OGIP Calibration Memo CAL/GEN/92-024

THE OGIP FORMAT FOR FILES CONTAINING FILTER & WINDOW TRANSMISSIONS

(TRANSVER = 1992a)

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SUMMARY

Ths document describes the standard format adopted by the OGIP for the storage of the transmission of a filter or window in front of an instrument as a function of energy, and position.
Intended audience: primarily OGIP programmers & hardware teams.

Log of Significant Changes

Release Date	**Sections Changed**	**Brief Notes**
1992 Jul 24	First Draft	(within memo CAL/GEN/92-003)
1993 Oct 03	All	Separation from CAL/GEN/92-003
1994 Apr 29	All	Reviewed & Updates
1994 Aug 09	All	General review/updates

RELATED DOCUMENTATION

The following documents may also be of use:

- *BCF & CPF Calibration File Guidelines*
  CAL/GEN/92-003 (George & Zellar)
- *Calibration Index Files*
  CAL/GEN/92-008 (George, Pence & Zellar)
- *Mandatory FITS Keywords for Calibration Files*
  CAL/GEN/92-011 (George, Zellar & Pence)
- *Virtual Calibration Files*
  CAL/GEN/92-013 (George, Zellar & White)
- *The OGIP Format for Vignetting Functions*
  CAL/GEN/92-021 (George & Zellar)
- *The OGIP Format for Obscuration Factors*
  CAL/GEN/92-022 (George & Zellar)

1 Introduction

In the general case the transmission of a filter or window consists of 3-dimensional grid, T_{tot}, with axes photon energy (E), and two coordinates specifying position of photon incidence (*e.g.* in physical cartesian coordinates X_{Phy} & Y_{Phy} across the window/filter). Thus within the OGIP caldb both filter and window transmission datasets are stored (in separate files) using an identical format (with the CCNM$xxxx$ codename used to distinguish between them), comprising of two extensions:

- an extension containing the 3-d grid giving the transmission at each E, X_{Phy}, Y_{Phy} grid point
- an (optional) extension containing the corresponding atomic data used construct the above transmissions (*i.e.* mass absorption coefficients or cross-sections as a function of E, and filter thickness as a function of X_{Phy}, Y_{Phy}).

Clearly the former is of most immediate use to s/w and users. The latter was designed to provide users with the ability to experiment with the nominal filter/window thicknesses, composition or mass absortion coefficients.

Notes:

- The OGIP caldb distinguishes between filters and windows purely on the basis of whether the structure is moveable: filters being able to be physically removed from the out of the optical path; windows being static fixtures along in the line of sight.
- Multiple windows (or filters), consisting of several layers of absorbing material, should be considered as a single (compound) window from the calibration point of view. Thus only a single calibration dataset is necessary. This is true even if the windows/filters are physically separated along the optical path (although not true if they are associated with different physical components such if one is associated with the detector, one with the X-ray mirror assembly).
- Many thin filters and windows require support structures in order to maintain their rigidity. In cases where this support is provided by the use of an underlying, spatially-(psuedo)-uniform substrate, the opacity of the substrate as a function of energy should be included in the transmission of the filter as a whole as given in Section 2 (and the appropriate atomic data included in the optional extension, *e.g.* Section 2.2). However in cases where (often additional) support is provided by a spatially non-uniform structure (*e.g.* a wire mesh), the position and transmission of this support structure is often stored separately elsewhere. The exact division of the calibration information between the two files is highly instrument dependent.

1.1 Storage Options

For instruments containing both a filter and a window, separate BCFs containing the respective transmission *etc.* should be created.

The extension containing the atomic data is not mandatory.

1.2 Dataset Origins & Storage Recommendations

The construction, format used (within the limitations discussed here) and delivery of the data to the HEASARC (including any updates) is the responsibility of the h/w teams and/or GOF. However, below, are the recommendations of the HEASARC calibration team based on their experience.

General
To avoid the chance of ambiguities, it is strongly urged that both the above extensions are supplied to the HEASARC. No other specific issues.

