

pysynphot/Synphot Throughput Files: Mapping to instrument components for ACS, COS, and WFC3

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ABSTRACT

This document describes the pysynphot/Synphot throughput tables, provides with a detailed mapping of these files to the HST instruments components as they follow the light path of the different detectors, and describes how these are used by py/Synphot to simulate observations.

Introduction

Synphot data files (or also known as throughput files) are binary FITS tables with a special format for the header and data. These files are used by The Synthetic Photometry package, known as pysynphot under the python environment and Synphot under IRAF; both of which simulate photometric data and spectra as they are observed with the Hubble Space Telescope (HST).

In this document we provide a general overview about the pysynphot/Synphot Throughput files for ACS, COS, and WFC3 and how these files are used in Synphot and pysynphot. For information about STIS Throughout files, please see STIS TIR 2006_01.

Synphot/pysynphot Framework overview

This document describes the framework of the pysynphot/Synphot software; for more details on the basic concepts, data structures, and software needed for dynamic throughput generation refer to Horne, Burrows, and Koornneef (1986), the Synphot User’s Guide (2005), and the Synphot Data User’s Manual.

The Synphot software is an IRAF-based suite of programs that, using data files, dynamically generates the throughput of all the HST observing modes. The pysynphot package, on the other hand, is a re-implementation of, and replacement for, the Synphot package (TSR 2009-01: Pysynphot Commissioning Report) . Pysynphot, like Synphot, has a user interface that allows to construct and manipulate model spectra and bandpasses, simulate observations, and query the resulting structures for quantities of interest such as countrate, effective wavelength, as well as the wavelength and flux arrays. Pysynphot has been determined to produce answers that are at least as accurate, and in some data domains, more accurate than Synphot.

All the information that pysynphot/Synphot needs to compute the throughput of an instrument mode is contained within five types of data files:

1. a observatory configuration graph table or better known as ”The master graph” table (hereafter referred as TMG). This is a FITS table that describes the allowed combination of the components or optical elements. Its format maps the light path as it travels through the spacecraft;
2. a master component lookup table or better know as ”The master component” table (hereafter referred as TMC) with information on the location of the throughput data files used by py/Synphot, and a master thermal background table (hereafter referred as TMT) with information on the location of the thermal emissivity files used for NICMOS and WFC3;
3. a set of pysynphot/Synphot data (or throughput files) for optical component (e.g. OTA, mirror, filter, polarizer, disperser, slit, detector) used in HST and supported photometric bandpass;
4. a set of pysynphot/Synphot thermal emissivity tables for NICMOS and WFC3; and
5. a wavecat table (or wavelength table) containing a list of wavelength values that specifies the wavelength arrays that should be used for a given obsmode or obsmode pattern. By default, the wavelength bin will be looked up in the wavecat table based on the observation mode of the b bandpass; if there is no matching obsmode, then the native wavelength of the spectrum will be used.

In the pysynphot/Synphot software, a particular observing mode is specified by a list of keywords, which might be familiar names of filters, detectors, and gratings. These keywords are then used to trace the light path of that mode via the TMG table. The grand throughput function is then constructed by multiplying together the individual throughput files at each wavelength that are provided via the TMC table (extension tmc.fits). Figure 1 shows an example of how the TMG and TMC tables are used to identify the throughput files for a particular HST mode. In this example the pysynphot/Synphot parameterized string

```
acs,wfc1,f550m,aper#0.5
```

is broken in separate keywords (acs, wfc1, f550m, aper#) that are used to identify the component names in the TMG file.

The TMG file has five columns, which contain the component name (COMPNAME), instrument keywords (KEYWORD), innode value (INNODE), outnode value (OUTNODE) and comments (COMMENT). To find the components of a given instrument configuration, the value of the outnode is matched with the row that has the same innode value, starting with the lowest innode value; in Figure 1 this corresponds to the row with a circled "1" at the right or Label value 17 of the column Label. If there are several rows with the same innode value (e.g. those with 10130 in the TMG table) the row with a keyword that matches any of the keywords of the instrument configuration is selected (in this case f550m with component acs_f550m_wfc). If there is no matching keyword, the row with the keyword "default" is selected (as in the case of the hst_ota). On the other hand, if there is only one row for the given innode value, this unique row is selected by default.

The broken lines in the TMG table of Figure 1 guide the reader on how the selection is done for the above example. Starting at the top, we select the rows indicated by the arrow, then we follow the line to the next arrow (or component). Once that all the component values have been identified (see the Keyword-COMPNAME Table in this figure), the path of the corresponding throughput file is extracted from the TMC file. This is done by matching the component name (COMPNAME column) in both tables.

The TMC file has four columns, these columns contain the time in which the individual throughput file was delivered (TIME), the component name (COMPNAME), the directory to where the STSDAS file is stored (FILENAME), and comments pertaining to the file (COMMENT). Note that in this file the time and comment columns are not used by pysynphot/Synphot, these are included for documentation only. In general, pysynphot/Synphot software does not know about time stamps and dependences on time should be introduced via parameterized keywords (see STIS TIR 2005-02).

In order to see the files that are used in a pysynphot/Synphot call, as extracted from

the TMG and TMC files, you can use the Synphot command *showfiles*. Using the same example as above we get:

```
--> showfiles acs,wfc1,f550m,aper#0.5
#Throughput table names:
crotacomp$hst_ota_007_syn.fits
cracscomp$acs_wfc_aper_002_syn.fits[aper#]
cracscomp$acs_wfc_im123_004_syn.fits
cracscomp$acs_f550m_wfc_007_syn.fits
cracscomp$acs_wfc_ebe_win12f_005_syn.fits
cracscomp$acs_wfc_ccd1_mjd_021_syn.fits
```

Each grating, camera, mirrors, detectors, etc., for a particular instrument, has a unique data file that the pysynphot/Synphot software uses to dynamically generate the throughput of a particular observing mode. Below we show the list of files and categories for each of the HST instruments, except for STIS which is described in STIS TIR 2006-01 and NICMOS.

The Thermal Master Component table (TMT) is analogous to the TMC table, but for the thermal emissivity files, and therefore not discussed here. The TMT file is used by the task *thermback* which predicts the thermal background flux for an specified WFC3 and NICMOS mode. For more details on this task, see The Synphot User's Guide (2005).

Master Graph Table (TMG)

Column Label	COMPNAME ¹	COMPNAME ²	KEYWORD ³	INNODE ⁴	OUTNODE ⁵	THCOMPNAME [_]
1	clear	nicmos		1	30	clear
2	clear	wfc3		1	30	clear
8	clear	cos		1	20	clear
9	clear	acs		1	20	clear
10	clear	default		1	100	clear
11	clear	ota		1	20	clear
16	clear	noota		20	30	clear
17	hst	ota		20	30	clear
18	hst	ota		20	30	clear
19	clear	foc		30	2000	clear
25	clear	wfpc2		30	7000	clear
26	clear	acs		30	10000	clear
27	clear	stis		30	8000	clear
28	clear					
2867	clear	default		9370	9400	clear
2868	nic3	dnh		9370	9400	nic3 dnh
2869	clear	sbc		10000	10199	clear
2870	clear	hrc		10000	10150	clear
2871	clear	wfc2		10000	10100	clear
2872	clear	wfc1		10000	10100	clear
2873	clear			10100	10101	clear
2874	acs	wfc_aperture		10100	10101	clear
2875	acs	im123		10101	10130	clear
2876	acs	f606w_wfc		10130	10140	clear
2877	clear			10130	10140	clear
2878	acs	f475w_wfc		10130	10140	clear
2879	acs	f502n_wfc		10130	10140	clear
2880	acs	f550m_wfc		10130	10140	clear
2881	acs	f555w_wfc		10130	10140	clear
2903	acs	fr1016n		10140	10300	clear
2904	acs	f435w_wfc		10140	10300	clear
2905	clear			10140	10300	clear
2906	acs	f604n		10140	10300	clear
2907	acs	fr551n		10140	10300	clear
2908	acs	fr505n		10140	10200	clear
2909	clear			10150	10200	clear
2952	acs	hrc_ccd_mjd	MJD#		10270	10280
2953	acs	wfc_ebe	win12f	wfc2	10300	10310
2954	acs	wfc_ebe	win12f	wfc2	10300	10311
2955	acs	wfc_ccd1	mjd		10310	10320
2956	acs	wfc_ccd1	mjd	MJD#		
2957	acs	wfc_ccd2	mjd		10311	10325
2958	acs	wfc_ccd2	mjd	MJD#		
2959	acs	pr101		pr101	10500	10530
2960	clear					

Master Component Table (TMC)

Column Label	TIME ¹	COMPNAME ²	FILE NAME ³
1	apr 3 2003 18:14:16	acs_csr_aper	cracscomp\$acs_csr_aper_002_syn.fits[aper#]
2	aug 14 2009 19:16:13:04	acs_f15lp	cracscomp\$acs_f15lp_005_syn.fits
3			
6			
4			
9			
5			
8			
1			
2			
3			
4			
5			
6			
7			
8			
9			

Fig. 1.— Schematic representation of the TMC and TMG tables and how these are used by Pysynphot/Synphot to select the throughput files in order to construct the grand throughput function. The dotted lines in the left box indicate that lines in the original table were omitted. To show how the TMG table traces the light path of STIS, the dashed lines connect the OUTNODE with the corresponding INNODE row. For clarity, the keyword and corresponding component file are provided in the table at the middle right. In all the tables the numbers inside a circle connect the COMPNAMES in the TMG file with those in the TMC table (top right box) and the Py/Synphot call (bottom right).

