



## **DESCRIPTION OF THE UVOT CALIBRATION FILES**

Version 2.0

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## Introduction

This document describes the format of UVOT Calibration Files and their organization into the UVOT CALibration DataBase (UVOTCALDB, chapter 2).

The Calibration Data are the results of the calibration activities and they are recorded in the Calibration Database for archive purposes and/or to be used in the UVOT Pipeline processing software. Specifically some the UVOT CALDB files are used in the UVOT pipeline to create Level 1 and Level 2 calibrated files. They are also used in the Level 3 Data Products Generation and analysis either via pipeline or interactive processing.

The files are stored in CALDB in FITS format with the layout described in this document. Whenever possible standard OGIP layouts were used.

### 1.1 Applicable Documents

[1] - BCF & CPF Calibration File Guidelines - OGIP Calibration Memo CAL/GEN/92-003

[2] - HFWG Recommendation R8 -1994 February 02

[3] - Required and Recommended FITS keywords for Calibration Files -OGIP Calibration Memo CAL/GEN/92-011

[4] - A Panchromatic Gamma Ray Burst MIDEX Mission - Phase A Study Report in response to AO-98-0SS-03

## 1.2 Definitions, acronyms and abbreviations

<b>ARF</b>	Ancillary Response File
<b>CCD</b>	Charge Coupled Device
<b>CTE</b>	Charge Transfer Efficiency
<b>EEF</b>	Encircled Energy Fraction
<b>FITS</b>	Flexible Image Transport System
<b>GNEST</b>	Ground Network for Swift
<b>GRB</b>	Gamma Ray Burst
<b>GSFC</b>	Goddard Space Flight Center
<b>GTI</b>	Good Time Intervals
<b>HEASARC</b>	High Energy Astrophysics Science Archive Research Center
<b>HK</b>	Housekeeping
<b>OGIP</b>	Office of the Guest Investigator Programs
<b>MSSL</b>	Mullard Space Science Laboratory
<b>PHA</b>	Pulse Height Amplitude
<b>PI</b>	Pulse Invariant
<b>PSF</b>	Point Spread Function
<b>PSU</b>	Penn state University
<b>QE</b>	Quantum Efficiency
<b>RMF</b>	Redistribution Matrix File
<b>SDC</b>	Swift Data Center
<b>SSC</b>	Swift Science Center
<b>TBD</b>	To Be Defined
<b>TBC</b>	To Be Confirmed
<b>UCFS</b>	UVOT Calibration File Set
<b>UVOT</b>	UV Optical Telescope



## 2 UVOT CALDB

The UVOT calibration database (UVOTCALDB) includes the pre-launch results obtained from the analysis of the ground calibration data and also those derived from calibration observations taken in flight during the lifetime of the mission. The results are stored in the OGIP CALDB structure as FITS file following the OGIP standard.

The UVOT calibration files are produced by the UVOT Calibration team and delivered to the SSC/UVOT that take care to verify the validity, integrity and format of the files and whether the proper CALDB mandatory keywords are included correctly.

The UVOTCALDB is delivered finally by the SSC to HEASARC. The delivery occurs each time the UVOTCALDB is updated.

### 2.1 Scope

During the course of the Swift mission the UVOTCALDB shall provide:

- a way to store and archive UVOT calibration data;
- naming convention and header structure for UVOT calibration files;
- indexing for software access to UVOT calibration data based on FITS header keywords;
- a traceable history of UVOT calibration data in the database by maintaining the history of versions

### 3 UVOT Calibration File Set (UCFS)

The Calibration Files are stored into the UVOTCALDB database. They are used in the data reduction software and in the data analysis.

#### 3.1 File Naming Convention

The UCFS constituents are named as follows:

swu<datatype>[<date>]v<version>.ext

where:

**datatype** is the calibration data type identifier (at most eight characters long);

**date** is an integer giving the date when the file should first be used, with the format: YYYYMMDD;

**version** is a three digit integer giving the file issue number;

**ext** is set to 'fits' for all files with the following exceptions: 'rmf' is used for the redistribution matrix, 'arf' is used for the ancillary response file and 'teldef' is used for the telescope definition file.

There are some exceptions to this naming convention to conform the names of some datatypes to the ones more frequently used by other missions. Names adopted for each datatype are described in the related paragraph.

#### 3.2 UCFS Datatypes

Table 1 lists the files included into the UCFS with a short description.

<i>datatype</i>	<i>Cal directory</i>	<i>Used in pipeline</i>	<i>Description</i>
teldef (*)	bfc	yes	Telescope definition file. This includes the Boresight definition and the distortion Different files for selected filters
badpix	bfc	yes	Bad Pixels
coltran	bfc	yes	Color transformation This file contains also the Zero points. Note, this is the color transformation product. <ul style="list-style-type: none"> <li>• Zero Point . Included in the color transformation</li> </ul>
coincloss	bfc	yes	Coincidence losses . This includes the frame rate data and the coincidence loss corrections.
filtram	bfc	No	Filter Transmission (and/or sensitivity and/or effective area).
grismeq	bfc	yes	Grism equation
mirrorea	bfc	No	Mirror effective area.
instea	bfc	no	Instrument effective area
skyflat	bfc	yes	Flat field. Large scale sensitivity. Not delivered pre-launched. Dummy file
calflats	bfc	yes	Flat field. This contains the pixel to pixel sensitivity changes and the LED map.
arf	cpf	In xspec	Ancillary Response. The effective area data include all contributions (filter, mirror)
dark	cpf	No	Dark Frame (map).
gallight	cpf	No	Galactic Light (map). This includes a spectrum of the Galactic light and count rates for each UVOTA filter.
zodlight	cpf	No,	Zodiacal Light (map). This includes a spectrum of the Zodiacal light a count rates for each UVOTA filter

psf	cpf	Yes	Point spread function as Encircled Energy Function and/or as double Gaussian fit. The PSF format needs to be defined.(OBSOLETE)
quickmag	cpf	No	Quick count rate conversion to magnitude
rmf	cpf	In xspec	Redistribution Matrix file
eff	cpf	Yes	Encicle Energy Function

***Table 1 -Datatypes and short description of UXCFS files***

(\*) These datatypes are not used in the filename.

## 4 UCFS Files General Description

All UCFS files are FITS files. Keywords required by FITS OGIP standards and listed in this paragraph are described in documents [1], [2] and [3] (section 1.1). See chapter 5 for a detailed description of UVOT calibration FITS files.

### 4.1 Mandatory keywords

Table 2 lists the mandatory keywords to be added to the primary header and to the headers of all extensions of the UCFS Fits files. See documents [1] [2] (section 1.1) for keyword description. On-board there are two detectors for the UVOT side A and side B. The value of the INSTRUME keyword is set to 'UVOTA' or 'UVOTB' to indicate which side is in use. The ground calibration products are provided only for the side A, but ground calibration were taken for both sides. The UVOT will start operating with the side A and there is no plan to switch detector during the LEO or PV to calibrate. If in orbit the side A fails, side B will be used and new calibration products, both from ground and orbit data, will be delivered.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
TELESCOP	'SWIFT'	/ Telescope (mission) name
INSTRUME	'UVOTA'	/ Instrument Name
DETNAM	'xxxx'	/Detector name
DATE	YYYY-MM-DDThh:mm:ss	/ Creation Date This keyword is omitted for empty Primary Headers.
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

**Table 2 - UCFS mandatory header keywords**

The value for DETNAM is a string containing the wheel position. This keyword appear in all the science data file and in CALDB files when relevant. Table 2a gives the default values assigned to the DETNAM keyword for the standard filter positions but also lists the allow range of values :

<i>Default</i>	<i>Name of the standard Filter position</i>	<i>Range for the wheel position</i>
160	UGRISM CLOCKED	100-300
200	VGRISM NOMINAL	
400	UVW2	300-500
600	V	500-700
800	UVM2	700-900
955	VGRISM CLOCKED	900-1100
1100	VGRISM NOMIMAL	
1200	UVW1	1100-1300
1400	U	1300-1500
1600	MAGNIFIER	1500-1700
1800	B	1700-1900
2000	WHITE	1900-2100
2200	UNKNOWN	2100-2300

**Table 3a -DETNAM values**

Table 3 lists the UCFS additional mandatory keywords common to all table headers. Each CALDB keywords has different values for different UCFS Calibration Files. The CALDB keywords and the EXTNAME keyword are specified for each datatype in the related paragraph in section 5.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
EXTNAME	<extension name>	/ Name of the binary table extension or /Name of the image extension This is omitted if data are stored in the Primary Header
ORIGIN	<organization name>	/ Source of FITS file
CREATOR	< task name and version number>	/ Creator
CONTENT	<short description of the content>	/File content
FILENAME	<file name>	/ File name
VERSION	<version number>	/ Extension version number

<b>CALDB keywords:</b>		<b>Comment</b>
CCLSxxxx	OGIP-class of calibration file	/Dataset is a Calibration Product File /Dataset is a Basic Calibration File
CDTPxxxx	<datatype code>	/Calibration file contains data
CCNMxxxx	<extension codename>	/Type of Calibration data
CDESxxxx	<descriptive string>	/ Description
CVSDxxxx	<start valid data>	/UTC date when file should first be used
CVSTxxxx	<start valid time>	/UTC time when file should first be used

**Table 4 - UCFS Table Headers mandatory keywords**

The UVOT adopted a specific scheme for the version number where values less than 100 reference to pre-launch data and version higher than 100 reference to data after launch.

Table 4 lists UCFS table header keywords required under certain circumstances. These keywords are specified, when necessary, for each datatype in the related paragraph in section 5.

<i>Keyword name</i>	<i>Keyword value</i>	<i>Comment</i>
CBDnxxxx	array describing parameter limitations of the dataset	/ Parameter boundary
CSYSNAME	spatial coordinate system in use	/spacial coord system used in this dataset
TDIMnnn	Number of elements & Ordering of <i>n</i> -d array	/ Array dimensions
HUCLASS	'OGIP '	/ format conforms to OGIP standards
HDUDOC	<document number>	/ Document describing the format
HUCLASn	<character string to classify the extension	/ (Specific to the type)
HDUVERSn	<string giving the format version>	/ Version of file format
TIMESYS	TT	/ Time system

MJDREFI	51910	/ Reference MJD, Integer part
MJDREFF	7.4287037e-4	/Reference MJD, fractional part
CLOCKAPP	F	/ If clock corrections are applied (F/T)
FILTER	<filter>	/ Filter value

**Table 5 - UCFS Table Headers keywords required under certain circumstances**

The UVOT operates in conjunction with filters. The filter name is specified in the keyword FILTER and needs to be present in all extensions specific to a filter. The string to use in the FILTER keyword is always written upper case and their values are listed in Table 5 together with their band-pass. The first column in the table is a running number used in the document when calibration files contains multiple extensions each dedicated to each filter.

Number	String value		Band-pass (These values are approximate)	
	In keywords	In filename	angstrom	keV
1	U	uu	2575 – 4325	0.00481-0.00287
2	B	bb	3410 – 5370	0.00364-0.00231
3	V	vv	4690 – 6190	0.00264-0.00200
4	UVW1	w1	1810 – 3210	0.00685-0.00386
5	UVW2	w2	1120 – 2640	0.01107-0.00470
6	UVM2	m2	1660 – 2680	0.00747-0.00463
7	WHITE	wh	1250 – 6450	0.00992-0.00192
8	MAGNIFIER	mg	1250 - 6450	0.00992-0.00192
9	UGRISM	gu	1800-3550	0.00689-0.00349
10	VGRISM	gv	2485-6212	0.00499-0.00200

**Table 5 – Filter name and band pass**

The order in which the header keywords are layout in the calibration files is the following :

- Required FITS keywords
- Descriptive column keywords for binary table
- EXTNAME, TELESCOP, INSTRUME, FILTER, ORIGIN, CREATOR, VERSION, FILENAME, CONTENT
- TIMESYS, MJDREFI, MJDREFF, CLOCKAPP
- Caldb keywords
- Comment keywords
- Additional Local keywords
- DATA, DATASUM, CHECKSUM

The description of the calibration file within this document includes the file structure the setting of CALDB keywords and specific keywords related to the file

## 5 UCFS files format

### 5.1 Telescope Definition File

#### 5.1.1 File Name

There are several files for the Telescope Definition file one of each lenticular filter and each of the default wheel position of the grisms. Their naming do not conform with the standard naming convention described in paragraph 3.1. These are :

swFFYYYYMMDDvNNN.teldef

for the lenticular filters where FF is a two character string as listed in table 5 and

swguNNNN\_YYYYMMDDvNNN.teldef and swgvNNNN\_YYYYMMDDvNNN.teldef

for the grisms where NNNN is a 4 digit number (padded with leading zeros) representing the position on the filter wheel.