Pre-launch
Prior to launch, the thickness of the flight filters are usually measured at a limited number of positions during ground calibration experiments and/or assumed from the h/w specifications. The transmission functions are usually measured at a (limited) number of photon energies during such experiemts and/or calculated from atomic constants.

Post-launch
The transmission of a filter or window usually cannot be measured directly in-orbit. Rather, observations of standard cosmic sources (*e.g.* the Crab) combined with spectral modelling enables the Spectral Response of the instrument to be determined. In the case of moveable filters, clearly a pair of such observations – one with the filter in place, one with the filter removed – enables the transmission to be calculated. In the case of static filters/windows, the transmission cannot be decoupled from the other components of the Spectral Response. However, should should measurements reveal a discrepancy with the expected spectral response which is identified with (or interpreted as) a mis-calibration of the filter/window transmission(s), h/w teams are urged to isolate and supply an updated dataset to the HEASARC.

1.3 Dataset vs Task Summary

Due to the complexity of the Transmission of a filter or window as a function of energy (as the result of sharp discontinuities due to atomic processes *etc.*), such a calibration dataset is not easily parameterized. Thus, whilst theoretically possible, it is recommended that Filter & Window Transmission datasets are *not* described by a virtual calibration files (CAL/GEN/92-013).

It is strongly recommended that the extension containing the atomic data should not be a virtual either.

1.4 Software Considerations

Data Files:
Interpolation between the X_{Phy}, Y_{Phy} grid points is usually required. By default, downstream software will use a simple 2-dimensional **linear** interpolation when calculating the Transmission between X_{Phy}, Y_{Phy} grid points. Thus the X_{Phy}, Y_{Phy} grid should be of sufficient resolution to enable this to be reasonable approximation.

As discussed in CAL/GEN/92-003 (George & Zellar), it is strongly recommended that the energy grid is of sufficient resolution and carefully chosen such that interpolation of this parameter is not required. However, in cases where interpolation is required, as simple 1-dimensional linear interpolation will be performed (which will clearly be inaccurate close to sharp features).

Virtual Files:
Not applicable (see Section 1.3).

1.5 Relationships to Other Calibration Datasets

Downstream s/w should assume further calibration input is required for a Window/Filter Transmission dataset under the following conditions:

- <u>*condition:*</u>
  Never.

and for the corresponding Atomic data extension under the following conditions:

- <u>*condition:*</u>
  Never.

A Window/Filter Transmission dataset is used in the construction of the following calibration datasets:

- A CCNM$xxxx$ = SPECRESP dataset, containing the total spectral response of an instrument

The corresponding atomic data extensions is used in the construction of the following calibration datasets:

- None (besides the transmission dataset discribed here)

2 Data File Formats

The dataset file formats currently allowed are:

- TRANSVER = 1992a, consisting of the mandatory extension containing the transmissions (Section 2.1)
- FATVERSN = 1992a consisting of the optional extension giving the effective window/filter surface densities (in units of cm^2 g^{-1}), and mass absorption coefficients from which the transmissions were calculated (Section 2.2)
- FATVERSN = 1992b consisting of the optional extension giving the effective window/filter thicknesses (in units of cm), and absorption cross-sections from which the transmissions were calculated (Section 2.3)

However, see the comments in Section 1 regarding the necessity of the optional extensions.

2.1 The Filter/Window Transmission Extension (TRANSVER = 1992a)

Description:
A single row BINTABLE extension for each window or filter on each instrument containing 5 columns.

Extension Header
Beyond the standard FITS keywords required, the following keywords/values are mandatory:

- TDIM*nnn* - the number of elements and ordering of the arrays (see CAL/GEN/92-003; George & Zellar 1992) of each multi-dimensional array.
  Only the TRANSMIS column here (with *nnn*=5 in the example below).
- CSYSNAME - the spatial coordinate system in use (see CAL/GEN/92-003; George & Zellar 1992)
  (CSYSNAME = PHY_DET is assumed in the example below)

and the following keywords/values are mandatory for CIF purposes (see CAL/GEN/92-011; George, Zellar & Pence 1992):

- TELESCOP - the name of the staellite/mission. Allowed values are given in CAL/GEN/92-011.

