector is reported for a given input flux.
- temp = 243 (default) or 296. The temperature, in Kelvin, of the IR filter.
- bandw = 10 (default). The bandwidth, in Angstroms, of the optical stimulus beam used in ground testing. The throughput is the average over the bandwidth, centered on the wavelength specified by the “wave” input parameter.
- plot = 0 (default) or 1. If set, a plot of count rate vs. wavelength is sent to the current device.
- help = 0 (default) or 1. If specified without any other parameters, a short summary is given of the various parameters.

Examples

Below, we provide examples of input and output to the `wfc3tp` routine, to demonstrate its use.

Get short help:

```
IDL> wfc3tp
```

```
Usage: wfc3tp,wave,flux,filter,cps,astro=astro,chip=chip,quad=quad,ir=ir,uv=uv,  
       qyield=qyield,temp=temp,bandw=bandw,help=help
```

Get long help:

```
IDL> wfc3tp,/help
```

```
Usage: wfc3tp,wave,flux,filter,cps,astro=astro,chip=chip,quad=quad,ir=ir,uv=uv,  
       qyield=qyield,temp=temp,bandw=bandw,help=help
```

wave (input) = wavelength in Angstroms

flux (input) = flux in either photons or erg/s/cm²/Å, depending upon astro

filter (input) = string specifying filter. Must be unique but does not have to be complete (e.g., "555" or "F555" or "F555W" are all valid).

...

Show the count rate on the UVIS detector, given an optical stimulus flux of 10 photons/sec at 5000 Angstroms, observed through the F555W filter:

```
IDL> wfc3tp,5000.0,10.0,'555'  
4.0045712
```

Do the same thing, but keep the result in a variable:

```
IDL> wfc3tp,5000.0,10.0,'555',cps  
IDL> print,cps  
4.0045712
```

Same calculation, but use the other chip:

```
IDL> wfc3tp,5000.0,10.0,'555',chip=2  
4.0888539
```

Assuming 5 photons/sec at 1.1 microns, calculate the rate observed with the F110W filter on the IR detector:

```
IDL> wfc3tp,11000.0,5.0,'F110W',/ir  
1.8441222
```

Try to do that for the UV detector:

```
IDL> wfc3tp,11000.0,5.0,'F110W'  
No such filter. Exiting.
```

Use the 3rd quadrant of the IR detector:

```
IDL> wfc3tp,11000.0,5.0,'F110W',/ir,quad=3  
1.7495686
```

Also assume a different temperature:

```
IDL> wfc3tp,11000.0,5.0,'F110W',/ir,quad=3,temp=296  
1.7390513
```

Calculate the count rate when observing a flat astronomical spectrum through the F225W filter (spectrum normalized to Johnson V = 20 mag here):

```
IDL> w=findgen(10000)+1000.0 & f=w/w*3.5e-17  
IDL> wfc3tp,w,f,'F225W',/astro  
5.0870729
```

Do the same calculation, but correct for the quantum yield:

```
IDL> wfc3tp,w,f,'F225W',/astro,/qyield  
3.5270366
```

Conclusion

The IDL routine `wfc3tp.pro` is a simple tool for calculating count rates on the WFC3 detectors, given an input flux at a given wavelength. Although the tool was written to assist with ground testing, it was trivial to add the option of computing count rates during observations of astronomical sources, so it also serves as a surrogate Exposure Time Calculator. Suggestions are welcome for improving its use.