Previous deliveries of the lenticular teldef files also used the following naming:

swumagniYYYYMMDDvNNN.teldef and swugenYYYYMMDDvNNN.teldef.

#### 5.1.2 Description

The UVOT data reduction software requires as input the Telescope Definition file (teldef). This is a FITS file containing in the primary HDU a set of keywords describing the telescope and instrument characteristics, the coordinate systems definition and the transformations between them. This file has been introduced for the first time for the ASCA mission. For the UVOT there is also an additional extension that contains the distortion values. The latter are applied during the linearization process from raw to detector coordinates.

There are three sets of coordinates defined for the SWIFT UVOT: raw, detector and sky. The keyword NCOORDS is set therefore to 3 (NCOORDS=3) and the keywords COORDn are set to:

COORD0='RAW'

COORD1='DET'

COORD2='SKY'

The RAW coordinates come from the telemetry and ranges between 0 and 2047 (RAWX) and between 0 and 2047 (RAWY); the DET coordinates are derived from the RAW coordinates and range from 1 to 2200 for the horizontal axis and from 1 to 2200 for the vertical axis.

The SKY coordinates run from 1 to 4000, to include the detector even when it is rotated 45 degrees with respect to RA/Dec reference frame.

The conversion from RAW to DET involves two steps:

The RAW coordinates are transformed in a set of internal coordinates. This is done to support detectors that are made by more than one sub-unit, each one with its own RAW coordinates system;

The internal coordinates system is transformed into a detector coordinates system.

The first transformation uses the formula:

$$X_{int} = COE\_Xn\_B * RAWX + COE\_Xn\_C * RAWY + COE\_Xn\_A$$
$$Y_{int} = COE\_Yn\_B * RAWX + COE\_Yn\_C * RAWY + COE\_Yn\_A$$

The UVOT focal plane detector is composed of only one CCD.

The second transformation uses the formula:

$$DET_X = DET\_XCEN + DETXFLIP * (X_{int} - INT\_XCEN - DET\_XOFF)/DET\_SCAL$$
$$DET_Y = DET\_YCEN + DETYFLIP * (Y_{int} - INT\_YCEN - DET\_YOFF)/DET\_SCAL$$
$$DET\_XCEN = DETXPPIX1 + (DET\_XSIZ - 1)/2.0$$
$$DET\_YCEN = DETYPPIX1 + (DET\_YSIZ - 1)/2.0$$

For one CCD we have:

$$INT\_XCEN = 1023.5$$
$$INT\_YCEN = 1023.5$$

DET\_XOFF = 0

DET\_YOFF = 0

The conversion from DET to SKY coordinates occurs via a separate transformation. The components of the 3x3 alignment matrix are specified in the teldef file and give the orientation of the detector coordinates with respect to the spacecraft axes. This matrix is specified is the ALIGNMij keywords.

Keywords containing other information about the detector such as number and size of the CCD pixels and focal length of the telescope are also included following the document "Teldef File Format Specification". There are two files to specify for the Telescope Definition: one for the magnifier filter and a second that applies to all other filters.

### 5.1.3 File Format

The file format uses the primary header to store the telescope definition keywords and a second to store the distortion. The distortion has two different formats. The first uses a bintable as described in table 6 and the second is described by an image extension as listed in table 6a. The bintable format was used in early CALDB releases to represent the distortion map for the all filters and magnifier, while the image extension was used in the first release of the grisms data and later on by all other filters. In April 2004 the teldef for valid for all filters has the second extension (distortion map) changed from a bintable to an image. In July 2005 also the second extension of the magnifier teldef adopted the image format to describe the distortion map. In April 2005 specific teldef for the grisms were introduced and prior this date the teldef for the grism was the same of all other filters. The description that follows show in table 6 and 6a the two formats adopted.

In December 2006 a new set of teldef were released. The teldefs are for each individual filter and for the two standard wheel position fro the grisms. In addition calibration found the need of time dependent teldefs. Different teldef filter and time dependent were released in Dec 2006 that cover the mission from the start.

Table 6 : distortion as a bintable: valid for all filter and the magnifier pre-April 2004 and pre-July 2005 respectively

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	NONLINEAR	
	<i>Column Names</i>	<i>Format</i>	<i>Units</i>
	X	E	pixel
	Y	E	pixel
	NEWX	E	pixel
	NEWY	E	pixel

**Table 6 - Telescope Description Calibration File Format for magnifier**

Table 6a valid for all other filters, magnifier and grism after July 2005:

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
0	PRIMARY	
1	IMAGE	NONLINEAR

**Table 6a - Telescope Description Calibration File Format for all filters**

### 5.1.4 Primary Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant for the Telescope Definition file relevant to all filters but the magnifier.



<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'TELDEF'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FILTER(U,B,V,UVW1,UVW2,UVM2,WHITE,UGRISM,VGRISM)'	/ Parameter Boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'TELESCOPE DEFINITION FILE'	/ Description

**Table 7- Telescope Description File Primary Header Keywords**

The table 7 lists the keywords as they were in CALDB releases pre-April 2005. After the 8 of April 2005 the CDB10001 was changed in the general teldef file to exclude the grisms because a specific teldef file for the grism was generated. Below are listed the string used for the CDB keywords valid after 8 of April 2005 for the general filter file and grism teldef files.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
<b>CALDB GENERAL after April 2005</b>		
CBD10001	'FILTER(U,B,V,UVW1,UVW2,UVM2,WHITE)'	/ Parameter Boundary
<b>CALDB GRISM TELDEF</b>		
CBD10001	'FILTER(XXXXX)'	/ Parameter Boundary
CBD20001	'CLOCKING(NNNN)' OR (see note)	/ Parameter Boundary
CBD20001	'WHEELPOS(NNNN)'	/ Parameter Boundary
CBD30001	'ORDER(0)'	/ Parameter Boundary

where the string XXXXX is either 'UGRISM' or 'VGRISM' and NNNN is the filter position wheel specified with no leading zeros. Also the in the teldef for the grism change one of the boundary keyword after the file version 102.

The following is a listing of the teldef portion of the Primary Header valid for the general filter and grism but not for the magnifier. This is an example header and the keywords value have changed with subsequent updates of the teldef. The specific CALDB keywords and difference compared to this template header for the magnifier are listed below.

```

COMMENT
COMMENT -----
COMMENT   Generic Coordinate Keywords
COMMENT -----
NCOORDS =                3 / Number of coordinates defined in this file
COORD0  = 'RAW      '      / 1st coordinate system (RAWX,RAWY)
COORD1  = 'DET      '      / 2nd coordinate system (DETX,DETY)
COORD2  = 'SKY      '      / 3rd coordinate system (X,Y)
COMMENT -----
COMMENT   RAW Coordinate Definition
COMMENT   These are the pixel coordinates in the telemetry
COMMENT -----
RAW_XSIZ=                2048 / [pixel] RAW address space X size

```

```

RAWPIX1=          0 / [pixel] RAW address space X first pixel number
RAW_XSCL=        0.009075 / [mm/pixel] RAW X scale
RAW_XCOL= 'RAWX   ' / Name of RAW X column in event file
RAW_YSIZ=        2048 / [pixel] RAW address space Y size
RAWYPIX1=        0 / [pixel] RAW address space Y first pixel number
RAW_YSCL=        0.009075 / [mm/pixel] RAW Y scale
RAW_YCOL= 'RAWY   ' / Name of RAW Y column in event file
RAW_UNIT= 'pixel  ' / Physical unit of RAW coordinates
COMMENT
COMMENT -----
COMMENT DET Coordinate Definition
COMMENT DET coordinates are fixed to the detector, look up
COMMENT -----
DET_XSIZ=        2200 / [pixel] DET address space X size
DETXPIX1=        1 / [pixel] DET address space X first pixel number
DET_XSCL=        0.009075 / [mm/pixel] DET X scale
DET_XCOL= 'DETX   ' / Name of DET X column in event file
DET_YSIZ=        2200 / [pixel] DET address space Y size
DETYPIX1=        1 / [pixel] DET address space Y first pixel number
DET_YSCL=        0.009075 / [mm/pixel] DET Y scale
DET_YCOL= 'DETY   ' / Name of DET Y column in event file
DET_UNIT= 'mm     ' / Physical unit of DET coordinates
COMMENT
COMMENT -----
COMMENT Translation from RAW to DET Coordinates
COMMENT This translation comes in two parts. First there is a translation to
COMMENT an intermediate coordinate system as follows:
COMMENT      Xint = COE_X0_A + COE_X0_B * RAWX + COE_X0_C * RAWY
COMMENT      Yint = COE_Y0_A + COE_Y0_B * RAWX + COE_Y0_C * RAWY
COMMENT The following is just a placeholder. It will be replace with an
COMMENT extension describing nonlinear corrections.
COMMENT -----
COE_X0_A=        0
COE_X0_B=        1 / These could be used to align the DET
COE_X0_C=        0 / coordinates to the spacecraft axes or to
COE_Y0_A=        0 / align the XRT and UVOT coordinates with one
COE_Y0_B=        0 / another.
COE_Y0_C=        1
COMMENT
COMMENT -----
COMMENT ...followed by a translation from the intermediate coordinates
COMMENT to the DET coordinates as follows:
COMMENT
COMMENT      DETX = DET_XCEN + DETXFLIP * (Xint - INT_XCEN - DET_XOFF) / DET_SCAL
COMMENT      DETY = DET_YCEN + DETYFLIP * (Yint - INT_YCEN - DET_YOFF) / DET_SCAL
COMMENT
COMMENT      DET_XCEN = DETXPIX1 + (DET_XSIZ - 1) / 2.0
COMMENT      DET_YCEN = DETYPIX1 + (DET_YSIZ - 1) / 2.0
COMMENT
COMMENT      PIXELY
COMMENT      ^
COMMENT      |
COMMENT      | X(DET_XOFF,DET_YOFF)
COMMENT      |
COMMENT      +----->PIXELX
COMMENT
COMMENT (DET_XOFF,DET_YOFF) is the origin of the DET coordinate system.
COMMENT
COMMENT -----
INT_XCEN=        1023.5 / X coordinate of intermediate coordinates
INT_YCEN=        1023.5 / Y coordinate of intermediate coordinates
DET_XOFF=        0. / X offset between intermediate and DET coords