- INSTRUME - the name of the telescope mirror/collimator assembly or detector.
  Allowed values are given in CAL/GEN/92-011.
  It should be noted that this keyword is used to further clarify the physical location of the filter/window concerned. For example a protective window on the front of the X-ray mirror assembly/collimator of an instrument would have INSTRUME = XMA (where XMA is an allowed value listed in CAL/GEN/92-011), whilst the front (or internal) window on a detector DET would have INSTRUME = DET (where again DET is an allowed value as listed in CAL/GEN/92-011).
- FILTER - (for CCNM0001 = FTRANS datasets only) the name of filter.
  Allowed values are given in CAL/GEN/92-011.
- CCLS0001 (=BCF) - the OGIP class of this calibration file
- CDTP0001 (=DATA) - the OGIP class of the data type
- CCNM0001 - the OGIP codename for the contents
  - CCNM0001 = FTRANS, for a filter transmission
  - CCNM0001 = WTRANS, for a window transmission
- CBDn0001 - the parameter limitation of the dataset (see below)
- CVSD0001 - calibration validity start date
- CVST0001 - calibration validity start time
- CDES0001 - a descriptive string of the calibration dataset

and the following mandatory to supply further information:

- TRANSVER - the OGIP version of the FITS format in use (in this case 1992a)

Data Format:
The data within this extension is organised as a BINTABLE with the following columns:

1. E_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower energy bounds of the energy bins.
   The FITS column name is **ENERG_LO**.
   The recommended units are keV.
2. E_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper energy bounds of the energy bins.
   The FITS column name is **ENERG_HI**.
   The recommended units are keV.

3. X_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical X-coordinates.
The FITS column name is **PHYX** (but see below).
The recommended units are mm.

4. Y_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical Y-coordinates.
The FITS column name is **PHYY** (but see below).
The recommended units are mm.

5. T_{tot}, a fixed length REAL vector (array, each element within which is 4-byte) containing the transmission of the filter/window at each E, X_{Phy}, Y_{Phy} grid point.
The FITS column name is **TRANSMIS**.
The order of data storage is $T_{tot}(E, X_{Phy}, Y_{Phy})$, where E represents the E_{low} and E_{high} array (see below).
(unitless).

These are summarized in Table 1.

Points to Note & Conventions

- The ordering of the columns is of course arbitrary, however that used here is recommended.
- The rules and conventions concerning the energy grid (E_{low} & E_{high}) given in CAL/GEN/92-003 apply.
- An alternate spatial coordinate frame may be used, in which case
  - the values of the CSYSNAME keyword should be replaced by the appropriate string listed in CAL/GEN/92-003
  - and/or (if necessary) the PHYX & PHYY column names replaced by more suitable alternatives if a different coordinate notation is employed. In this case the CSYSNAME keyword is mandatory and should give the column names used (see CAL/GEN/92-003).
- The parameter-space limitations on the dataset involving the following *pname* strings are recommended to be specified via the CBDn0001 keywords (see CA:/GEN/92-003):
  - *pname* = PHYX & PHYY - giving the range of detector positions for which the dataset is valid;

  (or corresponding alternate values of *pname* if a different coordinate notation is employed) along with any other limitations the authors consider necessary.

- Alternative physical units are allowed for all columns of the table as long as they conform to the rules given in CAL/GEN/93-001. The same is true for the physical units associated with the CBDn0001 keywords.

Table 1: Summary of the OGIP format for Filter/Window Transmissions (TRANSVER = 1992a).