ACS Throughput Files

For ACS, the throughput files can be grouped into three categories of files: optical elements, filters, and dispersers. Figure 2 shows an schematic of the ACS light path through the different optical components that are used by the Wide Field Camera (WFC).

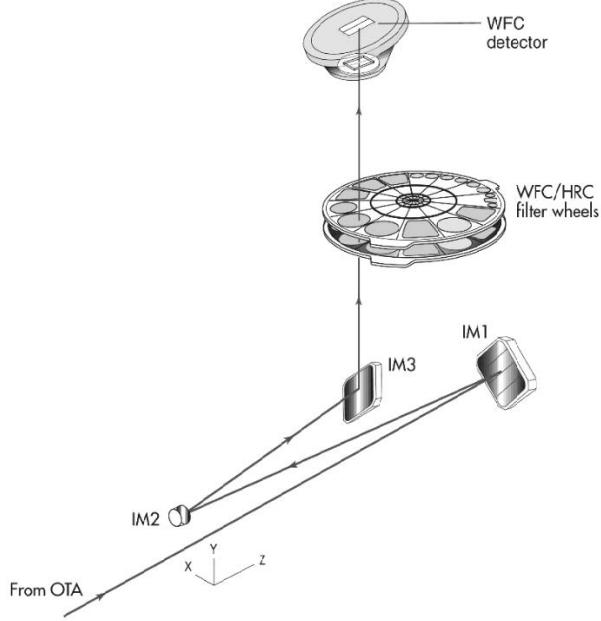


Fig. 2.— ACS WFC detector light path

Figure 3 shows the same for the Solar Blind Camera (SBC) and the High Resolution Camera (HRC).

There is one throughput file for each of the optical elements, filters, and dispersers in each of the ACS instruments. Table 1 and Table 4 provide a list of all the optical elements for ACS; plus some corrections due to DQE, encircled energy or QE. Column one provides the throughput file root-name assigned to each of the optical elements, described in column three. The corresponding wavelength range is given in column two. To better understand how the data files are used by pysynphot/Synphot and how they relate to the light path in the instrument, we provide in column five the keyword value that determines if a given file is used by default or only when a keyword value is present in the pysynphot/Synphot call. The column named "type" gives the type of data used to construct the throughput files.

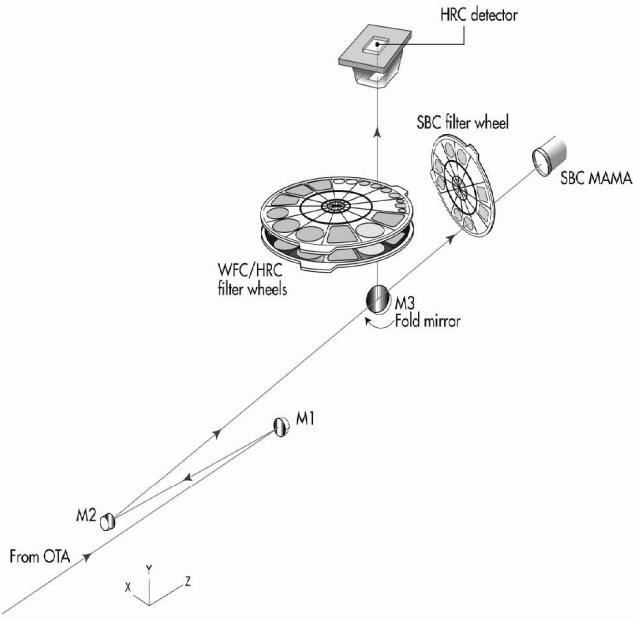


Fig. 3.— ACS HRC/SBC detector light path

Type "Inflight" indicates that the data was derived mostly, or all, using Inflight data. The type "dummy" is used for those files that have all ones in their throughput column. Model indicates the values were derived from ground data or models.

Table 1: Throughput Files for ACS/WFC optical components

filename	Wavelength range	Description	type	keyword
acs_wfc_aper	3500 - 11000	Encircled energy table for ACS/WFC	Inflight	aper#
acs_wfc_im123	2000 - 11000	Integrated folding mirrors 1, 2, & 3 (IM1 + IM2 + IM3)	Model	default
acs_wfc_ccd1	3000 - 10924	DQE response WFC/Chip 1	Inflight	default
acs_wfc_ccd1_mjd	3000 - 10924	DQE response WFC/Chip 1 with MJD	Inflight	MJD#
acs_wfc_ccd2	3000 - 10924	DQE response WFC/Chip 2	Inflight	default
acs_wfc_ccd2_mjd	3000 - 10924	DQE response WFC/Chip 2 with MJD	Inflight	MJD#
acs_wfc_ebe_win12f	2500 - 11000	EBC OWS data	Model	wfc1/wfc2

In the case of WFC, all modes use the integrated response of the three folding mirrors (see Figure 4). Then, if CCD Chip 1 is selected the calculation is corrected by the DQE response of Chip 1; while if CCD Chip2 selected then the correction is for Chip 2. For those cases with keyword "#" the pysynphot/Synphot call supports parameterization; this is, the software applies an extra correction depending on the Modified Julian Date (MJD) or a given encircled energy values (aper#0.0 to 1.5). This value is provided at the end of the pysynphot/Synphot command. For example, the throughput files used for a calculation for a particular MJD are those with extension ".mjd" used in a call like this:

$$countrate acs, wfc1, f555w, mjd\#55345.5 \quad (1)$$

in the case of the encircled energy or an aperture:

$$countrate acs, wfc1, f555w, aper\#0.4 \quad (2)$$

Once the Chip is selected, the calculation can be made for a filter, a grating, a ramp filter or a polarizer. A final correction is done for the EBE OWS and the DQE response, the later depends on the Chip selected.

Table 2 provides a list of all the ACS/WFC filters. These are located in the WFC/HRC filter wheel; shown in Figure 2. The columns of this table are the same as for Table 1, except for column six which gives the filter wheel where the filter is located.

Table 2: Throughput Files for ACS WFC filter components

filename	Wavelength range	Bandpass	type	keyword	wheel
acs_f555w_wfc	3480 - 10500	Johnson V	Inflight	f555w	1
acs_f775w_wfc	4000 - 10470	SDSS i	Inflight	f775w	1
acs_f550m_wfc	2500 - 10500	Narrow V	Inflight	f550m	1
acs_f625w_wfc	3000 - 10450	SDSS r	Inflight	f625w	1
acs_f850lp_wfc	4000 - 11000	SDSS z	Inflight	f850lp	1
acs_f892n_wfc	2500 - 11000	Methane (2%)	Inflight	f892n	1
acs_f606w_wfc	3000 - 10500	Broad V	Inflight	f606w	1
acs_f502n_wfc	3000 - 10500	[OIII] (1%)	Inflight	f502n	1
acs_f658n_wfc	2500 - 10450	H α (1%)	Inflight	f658n	1
acs_f475w_wfc	3510 - 10500	SDSS g	Inflight	f475w	1
acs_f660n_wfc	2500 - 10800	[NII] (1%)	Inflight	f660n	2
acs_f435w_wfc	2500 - 10500	Johnson B	Inflight	f435w	2
acs_f814w_wfc	4000 - 10600	Broad I	Inflight	f814w	2

Table 3 provides a list of all the ramp filters used with WFC or HRC. These are all in wheel 2. In column three "(WFC only)" indicates those cases when the filter is used only with WFC.

Table 3: Throughput Files, ACS WFC/HRC Ramp Filters for inner, middle & outer segment

filename	Wavelength range	Optical Element	type	keyword
acs_fr388n	3339 - 11000	[OII] Ramp middle	Ground	fr388n#
acs_fr423n	3500 - 11000	[OII] Ramp inner (WFC only)	Ground	fr423n#
acs_fr462n	3500 - 11000	[OII] Ramp outer (WFC only)	Ground	fr462n#
acs_fr656n	3500 - 11000	H α Ramp middle	Ground	fr656n#
acs_fr716n	3500 - 11000	H α Ramp inner (WFC only)	Ground	fr716n#
acs_fr782n	3500 - 11000	H α Ramp outer (WFC only)	Ground	fr782n#
acs_fr914m	3500 - 11776	Broad Ramp middle	Ground	fr914m#
acs_fr459m	3429 - 11000	Broad Ramp middle	Ground	fr459m#
acs_fr505n	3500 - 11000	[OIII] Ramp middle t	Ground	fr505n#
acs_fr853n	3500 - 11000	IR Ramp inner (WFC only)	Ground	fr853n#
acs_fr931n	3500 - 11000	IR Ramp outer (WFC only)	dummy	fr931n#
acs_fr1016n	3500 - 11667	IR Ramp outer (WFC only)	Ground	fr1016n#
acs_fr551n	3500 - 11000	[OIII] Ramp inner (WFC only)	Ground	fr551n#
acs_fr601n	3500 - 11000	[OIII] Ramp outer (WFC only)	Ground	fr601n#
acs_fr647m	3500 - 11000	Broad Ramp inner(WFC only)	Ground	fr647m#

Just as in Table 1 , Table 4 provides with a list of all the optical elements for ACS/HRC and ACS/SBC.