```

```

DET_YOFF=          0. / Y offset between intermediate and DET coords
DETFLIPX=          1 / Do not flip X-axis in RAW -> DET
DETFLIPY=         -1 / Flip Y-axis in RAW (look down) -> DET (look up)
DET_SCAL=          1. / No scaling done
DET_ROT=           0. / No rotation done
COMMENT -----
COMMENT Sky Coordinate Definition
COMMENT -----
SKY_XSIZ=          4000 / [pixel] SKY address space X size
SKYXPIX1=          1 / [pixel] SKY address space X first pixel number
SKY_XCOL= 'X      ' / Name of SKY X column in event file
SKY_YSIZ=          4000 / [pixel] SKY address space Y size
SKYYPIX1=          1 / [pixel] SKY address space Y first pixel number
SKY_YCOL= 'Y      ' / Name of SKY Y column in event file
SKY_FROM= 'DET    ' / SKY coordinates are calculated from DET coords
SKY_UNIT= 'deg    ' / Physical unit of SKY coordinates
COMMENT -----
COMMENT Translation from DET to SKY Coordinates
COMMENT
COMMENT SKY coordinates are a tangent-place projection of RA and Dec.
COMMENT The DET -> SKY transformation is done by first adding a third axis
COMMENT perpendicular to each coordinates system, then rotating one with
COMMENT respect to the other and projecting onto the original 2d SKY
COMMENT coordinates.
COMMENT
COMMENT The 3d rotation between DET and SKY has two components.
COMMENT One is the orientation of the spacecraft with respect to the celestial
COMMENT sphere. The other is the rotation of the DET axes to make them line
COMMENT up with the satellite axes. Note that we assume that the telescope
COMMENT axis is directly over the centre of the DET coordinates. Any
COMMENT misalignment is represented by a fictional tilt.
COMMENT
COMMENT The orientation of the DET coordinates with respect to the
COMMENT satellite axes is specified by the following matrix.
COMMENT -----
ALIGNM11=          0.00034347464127 / DET -> SAT coords alignment matrix element Mij
ALIGNM12=          0.00002491262377
ALIGNM13=          -0.99999994070226
ALIGNM21=          0.50952568153419 / [3x3 rotation matrix, common to all sensors]
ALIGNM22=          0.86045542665866
ALIGNM23=          0.00019644536465 / SATX = M11 * DETX + M12 * DETY + M13 * DETZ
ALIGNM31=          0.86045538052957 / SATY = M21 * DETX + M22 * DETY + M23 * DETZ
ALIGNM32=          -0.50952571879447 / SATZ = M31 * DETX + M32 * DETY + M33 * DETZ
ALIGNM33=          0.00028285099739
COMMENT -----
COMMENT The plate scale is determined from the size of the SKY pixels in the
COMMENT focal plane and the focal length of the telescope.
COMMENT 1 mm roughly corresponds to atan(1/FOCALLEN) radians on the sky.
COMMENT -----
FOCALLEN=          3773.90 / [mm] Telescope focal length (mm)
COMMENT -----
COMMENT The offset of the optical axis from the centre of the coordinate
COMMENT system specified by OPTCOORD. If the OPTCOORD keyword is not present
COMMENT its value is assumed to be 'SKY_FROM'.
COMMENT The true optical axis position is not used in the coordinate
COMMENT transformations, but it is needed to calculate the detector response.
COMMENT -----
OPTCOORD= 'DET    ' / Optical axis is defined in DET coordinates

```

OPTAXISX= 0.0 / [pixel] Optical axis x offset, DET coordinates  
 OPTAXISY= 0.0 / [pixel] Optical axis y offset, DET coordinates  
 COMMENT -----

The magnifier telescope definition has in addition the keyword filter added and the different values for some of the CALDB keywords. The differences are listed in the following table :

<i>Keyword name</i>	<i>Keyword value</i>	<i>Comment</i>
FILTER	MAGNIFIER	/ Filter
FOCALLEN	15095.6	/[mm] Telescope focal length (mm)
<b>CALDB Keywords</b>		
CDB10001	'FILTER(MAGNIFIER)'	/Parameter Boundary
CDES0001	'MAGNIFIER TELESCOPE DEFINITION FILE'	/Description

### 5.1.5 Extension 1 – Header keywords

This extension contains the corrections for the nonlinear distortion. The information is provided in two different formats. In the first the data are in a binary table listing positions before and after the corrections are applied. This method is described further in Section 2.4.2 of the *Teldef File Format Specification* document. The second instead uses an NxNx2 image extension. All teldef files were changed to use the image format in the second extension on April 2004 for all filters and July 2005 for the magnifier. Prior these dates the binary format was in use. In addition the on April 2005 specific teldef files for the grism were introduced, prior this date the information for the grism was included in the teldef valid for all filters.

Both formats required keywords for the NONLINEAR extension header. These are :

<i>Keyword name</i>	<i>Keyword value</i>	<i>Comment</i>
Table 2 &3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'DET_POSCOR'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FILTER(XXXX)'	/ Parameter Boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'NON LINEAR DISTORTION CORRECTION'	/Description
CBD10001	RAWX(0-2047)pixel	/Parameter Boundary
CBD10002	RAWY(0-2047)pixel	/Parameter Boundary
<b>Teldef non linearity extension keywords</b>		
CORINTRAW	T	/This table is in RAW coordinates
METHOD	DISTANCE	/Interpolation method (distance weighted)
SAMPLEX	16	/Number of RAW or DET pixels per grid pixel

SAMPLEY	16	/Number of RAW or DET pixels per grid pixel
EXTNAME	'NONLINEAR'	/ Name of the binary table extension

**Table 8- Teldef Calibration File Format**

where the value for the XXXX in the CDB10001 follow the same convention for the primary header. Note these value where changed when the teldef for the grism was introduced on April 8 2005.

In the magnifier extension the following keywords are either added or have the following values:

<b>Keyword name</b>	<b>Keyword value</b>	<b>Comment</b>
FILTER	MAGNIFIER	/ Filter
<b>CALDB Keywords</b>		
CDB10001	'FILTER(MAGNIFIER)'	/Parameter Boundary
CDES0001	'MAGNIFIER NONLINEAR DISTORTION CORRECTIONS'	/Description

In the image extension valid for all other filters the WCS keywords are added for each axis (where n=1,2):

<b>Keyword name</b>	<b>Keyword value</b>	<b>Comment</b>
CRPIXn	1	/ Reference pixel
CDELTn	8	/Increment
CRVALn	0	/Reference value

## 5.2 Bad Pixels

### 5.2.1 File Name

swubadpixYYYYMMDDvNNN.fits

### 5.2.2 Description

The file contains the UVOT bad pixels and these are used in the ground processing. The data are stored in a FITS binary extension named 'BADPIX' and containing the following columns:

- TIME : record the time when the pixel became bad. It is foreseen that the bad pixel list will change during the mission. Each new bad pixel added is tagged by the time when that pixel became bad. Software will read the TIME column to apply the valid bad pixels for a given observation;
- RAWX & RAWY: give the position of the bad pixel in raw coordinates;
- YLENGTH: gives the number of consecutive bad pixels in the Y direction starting from the first bad pixel located at RAWX and RAWY. RAWX and RAWY are the coordinates of the pixel at the top of the column of bad pixels. If there is a row of bad pixels (i.e. bad pixels extending in the X direction) then each bad pixel is recorded separately. An example is a T-shape pattern of bad (hot) pixels located at (511,514), (512,512), (512,513), (512,514), and (513,514) that became hot 123.456 seconds after the reference time. The corresponding entries in the file are:

511	514	1	4	123.456
512	514	3	4	123.456
513	514	1	4	123.456

- QUALITY contains a value describing the reason why the pixel is flagged bad. The QUALITY data is stored in a byte. The values for the bad pixel description are listed below and they can be combined by summing the appropriate value. For example, a cold pixel that flickers would have a value of  $2 + 8 = 10$ .

QUALITY Value	Description
0	Good pixel
1	Dead pixel
2	Cold pixel
4	Hot pixel
8	Flickering pixel

### 5.2.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	BADPIX	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	RAWX	I	pixel
	RAWY	I	pixel
	YLENGTH	I	pixel
	QUALITY	8X	-
	TIME	D	s

*Table 9- Bad Pixel Calibration File Format*

### 5.2.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords

### 5.2.5 Extension 1 - Header Keywords

<i>Keyword name</i>	<i>Keyword value</i>	<i>Comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'BADPIX'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAD PIXELS, COLUMNS & ROWS'	/Description

Bad Pixel extension keywords		
EXTNAME	'BADPIX'	/ Name of the binary table extension
CONTENT	'BADPIX'	/File content
TIMESYS	'TT'	/ Time system
MJDREFI	51910	/ Reference MJD integer part
MJDREFF	7.4287037e-4	/ Reference MJD fractional part
CLOCKAPP	F	/ If clock corrections are applied (F/T)

*Table 10- Bad Pixel Calibration File Format*

### 5.3 Photometric Zero Points and Colour Transformations

#### 5.3.1 File Name

swuphotYYYYMMDDvNNN.fits

#### 5.3.2 Description

This file contains the information needed to convert from a count rate to a standard Johnson—Morgan magnitude. The photometric zero points for each filter are stored as keywords. The colour transformation data is stored in a binary table extension named COLORTRANS. This section explains how corrected count rates are converted to instrumental magnitudes and instrumental fluxes. It also explains how the instrumental magnitudes are converted into the standard magnitude system.

The first step is to convert the corrected count rate,  $C$ , in units of counts per second to an instrumental magnitude,  $m$ , in units of magnitude using

$$M = ZPT - 2.5 \log_{10}(C)$$

where  $C$  is in counts per second and has been fully corrected for dead time, coincidence losses and any other effects. The zero points,  $ZPT$ , are stored in FITS keywords named  $ZPT<filter>$ . The  $ZPT<filter>$  keywords give the magnitudes that correspond to count rates of one count per second through the  $<filter>$  filter.

The one-sigma errors in the zero points are stored in FITS keywords named  $ZPE<filter>$ . Zero point errors are provided for each UVOT filter, the magnifier and the zeroth orders of the two grisms. The uncertainty in the instrumental magnitude,  $\sigma_m$ , is calculated using

$$\sigma_m = (2.5/\ln(10)) \times \sigma_C/C$$

where  $\sigma_C$  is the one-sigma uncertainty in the fully corrected count rate. The instrumental flux density through the filter,  $f_i$ , is calculated from the corrected count rate using

$$f_i = FCF \times C$$

where the flux density is in units of  $\text{erg s}^{-1} \text{cm}^{-2} \text{\AA}^{-1}$ . The flux conversion factors are stored in the  $FCF<filter>$  keywords. Flux conversion factors are provided for each filter, the magnifier, and the zeroth orders of each grism. Note that the flux conversion factors were derived using model GRB spectra.

The one-sigma errors in the flux conversion factors are stored in FITS keywords named  $FCE<filter>$ . Flux conversion factor errors are provided for each UVOT filter, the magnifier and the zeroth orders of the two grisms. The uncertainty in the flux conversion factor,  $\sigma_f$ , is calculated using

$$\sigma_f = (FCF \times \sigma_C)$$

The effective wavelengths of each filter are recorded in the  $WAV<filter>$  keywords. These wavelengths were computed for a Vega spectrum.

The extraction radius that was used to compute each zero point is stored in the APT<filter> keywords. The instrumental magnitude and flux calibrations provided here are only valid for count rates that were extracted in an aperture with the same radius. The instrumental magnitude,  $m_2$ , is converted to a calibrated magnitude,  $M_2$ , by applying the following transformation

$$M_2 = m_2 + \text{TRAFOP}2_1 + \text{TRAFOP}2_2 \times (m_1 - m_2) + \text{TRAFOP}2_3 \times (m_1 - m_2)^2 + \dots$$

where  $(m_1 - m_2)$  is an instrumental colour, e.g.  $(b - v)$ , and  $\text{TRAFOP}_i$  is the  $i^{\text{th}}$  polynomial coefficient of the transformation. Up to ten (10) coefficients can be stored. The calibrated colour,  $(M_1 - M_2)$  is computed using

$$M_1 - M_2 = \text{TRAFOP}1_1 + \text{TRAFOP}1_2 \times (m_1 - m_2) + \text{TRAFOP}1_3 \times (m_1 - m_2)^2 + \dots,$$

which is analogous to the expression for  $M_2$ . The uncertainties in  $M_2$  and  $M_1 - M_2$  should be the RMS residual in the fit. At present this data is not stored in the calibration product. Typical RMS values are approximately 0.02 mag.

The method used to calibrate the instrumental magnitudes is similar to that described in Harris et al. (1981, PASP, 93, 507). The transformation equations are based on Eq. 2.9 of Harris et al. (1981) with the airmass terms omitted. The transformations are the inverse of those given by Harris et al. (1981). They solved for the instrumental magnitudes and colours while we are solving for the calibrated magnitudes and colours. This is done so that instrumental magnitudes are entered into the right-hand side of each equation and calibrated magnitudes are calculated. This is appropriate when the transformation coefficients are known. The Harris et al. (1981) method is correct when the goal is to compute the coefficients of colour transformations, but the method used here is conceptually easier when the coefficients have already been determined.