Extension **to** *(filename).(ext)*

Name: TRANSMISSION
Version: TRANSVER = 1992a
Description: Transmission as a function of energy and position for filters and windows
An alternate spatial coordinate frame may also be used (see text).
Optional columns containing the statistical and systematic error arrays are not shown.
Format: BINTABLE

column 1	2	3	4	5
contents				
Low energy bounds	**High energy bounds**	**Position**	**Grid coords**	**Transmission**
E_{low}	E_{high}	X_{Phy}	Y_{Phy}	T_{tot}
format of each column				
4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array
total number of elements per row				
i	i	j	j	$i \times j$
column name				
ENERG_LO	ENERG_HI	PHYX	PHYY	TRANSMIS

- Datasets in which T_tot is independent of either spatial coordinate should **NOT** contain the corresponding column. It is recommended that a COMMENT card is used within the header to explain this fact to human readers (eg see Section 5.1).
- The order of $T_{tot}(E, X_{Phy}, Y_{Phy})$ whereby energy parameters changes fastest, and (arbitarily) the Y_{Phy} parameter slowest was chosen to facilitate access for the most common applications: interpolation in X_{Phy}, Y_{Phy}-space of T_{tot} vs E_{low}, E_{high} arrays. This ordering is further confirmed by the value of the mandatory TDIM*nnn* and *i*CTYP*nnn* keywords (where *nnn* is the column number, and *i* the axis number). The rules and conventions governing these keywords are given in CAL/GEN/92-003 (see also Section 5).
- The optional arrays containing the 1σ statistical error associated with each element of T_{tot} (if required) should be contained in additional columns named **STAT_MIN** (for the negative error) and **STAT_MAX** (for the positive error).
  Similarly, the optional arrays containing the 1σ fractional systematic error associated with each element of T_{tot} (if required) should be contained in additional columns named **SYS_MIN** (for the negative error) and **SYS_MAX** (for the positive error).
  The rules and conventions governing such arrays (if present) are given in CAL/GEN/92-003. These arrays are provided here for completeness, and rarely either provided by the h/w teams or used by downstream s/w.

2.2 Filter Atomic Data Extension (FATVERSN = 1992a)

This (optional) extension was originally designed to provide users with the ability (should they wish) to experiment with the nominal filter/window thicknesses, composition or mass absortion coefficients. However, following the design of formats for General Atomic (Section **??**) and Filter/Window Thickness (Section **??**) datasets, the necessity for this extension has reduced. Therefore, if General Atomic and Filter/Window Thickness datasets are supplied for a given instrument, this extension is **not** required.

Description:
There are two types of calibration information stored within this single (optional) extension:

1. the mass absorption coefficient (K^j_{abs}, in units of cm^2 g^{-1}) as a function of energy (E) for each of the j components of the filter/window
2. the effective surface thickness (L^j_{thick}, in units of g cm^{-2}) of each of these components as a function of position (X_{Phy}, Y_{Phy} *etc.*) on the filter/window.

Thus the transmission T^j at an energy E and position X_{Phy}, Y_{Phy} of the $j^{\rm th}$ component within the filter/window is given by

$$T^j(E) = \exp\left(-L^j_{thick} \times K^j_{abs}(E)\right) \tag{1}$$

where $L^j_{thick}(= \rho \times d)$ is the surface density of atom/molecule j ($L^j_{thick} = \rho \times d$ where m^j is the mass of an atom/molecule of j and ρ the denisty).

The total transmission T_{tot} of the complete filter/window (including all n_{comp} components) at a given E, X_{Phy}, Y_{Phy} (*i.e.* as stored explicitly in the Transmission extension, *e.g.* see Section 2.1) is given by

$$T_{tot}(E, X_{Lin}, Y_{Lin}) = \prod_{j=1}^{n_{comp}} T^j(E, X_{Lin}, Y_{Lin}) \tag{2}$$

Extension Header
Beyond the standard FITS keywords required, the following keywords/values are mandatory:

- TDIM*nnn* - the number of elements and ordering of the arrays (see CAL/GEN/92-003; George & Zellar 1992) of each multi-dimensional array.
  Only the MASS_ABS & THICKNES columns here (with *nnn*=4 & 7 respectively in the example below).
- CSYSNAME - the spatial coordinate system in use (see CAL/GEN/92-003; George & Zellar 1992)
  (CSYSNAME = PHY_DET is assumed in the example below)

and the following keywords/values are mandatory for CIF purposes (see CAL/GEN/92-011; George, Zellar & Pence 1992):