Table 4: Throughput Files for ACS/HRC and ACS/SBC optical components

filename	Wavelength range	Description	type	keyword
acs_cor_aper	1800 - 11000	Encircled energy for coronagraph	Inflight	aper#
acs_hrc_coron	10 - 100000	HRC Coronagraph transmission	Model	coron
acs_hrc_aper	1800 - 11000	Encircled energy for HRC	Inflight	aper#
acs_hrc_m12	1100 - 11000	Fold Mirror 1 and 2 (HRC)	Model	default
acs_hrc_m3	1162 - 11000	Fold Mirror 3 (HRC)	Model	default
acs_hrc_win	1500 - 11000	Window data (HRC)	Model	default
acs_hrc_ccd	1700 - 10916	QE curves HRC	Inflight	default
acs_hrc_ccd_mjd	1700 - 10916	QE curves HRC (supports MJD)	dummy	MJD#
acs_sbc_aper	1150 - 6000	Encircled energy table for SBC	Inflight	aper#
acs_sbc_mama	1150 - 8002	DQE response for SBC	Inflight	default

Table 5, on the other hand, is the list of all the HRC filters. These are located in the WFC/HRC filter wheel; shown in Figure 2. The columns of this table are the same as for Table 1, except for column six which gives the filter wheel where the filter is located.

Table 5: Throughput Files for ACS HRC filter components

filename	Wavelength range	Bandpass	type	keyword	wheel
acs_f555w_hrc	3480 - 10500	Johnson V	Inflight	f555w	1
acs_f775w_hrc	4000 - 10470	SDSS i	Inflight	f775w	1
acs_f625w_hrc	3000 - 10450	SDSS r	Inflight	f625w	1
acs_f550m_hrc	2500 - 10500	Narrow V	Inflight	f550m	1
acs_f850lp_hrc	4000 - 11000	SDSS z	Inflight	f850lp	1
acs_f892n_hrc	2500 - 11000	Methane (2%)	Inflight	f892n	1
acs_f606w_hrc	3000 - 10500	Broad V	Inflight	f606w	1
acs_f502n_hrc	3000 - 10500	[OIII] (1%)	Inflight	f502n	1
acs_f658n_hrc	2500 - 10450	H α (1%)	Inflight	f658n	1
acs_f475w_hrc	3510 - 10500	SDSS g	Inflight	f475w	1
acs_f660n_hrc	2500 - 10800	[NII] (1%)	Inflight	f660n	2
acs_f330w_hrc	2500.3 - 10800	HRC U	Inflight	f330w	2
acs_f435w_hrc	2500 - 10500	Johnson B	Inflight	f435w	2
acs_f814w_hrc	4000 - 10600	Broad I	Inflight	f814w	2
acs_f250w_hrc	1940.3 - 10499.4	Near-UV broadband	Inflight	f250w	2
acs_f344n_hrc	2500 - 10500	Ne V (2%)	Not used	f344n	2
acs_f220w_hrc	1850.3 - 10800	Near-UV broadband	Inflight	f220w	2

Table 6 provides a list of all the dispersers: Grism, Prism, and Polarizer used with WFC or HRC. As in the previous table, column six indicates if these are in wheel 1 or wheel 2.

Table 6: Throughput Files for ACS WFC/HRC Polarizer, Grism, and Prism components

filename	Wavelength range	Optical Element	type	keyword	wheel
acs_pol_uv	1900 - 20000	UV Polarizer	Model	pol_uv	1
acs_pol_v	3750 - 20000	V Polarizer	Model	pol_v	2
acs_g800l	5500 - 11000	Grism (WFC/HRC)	Model	g800l	1
acs_pr200l	1608 - 4000	Prism	Model	pr200l	2

All the SBC Filters are located in the SBC filter wheel. Table 7 gives the list of all the available filters. The column are the same as for Table 1

Table 8 contains the list of ACS throughput files currently in CDBS but not used by pysynphot/Synphot. These are in the system and therefore worth mention here.

Table 7: Throughput Files for ACS SBC filter and prism components

filename	Wavelength range	Bandpass	type	keyword
acs_f115lp	1150.0 - 1900.0	$MgF_2(1150\text{\AA} longpass)$	Model	f115lp
acs_f122m	1144.0 - 2320.0	$Ly - \alpha(\lambda = 1200\text{\AA}, \delta\lambda = 60\text{\AA})$	Model	f122m
acs_f125lp	1160.0 - 2000.0	$CaF_2(1250\text{\AA} longpass)$	Model	f125lp
acs_f140lp	1230.0 - 2000.0	$BaF_2(1400\text{\AA} longpass)$	Model	f140lp
acs_f150lp	1420.0 - 1950.0	Crystal quartz (1500 Å longpass)	Model	f150lp
acs_f165lp	1500.0 - 1950.0	Fused Silica (1650 Å longpass)	Model	f165lp
acs_pr110l	1230.0 - 1900.0	LiF Prism (R 100)	Model	pr110l
acs_pr130l	1230.0 - 1900.0	CaF_2 Prism (R 100)	Model	pr130l

Table 8: Throughput Files for ACS not used

filename	Wavelength range	Optical Element	type	keyword
acs_f410w_hrc	2500 - 10500	Filter transmission	Not used	f410w
acs_f410w_wfc	2500 - 10500	Filter transmission	Not used	f410w
acs_f425w_hrc	2500 - 10500	Filter transmission	Not used	f425w

Figure 4 shows a flow diagram of how the throughput files, mentioned before, are combined in order to produce the observed mode for each of its three detectors. The diagram also indicates the Table number of this document where the corresponding HST Instrument component is described.

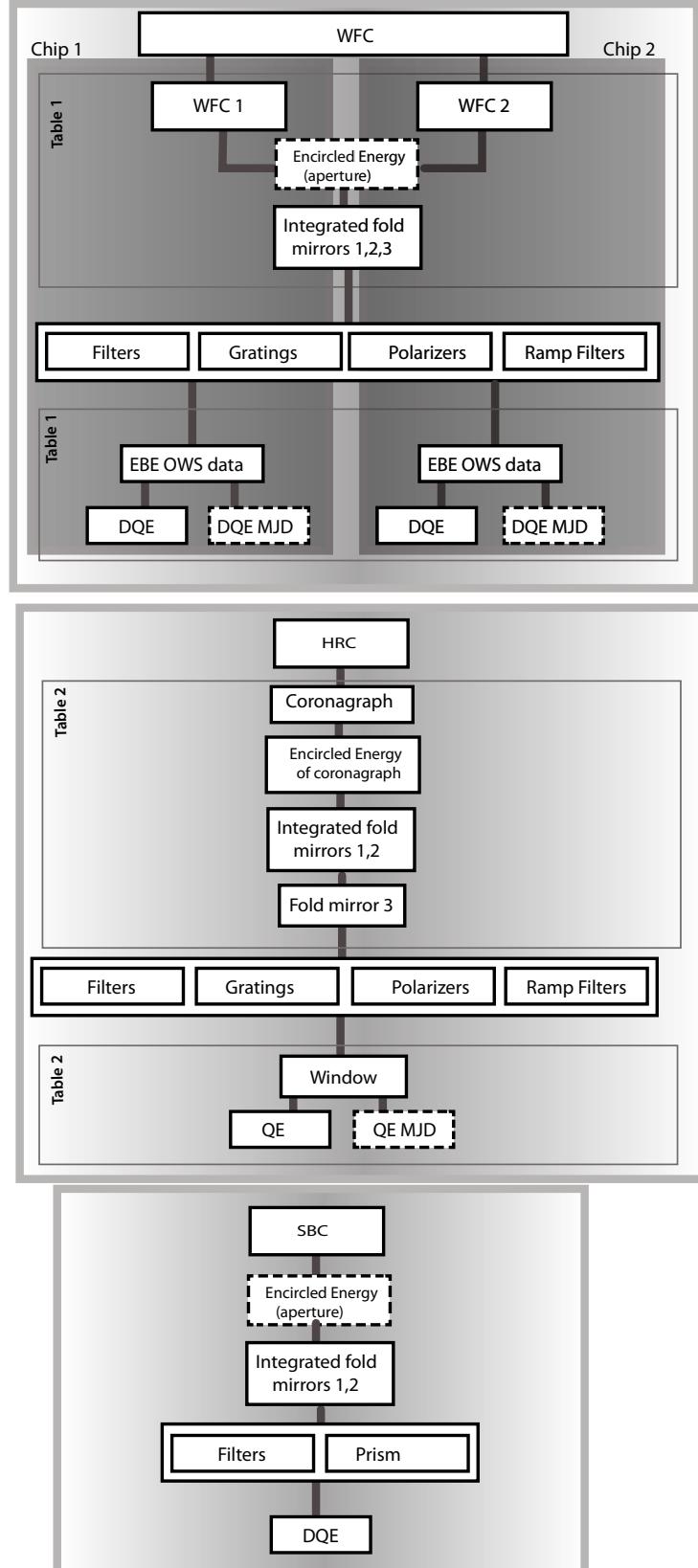


Fig. 4.— ACS flow diagram for throughput tables. The dotted boxes indicate those throughput files that are optional; via parameterized or special keywords.

COS Throughput Files

COS has two instruments identified as FUV and NUV. The schematic for the NUV instrument is shown in Figure 5 top and for the FUV detector in the bottom diagram.