The data are stored in a FITS binary extension named “COLORMAG” and contains the following columns:

- FILTERID1 is a string that identifies the short-wavelength filter that  $m_1$  was measured in;
- FILTERID2 is a string that identifies the long-wavelength filter that  $m_2$  was measured in;
- TRAFOLIMIT is a pair of numbers that gives the colour range that the transformation is valid for. The limits are  $\text{TRAFOLIMIT}_1 \leq (m_1 - m_2) \leq \text{TRAFOLIMIT}_2$ . For example, the case where the transformation is valid in the range  $-1.2 \leq (b - v) \leq +2.1$  has  $\text{TRAFOLIMIT} = (-1.2, +2.1)$  with  $\text{FILTERID}_1 = \text{“B”}$  and  $\text{FILTERID}_2 = \text{“V”}$ ;
- TRAFOP1 is a vector containing the coefficients for transforming the instrumental colours into standard colours;
- TRAFOP1E is a vector containing the one-sigma errors in the corresponding values of TRAFOP1;
- TRAFOP2 is a vector containing the coefficients for transforming an instrumental magnitude into a standard magnitude given instrumental colour data;
- TRAFOP2E is a vector containing the one-sigma errors in the corresponding values of TRAFOP2;
- RMS1 give the rms of the fit to the color transformation equation 1 , e.g. TRAFOP1 value;
- RMS2 give the rms of the fit to the color transformation equation 1 , e.g. TRAFOP2 value;
- BRANCH is an integer that identifies the type of sources that the colour transformations are valid for. The current values are :

BRANCH	Source Type
0	Main Sequence Stars

The header contains also a set of keywords that define the zero-point magnitudes of the different filters, the conversion factors from counts per second to instrumental magnitude, and the aperture radius used for the photometric calibration. These quantities are provided with errors and units and given for each of the filters. The keyword root for each of these quantities is the following:

ZPTn	Gives the zero point magnitude (real value)
ZPEn	Gives the zero point magnitude error (real value)
ZPTUNIT	Gives the unit in which the zero point measurement is provided (‘mag’)
FCFn	Gives the conversion factor from instrumental magnitude to flux (real)
FCEn	Gives the error on the conversion factor
FCFUNIT	Gives the unit in which the conversion factor is provided



	('ergs/cm**(2)/angstroms/count')
APTn	Gives the aperture radius use to estimate the zero point (real)
APTUNIT	Gives the unit of the aperture radius ('pixel')
WAVn	Gives the effective wavelength of each filter
WAVUNIT	Gives the unit of the effective wavelength ('angstrom')

**Table 11- List of additional header keywords for the Color transformation Calibration File**

where the suffix 'n' is a string identifying the filter as listed in Table 5. If the properties of the detector & filters change with time, new files with different validity dates will be issued.

### 5.3.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	COLORMAG	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	FILTERID1	9A	-
	FILTERID2	9A	-
	TRAFLIMIT	2E	mag
	TRAFOP1	10E	-
	TRAFOP1E	10E	-
	TRAFOP2	10E	-
	TRAFOP2E	10E	-
	RMS1	1E	mag
	RMS2	1E	mag
	BRANCH	I	-

**Table 12- Color transformation Calibration File Format**

### 5.3.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.3.5 Extension 1 - Header Keywords

All keywords listed in Table 2 and 3 are included in the header of this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>Keyword name</i>	<i>Keyword value</i>	<i>Comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File

CCNM0001	'COLORTABLE'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'ZERO POINTS & COLOR TRANSFORMATION COEFFICIENTS'	/ Description
<b>Colour transformation keywords</b>		
EXTNAME	'COLORMAG'	/ Name of the binary table extension
CONTENT	'COLORTRANS'	/ File content
Table 10- UVOT specific keywords		

*Table 13- Color transformation Calibration File Format*

## 5.4 Coincidence losses

### 5.4.1 File Name

swucountcorYYYYMMDDvNNN.fits

### 5.4.2 Description

This file contains the coincidence losses corrections. It consists of a table containing three columns:

- PLINFUNC contains the coefficients of the polynomial function that describes the empirical coincidence loss correction. The analytic coincidence correction is divided by this polynomial;
- MULTIFUNC contains the coefficients of a polynomial that describes the empirical coincidence loss corrections. The analytic coincidence correction is multiplied by this polynomial.
- TIME is the time, in seconds, since the reference time that this coincidence loss correction becomes valid.

Only one of PLINFUNC or MULTIFUNC is applied to the analytic correction. The choice of which is up to the user. The final correction is the same in both cases.

The header contains addition UVOT specific keywords containing the frame rate information. There are also keywords identifying the fraction and detector threshold.

The information stored in keywords is the following:

<i>Keyword name</i>	<i>Value</i>	<i>Comment</i>
<b>Frame rate information</b>		
NHP	407	Total horizontal clocks for one row
NVPS	288	Total vertical clocks for a frame transfer
VTRANS	6.0e-7	[s] Time required for a shift by one pixel in the vertical direction
HTRANS	1.0e-7	[s] Time required for a shift by one pixel in the

		horizontal direction
NVPI	290	Number of rows in the image area
V2HTIME	2.0e-7	[s] Vertical to horizontal switch time
H2VTIME	1.0e-7	[s] Horizontal to vertical switch time
AOFFSET	3	Start of logical CCD window in UVOTA CCD
BOFFSET	17	Start of logical CCD window in UVOTB CCD
<b>Threshold</b>		
PHDRAC	0.0	Fraction of events above detector threshold
THRESH	0	[adu] Detector threshold

**Table 14- Keyword description Coincidence losses tables**

PHDFRAC is the fraction of events that are above the detection threshold. This is stored as unit-less real value. It is used to correct the detected counts for the global loss of detector efficiency (e.g. due to aging). THRESH is the event detection threshold given as integer in [adu] units.

### 5.4.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	COINCIDENCE	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	PLINFUNC	10E	-
	MULTFUNC	10E	-
	COIAPT	D	arcsec
	TIME	D	s

**Table 15 – Count rate Corrections Calibration File Format**

### 5.4.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.4.5 Extension 1 - Header Keywords

The extension contains the coincidence loss corrections. All keywords listed in Table 2 and Table 3 are included in the header of this HDU. Below are listed specific settings of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'COINCIDENCE'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data

CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'COINCIDENCE LOSS AND CLOCKING PARAMETERS'	/ Description
<b>Coincidence Losses extension keywords</b>		
EXTNAME	'COINCIDENCE'	/ Name of the binary table extension
CONTENT	'COINCIDENCE'	/File content
TIMESYS	'TT'	/ Time system
MJDREFI	51910	/ Reference MJD integer part
MJDREFF	7.4287037e-4	/ Reference MJD fractional part
CLOCKAPP	F	/ If clock corrections are applied (F/T)
COIAPT	5	/[arcsec] Radius of CoI aperture
Table 14- UVOTA specific keywords		

*Table 16 – Count rate Correction Calibration File Extension*

## 5.5 Filter Transmission Calibration File

### 5.5.1 File Name

swuftransYYYYMMDDvNNN.fits

### 5.5.2 Description

The UVOT operates in conjunction with filters to block optical and ultraviolet light. Ground calibrations have measured the filter transmission properties and the results are stored in this calibration file. The file contains 8 extensions, each with the same structure. Each extension is dedicated to a specific filter (UGRISM and VGRISM are excluded) and contains the following columns :

- ENERGY gives the discrete energy values in eV where the filter transmission is evaluated ;
- WAVELENGTH gives the equivalent in wavelength where the filter transmission is evaluated;
- TRANSMIS gives the corresponding transmission value as a fraction of the total flux at this energy.

### 5.5.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	TRANSMISSIONU	
		<b>Column Names</b>	<b>Format</b>
		ENERGY	E
		WAVELENGTH	E
			<b>Units</b>
			eV
			angstrom
			-
2	BINTABLE	TRANSMISSIONB	

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
3	BINTABLE	TRANSMISSIONV
4	BINTABLE	TRANSMISSIONUVW1
5	BINTABLE	TRANSMISSIONUVW2
6	BINTABLE	TRANSMISSIONUVM2
7	BINTABLE	TRANSMISSIONWHITE
8	BINTABLE	TRANSMISSIONMAGNI

**Table 16 - Filter Transmission Calibration File Format**

#### 5.5.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

#### 5.5.5 Extension 1-8 - Header Keywords

This is an example of tone of the eight extensions in this file. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

The extension differ for the value of the FILTER keyword set to the strings value from one to eight as listed in table 5.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'FTRANS'	/ Type of calibration data
CDES0001	'<filter> FILTER TRANSMISSION'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
COMMENT Dataset is assumed to be independent of THETA		
CBD10001	'THETA(0-90)deg'	/ Parameter boundary
COMMENT Dataset is assumed to be independent of PHI		
CBD20001	'PHI(0-360)deg'	/ Parameter boundary
CBD30001	'ENERG(<min>-<max>keV'	/ Parameter boundary
CBD40001	'FILTER(<filter>'	/ Parameter boundary
<b>Transmission keywords extension</b>		
EXTNAME	'TRANSMISSION<filter>'	/ Name of the binary table extension
CONTENT	'FTRANS'	/File Content
FILTER	'<filter>'	/ Filter name

**Table 17 - Filter Transmission Calibration File Extension 1 Keywords**

The values for the energy boundary of the CBD3001 are listed in table 5

## 5.6 Grism Equation, Line-Spread function and Grism translations

### 5.6.1 File Name

swugrismYYYYMMDDvNNN.fits and swvgrigmYYYYMMDDvNNN.fits

### 5.6.2 Description

These files contain the grism equation for each of the UVOT grisms. The format for this calibration file established pre-launch may change with as a result of the on-orbit calibration. The grism equation converts the displacement of a point in the first order spectrum from the location of the centroid of the zeroth order light. The displacement is measured in DET coordinatess. and translated into wavelength. The displacement is measured in DET coordinatess. and translated into wavelength. The grism equation is a polynomial equation,

$$\lambda = \text{COEFF}_i \times d^i, \quad i = 0 \dots N - 1$$

where  $\lambda$  is the wavelength and  $d$  is the dispersion in DET pixels. The equation can have up to  $N = 10$  terms.

The file contains an empty primary array and three bintable extensions. The first extension contains the translation of the location in a lenticular filter of a source to the zeroth order of the grism and it contains the following columns :

- DETX and DETY are the DET coordinates that correspond to the position of the source if a lenticular filter was used.
- CLOCKING. The filter wheel has several possible positions for a given filter. This ID the position on the wheel for the given grism filter;
- DELTAX and DELTAY are the values to add to the DETX and DETY to obtain the DET coordinates of the zeroth order grism.

The second extension contains the coefficient of the grism equation and it contains the following columns:

- DETX and DETY are the DET coordinates that correspond to the position of the source if a lenticular filter was used.
- CLOCKING. The filter wheel has several possible positions for a given filter. This ID the position on the wheel for the given grism filter;
- COEFF is a vector containing the polynomial coefficients of the grism equation. At present coefficients for up to 10 terms can be stored;

The third extension contains the line spread function for a given wavelength :

- DETX and DETY are the DET coordinates that correspond to the position of the source if a lenticular filter was used.
- CLOCKING. The filter wheel has several possible positions for a given filter. This ID the position on the wheel for the given grism filter;
- WAVELENGTH is the value of the wavelength where there is a corresponding line spread;
- LINESF this is the Full-Width Half Maximum (FWHM) of the line with the energy listed in the column WAVELENGTH.

### 5.6.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
0	PRIMARY	
1	BINTABLE	<ff>TRANSLATION

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	DETX	E	pixel
	DETY	E	pixel
	CLOCKING	I	-
	DELTA X	E	pixel
	DELTA Y	E	pixel
2	BINTABLE	<ff>GRISMEQ	
	DETX	E	pixel
	DETY	E	pixel
	CLOCKING	I	-
	COEFF	10E	-
3	BINTABLE	<ff>GRISMLSF	
	DETX	E	pixel
	DETY	E	pixel
	CLOCKING	I	-
	WAVELENGTH	E	angstrom
	LINESF	E	angstrom

**Table 18 – Grism Equation Calibration File Format**

where <ff> is either U or V for the UGRISM and VGRISM respectively. In early version of this file there were two additional columns DSP\_UNIT and WAV\_UNIT that were constant for all entries and set as header keywords in later and current version.

#### 5.6.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords. The FILTER keyword is also added set to the values of UGRISM or VGRISM for the U grism and V grism files respectively.