- TELESCOP - the name of the staellite/mission.
  Allowed values are given in CAL/GEN/92-011.
- INSTRUME - the name of the telescope mirror/collimator assembly or detector.
  Allowed values are given in CAL/GEN/92-011.
  It should be noted that this keyword is used to further clarify the physical location of the filter/window concerned. See the corresponding discussion in Section 2.1.
- CCLS0001, 0002 (=BCF) - the OGIP class of this calibration file
- CDTP0001, 0002 (=DATA) - the OGIP class of the data type
- CCNM0001 - the OGIP codename for the contents
  - CCNM0001 = FATOM, for atomic data related to a filter transmission ... *under revision*
  - CCNM0001 = WATOM, for atomic data related to a window transmission ... *under revision*
  - CCNM0002 = FTHICK, for the thickness of a filter
  - CCNM0002 = WTHICK, for the thickness of a window

- CBDn0001, 0002 - the parameter limitation of the dataset (see below)
- CVSD0001, 0002 - calibration validity start date
- CVST0001, 0002 - calibration validity start time
- CDES0001, 0002 - a descriptive string of the calibration dataset

and the following mandatory to supply further information:

- FATVERSN - the OGIP version of the FITS format in use (in this case 1992a)

Data Format:
The data within this extension is organised as a BINTABLE with the following columns:

1. E_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower energy bounds of the energy bins.
   The FITS column name is **ENERG_LO**.
   The recommended units are keV.
2. E_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper energy bounds of the energy bins.
   The FITS column name is **ENERG_HI**.
   The recommended units are keV.
3. *Comp*, a fixed-length CHARACTER vector (array, each element within which is 10-bytes) containing the names/symbols of each component of the filter/window.
   The FITS column name is **COMPNAME**.
   (unitless)
4. K^j_{abs}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the mass absorption coefficient for each component j of the filter/window.
   The FITS column name is **MASS_ABS**.
   The recommended units are cm^2 g^{-1}.
5. X_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical X-coordinates.
   The FITS column name is **PHYX** (but see below).
   The recommended units are mm.
6. Y_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical Y-coordinates.
   The FITS column name is **PHYY** (but see below).
   The recommended units are mm.

7. L_{thick}, a fixed length REAL vector (array, each element within which is 4-byte) containing the effective surface density thickness at each E, X_{Phy}, Y_{Phy} grid point for each component j of the filter/window.
   The FITS column name is **THICKNES**.
   The order of data storage is $L_{thick}(E, X_{Phy}, Y_{Phy}, Comp)$, where E represents the E_{low} and E_{high} array (see below).
   The recommended units are g/cm^{-2}.

These are summarized in Table 2.

Points to Note & Conventions

- The ordering of the columns is of course arbitrary, however that used here is recommended.
- The rules and conventions concerning E_{low} & E_{high} given in CAL/GEN/92-003 apply.
- An alternate spatial coordinate frame may be used, in which case
  - the values of the CSYSNAME keywords should be replaced by the appropriate string listed in CAL/GEN/92-003
  - and/or (if necessary) the PHYX & PHYY column names replaced by more suitable alternatives if a different coordinate notation is employed. In this case the CSYSNAME keyword is mandatory and should give the column names used (see CAL/GEN/92-003)

  Physical or Detector coordinates are strongly recommended.
- Datasets in which L_{thick} is independent of either spatial coordinate should **NOT** contain the corresponding column. It is recommended that a COMMENT card is used within the header to explain this fact to human readers.
- The order of $L_{thick}(E, X_{Phy}, Y_{Phy}, Comp)$ whereby energy parameters changes fastest, and the $Comp$ parameter slowest was chosen to facilitate access for the most common applications: interpolation in X_{Phy}, Y_{Phy}-space of T_{tot} vs E_{low}, E_{high} arrays for individual components. This ordering is further confirmed by the value of the mandatory TDIM*nnn* and *i*CTYP*nnn* keywords (where *nnn* is the column number, and *i* the axis number). The rules and conventions governing these keywords are given in CAL/GEN/92-003.
- The optional arrays containing the 1σ statistical error associated with each element of K_{ma} (if required) should be contained in additional columns named **MAST_MIN** (for the negative error) and **MAST_MAX** (for the positive error).
  Similarly, the optional arrays containing the 1σ fractional systematic error associated with each element of L_{thick} (if required) should be contained in additional columns named **MASY_MIN** (for the negative error) and **MASY_MAX** (for the positive error).
- The optional arrays containing the 1σ statistical error associated with each element of L_{thick} (if required) should be contained in additional columns named **STAT_MIN** (for