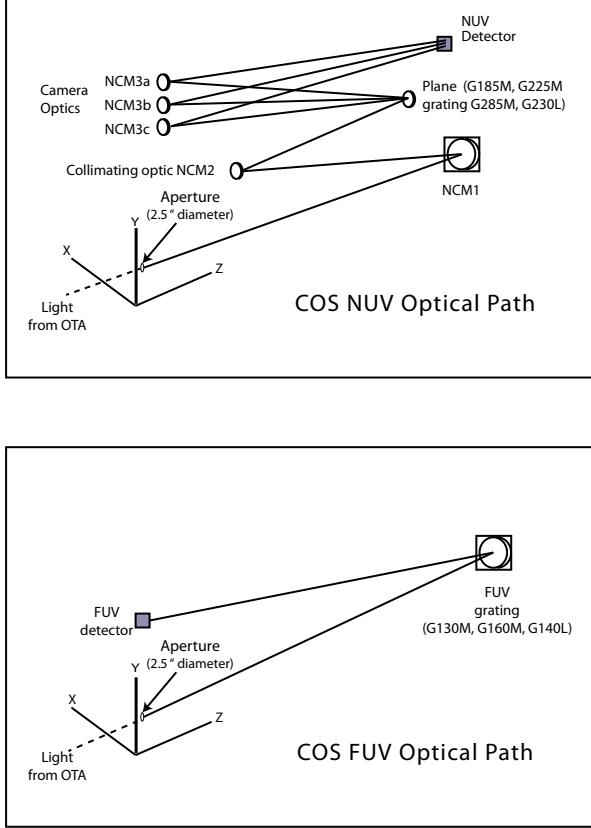


Fig. 5.— COS NUV (top) and FUV (bottom) detector light path

There is one throughput file for each of the optical elements in each of the COS instruments. Table 9 provides a list of all these files. Just as in the case of ACS, column one provides the throughput file root name assigned to each of the COS optical element described in column three. The corresponding wavelength range is given in column two. To better understand how the data files are used by pysynphot/Synphot and how they relate to the light path in the instrument, we provide in column five the keyword value that can be used in conjunction with Figure 5 to construct the TMG file; following the light path of the detector in order to simulate the photometry of a particular mode.

Table 9: Throughput Files for COS Optical Elements

Filename	Wavelength range	Optical Element	Type	Keyword
cos_boa	700.0 - 12000.0	Bright Object Aperture	data	BOA
cos_psa	700.0 - 12000.0	Primary Science Aperture	dummy	PSA
cos_fuv_correction	700.0 - 12000.0	FUV throughput correction	dummy	default
cos_nuv_correction	700.0 - 12000.0	NUV throughput correction	dummy	default
cos_ncm1	700.0 - 12000.0	NUV Correcting Mirror 1 (start nuv light path)	dummy	NCM1
cos_ncm2	700.0 - 12000.0	NUV Correcting Mirror 2	dummy	NCM2
cos_mirrrora	700.0 - 11999.0	imaging and target acq mirror	data	MIRRORA
cos_mirrorb	700.0 - 11999.0	imaging and target acq mirror	data	MIRRORB
cos_ncm3b	700.0 - 12001.0		dummy	NCM3B
cos_nuv_mama	700.0 - 12000.0	nuv detector	dummy	NUV detector

Table 10 provides a list of all these grating files for the FUV and NUV detectors. The column named "type" gives the type of data used in the throughput files. Type "Inflight", appearing in the previous table, indicates that the data was derived mostly, or all, using Inflight data. The type "dummy" is used for those files that have all ones in their throughput column. "Model" indicates the values were derived from ground data or models. As can be seen in the column Type of this table, all the files are "dummy". This is because for COS the total throughput is usually contained in one file; in this case the grating setting files per central wavelength listed in Table 11 and Table 12.

Table 10: Throughput Files for COS gratings

Filename	Wavelength range	Optical Element	Type	Keyword
cos_g140l	700.0 - 5000.0	g140l grating	dummy	G140L
cos_g160m	700.0 - 5000.0	g160m grating	dummy	G160M
cos_g130m	700.0 - 5000.0	g130 grating	dummy	G130M
cos_g185m	700.0 - 5000.0	g185m grating	dummy	G185M
cos_g225m	700.0 - 5000.0	g225m grating	dummy	G225M
cos_g285m	700.0 - 5000.0	g285m grating	dummy	G285M
cos_g230l	700.0 - 5000.0	g230l grating	dummy	G230L

We could ask ourselves, why these files even exist if these are filled with ones? The reason is in part historic and in part system related. The purpose of pysynphot/Synphot is

to simulate the photometry of all HST modes by combining the throughput or response of each of the optical elements in each of the instruments and detectors. Therefore, it seems quite logic to have one file per optical element in the instrument. However, characterization of each of these components can only be done in the ground; i.e. when the detectors are being tested. This means that no updates can be made once the detectors are in orbit. But detectors evolve with time and therefore changes are necessary. We do have information about changes in the transmission by comparing the images in the detector. Since for COS this varies depending on the grating and central wavelength, we then put all the information needed by pysynphot/Synphot simulations for COS in the grating/central wavelength files and leave alone the grating only files.

Table 11 provides with a list of all the Grating settings for the FUV detector. In this case, column 3 indicates the central wavelength that is associated with the component name given in column 1. Table 12 is the same as Table 11 but for NUV

Table 11: pysynphot/Synphot Grating Setting Files for COS FUV

Filename	Wavelength range	Central Wavelength
cos_mcp_g130mc1096	939.0 - 1237.0	c1096
cos_mcp_g130mc1055	899.0 - 1196.0	c1055
cos_mcp_g130mc1222	1067.0 - 1363.0	c1222
cos_mcp_g130mc1309	1153.0 - 1449.0	c1309
cos_mcp_g130mc1318	1163.0 - 1460.0	c1318
cos_mcp_g130mc1327	1172.0 - 1469.0	c1327
cos_mcp_g130mc1291	1136.0 - 1433.0	c1291
cos_mcp_g130mc1300	1146.0 - 1442.0	c1300
cos_mcp_g160mc1600	1410.0 - 1772.0	c1600
cos_mcp_g160mc1589	1386.0 - 1750.0	c1589
cos_mcp_g160mc1577	1382.0 - 1762.0	c1577
cos_mcp_g160mc1623	1433.0 - 1798.0	c1623
cos_mcp_g160mc1611	1420.0 - 1785.0	c1611
cos_mcp_g140lc1230	700.0 - 2385.0	c1230
cos_mcp_g140lc1280	700.0 - 2385.0	c1280
cos_mcp_g140lc1105	1120.0 - 2250.0	c1105

A diagram of how these files are combined by Synphot is given in Figure 6. The order in which they appear in the diagram is the light path from the aperture to the detector; the same order they appear in the TMG table.

Table 12: Throughput Grating Setting Files for COS NUV

Filename	Wavelength range	Central Wavelength
cosncm3_g185mc1890	1774.0 - 2006.0	c1890
cosncm3_g185mc1786	1670.0 - 1903.0	c1786
cosncm3_g185mc1817	1701.0 - 1934.0	c1817
cosncm3_g185mc1835	1719.0 - 1951.0	c1835
cosncm3_g185mc1850	1734.0 - 1966.0	c1850
cosncm3_g185mc1864	1748.0 - 1980.0	c1864
cosncm3_g185mc1882	1766.0 - 1999.0	c1882
cosncm3_g185mc1900	1783.0 - 2016.0	c1900
cosncm3_g185mc1913	1796.0 - 2028.0	c1913
cosncm3_g185mc1921	1804.0 - 2037.0	c1921
cosncm3_g185mc1941	1825.0 - 2058.0	c1941

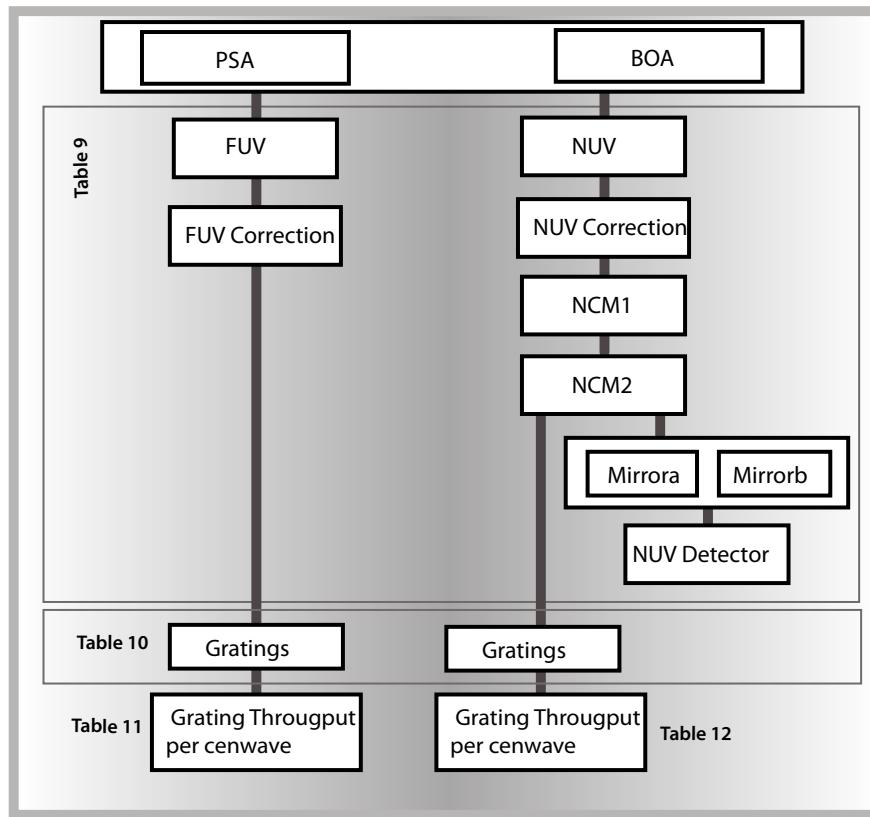


Fig. 6.— COS light path for the NUV and FUV detectors

Table 12: Throughput Grating Setting Files for COS NUV (continued)