#### 5.6.5 Extension 1-3 - Header Keywords

The two files are identical in structure and differ for the values of the FILTER and the CALDB boundary keywords. The additional keyword SPORDER specifies the spectral order of validity. All keywords listed in Table 2 and Table 3 are included in the header of this HDU. Below are specific settings for the CALDB keywords and other keywords relevant to these files.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
<b>First extension</b>		
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		

CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'GRISMTRANS'	/ Type of calibration data
CDES0001	'<fd> GRISM TRANSLATIONS'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'FILTER(<filter>')	/ Parameter boundary
CBD20001	'ORDER(0)'	/ Parameter boundary
CBD30001	'DETX(1-2200)pixel'	/Parameter boundary
CBD40001	'DETY(1-2200)pixel'	/Parameter boundary
<b>Grism Equation keywords 1<sup>st</sup> extension</b>		
EXTNAME	'<ff>TRANSLATION'	/ Name of the binary table extension
CONTENT	'GRISM_TRANSLATION'	/File content
FILTER	'<filter>'	/ Filter name
SPORDER	0	/ Spectral order
<b>Second Extension</b>		
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'GRISMEQ'	/ Type of calibration data
CDES0001	'<fd> GRISM EQUATION'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'FILTER(<filter>')	/ Parameter boundary
CBD20001	'ORDER(1)'	/ Parameter boundary
<b>Grism Equation keywords 2<sup>nd</sup> extension</b>		
EXTNAME	'<ff>GRISMEQ'	/ Name of the binary table extension
CONTENT	'GRISM_EQUATION'	/File content
FILTER	'<filter>'	/ Filter name
SPORDER	1	/ Spectral order
DSP_UNIT	'pixel'	/Units of the dispersion



WAV_UNIT	'angstrom'	/Units of the wavelength
<b>Third Extension</b>		
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'GRISMLSF'	/ Type of calibration data
CDES0001	'<fd> GRISM LINE SPREAD FUNCTION'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'FILTER(<filter>')	/ Parameter boundary
CBD20001	'ORDER(1)'	/ Parameter boundary
<b>Grism Equation keywords 3<sup>rd</sup> extension</b>		
EXTNAME	'<ff>GRISMLSP'	/ Name of the binary table extension
CONTENT	'GRISM_LINESF'	/File content
FILTER	'<filter>'	/ Filter name
SPORDER	1	/ Spectral order

**Table 19 – Grism Equation Calibration File Extension 1-3 keywords**

Note that the keywords DSP\_UNIT and WAV\_UNIT were added in latest version of the file prior. In prior version these were set in columns with constant values.

The values for <fd>, <ff> and <filter> are :

- <fd> UV and VISUAL for the UGRISM and VGRISM respectively
- <ff> U and V for the UGRISM and VGRISM respectively
- <filter > UGRISM and VGRISM for the UGRISM and VGRISM respectively.

## 5.7 Mirror Effective Area Calibration File

### 5.7.1 File Name

swumirroeaYYYYMMDDvNNN.fits

### 5.7.2 Description

The file contains the on-axis telescope mirror effective area as a function of the energy. These effective area values are expressed in units of cm<sup>2</sup> and they are in steps of 100 angstrom. The data are stored in a FITS binary table containing the following columns:

- ENERGY: energy in units of eV for which the effective area is provided in the EA column ;
- WAVELENGTH: ENERGY column in angstrom;
- EA: mirror effective area in units of cm<sup>2</sup>.

NOTE : This file used to be named effarea prior the ingest (Nov 2007) of the instrument effective area.

### 5.7.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	EFFAREA	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	ENERGY	E	eV
	WAVELENGTH	E	angstrom
	EA	E	cm <sup>2</sup>

*Table 20 - Mirror Effective Area Calibration File Format*

### 5.7.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.7.5 Extension 1 - Header Keywords

Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'MIRROR EFFECTIVE AREA'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'MIRROR ON-AXIS EFFECTIVE AREA'	/Description
CBD10001	FILTER(V,B,U,UVW1,UVM2,UVW2,WHITE,MAGNIFIER,UGRISM,VGRISM,BLOCKED)	/Parameter boundary
CBD20001	'ENERG(0.00204-0.00686)keV'	/Parameter boundary
CBD30001	'THETA(0)arcmin'	/Parameter boundary
CBD40001	'PHI(0)deg'	/Parameter boundary
CBD50001	AREA(MIRROR)'	/Parameter boundary
<b>Mirror Effective Area File Keywords</b>		
EXTNAME	'MIRROREFFAREA'	/ Name of the binary table extension
CONTENT	'MIRROR EFFAREA'	/File format

*Table 21 - Mirror Effective Area Calibration File Extension 1 Keywords*

## 5.8 Large-Scale Sensitivity Map or Sky Flat

### 5.8.1 File Name

swulssYYYYMMDDvNNN.fits

### 5.8.2 Description

The large scale sensitivity, or the sky flat, contains information about how the sensitivity of the detector changes across the detector. The file format consists of an empty primary array and ten image extensions. The first seven are from the filters 1-7, as listed in Table 5. For each of the grisms there are two extensions associated with the zero and first order respectively. The first measurements of the sky flat is done on orbit, and the pre-launch file assumes the same sensitivity in each pixel. A large number of observations is required to construct the sky flats, therefore this calibration product is periodically updated as more data are available.

The sky flat is constructed by taking a large number of exposures from sky regions where there are only a few sources. The exposures are combined and normalized so that the modal pixel value is one. The sky flat is used to correct the data for large-scale variations in sensitivity across the detector, e.g. the science maps are divided by the sky flats. The sky flat needs to have a modal value of unity to conserve flux. The value stored in the pixels are dimensionless.

### 5.8.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
0	PRIMARY	
1	IMAGE	LSSSENSU
2	IMAGE	LSSSENSB
3	IMAGE	LSSSENSV
4	IMAGE	LSSSENSUVW1
5	IMAGE	LSSSENSUVW2
6	IMAGE	LSSSENSVM2
7	IMAGE	LSSSENSWHITE
8	IMAGE	LSSSENSMAGNI
9	IMAGE	LSSSENSUGRISM
10	IMAGE	LSSSENSVGRISM

*Table 22 – Sky flat Calibration File Format*

### 5.8.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.8.5 Extension 1 -10 Header Keywords

The extensions from 1-10 contain maps of the sky flats obtained for each of the filter used by the UVOT. The maps are in RAW coordinates described by the WCS and the pixel values are dimensionless. The format for each of the ten extensions is identical but differs only for the content of the FILTER, EXTNAME values and the CALDB keywords related to the filters. The filter values are from Table 5. For the extensions containing grism data an additional header keyword SPORDER and a CALDB keyword are added to identify the spectral order. The allowed values for the order are 0 or 1 to indicate the order 0 and 1 respectively. All keywords listed in Table 2 and 3 are included in the header for the 11 HDUs. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'SKYFLAT'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CDES0001	'<filter> FILTER LARGE-SCALE SENSITIVITY'	/ Description
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'FILTER(<filter>)'	/ Parameter boundary
CBD20001	ORDER(<order>)	/ Parameter boundary Only for extensions containing grism data
<b>WCS keywords</b>		
CTYPE1	RAWX	/ Name coordinates axis 1
CUNIT1	pixel	/ Units of axis 1
CRVAL1	0.0	/ Reference value for axis 1
CDEL1	1.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	RAWY	/ Name coordinates axis 2
CUNIT2	pixel	/ Units of axis 2
CRVAL2	0.0	/ Reference value for axis 1
CDEL2	1.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Sky Flat Keywords</b>		
EXTNAME	'LSSENS<filter>'	/ Name of the image extension
CONTENT	'SKY_FLAT'	/File content
FILTER	'<filter>'	/ Filter name
SPORDER	0	/ Spectral order Only for extensions containing grism data

*Table 23 – Large scale sensitivity Calibration File Extensions Keywords*

## 5.9 Pixel-to-Pixel Sensitivity Map or Calibration Flat

### 5.9.1 File Name

swuppsensYYYYMMDDvNNN.fits

### 5.9.2 Description

The file format for the pixel-to-pixel sensitivity map, or calibration flat, contains an empty primary array and two image extensions. The first is the pixel-to-pixel sensitivity map and the second the led illumination pattern. The pixel 2 pixel map is obtained by putting the UVOT filter wheel into its blocked position and taking an image of the LED light. The LED pattern is stored in the LEDTEMPLATE extension. Since the LED illumination is known the response of each UVOT pixel can be determined. There is only one pixel-to-pixel sensitivity map since the data is collected with no filter between the detector and the source. The pixel-to-pixel sensitivity map is normalized so that the modal value of the good pixels is set to unity and the flux is conserved. The pixels values are dimensionless, instead in the LED illumination pattern map the pixels have unit of count/s. The data are corrected by dividing the science images for pixel-to-pixel sensitivity map. The first measurements of the pixel 2 pixel done is done on orbit, and the pre-launch file assumes a perfect detector response with a value of unity in each pixel. It is expected that the pixel2pixel sensitivity and the LED illumination maps are periodically updated during the mission. The prelaunch file is a dummy file where every pixel has a value of unity---which corresponds to a perfectly flat detector response. The first measurements of the pixel-to-pixel sensitivity will be done on orbit. It is expected that the pixel-to-pixel sensitivity map, and the LED illumination map, will be updated periodically during the *Swift* mission.

### 5.9.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
0	PRIMARY	
1	Image	PIXTOPIXSENS
2	Image	LEDTEMPLATE

Table 24 – Cal flat Calibration File Format

### 5.9.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.9.5 Extension 1 Header Keywords

The first extension contains the pixel-to-pixel sensitivity map. The map is in RAW coordinates described by the WCS and the pixel values are dimensionless. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file. The following keywords record the statistical values for each of the sky flats:

- AVERAGE: This is the mean value of the good pixels in the detector. It is dimensionless.
- DAVERAGE: This is the one-sigma standard deviation in the mean pixel value.
- PIXERR: This is the mean statistical error in the individual pixels expressed as a percentage of the mean pixel value.
- PIXERR is computed from the sky flat data *before* it is normalized.
- MEANCNTS: This is the mean of the total counts in each pixel. MEANCNTS is computed from the calibration flat data before it is normalized.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'CAL_FLAT'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CDES0001	"PIXEL-TO-PIXEL SENSITIVITY MAP"	/ Description

CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
<b>WCS keywords</b>		
CTYPE1	RAWX	/ Name coordinates axis 1
CUNIT1	pixel	/ Units of axis 1
CRVAL1	0.0	/ Reference value for axis 1
CDELTA1	1.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	RAWY	/ Name coordinates axis 2
CUNIT2	pixel	/ Units of axis 2
CRVAL2	0.0	/ Reference value for axis 1
CDELTA2	1.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Pixel 2 pixel sensitivity extension keywords</b>		
EXTNAME	'PIXTOPIXSENS'	/ Name of the image extension
CONTENT	'CAL_FLAT'	/File content
PIXERR	0.0	/ Mean statistical error in each pixel [percentage]
MEANCNTS	1.0	/ Mean counts per pixel
AVERAGE	1.0	/ Mean count rate in detector
DAVERAGE	0.0	/ One sigma error in AVERAGE

*Table 25 – Pixel to pixel Calibration File 1<sup>st</sup> Extensions Keywords*

### 5.9.6 Extension 2 Header Keywords

The second extension contains the LED illumination pattern. This is a map of the light used to produce the pixel-to-pixel sensitivity map. In orbit the measurement will be made as required. The map is in RAW coordinates and the pixel values are in units of counts per second per pixel. All keywords listed in Table 2 and Table 3 are included in the header of this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'LED_MAP'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CDES0001	'LED ILLUMINATION MAP'	/ Description

CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
<b>WCS keywords</b>		
CTYPE1	RAWX	/ Name coordinates axis 1
CUNIT1	pixel	/ Units of axis 1
CRVAL1	0.0	/ Reference value for axis 1
CDELTA1	1.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	RAWY	/ Name coordinates axis 2
CUNIT2	pixel	/ Units of axis 2
CRVAL2	0.0	/ Reference value for axis 1
CDELTA2	1.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Led illumination extension keywords</b>		
BUNIT	'count/s'	/ Units of the image
EXTNAME	'LEDTEMPLATE'	/ Name of the image extension
CONTENT	'LED'	/File Content
PIXERR	0.0	/ Mean statistical error in each pixel [percentage]
MEANCNTS	1.0	/ Mean counts per pixel
AVERAGE	1.0	/ count rate in detector
DAVERAGE	0.0	/ One sigma error in AVERAGE

*Table 26 – Pixel To pixel Calibration File 2nd Extensions Keywords*

## 5.10 Ancillary Response File

### 5.10.1 File name

The name of the arf files do not follow the naming convention described in the paragraph 3.1. This instead is :  
swu<filter>\_YYYYMMDDvNNN.arf

### 5.10.2 Description

The ARF stored in the CALDB is the contribution to the effective area of the entire instrument from the optics to the detector. The ARF is basically flat all over the detector with no dependence on position, There is one file for each of the UVOT filter with identical structure. Each contains one extension containing the following columns:

- ENERG\_LO: gives the lower boundary of the energy bin expressed in keV;
- ENERG\_HI : gives the higher boundary of the energy bin expressed in keV;
- WAVE\_MIN : gives the lower boundary of the bin in the ENERG\_LO column expressed in angstrom ;

- WAVE\_MAX : gives the higher boundary of the bin in the ENERG\_HI column expressed in angstrom;
- SPECRESP : gives the total effective area in cm<sup>2</sup>

Note in early version of the files the columns WAVW\_MIN and WAVE\_MAX were named WAVE\_LO and WAVE\_HI to mirror the energy columns.