Table 2: Summary of the OGIP format for Filter/Window Atomic Data (FATVERSN = 1992a).

Extension **to** *(filename).(ext)*

Name: FATOM or WATOM
Version: FATVERSN = 1992a
Description: Atomic Data required to calculate the transmission of a filter/window as a function of energy and position.
An alternate spatial coordinate frame may also be used (see text).
Optional columns containing the statistical and systematic error arrays are not shown.
Format: BINTABLE

column	1	2	3	4	5	6	7
contents	**Low energy bounds**	**High energy bounds**	**Component Name**	**Mass Absorption Coefficient**	**Position Grid coords**		**Surface Density**
	E_{low}	E_{high}	$Comp$	K_{ma}	X_{Phy}	Y_{Phy}	L_{thick}
format of each column	4-byte real array	4-byte real array	10-byte character array	4-byte real array	4-byte real array	4-byte real array	4-byte real array
total number of elements per row	i	i	j	$i \times j$	k	k	$k \times j$
column name	ENERG_LO	ENERG_HI	COMPNAME	MASS_ABS	PHYX	PHYY	THICKNES

the negative error) and **STAT_MAX** (for the positive error).
Similarly, the optional arrays containing the 1σ fractional systematic error associated with each element of L_{thick} (if required) should be contained in additional columns named **SYS_MIN** (for the negative error) and **SYS_MAX** (for the positive error).
The rules and conventions governing such arrays (if present) are given in CA:/GEN/92-003. These arrays are provided here for completeness, and rarely either provided by the h/w teams or used by downstream s/w.

2.3 Filter Atomic Data Extension (FATVERSN = 1992b)

As for comments in Section 2.2.

Description:
There are four types of calibration information stored within this single (optional) extension:

1. the total absorption cross-section (σ^j_{abs}, in units of cm^2) as a function of energy (E) for each of the j components of the filter/window
2. the mass (m^j, in units of g) of a single atom/molecule of each of the j components of the filter/window
3. the density (ρ^j, in units of g/cm^{-3}) of each of the j components of the filter/window
4. the effective thickness (d^j, in units of cm) of each of these components as a function of position (X_{Phy}, Y_{Phy} *etc.*) on the filter/window.

Thus the transmission T^j at an energy E and position X_{Phy}, Y_{Phy} of the j^{th} component within the filter/window is given by

$$T^j(E) = \exp\left(-\frac{\rho}{m^j} \times \sigma^j_{abs}(E) \times d^j\right) \tag{3}$$

The total transmission T_{tot} of the complete filter/window (including all n_{comp} components) at a given E, X_{Phy}, Y_{Phy} (*i.e.* as stored explicitly in the Transmission extension, *e.g.* see Section 2.1) is given by Equation 2 (Section 2.2).

Extension Header
As in Section 2.2, except that:

- TDIM*nnn* - the number of elements and ordering of the arrays, is required for the ABS_XSECT, MASS, DENSITY & THICKNES columns below.
- Mandatory CIF keywords are required for all 4 calibration datasets. These are straightforward, except:

  - CCNM0001 = FATOM (or WATOM) ... *under revision*
  - CCNM0002 = MASS ... *under revision*
  - CCNM0003 = DENS ... *under revision*
  - CCNM0004 = FTHICK (or WTHICK) ... *under revision*

- FATVERSN (= 1992b)

Data Format:
The data within this extension is organised as a BINTABLE with the following columns:

1. E_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower energy bounds of the energy bins.
The FITS column name is **ENERG_LO**.
The recommended units are keV.