Filename	Wavelength range	Central Wavelength
cosncm3_g185mc1953	1837.0 - 2069.0	c1953
cosncm3_g185mc1971	1854.0 - 2087.0	c1971
cosncm3_g185mc1986	1870.0 - 2103.0	c1986
cosncm3_g185mc2010	1894.0 - 2127.0	c2010
cosncm3_g225mc2339	2223.0 - 2456.0	c2339
cosncm3_g225mc2410	2294.0 - 2527.0	c2410
cosncm3_g225mc2373	2256.0 - 2489.0	c2373
cosncm3_g225mc2186	2070.0 - 2303.0	c2186
cosncm3_g225mc2217	2101.0 - 2334.0	c2217
cosncm3_g225mc2233	2117.0 - 2349.0	c2233
cosncm3_g225mc2250	2134.0 - 2367.0	c2250
cosncm3_g225mc2357	2241.0 - 2474.0	c2357
cosncm3_g225mc2268	2152.0 - 2385.0	c2268
cosncm3_g225mc2283	2167.0 - 2399.0	c2283
cosncm3_g225mc2306	2190.0 - 2422.0	c2306
cosncm3_g225mc2325	2208.0 - 2441.0	c2325
cosncm3_g225mc2390	2274.0 - 2507.0	c2390
cosncm3_g285mc3035	2898.0 - 3170.0	c3035
cosncm3_g285mc3057	2920.0 - 3192.0	c3057
cosncm3_g285mc3074	2937.0 - 3209.0	c3074
cosncm3_g285mc3094	2957.0 - 3229.0	c3094
cosncm3_g285mc2979	2842.0 - 3114.0	c2979
cosncm3_g285mc2617	2480.0 - 2752.0	c2617
cosncm3_g285mc2637	2500.0 - 2772.0	c2637
cosncm3_g285mc2657	2520.0 - 2792.0	c2657
cosncm3_g285mc2676	2539.0 - 2811.0	c2676
cosncm3_g285mc2695	2558.0 - 2830.0	c2695
cosncm3_g285mc2709	2572.0 - 2844.0	c2709
cosncm3_g285mc2719	2582.0 - 2854.0	c2719
cosncm3_g285mc2739	2602.0 - 2878.0	c2739
cosncm3_g285mc2850	2714.0 - 2986.0	c2850
cosncm3_g285mc2952	2815.0 - 3087.0	c2952
cosncm3_g285mc2996	2859.0 - 3131.0	c2996
cosncm3_g285mc3018	2881.0 - 3153.0	c3018
cosncm3_g230lc2635	1333.5 - 2835.0	c2635
cosncm3_g230lc2950	1649.5 - 3151.0	c2950
cosncm3_g230lc3000	1699.5 - 3200.5	c3000
cosncm3_g230lc3360	2058.5 - 3561.0	c3360

WFC3 Throughput Files

Synphot files for WFC3 are separated in two main groups: one for the UVIS channel and another set of files for the IR channel. Figure 7 shows and schematic of the light path as it travels to the instruments for each of these channels. Each utilizes different optical components; except for the pick off mirror and the channel selection mechanism with its flat mirror.

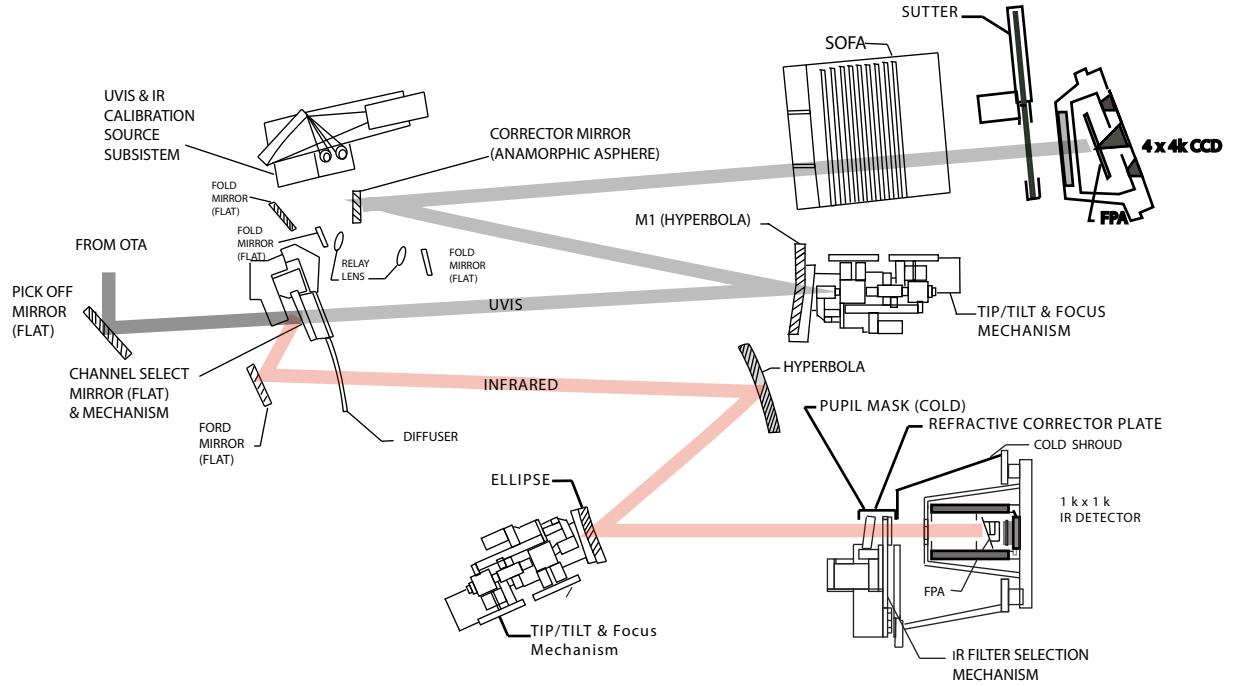


Fig. 7.— WFC3 light path UVIS and IR channels

The corresponding Throughput files for the shared optical elements (for IR and UVIS channels) are listed in Table 13.

UVIS Imaging modes then go through the filter transmission wheel which requires these modes to be corrected by the transmission of the UVIS inner and outer windows. The corresponding files for the inner and outer windows are given in Table 14. This table also provides with the transmission files that are used to account for the raw quantum efficiency of each of the UVIS detector chips.

Table 13: Throughput Files: shared IR + UVIS Optical Elements

filename	Wavelength range	Optical Element	type	keyword
wfc3_pom	1990 - 20000	Reflectivity of pickoff mirror	data	default
wfc3_uvvis_mir1	1990 - 11200	Reflectivity of UVIS mirror 1	data	default
wfc3_uvvis_mir2	1990 - 11200	Reflectivity of UVIS mirror 2	data	default

A complete list of the available filter transmission files for the UVIS channel is given in Table 15.

Modes that are flat-fielded are then normalized. Since the normalization varies from filter to filter; there is a transmission file for each of them. Table 16 for provides with the list of the files used for chip 1 and Table 17 for chip 2.

The transmission is then corrected by variations unattributable to a single component along with quantum efficiency variations with chip and wavelength in the UVIS. If applicable, the resulting values are then converted from electrons to DN and corrected for the different aperture radius. The files used to account for all these variations are given in Table 18

For the spectroscopic cases, files for G280 grism are used instead of those given in Table 15 to Table 17. For astronomical sources the first-order throughput curves are used; while for diffuse background calculations that total throughput of the grism is used. Both of these files are listed in Table 19

In the infrared band, the contribution of the primary and secondary mirrors are included. These are then combined with the reflectability of the pick-off mirror, the channel select mechanism, and the different mirrors used to bend the light path. A list of the throughput files used in these cases are given in Table 20; except for that of the PMO which is contribution is included in the same file used for the UVIS.

Table 14: Throughput Files for WFC3 UVIS Optical Elements

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_owin	1990 - 11200	Transmission outer window	data	default
wfc3_uvvis_iwin	1990 - 11200	Transmission inner window	data	default
wfc3_uvvis_ccd1	1900 - 11000	Raw quantum efficiency for detector chip 1	data	uvvis1
wfc3_uvvis_ccd2	1900 - 11000	Raw quantum efficiency for detector chip 2	data	uvvis2