### 5.10.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	MATRIX	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	ENERG_LO	E	keV
	ENERG_HI	E	keV
	WAVE_MIN	E	angstrom
	WAVE_MAX	E	angstrom
	SPECRESP	E	cm**2

*Table 27 - Ancillary Response Calibration File Format*

### 5.10.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.10.5 Extension 1-9 - Header Keywords

The format for each of the files is identical but differs only for the content of the FILTER, EXTNAME values and the CALDB keywords related to the filters. The filter values are from Table 5. For the extensions containing grism data the additional header keywords SPORDER and a CALDB keyword is added to identify the spectral order. The arf for the grism is given for the first order dispersion. Below are listed specific settings of some of the CALDB keywords and others relevant to these files.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is Calibration Product File
CCNM0001	'SPECRESP'	/ Type of calibration data
CDES0001	'<filter> FILTER SPECTRAL RESPONSE'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'FILTER(<filter>)'	/ Parameter boundary
CBD2001	'ENERG(<min>-<max>)keV'	/ Parameter boundary
CBD30001	'RADIUS(0-10)pixel'	/ Parameter boundary



CBD40001	'THETA(0-17)arcmin'	/ Parameter boundary
CBD50001	'WHEELPOS(x)'	/ Parameter boundary Only for extensions containing grism data
CBD60001	'ORDER(1)'	/ Parameter boundary Only for extensions containing grism data
<b>Ancillary Response Keywords</b>		
EXTNAME	'SPECRESP<filter>'	/ Name of the binary table extension
CONTENT	'SPECRESP'	/File content
HDUCLASS	'OGIP'	/ Format conforms to OGIP standard
HDUCLAS1	RESPONSE	
HDUCLAS2	SPECRESP	
SPORDER	1	/ Spectral order Only for extensions containing grism data.

**Table 28-Ancillary Response Calibration File format**

The keywords with the value of variable <ff> differ in the 10 extensions. They correspond to the different filters and their values are listed in table 5 together with the corresponding energy <min> and <max>. The of <x> for the wheel position ranges between 0-2200.

## 5.11 Dark Frame

### 5.11.1 File Name

swudarkYYYYMMDDvNNN.fits

### 5.11.2 Description

The dark frame is a map of the counts created by randomly generated electrons in the detector. The file format consists in an empty primary array and one image extension named 'DARKFRAME'. Dark current is expected to be very small and can thus generally be ignored except for very long exposures. The dark current for the *XMM-Newton*'s Optical Monitor is approximately 0.9 counts per pixel per hour. The dark frame stored here is an image where each pixel has unit of count/s. The first measurements of the dark frame is done on orbit, and the pre-launch files assumes a flat dark current map with each pixel set to zero. The dark frame measurements on orbit is done with the filter wheel in its blocked position and the LEDs turned off. Several exposures are taken and averaged to improve the statistical properties of the dark frame.

### 5.11.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>
0	PRIMARY	
1	IMAGE	DARKFRAME

**Table 29- Dark Frame calibration file format**

### 5.11.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.11.5 Extension 1 - Header Keywords

The DARKFRAME extension map is in RAW coordinates described by the WCS. The image extension contains the following keywords to record the statistical values of the dark frame:

- AVERAGE: This is the mean dark frame count/s in all the good pixels in the detector. Units are count/s.
- DAVERAGE: This is the one-sigma standard deviation in the mean count/s (as given in AVERAGE).
- PIXERR: This is the mean statistical error in the individual pixels expressed as a percentage of the mean pixel value.
- PIXERR is computed from the dark current data *before* dividing the dark frame map by the exposure.
- MEANCNTS: This is the mean of the total counts in each pixel. MEANCNTS is computed from the dark frame data before dividing by the exposure time.

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is Calibration Product File
CCNM0001	'DARKFRAME'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CDES0001	'DARK FRAME MAP'	/ Description
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
<b>WCS keywords</b>		
CTYPE1	RAWX	/ Name coordinates axis 1
CUNIT1	pixel	/ Units of axis 1
CRVAL1	0.0	/ Reference value for axis 1
CDELTA1	1.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	RAWY	/ Name coordinates axis 2
CUNIT2	pixel	/ Units of axis 2
CRVAL2	0.0	/ Reference value for axis 1
CDELTA2	1.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Dark Frame File Keywords</b>		
EXTNAME	'DARKFRAME'	/ Name of the image extension
CONTENT	'DARKCURRENT'	/ File content

BUNIT	'count/s	/ Units of the image
PIXERR	0.0	/ Mean statistical error in each pixel [percentage]
MEANCNTS	0.0	/ Mean counts per pixel
AVERAGE	0.0	/ Mean count rate in detector
DAVERAGE	0.0	/ One sigma error in AVERAGE

*Table 30 – Dark frame Calibration File Extension 1 Keywords*

## 5.12 Galactic Light

### 5.12.1 File Name

swugalYYYYMMDDvNNN.fits

### 5.12.2 Description

The file contains information on the galactic background diffuse component produced by the scattering of the stellar photons by the dust grain in the interstellar media. The data were obtained by a compilation of measurements obtained from the literature and modeled accordingly to the UVOT response. The file format consists in an empty primary header with three separate extensions, DGL\_MAP, DLG\_SPEC and DLG\_COUNTS. The first in an image extension the last two are bintable extensions.

### 5.12.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	IMAGE	DGL_MAP	
2	BINTABLE	DGL_SPEC	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	ENERGY	E	keV
	WAVELENGTH	E	angstrom
3	BINTABLE	DGL_COUNT	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	FILTER	9A	-
	RATE	E	count/s/arcsec**2

*Table 31 - Galactic Calibration File Format*

### 5.12.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.12.5 Extension 1 - Header Keywords

The DLG\_MAP extension contains a map of the diffuse galactic emission in galactic coordinates. The values in the pixel map are in S10(B) units, where S10(x) is surface brightness of a standard star with a V-band magnitude of 10 measured in the x filter. The conversion factor of S10=1 to standard units is  $S10 = 27.78 \text{ mag/arcsec}^{-2}$  and it is kept in the keyword KS10. The map is in galactic coordinates described by the WCS. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'DGL_MAP'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'DIFFUSE GALACTIC LIGHT MAP'	/ Description
<b>WCS keywords</b>		
CTYPE1	GLON-TAN	/ Name coordinates axis 1
CUNIT1	deg	/ Units of axis 1
CRVAL1	0.0	/ Reference value for axis 1
CDEL1	10.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	GLAT-TAN	/ Name coordinates axis 2
CUNIT2	deg	/ Units of axis 2
CRVAL2	-90.0	/ Reference value for axis 1
CDEL2	10.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Galactic light File Keywords</b>		
EXTNAME	'DGL_MAP'	/ Name of the image extension
CONTENT	'DGL_MAP'	/File content
BUNIT	S10(B)	/ Units of the image
KS10	27.78	/[mag arcsec <sup>-2</sup> (-2)] Surface brightness for S10 =1.0

*Table 32 – Galactic light Calibration File Extension 1 Keywords*

### 5.12.6 Extension 2 - Header Keywords

The DGL\_SPEC extension contains the spectrum of the diffuse emission. The conversion factor from flux density to flux is stored in the keyword CONVFLUX, the reference value from flux to S10 is stored in the keyword REFINTEN. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'DGL_SPEC'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'DIFFUSE GALACTIC LIGHT SPECTRUM'	/ Calibration file description
<b>Galactic light File Keywords</b>		
EXTNAME	'DGL_SPEC'	/ Name of the binary table extension
CONTENT	'DGL_SPEC'	/File content
CONVFLUX	100.0	/ [erg s <sup>-1</sup> cm <sup>-2</sup> angstrom <sup>-1</sup> W <sup>-1</sup> m <sup>2</sup> nm]
KS10	27.78	/[mag arcsec <sup>-2</sup> ] Surface brightness for S10 =1.0
REFINTEN	43.0	/ Reference intensity of spectrum in S10(B)

Table 33 – Galactic light Calibration File Extension 2 Keywords

### 5.12.7 Extension 3 - Header Keywords

The DLG\_COUNTS extension contains the expected count rate per pixel of the diffuse Galactic light in each of the UVOT filters. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'DGL_COUNTS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'DIFFUSE GALACTIC LIGHT COUNT RATE'	/ Calibration file description

Galactic light File Keywords		
EXTNAME	'DGL_COUNTS'	/ Name of the binary table extension
CONTENT	'DGL_COUNTS'	/File content
KS10	27.78	/[mag arcsec**(-2)] Surface brightness for S10 =1.0
REFINTEN	43.0	/ Reference intensity of spectrum in S10(B)

*Table 34 – Galactic light Calibration File Extension 1 Keywords*

## 5.13 Zodiacal Light

### 5.13.1 File Name

swuzodYYYYMMDDvNNN.fits

### 5.13.2 Description

The file contains the information to the zodiacal background component. The data were obtained by a compilation of values obtained from the literature and modeled accordingly to the UVOT response (?). The file contains three separate extensions: ZODIACAL\_MAP, ZODIACAL\_SPEC, ZODIACAL\_COUNTS.

### 5.13.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	IMAGE	ZODIACAL_MAP	
2	BINTABLE	ZODIACAL_SPEC	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	ENERGY	E	keV
	WAVELENGTH	E	angstrom
3	FLUX	E	W/m**2/nm/deg**2
	BINTABLE	ZODIACAL_COUNT	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	FILTER	9A	-
	RATE	E	count/s/arcsec**2

*Table 35 - Zodiacal Calibration File Format*

### 5.13.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.13.5 Extension 1 - Header Keywords

The ZODIACAL\_MAP extension contains a map of the zodiacal emission in ecliptic coordinates defined in the WCS. The values in the pixel map are units of S10(V), defined as in the galactic light file. All keywords listed in Table 2 and Table 3 are

included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'ZODIACAL_MAP'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'ZODIACAL LIGHT MAP'	/ Description
<b>WCS keywords</b>		
CTYPE1	ELON--TAN	/ Name coordinates axis 1
CUNIT1	deg	/ Units of axis 1
CRVAL1	50.0	/ Reference value for axis 1
CDEL1	-90.0	/ Increment for axis 1
CRPIX1	1	/ Reference pixel for axis 1
CTYPE2	ELAT--TAN	/ Name coordinates axis 2
CUNIT2	deg	/ Units of axis 2
CRVAL2	50.0	/ Reference value for axis 1
CDEL2	50.0	/ Increment for axis 1
CRPIX2	1	/ Reference pixel for axis 2
<b>Zodiacal light File Keywords</b>		
EXTNAME	'ZODIACAL_MAP'	/ Name of the image extension
CONTENT	'ZODIACAL LIGHT'	/File content
BUNIT	S10(V)	/ Units of the image
KS10	27.78	/[mag arcsec**(-2)] Surface brightness for S10 =1.0