2. E_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper energy bounds of the energy bins.
The FITS column name is **ENERG_HI**.
The recommended units are keV.

3. *Comp*, a fixed-length CHARACTER vector (array, each element within which is 10-bytes) containing the names/symbols of each component of the filter/window.
The FITS column name is **COMPNAME**.
(unitless)

4. σ^j_{abs}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the absorption cross-section for each component j of the filter/window.
The FITS column name is **ABS_XSECT**.
The recommended units are cm^2.

5. m^j, a fixed-length REAL vector (array, each element within which is 4-byte) containing the mass of one atom/moelcule of each component j of the filter/window.
The FITS column name is **MASS**.
The recommended units are g.

6. ρ^j, a fixed-length REAL vector (array, each element within which is 4-byte) containing the density of each component j of the filter/window.
The FITS column name is **DENSITY**.
The recommended units are g/cm^{-3}.

7. X_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical X-coordinates.
The FITS column name is **PHYX** (but see below).
The recommended units are mm.

8. Y_{Phy}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the physical Y-coordinates.
   The FITS column name is **PHYY** (but see below).
   The recommended units are mm.

9. $d(j)$, a fixed length REAL vector (array, each element within which is 4-byte) containing the effective thickness at each E, X_{Phy}, Y_{Phy} grid point for each component j of the filter/window.
   The FITS column name is **THICKNES**.
   The order of data storage is $d^j(E, X_{Phy}, Y_{Phy}, Comp)$, where E represents the E_{low} and E_{high} array (see below).
   The recommended units are g/cm^{-2}.

These are summarized in Table 3.

Points to Note & Conventions

- The ordering of the columns is of course arbitrary, however that used here is recommended.
- The rules and conventions concerning E_{low} & E_{high} given in CAL/GEN/92-003 apply.
- An alternate spatial coordinate frame may be used, in which case
  - the values of the CSYSNAME keywords should be replaced by the appropriate string listed in CAL/GEN/92-003
  - and/or (if necessary) the PHYX & PHYY column names replaced by more suitable alternatives if a different coordinate notation is employed. In this case the CSYSNAME keyword is mandatory and should give the column names used (see CAL/GEN/92-003).

  Physical or Detector coordinates are strongly recommended.

3 Virtual File Formats & Allowed Standalone Tasks

As noted in Section 1.3, given the difficulty parameterizing the Filter transmission in energy-space, it is not recommended that such datasets are stored as Virtual Calibration Files.

4 Related Software

The following list of subroutines/tasks are available:

- FORTRAN subroutine `wttrs1.f` (callib)
  writes an TRANSVER = 1992a dataset (Section 2.1)

Table 3: Summary of the OGIP format for Filter/Window Atomic Data (FATVERSN = 1992b).

Extension **to** *(filename).(ext)*

Name: FATOM or WATOM
Version: FATVERSN = 1992b
Description: Atomic Data required to calculate the transmission of a filter/window as a function of energy and position.
An alternate spatial coordinate frame may also be used (see text).
Optional columns containing the statistical and systematic error arrays are not shown.
Format: BINTABLE

column	1	2	3	4	5	6
contents	**Low energy bounds**	**High energy bounds**	**Component Name**	**Total Absorption Cross-Section**	**Mass per atom/moelcule**	**Density**
	E_{low}	E_{high}	$Comp$	σ^j_{abs}	m^j	ρ^j
format of each column	4-byte real array	4-byte real array	10-byte character array	4-byte real array	4-byte real array	4-byte real array
total number of elements per row	i	i	j	$i \times j$	$i \times j$	$i \times j$
column name	ENERG_LO	ENERG_HI	COMPNAME	ABS_XSECT	MASS	DENSITY

column	7	8	9
contents	**Position Grid coords**		**Component Thickness**
	X_{Phy}	Y_{Phy}	d^j
format of each column	4-byte real array	4-byte real array	4-byte real array
total number of elements per row	k	k	$k \times j$
column name	PHYX	PHYY	THICKNES

5 Example FITS headers

Below are several examples of files currently available within the OGIP Caldb. Note that the authors of datasets are encouraged to supply copious COMMENT cards to aide human readers.