Table 15: Filter Transmission Files for WFC3 filters for UVIS Channel

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_f673n	1002 - 14998	Filter F673N	data	f673n
wfc3_uvvis_f373n	1002 - 14998	Filter F373N	data	f373n
wfc3_uvvis_f390m	1002 - 14998	Filter F390M	data	f390m
wfc3_uvvis_f390w	1002 - 14998	Filter F390W	data	f390w
wfc3_uvvis_f395n	1002 - 14998	Filter F395N	data	f395n
wfc3_uvvis_f410m	1002 - 14998	Filter F410M	data	f410m
wfc3_uvvis_f438w	1002 - 14998	Filter F438W	data	f438w
wfc3_uvvis_f467m	1002 - 14998	Filter F467M	data	f467m
wfc3_uvvis_f469n	1002 - 14998	Filter F469N	data	f469n
wfc3_uvvis_f475w	1002 - 14998	Filter F475W	data	f475w
wfc3_uvvis_f475x	1002 - 14998	Filter F475X	data	f475x
wfc3_uvvis_f487n	1002 - 14998	Filter F487N	data	f487n
wfc3_uvvis_f502n	1002 - 14998	Filter F502N	data	f502n
wfc3_uvvis_fq508n	1002 - 14998	Filter FQ508N	data	fq508n
wfc3_uvvis_f547m	1002 - 14998	Filter F547M	data	f547m
wfc3_uvvis_f555w	1002 - 14998	Filter F555W	data	f555w
wfc3_uvvis_f600lp	1002 - 14998	Filter F600LP	data	f600lp
wfc3_uvvis_f606w	1002 - 14998	Filter F606W	data	f606w
wfc3_uvvis_f621m	1002 - 14998	Filter F621M	data	f621m
wfc3_uvvis_f625w	1002 - 14998	Filter F625W	data	f625w
wfc3_uvvis_f631n	1002 - 14998	Filter F631N	data	f631n
wfc3_uvvis_f645n	1002 - 14998	Filter F645N	data	f645n
wfc3_uvvis_f656n	1002 - 14998	Filter F656N	data	f656n
wfc3_uvvis_f657n	1002 - 14998	Filter F657N	data	f657n
wfc3_uvvis_f658n	1002 - 14998	Filter F658N	data	f658n
wfc3_uvvis_f665n	1002 - 14998	Filter F665N	data	f665n
wfc3_uvvis_f680n	1002 - 14998	Filter F680N	data	f680n
wfc3_uvvis_f689m	1002 - 14998	Filter F689M	data	f689m
wfc3_uvvis_f763m	1002 - 14998	Filter F763M	data	f763m
wfc3_uvvis_f775w	1002 - 14998	Filter F775W	data	f775w
wfc3_uvvis_f814w	1002 - 14998	Filter F814W	data	f814w
wfc3_uvvis_f845m	1002 - 14998	Filter F845M	data	f845m
wfc3_uvvis_f850lp	1002 - 14998	Filter F850LP	data	f850lp
wfc3_uvvis_f953n	1002 - 14998	Filter F953N	data	f953n
wfc3_uvvis_fq232n	1002 - 14998	Filter FQ232N	data	fq232n
wfc3_uvvis_fq243n	1002 - 14998	Filter FQ243N	data	fq243n
wfc3_uvvis_fq378n	1002 - 14998	Filter FQ378N	data	fq378n
wfc3_uvvis_fq387n	1002 - 14998	Filter FQ387N	data	fq387n
wfc3_uvvis_fq422m	1002 - 14998	Filter FQ422M	data	fq422m

Table 15: Filter Throughput Files for WFC3 flat UVIS Channel (cont)

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis fq436n	1002 - 14998	Filter FQ436N	data	fq436n
wfc3_uvvis fq437n	1002 - 14998	Filter FQ437N	data	fq437n
wfc3_uvvis fq492n	1002 - 14998	Filter FQ492N	data	fq492n
wfc3_uvvis fq575n	1002 - 14998	Filter FQ575N	data	fq575n
wfc3_uvvis fq619n	1002 - 14998	Filter FQ619N	data	fq619n
wfc3_uvvis fq634n	1002 - 14998	Filter FQ634N	data	fq634n
wfc3_uvvis fq672n	1002 - 14998	Filter FQ672N	data	fq672n
wfc3_uvvis fq674n	1002 - 14998	Filter FQ674N	data	fq674n
wfc3_uvvis fq727n	1002 - 14998	Filter FQ727N	data	fq727n
wfc3_uvvis fq750n	1002 - 14998	Filter FQ750N	data	fq750n
wfc3_uvvis fq889n	1002 - 14998	Filter FQ889N	data	fq889n
wfc3_uvvis fq906n	1002 - 14998	Filter FQ906N	data	fq906n
wfc3_uvvis fq924n	1002 - 14998	Filter FQ924N	data	fq924n
wfc3_uvvis fq937n	1002 - 14998	Filter FQ937N	data	fq937n
wfc3_uvvis f200lp	1002 - 14998	Filter F200LP	data	f200lp
wfc3_uvvis f218w	1002 - 14998	Filter F218W	data	f218w
wfc3_uvvis f225w	1002 - 14998	Filter F225W	data	f225w
wfc3_uvvis f275w	1002 - 14998	Filter F275W	data	f275w
wfc3_uvvis f280n	1002 - 14998	Filter F280N	data	f280n
wfc3_uvvis f300x	1002 - 14998	Filter F300X	data	f300x
wfc3_uvvis f336w	1002 - 14998	Filter F336W	data	f336w
wfc3_uvvis f343n	1002 - 14998	Filter F343N	data	f343n
wfc3_uvvis f350lp	1002 - 14998	Filter F350LP	data	f350lp

The resulting throughput is then combined with the filter transmission curves for the imaging case. The complete list of IR filter transmission files is given in Table 21.

These are then combined with the transmission of the IR window, corrected by variations of the quantum efficiency of the IR detector, and variations that cannot be accounted by a single component. Finally, if applicable, the electrons are converted to data numbers and corrected for apertures of different radius. The list of files accounting for all the effects mentioned above are given in Table 22.

In the spectroscopic cases, the filter files are replaced by grism files. In the case of calculations for astronomical sources, the combination is made with the first order throughput

Table 16: Filter Throughput for WFC3 flat-fielded UVIS Channel 1

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_f673nf1	1002 - 14998	F673N chip 1	data	f673n
wfc3_uvvis_f373nf1	1002 - 14998	F373N chip 1	data	f373n
wfc3_uvvis_f390mf1	1002 - 14998	F390M chip 1	data	f390m
wfc3_uvvis_f390wf1	1002 - 14998	F390W chip 1	data	f390w
wfc3_uvvis_f395nf1	1002 - 14998	F395N chip 1	data	f395n
wfc3_uvvis_f410mf1	1002 - 14998	F410M chip 1	data	f410m
wfc3_uvvis_f438wf1	1002 - 14998	F438W chip 1	data	f438w
wfc3_uvvis_f467mf1	1002 - 14998	F467M chip 1	data	f467m
wfc3_uvvis_f469nf1	1002 - 14998	F469N chip 1	data	f469n
wfc3_uvvis_f475wf1	1002 - 14998	F475W chip 1	data	f475w
wfc3_uvvis_f475xf1	1002 - 14998	F475X chip 1	data	f475x
wfc3_uvvis_f487nf1	1002 - 14998	F487N chip 1	data	f487n
wfc3_uvvis_f502nf1	1002 - 14998	F502N chip 1	data	f502n
wfc3_uvvis_fq508nf1	1002 - 14998	FQ508N chip 1	data	fq508n
wfc3_uvvis_f547mf1	1002 - 14998	F547M chip 1	data	f547m
wfc3_uvvis_f555wf1	1002 - 14998	F555W chip 1	data	f555w
wfc3_uvvis_f600lpf1	1002 - 14998	F600LP chip 1	data	f600lp
wfc3_uvvis_f606wf1	1002 - 14998	F606W chip 1	data	f606w
wfc3_uvvis_f621mf1	1002 - 14998	F621M chip 1	data	f621m
wfc3_uvvis_f625wf1	1002 - 14998	F625W chip 1	data	f625w
wfc3_uvvis_f631nf1	1002 - 14998	F631N chip 1	data	f631n
wfc3_uvvis_f645nf1	1002 - 14998	F645N chip 1	data	f645n
wfc3_uvvis_f656nf1	1002 - 14998	F656N chip 1	data	f656n
wfc3_uvvis_f657nf1	1002 - 14998	F657N chip 1	data	f657n
wfc3_uvvis_f658nf1	1002 - 14998	F658N chip 1	data	f658n
wfc3_uvvis_f665nf1	1002 - 14998	F665N chip 1	data	f665n
wfc3_uvvis_f680nf1	1002 - 14998	F680N chip 1	data	f680n
wfc3_uvvis_f689mf1	1002 - 14998	F689M chip 1	data	f689m
wfc3_uvvis_f763mf1	1002 - 14998	F763M chip 1	data	f763m
wfc3_uvvis_f775wf1	1002 - 14998	F775W chip 1	data	f775w
wfc3_uvvis_f814wf1	1002 - 14998	F814W chip 1	data	f814w
wfc3_uvvis_f845mf1	1002 - 14998	F845M chip 1	data	f845m
wfc3_uvvis_f850lpf1	1002 - 14998	F850LP chip 1	data	f850lp
wfc3_uvvis_f953nf1	1002 - 14998	F953N chip 1	data	f953n
wfc3_uvvis_fq232nf1	1002 - 14998	FQ232N chip 1	data	fq232n
wfc3_uvvis_fq243nf1	1002 - 14998	FQ243N chip 1	data	fq243n
wfc3_uvvis_fq378nf1	1002 - 14998	FQ378N chip 1	data	fq378n
wfc3_uvvis_fq387nf1	1002 - 14998 ²²	FQ387N chip 1	data	fq387n
wfc3_uvvis_fq422mf1	1002 - 14998	FQ422M chip 1	data	fq422m