*Table 36 – Zodiacal light Calibration File Extension 1 Keywords*

### 5.13.6 Extension 2 - Header Keywords

The ZODIACAL\_SPEC extension contains the spectrum of the diffuse emission. All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>Comment</i>
Table 2 & 3 - UCFS mandatory header keywords		

<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'ZODIACAL_SPEC'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'ZODIACAL LIGHT SPECTRUM'	/ Calibration file description
<b>Galactic light File Keywords</b>		
EXTNAME	'ZODIACAL_SPEC'	/ Name of the binary table extension
CONTENT	'ZODIACAL_SPEC'	/File content
CONVFLUX	100.0	/ [erg s <sup>-1</sup> cm <sup>-2</sup> angstrom <sup>-1</sup> W <sup>-1</sup> m <sup>2</sup> nm]
KS10	27.78	/[mag arcsec <sup>-2</sup> ] Surface brightness for S10 =1.0
REFINTEN	100.0	/ Reference intensity of spectrum in S10(V)

*Table 37 – Zodiacal light Calibration File Extension 2 Keywords*

### 5.13.7 Extension 3 - Header Keywords

The ZODIACAL\_COUNTS extension contains the expected count rate per pixel of the diffuse Galactic light in each of the UVOT filters. All keywords listed in Table 2 and 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'ZODIACAL_COUNTS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'ZODIACAL LIGHT COUNT RATE'	/ Calibration file description
<b>Galactic light File Keywords</b>		
EXTNAME	'ZODIACAL_COUNTS'	/ Name of the binary table extension
CONTENT	'ZODIACAL_COUNTS'	/File content
KS10	27.78	/[mag arcsec <sup>-2</sup> ] Surface brightness for S10 =1.0
REFINTEN	100.0	/ Reference intensity of spectrum in S10(V)

*Table 38 – Zodiacal light Calibration File Extension 1 Keywords*



## 5.14 Point Spread Function (obsolete)

### 5.14.1 File Name

swuspsf YYYYMMDDvNNN.fits

### 5.14.2 Description

The point-spread function (PSF) file contains the description of the point-spread function of each filter and the zero order of each grism. The PSF describes the way that photons from a point source are redistributed onto the detector. The PSF varies with count rate and may vary with position on the detector. The PSF is assumed radially symmetric and it has been modeled as a radial profile whose width can vary with distance from the optical axis. The format for this calibration file established pre-launch may change with as a result of the on-orbit calibration.

For each filter a circular annulus with an inner radius of RMIN and outer radius of RMAX is used to extract the source counts. This is repeated for a set of annuli with increasing radii out to some maximum radius. The value of the cumulative PSF is normalized to 1.0 count inside this fixed maximum aperture radius. The aperture radius is listed for each filter in the APERTURE keyword. The integrated flux inside the APERTURE radius is defined to contain all of the flux from the source.

The PSF may vary with position on the detector. The off-axis distance of the source,  $r$ , is given by

$$r = \sqrt{(\text{DETX} - x_{\text{opt}})^2 + (\text{DETY} - y_{\text{opt}})^2}$$

where (DETX, DETY) are positions of the source and (x\_opt,y\_opt) are the coordinates of the optical axis both in DET coordinates. The change of the PSF with off-axis is given by the third-order polynomial

$$\begin{aligned} f(r) = & \text{PARX0Y0} + \text{PARX0Y1}*\text{DETY} + \text{PARX0Y2}*\text{DETY}^2 + \text{PARX0Y3}*\text{DETX}^3 \\ & + \text{PARX1Y0}*\text{DETX} + \text{PARX1Y1}*\text{DETX}*\text{DETY} + \text{PARX1Y2}*\text{DETX}*\text{DETY}^2 \\ & + \text{PARX2Y0}*\text{DETX}^2 + \text{PARX2Y1}*\text{DETX}^2*\text{DETY} + \text{PARX3Y0}*\text{DETX}^3 \end{aligned}$$

where the coefficient PARX0Y0, PARX0Y1, PARX0Y2, PARX0Y3, PARX1Y0, PARX1Y1, PARX1Y2, PARX2Y0, PARX2Y1 and PARX3Y0 are listed as keywords. The offaxis correction is applied by ?????? ?

The file format consists of an empty primary header and 10 extensions, each with the same structure. Each extension is dedicated to a specific filter or grism and contains the following columns :

- CFRR is the ratio of the count rate to the frame rate for which the PSF is valid ;
- RMIN gives the lower limit of the radius where the PSF is evaluated
- RMAX gives the upper limit of the radius where the PSF is evaluated
- INTENSITY is the integrated intensity of the PSF evaluated within RMIN and RMAX and normalized such that the cumulative PSF within the aperture (specified in the keyword APERTURE) is set to 1.

The PSF is evaluated during the in-orbit calibration phase and an updated CALDB file is generated from these flight data.

### 5.14.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1—10	BINTABLE	PSF<filter>	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	CFRR	E	count
	RMIN	E	pixel
	RMAX	E	pixel
	INTENSITY	E	pixel**(-2)

*Table 39- Description of the PSF Calibration File Format*

### 5.14.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords

### 5.14.5 Extension 1-8 - Header Keywords

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'PSF'	/ Type of calibration data
CDES0001	'<ff> FILTER POINT-SPREAD FUNCTION'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDB10001	'FILTER(<ff>)'	/ Parameter boundary
CDB20001	'THETA(0-12.03)arcmin'	/Parameter boundary
CDB30001	'PHI(0-360)deg'	/Parameter boundary
CDB40001	'ENERG(<min>-<max>)keV'	/Parameter boundary
CDB50001	'ORDER(0)'	/Parameter boundary This keyword is only used for grism data.
<b>PSF Specific keyword</b>		
EXTNAME	PSF<ff>	/ Name of the binary table extension
FILTER	'<ff>'	/ Filter value
SPORDER	0	/ Spectral order This keyword is only used for grism data.
CONTENT	'PSF'	/ <filter> filter point-spread function
PARXnYn	<value>	/Coefficient for the f ( r ) function n=0,1,2,3
APERTURE	35	/ [pixel] Radius enclosing 100% of the flux
PIXSCALE	0.496	/[arcsec] pixel scale

**Table 40- PSF Calibration File extension 1-10 keywords**

The keywords with the value of variable <ff> differ in the 10 extensions. They correspond to the different filters and their values are listed in table 5 together with the corresponding energy <min> and <max>.

## 5.15 Quick count rate conversion

### 5.15.1 File Name

swuqmagYYYYMMDDvNNN.fits

### 5.15.2 Description

The following equation allows to estimate the source expected count rate from its magnitude:

$$\text{Count Rate} = C10 * 10^{(0.4 \cdot (10 - \text{mag}))}$$

where the count rate is the corrected counts per second from the source, C10 is the count rate from a star with a *V*-band magnitude of  $m_V = 10$ , and mag is the magnitude of the source. The coefficients C10 are dependent on the spectrum of the source and on the filter used in the magnitude measurement. The expected count rates from several types of sources have been estimated and used to construct a look-up table which are stored in this calibration file. The count rates estimate are intended for simulations.

The file format consists of an empty primary header and one extension with several columns as listed in the following table. The first column contains a string that gives the name of the UVOT filter. The remaining columns give the C10 values for forty-three different spectral types and their names are set to the spectral type.

### 5.15.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	QUICKMAG	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	FILTER	9A	count/s
	O5V	E	count/s
	O9V	E	count/s
	B0V	E	count/s
	B5_7V	E	count/s
	B9V	E	count/s
	A0V	E	count/s
	A5V	E	count/s
	7V	E	count/s
	F0V	E	count/s
	F5V	E	count/s
	F8V	E	count/s
	G0V	E	count/s
	G2V	E	count/s
	G5V	E	count/s
	G8V	E	count/s
	K0V	E	count/s
	K5V	E	count/s
K7V	E	count/s	

M0V	E	count/s
M5V	E	count/s
B5I	E	count/s
A2I	E	count/s
F5I	E	count/s
G5I	E	count/s
K4I	E	count/s
M2I	E	count/s
B5II	E	count/s
F2II	E	count/s
G5II	E	count/s
K3_4II	E	count/s
M3II	E	count/s
O8III	E	count/s
B5III	E	count/s
A5III	E	count/s
F5III	E	count/s
G5III	E	count/s
K5III	E	count/s
M5III	E	count/s
B6IV	E	count/s
A4_7IV	E	count/s
F5IV	E	count/s
G5IV	E	count/s
K3IV	E	count/s

*Table 41- Coefficients for count rate evaluation Calibration File Format*

**5.15.4 Primary Header Keywords**

All keywords of Table 2 - UCFS mandatory header keywords

**5.15.5 Extension 1-8 - Header Keywords**

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3- UCFS mandatory header keywords		
<b>CALDB Keywords</b>		

CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'QUICKMAG'	/ Type of calibration data
CDES0001	'COUNT RATE CONVERSION TO MAGNITUDE'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
<b>Quick mag file keywords</b>		
EXTNAME	'QUICKMAG'	/ Name of the binary table extension
CONTENT	'QUICKMAG'	/ File content

*Table 42- Coefficients for count rate evaluation Calibration File Format*

## 5.16 Response matrix

The name of the Redistribution Matrix file does not conform standard naming convention described in paragraph 3.1.

swu<filter>\_YYYYMMDDvNNN.rmf broad band filter

swu<filter>NNNN\_YYYYMMDDvNNN.rmf grism rmf

where NNNN is the filter wheel position (ranging from 0-2200)

### 5.16.1 Description

The response matrices are file are generated for all filters. They are applicable for spectra extracted in PI channel type. All available response matrices are included in CALDB. The file format consists of an empty primary table and two binary table extensions named 'MATRIX' and 'EBOUNDS'. The 'MATRIX' includes the following columns:

- ENERG\_LO: lower energy bound of the energy bin;
- ENERG\_HI: upper energy bound of the energy bin;
- N\_GRP: number of channel subset for the energy bin;
- F\_CHAN: channel number of the of the start of each 'channel subset' for the energy bin;
- N\_CHAN: number of channels within each 'channel subset' for the energy bin;
- MATRIX: response values for each 'channel subset' for the energy bin.

The 'EBOUNDS' extension includes the following columns :

- CHANNEL : contains the channel number
- E\_MIN: Channel lower energy boundary in keV
- E\_MAX: Channel upper energy boundary in keV

### 5.16.2 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	MATRIX	
		<b>Format</b>	<b>Units</b>

	ENERG_LO	E	keV
	ENERG_HI	E	keV
	N_GRP	I	-
	F_CHAN	II	-
	N_CHAN	II	-
	MATRIX	1E	-
2	BINTABLE	EBOUNDS	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	CHANNEL	I	-
	E_MIN	E	keV
	E_MAX	E	keV

**Table 43 - Response Matrix Calibration File Format**

### 5.16.3 Primary Header Keywords

All keywords of Table 2 - XCFS mandatory header keywords.

### 5.16.4 Extension 1 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - XCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration product File
CCNM0001	'MATRIX'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FILTER(<ff>')	/Parameter boundary
CBD20001	'ORDER(x)'	/ Parameter boundary Only for extensions containing grism data
CDB3001	'WHEELPOS(<x>')	/ Parameter boundary Only for extensions containing grism data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'REDISTRIBUTION MATRIX'	/Description
<b>Response Matrix File Keywords</b>		
EXTNAME	'MATRIX'	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP standards

HDUCLAS1	RESPONSE	/Extension contains response data
HDUCLAS2	RSP_MATRIX	/Extension contains RMF
TLMIN4	0	/First channel in the response
TLMAX	433	/Last channel in the response
CHANTYPE	PI	/Channel type

**Table 44 - Response Matrix Calibration File Extension 1 Keywords**

where <ff> is set to the filter values as listed in table 5 and <x> is the filter wheel position valid only for the grism.

### 5.16.5 Extension 2 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3- XCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is Basic Calibration File
CCNM0001	'EBOUNDS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FILTER(<ff>)'	/Parameter boundary
CBD20001	'WHEELPOS(<x>)'	/ Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'ENERGY BOUNDS'	/Description
<b>Response Matrix File Keywords</b>		
EXTNAME	'EBOUNDS'	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP standards
HDUCLAS1	'RESPONSE'	/Extension contains response data
HDUCLAS2	'EBOUNDS'	/Extension contains EBOUNDS
CHANTYPE	'PI'	/Channel type

**Table 45 - Response Matrix Calibration File Extension 2 Keyword**

where where <ff> is set to the filter values as listed in table 5 and <x> is the filter wheel position valid only for the grism.