5.1 *ROSAT*

Follows is the header from an extension containing a TRANSVER=1992a dataset. The Window Transmission dataset is stored in column 3 and is a function of 729 energies. There is no THETA or PHI dependence for this dataset. The *i*CTYP3 and TDIM4 keywords confirm that there is only one dimension to the array, and that that axis is 'ENERGY'.

```
XTENSION= 'BINTABLE'          / binary table extension
BITPIX  =                   8 / 8-bit bytes
NAXIS   =                   2 / 2-dimensional binary table
NAXIS1  =                8748 / width of table in bytes
NAXIS2  =                   1 / number of rows in table
PCOUNT  =                   0 / size of special data area
GCOUNT  =                   1 / one data group (required keyword)
TFIELDS =                   3 / number of fields in each row
TTYPE1  = 'ENERG_LO'          / Lower boundaries of energy bins
TFORM1  = '729E    '          / data format of the field: 4-byte REAL
TUNIT1  = 'keV     '          / physical unit of field
TTYPE2  = 'ENERG_HI'          / Upper boundaries of energy bins
TFORM2  = '729E    '          / data format of the field: 4-byte REAL
TUNIT2  = 'keV     '          / physical unit of field
TTYPE3  = 'TRANSMIS'          / Transmission dataset
TFORM3  = '729E    '          / data format of the field: 4-byte REAL
EXTNAME = 'TRANSMISSION'      / name of this binary table extension
HDUCLASS= 'OGIP    '          / format conforms to OGIP standard
HDUCLAS1= 'RESPONSE'          / dataset relates to instrument response
HDUVERS1= '1.0.0   '          / Version of family of formats
HDUCLAS2= 'TRANSMISSION'      / dataset is a transmission
HDUVERS2= '1.1.0   '          / Version of format (OGIP memo CAL/GEN/92-024)
HDUCLAS3= 'WINDOW  '          / for device given by INSTRUME (+DETNAM) kywrd
CSYSNAME= 'XMA_POL '          / spatial coord system used in this dataset
TELESCOP= 'ROSAT   '          / mission/satellite name
INSTRUME= 'PSPCB   '          / instrument/detector name
FILTER  = 'NONE    '          / filter in use
COMMENT   Dataset assumed to be independent of THETA
COMMENT   Dataset assumed to be independent of PHI
TDIM3   = '(729)   '          / Ordering of n-d TRANSMIS array
1CTYP3  = 'ENERGY  '          / Axis of 1st dimension of TRANSMIS array
```

```
TRANSVER= '1992a   '           / OGIP classification of FITS format
HISTORY    Extension written by WTTRS1 1.1.0
COMMENT
COMMENT     The following keywords are required for the OGIP CALDB
CCLS0001= 'BCF     '           / OGIP class of calibration file
CDTP0001= 'DATA    '           / OGIP type of dataset (DATA, TASK etc)
CCNM0001= 'WTRANS  '           / OGIP codename for this type of cal file
CVSD0001= '01/06/90'           / Dataset validity start date (UTC)
CVST0001= '00:00:00'           / Dataset validity start time (UTC, of day CVSD)
CDES0001= 'PSPCB Window Transmission (version 1); 729 energies'
CBD10001= 'THETA(0-60.0)arcmin' / dataset parameter boundary
CBD20001= 'PHI(0-360)deg'      / dataset parameter boundary
CBD30001= 'ENERG(0.0546-3.01)keV' / dataset parameter boundary
COMMENT
COMMENT     NOTES: 1994 Jul 21       (Ian M George, HEASARC)
COMMENT     ------------------
COMMENT     This dataset was converted to OGIP FITS format by
COMMENT     Ian M George (HEASARC) from the ASCII file
COMMENT            pspc_b_win.asc
COMMENT     supplied by Steve Snowden (ROSAT GOF, NASA/GSFC).
COMMENT
```

REFERENCES

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