Table 17: Filter Throughput Files for WFC3 flat-fielded UVIS Channel2

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_f673nf2	1002 - 14998	F673N chip 2	data	f673n
wfc3_uvvis_f373nf2	1002 - 14998	F373N chip 2	data	f373n
wfc3_uvvis_f390mf2	1002 - 14998	F390M chip 2	data	f390m
wfc3_uvvis_f390wf2	1002 - 14998	F390W chip 2	data	f390w
wfc3_uvvis_f395nf2	1002 - 14998	F395N chip 2	data	f395n
wfc3_uvvis_f410mf2	1002 - 14998	F410M chip 2	data	f410m
wfc3_uvvis_f438wf2	1002 - 14998	F438W chip 2	data	f438w
wfc3_uvvis_f467mf2	1002 - 14998	F467M chip 2	data	f467m
wfc3_uvvis_f469nf2	1002 - 14998	F469N chip 2	data	f469n
wfc3_uvvis_f475wf2	1002 - 14998	F475W chip 2	data	f475w
wfc3_uvvis_f475xf2	1002 - 14998	F475X chip 2	data	f475x
wfc3_uvvis_f487nf2	1002 - 14998	F487N chip 2	data	f487n
wfc3_uvvis_f502nf2	1002 - 14998	F502N chip 2	data	f502n
wfc3_uvvis_fq508nf2	1002 - 14998	FQ508N chip 2	data	fq508n
wfc3_uvvis_f547mf2	1002 - 14998	F547M chip 2	data	f547m
wfc3_uvvis_f555wf2	1002 - 14998	F555W chip 2	data	f555w
wfc3_uvvis_f600lpf2	1002 - 14998	F600LP chip 2	data	f600lp
wfc3_uvvis_f606wf2	1002 - 14998	F606W chip 2	data	f606w
wfc3_uvvis_f621mf2	1002 - 14998	F621M chip 2	data	f621m
wfc3_uvvis_f625wf2	1002 - 14998	F625W chip 2	data	f625w
wfc3_uvvis_f631nf2	1002 - 14998	F631N chip 2	data	f631n
wfc3_uvvis_f645nf2	1002 - 14998	F645N chip 2	data	f645n
wfc3_uvvis_f656nf2	1002 - 14998	F656N chip 2	data	f656n
wfc3_uvvis_f657nf2	1002 - 14998	F657N chip 2	data	f657n
wfc3_uvvis_f658nf2	1002 - 14998	F658N chip 2	data	f658n
wfc3_uvvis_f665nf2	1002 - 14998	F665N chip 2	data	f665n
wfc3_uvvis_f680nf2	1002 - 14998	F680N chip 2	data	f680n
wfc3_uvvis_f689mf2	1002 - 14998	F689M chip 2	data	f689m
wfc3_uvvis_f763mf2	1002 - 14998	F763M chip 2	data	f763m
wfc3_uvvis_f775wf2	1002 - 14998	F775W chip 2	data	f775w
wfc3_uvvis_f814wf2	1002 - 14998	F814W chip 2	data	f814w
wfc3_uvvis_f845mf2	1002 - 14998	F845M chip 2	data	f845m
wfc3_uvvis_f850lpf2	1002 - 14998	F850LP chip 2	data	f850lp
wfc3_uvvis_f953nf2	1002 - 14998	F953N chip 2	data	f953n

Table 17: Filter Throughput Files for WFC3 flat-fielded UVIS Channel2 (cont)

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_fq232nf2	1002 - 14998	FQ232N chip 2	data	fq232n
wfc3_uvvis_fq243nf2	1002 - 14998	FQ243N chip 2	data	fq243n
wfc3_uvvis_fq378nf2	1002 - 14998	FQ378N chip 2	data	fq378n
wfc3_uvvis_fq387nf2	1002 - 14998	FQ387N chip 2	data	fq387n
wfc3_uvvis_fq422mf2	1002 - 14998	FQ422M chip 2	data	fq422m
wfc3_uvvis_fq436nf2	1002 - 14998	FQ436N chip 2	data	fq436n
wfc3_uvvis_fq437nf2	1002 - 14998	FQ437N chip 2	data	fq437n
wfc3_uvvis_fq492nf2	1002 - 14998	FQ492N chip 2	data	fq492n
wfc3_uvvis_fq575nf2	1002 - 14998	FQ575N chip 2	data	fq575n
wfc3_uvvis_fq619nf2	1002 - 14998	FQ619N chip 2	data	fq619n
wfc3_uvvis_fq634nf2	1002 - 14998	FQ634N chip 2	data	fq634n
wfc3_uvvis_fq672nf2	1002 - 14998	FQ672N chip 2	data	fq672n
wfc3_uvvis_fq674nf2	1002 - 14998	FQ674N chip 2	data	fq674n
wfc3_uvvis_fq727nf2	1002 - 14998	FQ727N chip 2	data	fq727n
wfc3_uvvis_fq750nf2	1002 - 14998	FQ750N chip 2	data	fq750n
wfc3_uvvis_fq889nf2	1002 - 14998	FQ889N chip 2	data	fq889n
wfc3_uvvis_fq906nf2	1002 - 14998	FQ906N chip 2	data	fq906n
wfc3_uvvis_fq924nf2	1002 - 14998	FQ924N chip 2	data	fq924n
wfc3_uvvis_fq937nf2	1002 - 14998	FQ937N chip 2	data	fq937n
wfc3_uvvis_g280f2	1002 - 14998	G280 chip 2	data	g280
wfc3_uvvis_f200lpf2	1002 - 14998	F200LP chip 2	data	f200lp
wfc3_uvvis_f218wf2	1002 - 14998	F218W chip 2	data	f218w
wfc3_uvvis_f225wf2	1002 - 14998	F225W chip 2	data	f225w
wfc3_uvvis_f275wf2	1002 - 14998	F275W chip 2	data	f275w
wfc3_uvvis_f280nf2	1002 - 14998	F280N chip 2	data	f280n
wfc3_uvvis_f300xf2	1002 - 14998	F300X chip 2	data	f300x
wfc3_uvvis_f336wf2	1002 - 14998	F336W chip 2	data	f336w
wfc3_uvvis_f343nf2	1002 - 14998	F343N chip 2	data	f343n
wfc3_uvvis_f350lpf2	1002 - 14998	F350LP chip 2	data	f350lp

Table 18: Throughput Files for WFC3 UVIS Optical Elements

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_cor	500 - 20000	Correction unattributable to a single component	data	default
wfc3_uvvis_qyc	1000 - 12000	Quantum yield correction	data	qyc
wfc3_uvvis_dn	1000 - 20000	Conversion from electrons to data numbers	data	dn
wfc3_uvvis_aper	2000 - 11000	Encircled energy at a given radius	data	aper#

Table 19: Throughput Files for WFC3 UVIS grism

filename	Wavelength range	Optical Element	type	keyword
wfc3_uvvis_g280_src	2000 - 9500	First-order throughput for G280	data	default
wfc3_uvvis_g280_bkg	2000 - 9500	Total throughput for G280	data	bkg

Table 20: Throughput Files for WFC3 IR Optical Elements

filename	Wavelength range	Optical Element	type	keyword
wfc3_ir_primary	1000 - 30000	HST primary mirror throughput	data	default
wfc3_ir_secondary	1000 - 30000	HST secondary mirror throughput	data	default
wfc3_ir_csm	8000 - 20000	Reflectivity of channel select mechanism	data	default
wfc3_ir_fold	8000 - 20000	Reflectivity of fold mirror	data	default
wfc3_ir_mir1	8000 - 20000	Reflectivity of mirror 1	data	default
wfc3_ir_mir2	8000 - 20000	Reflectivity of mirror 2	data	default
wfc3_ir_mask	8000 - 20000	Throughput of cold mask	dummy	default
wfc3_ir_rcp	8000 - 20000	Transmission of refractive corrector plate	data	default

curves; while for background calculations the total throughput of the grism is used. The list of the throughput files is given in Table 23

Figure 8 shows a diagram with the different components used in a pysynphot/Synphot call in the order they are listed in the Master Graph Table. This order will be the same path taken by the light from the astronomical source to the different WFC3 detectors. The left hand side of the figure shows the order in which the UVIS channels are combined. The right hand side shows the order for the IR. This figure also indicates the Table number where these files can be found in this document.. When a table covers more than one type of optical element, these are enclosed within a box. For a table that hold the same type of component (e.g. filters) the table number will be found next to individual box.