## 5.17 Encircle Energy function

### 5.17.1 File Name

swureef YYYMMDDvNNN.fits

### 5.17.2 Description

The Radial Encircle Energy Function (REEF) file contains the fraction of the point-spread function at different radii for the following filters: U, B, V, W1, W2 and M2. The EEF is assumed to be: radially symmetric, not varying across the detector and valid for all count-to-frame rate ratios. The file format consists of an empty primary header and in six extensions, each with the same structure. Each extension is dedicated to a single filter and contains the following columns :

- RADIUS is the radius at which the EEF is valuated. This is given in arcsec ;
- REEF is the fraction of PSF included in that Radius (unitless).

### 5.17.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1—6	BINTABLE	PSF<filter>	
		<b>Column Names</b>	<b>Format</b> <b>Units</b>
		RADIUS	E      arcsec
		REEF	E

*Table 46- Description of the EEF Calibration File Format*

### 5.17.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords

### 5.17.5 Extension 1-8 - Header Keywords

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'PSF'	/ Type of calibration data
CDES0001	'<ff> FILTER ENCIRCLE ENERGY FUNCTION'	/ Description
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDB10001	'FILTER(<ff>)'	/ Parameter boundary
CDB20001	'THETA(0-24)arcmin'	/Parameter boundary
CDB30001	'PHI(0-360)deg'	/Parameter boundary
CDB40001	'ENERG(<min>-<max>)keV'	/Parameter boundary
<b>PSF Specific keyword</b>		
EXTNAME	REEF<ff>	/ Name of the binary table extension
FILTER	'<ff>'	/ Filter value



SPORDER	0	/ Spectral order This keyword is only used for grism data.
CONTENT	'REEF'	/ <filter> filter point-spread function
PIXSIZE	<value>	/[deg] Pixel size (0.502 arcsec/pixel)

**Table 47- EEf Calibration File extension 1-6 keywords**

The keywords with the value of variable <ff> differ in the 6 extensions. They correspond to the different filters and their values are listed in table 5 together with the corresponding energy <min> and <max>.

## 5.18 Instrument Effective Area Calibration File

### 5.18.1 File Name

swuinsteaYYYYMMDDvNNN.fits

### 5.18.2 Description

The file contains the instrument response as a function of the energy. The values are expressed in units of cm<sup>2</sup> and they are in steps of 100 angstrom. The data are stored in a FITS binary table containing the following columns:

- ENERGY: energy in units of eV for which the effective area is provided in the EA column ;
- WAVELENGTH: ENERGY column in angstrom;
- EA: mirror effective area in units of cm<sup>2</sup>.

### 5.18.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	EFFAREA	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	ENERGY	E	eV
	WAVELENGTH	E	angstrom
	EA	E	cm <sup>2</sup>

**Table 48 - Instrument Effective Area Calibration File Format**

### 5.18.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.18.5 Extension 1 - Header Keywords

Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'EFFAREA'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data

CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'INSTRUMENTAL EFFECTIVE AREA'	/Description
CBD10001	'FILTER(V,B,U,UVW1,UVM2,UVW2,WHITE,MAGNIFIER,UGRISM,VGRISM,BLOCKED)'	/Parameter boundary
CBD20001	'ENERG(0.00204-0.00686)keV'	/Parameter boundary
CBD30001	'THETA(0)arcmin'	/Parameter boundary
CBD40001	'PHI(0)deg'	/Parameter boundary
CBD50001	'AREA(INSTRUMENT)'	/Parameter boundary
<b>Mirror Effective Area File Keywords</b>		
EXTNAME	'INSTEFFAREA'	/ Name of the binary table extension
CONTENT	'INSTRUMENT EFFAREA'	/File format

*Table 49 - Mirror Effective Area Calibration File Extension 1 Keywords*

## 5.19 Sensitivity Correction Table

### 5.19.1 File Name

swusenscorrYYYYMMDD.fits

### 5.19.2 Description

The files contain the corrections to the fully-corrected count rate to account for the long-term in sensitivity of the UVOT detector and optical train. The file format consists of an empty primary header and eight extensions with identical layout one for each of the six broad band filters. Each extension contains the following columns:

- TIME: is the mission elapse time (seconds) after which the corrections stored in the slope and offset columns are valid ;
- OFFSET : This is the offset tp apply to the count rate ;
- SLOPE : This is the rate of change of the sensitivity .

The count rate is corrected accordingly with the following formula:

COMMENT

COMMENT This extension contains the sensitivity loss correction data

COMMENT for the Swift/UVOTA filters. The correction is

COMMENT

COMMENT  $C_{new} = C * (1 + OFFSET) * (1 + SLOPE)**DT$

COMMENT

COMMENT where  $C_{new}$  = corrected count rate

COMMENT  $C$  = observed count rate

COMMENT  $DT = (T_{MID} - TIME) / seconds\_per\_year$

COMMENT

A new row is added to the appropriate extension of this file whenever new calibration for the sensitivity change is available for each of the filter. The time value is used by the ground software to determine when the correction becomes valid.

### 5.19.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1-8	BINTABLE	SENSCORR	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	TIME	D	s
	OFFSET	I	
	SLOPE	I	

**Table 50 – Sensitivity Correction Calibration File Format**

### 5.19.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords.

### 5.19.5 Extension 1 & \* - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for these HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'SENSCORR'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	FILTER(<ff>)	/Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'<ff> FILTER SENSITIVITY CHANGES'	/Description see separate table
<b>Sensitivity File Keywords</b>		
EXTNAME	'SENSCORR<ff>'	/ Name of the binary table extension
CONTENT	'SENSCORR<ff>'	/ File content
TIMESYS	'TT'	/ Time system
MJDREFI	51910	/ Reference MJD integer part
MJDREFF	7.4287037e-4	/ Reference MJD fractional part
CLOCKAPP	F	/ If clock corrections are applied (F/T)

**Table 51 – Sensitivity Correction Calibration File Extension 1-8 Keywords**

The keywords with the value of variable <ff> differ in the eight extensions. They correspond to the different filters and their values are listed in table 5 together with the corresponding energy <min> and <max>.

## 5.20 Grism Wavelength Calibration

### 5.20.1 File Name

swuFFNNNNwcalYYYYMMDD.fits where FF is either 'gu' or 'gv' and NNNN a number signifying to grism clocking position.

### 5.20.2 Description

These files contain the wavelength calibration for the UVOTA grisms that is applied to detector plane images. There is one file for each of the four filter and grism clocking position combinations. These files describe the parameters for the wavelength scale over the face of the detector. The anchor position DETX1ANK, DETY1ANK of the first order wavelength scale is found in relation to the input angle (PHY\_X, PHY\_Y) of the incoming ray to the instrument. So is the second order anchor position (DETX2ANK, DETY2ANK). The angle of the spectrum at the first order anchor position is given in SP1SLOPE.

These files contain dispersion coefficients for the first and second spectral orders as polynomials on a regular grid over the detector, as well as a field describing the order of the polynomial. If the dispersion was found from extrapolation the field describing the order has been set to zero. The wavelength (in Angstrom) of the first order is found from:

$$\text{wavelength} = \text{DISP1}_0 + X * (\text{DISP1}_1 + X * (\text{DISP1}_2 + X * (\text{DISP1}_3 + X * \text{DISP1}_4)))$$

where X is the distance from the first order anchor point in detector pixels. Similarly, for the second order:

$$\text{wavelength} = \text{DISP2}_0 + X * (\text{DISP2}_1 + X * \text{DISP2}_2)$$

where X is the distance from the second order anchor point in detector pixels.

The input angle can be related to the position of the source in one of the lenticular filters, or the position of the source in the sky via algorithms that are described in the full UVOT grism documentation. The calibration is independent of the boresight position, but a fixed boresight value was adopted as a point of reference.

### 5.20.3 File Format

<i>Extension N.</i>	<i>Type</i>	<i>Ext. Name</i>	
0	PRIMARY		
1	BINTABLE	WAVECAL<GRISM><NNNN>	
	<b>Column Names</b>	<b>Format</b>	<b>Units</b>
	PHI_X	E	deg
	PHI_Y	E	deg
	DETX1ANK	E	pixel
	DETY1ANK	E	pixel
	SP1SLOPE	E	deg
	DISP1_0	E	
	DISP1_1	E	
	....	....	
	DISP1_N	I	
	DETX2ANK	E	pixel
	DETY2ANK	E	pixel

	DISP2_0	E	
	DISP2_1	E	
	.....	E	
	DISP2_N	I	

**Table 52 – Grism Wavelength Calibration File Format**

where <GRISM> is the name of the grism, either UGRISM or VGRISM, and <NNNN> is the clocking position number. There are DISP1\_N columns for the first order dispersion coefficients. These are named DISP1\_1 through DISP1\_<DISP1\_N>. Similarly, there are DISP2\_N columns for these second order dispersion coefficients. These are named DISP2\_1 through DISP2\_<DISP1\_N>.

#### 5.20.4 Primary Header Keywords

All keywords of Table 2 - UCFS mandatory header keywords. The DETNAM and FILTER keywords are added to record the grism clocking position and grism name respectively. The CREATED, CRDATE, AUTHOR, and CALVERS keywords record creation and version information for this file.

#### 5.20.5 Extension 1 - Header Keywords

The files are identical in structure, but each file may contain a different number of dispersion coefficient columns, as specified by DISP<ORDER>\_N where <ORDER> is the order of the spectrum. All keywords listed in Table 2 and Table 3 are included in the header of this HDU. Below are specific settings for the CALDB and other keywords relevant to these files.

<i>keyword name</i>	<i>keyword value</i>	<i>comment</i>
Table 2 & 3 - UCFS mandatory header keywords		
<b>CALDB Keywords</b>		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'WAVECAL'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FILTER(<GRISM>)'	/Parameter boundary
CBD20001	'WHEELPOS(<NNNN>)'	/Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'<GRISM> <NNNN> WAVELENGTH CALIBRATION'	/Description see separate table
<b>Grism Wavelength File Keywords</b>		
ORDERS	12	/ List of orders included
BOXG_260	1102.1	/ Grism boresight X at 260mm first order
BOYG_260	1022.3	/ Grism boresight Y at 260 mmm first order

**Table 52 – Grism Wavelength Calibration File Extension 1 Keywords**

The values for <GRISM> and <NNNN> are:

\*) <GRISM> UGRISM and VGRISM

\*) <NNNN> a number signifying to grism clocking position

## 6 File distribution and maintenance

The UVOT calibration files are produced by the UVOT Calibration team and delivered to the SSC that take care to verify the validity, integrity and format of the files and whether the proper CALDB mandatory keywords are included correctly. The CALDB files are finally delivered by the SSC to the HEASARC for public access. The delivery occurs each time UVOT calibration files are updated.

The UVOT CALDB files include data results obtained before launch from ground calibration tests and those obtained during flight. Calibration observations will be performed in flight after launch and periodically repeated to monitor the instrument performance. Therefore it is expected for the Calibration files to change or to be updated during the mission as result of the analysis of these calibration observations. The Calibration Team will provide updated files to the SSC/UVOT. In the following Table all calibration files are listed with the following information:

- Institution responsible for that calibration file;
- first release;
- foreseen periodicity of files delivery after launch.

Filename	Institution	First release	Periodicity after launch
Telescope definition file: Boresight & Distortion	PSU	September 2004	
Bad pixel	PSU	September 2004	
Color Transformation	PSU	September 2004	
Coincidence losses & zero point	PSU	September 2004	
Filter transmission	PSU	September 2004	No change expected
Grism equation	PSU	September 2004	
Mirror area	PSU	September 2004	No change expected
Psf	PSU	September 2004	
Large scale sensitivity, Skyflat		September 2004	
Pixel to pixel sensitivity, Calflat		September 2004	
Arf, grism sensitivity, line spread function		September 2004	
Dark Frame		September 2004	
Galactic Light	MSSL	September 2004	
Zodiacal light	MSSL	September 2004	
Quick mag	MSSL	September 2004	
Redistribution Matrix		September 2004	