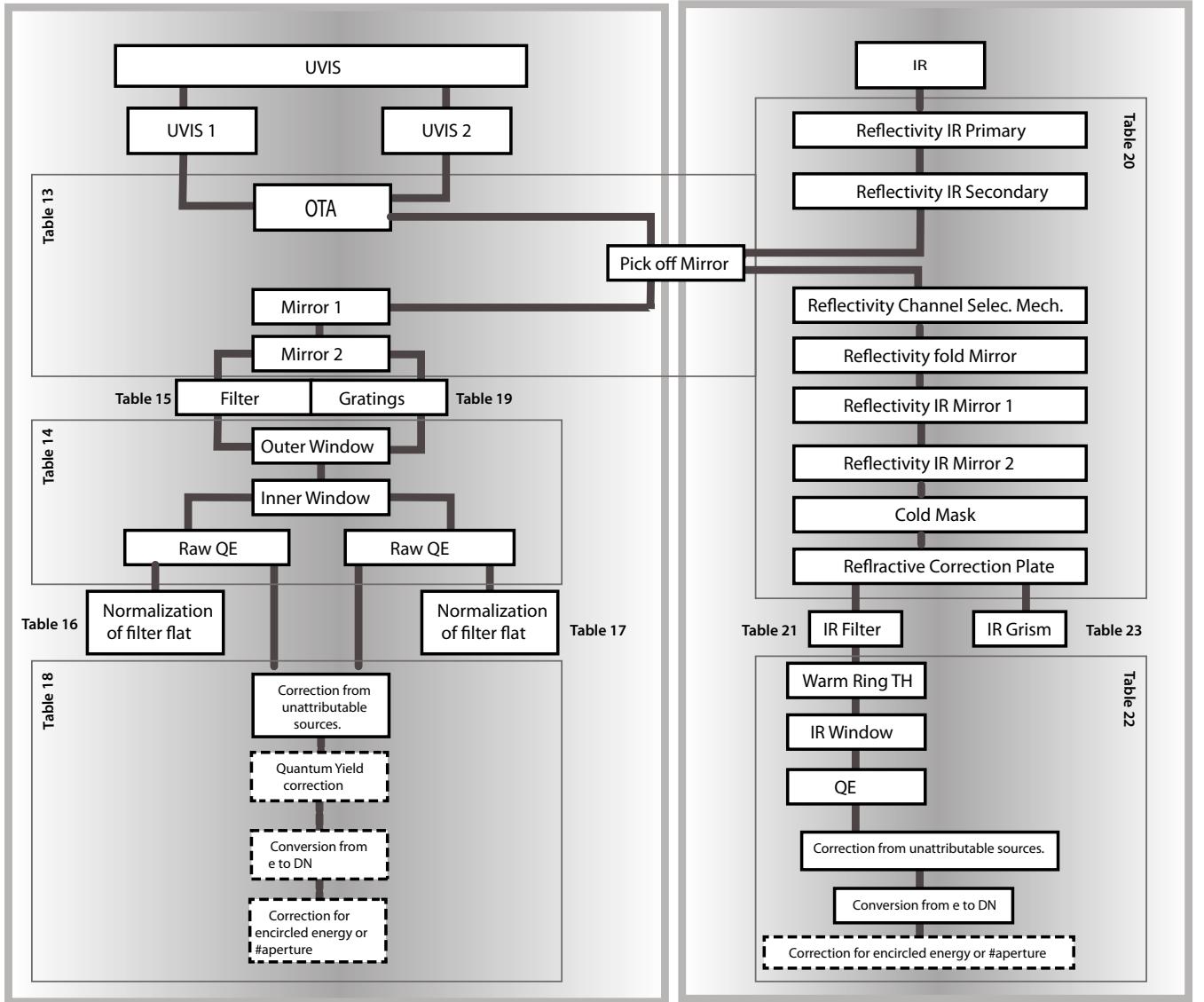


Fig. 8.— Schematics of the TMG table for WFC3 along with the Table number where these files can be found. The dotted boxes indicate those throughput files that are optional; via parameterized or special keywords.

Table 21: Throughput Files for IR WFC3 Filters

filename	Wavelength range	Optical Element	type	keyword
wfc3_ir_f167n	73021 - 20005.5	Filter transmission for F167N	data	f167n
wfc3_ir_f105w	75528 - 20005.5	Filter transmission for F105W	data	f105w
wfc3_ir_f110w	7001.93 - 19005.2	Filter transmission for F110W	data	f110w
wfc3_ir_f125w	7001.93 - 19005.2	Filter transmission for F125W	data	f125w
wfc3_ir_f126n	7001.93 - 20005.5	Filter transmission for F126N	data	f126n
wfc3_ir_f127m	7001.93 - 20005.5	Filter transmission for F127M	data	f127m
wfc3_ir_f128n	7001.93 - 20005.5	Filter transmission for F128N	data	f128n
wfc3_ir_f130n	73021 - 20005.5	Filter transmission for F130N	data	f130n
wfc3_ir_f132n	7252 - 20005.5	Filter transmission for F132N	data	f132n
wfc3_ir_f139m	7001.93 - 20005.5	Filter transmission for F139M	data	f139m
wfc3_ir_f153m	7001.93 - 20005.5	Filter transmission for F153M	data	f153m
wfc3_ir_f160w	74525 - 19224.7	Filter transmission for F160W	data	f160w
wfc3_ir_f164n	7001.93 - 20005.5	Filter transmission for F164N	data	f164n
wfc3_ir_f140w	73021 - 19604.5	Filter transmission for F140W	data	f140w
wfc3_ir_f098m	7001.93 - 19605.4	Filter transmission for F098M	data	f098m

Table 22: Throughput Files for WFC3 IR Optical Elements

filename	Wavelength range	Optical Element	type	keyword
wfc3_ir_win	8000 - 20000	Transmission of IR window	data	default
wfc3_ir_qe	4000 - 18000	Quantum efficiency for IR detector	data	default
wfc3_ir_cor	1000 - 20000	IR throughput correction unattributable to a single component.	data	default
wfc3_ir_dn	1000 - 20000	Conversion from electrons to data numbers	data	dn
wfc3_ir_aper	7000 - 16000	Encircled energy at a given radius	data	aper#

In the case of IR WFC3, the thermal contribution from the background is also important. In pysynphot/Synphot the task: *thermback* will evaluate the thermal background count rate for an observing mode. Table 24 provides with a list of all the WFC3 and HST components contributing to thermal emissivity. The observing mode is specified by *Instrument*, *detector*, *spectral element*, and *aperture*; although only the *instrument* name is required.

Table 23: Throughput Files for WFC3 IR grisms

filename	Wavelength range	Optical Element	type	keyword
wfc3_ir_g102_bkg	5021.4 - 19005.2	Total throughput for G102	data	bkg
wfc3_ir_g102_src	76029 - 13103.6	First-order throughput for G102	data	default
wfc3_ir_g141_bkg	7001.93 - 20005.5	Total throughput for G141	data	bkg
wfc3_ir_g141_src	9702.66 - 17904.9	First-order throughput for G141	data	default

Table 24: Emissivity Files for WFC3 IR modes

Filename	Description	Component
wfc3_ir_primary	HST primary mirror	wfc3_ir_primary
wfc3_ir_pads	HST mirror pads	wfc3_ir_pads
wfc3_ir_secondary	HST secondary mirror	wfc3_ir_secondary
wfc3_ir_cor	IR throughput correction unattributable to a single component	wfc3_ir_cor
wfc3_ir_csm	Reflectivity of channel select mechanism	wfc3_ir_csm
wfc3_ir_fold	Reflectivity of IR fold mirror	wfc3_ir_fold
wfc3_ir_mir1	Reflectivity of IR mirror 1	wfc3_ir_mir1
wfc3_ir_mir2	Reflectivity of IR mirror 2	wfc3_ir_mir2
wfc3_ir_rcp	Transmission of refractive corrector plate	wfc3_ir_rcp
wfc3_ir_wmring	WFC3 warm ring	wfc3_ir_wmring
wfc3_ir_win	Transmission of IR window	wfc3_ir_win
wfc3_pom	Reflectivity of pickoff mirror	wfc3_pom
wfc3_ir_mask	Throughput of cold mask	wfc3_ir_mask
wfc3_ir_qe	quantum efficiency for IR detector	wfc3_ir_qe
wfc3_ir_dn	Conversion from electrons to data numbers	wfc3_ir_dn
wfc3_ir_g102_src	First-order throughput for IR grism G102	wfc3_ir_g102_src
wfc3_ir_g102_bkg	Throughput for IR grism G102	wfc3_ir_g102_bkg
wfc3_ir_g141_src	First-order throughput for IR grism G141	wfc3_ir_g141_src
wfc3_ir_g141_bkg	Total throughput for IR grism G141	wfc3_ir_g141_bkg
wfc3_ir_f140w	Filter transmission for F140W	wfc3_ir_f140w
wfc3_ir_f098m	Filter transmission for F098M	wfc3_ir_f098m
wfc3_ir_f105w	Filter transmission for F105W	wfc3_ir_f105w
wfc3_ir_f110w	Filter transmission for F110W	wfc3_ir_f110w
wfc3_ir_f125w	Filter transmission for F125W	wfc3_ir_f125w
wfc3_ir_f126n	Filter transmission for F126N	wfc3_ir_f126n
wfc3_ir_f127m	Filter transmission for F127M	wfc3_ir_f127m
wfc3_ir_f128n	Filter transmission for F128N	wfc3_ir_f128n
wfc3_ir_f130n	Filter transmission for F130N	wfc3_ir_f130n
wfc3_ir_f132n	Filter transmission for F132N	wfc3_ir_f132n
wfc3_ir_f139m	Filter transmission for F139M	wfc3_ir_f139m
wfc3_ir_f153m	Filter transmission for F153M	wfc3_ir_f153m
wfc3_ir_f160w	Filter transmission for F160W	wfc3_ir_f160w
wfc3_ir_f164n	Filter transmission for F164N	wfc3_ir_f164n
wfc3_ir_f167n	Filter transmission for F167N	wfc3_ir_f167n

Wavecat file

The wavecat file is a best lookup table that specifies the wavelength array should be used for a given obsmode or obsmode pattern. For example, if there are two entries like:

```
acs,hrc some_value - acs,hrc,f555w some_other_value
```

the coefficients in acs,hrc,f555w will use a specific value, while all other acs,hrc obsmodes will use the first one. The wavecat files consist of a set of four coefficients per mode indicating either the name of a file or the wavelength range covered by the mode and spacing:

```
stis,g140m,i1218 (1190.5,1245.5,0.05)
```

The coefficients are given in parenthesis and according to their position are the short wavelength (in Å), long wavelength (in Å), dispersion at the short wavelength (Å/pixel), and dispersion at the long wavelength (Å/pixel). In the above example we only have three coefficients. This is because either one or both of the dispersions are optional. In the case of spectroscopic modes, the wavelength spacing is set to equal the detector spacing.

In the case where the coefficient is a file; for example:

```
cos,nuv,g185m,c1786      synphot$data/cos_nuv_g185m_1786.txt
```

the file contains a list of wavelengths; with a dispersion that varies more than twice. If there is no wavecat entry, both SYNPHOT and pysynphot use the wavelength array of the spectrum.

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References

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