AXAF Science Center

Analysis Reference Data for Grating Spectral Analysis

ASC Archive Interface Control Document

(http://space.mit.edu/ASC/docs/ARD_ICD_sp.ps.gz)

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Submitted:	____________________ John Houck Grating Scientist, ASC Science Data Systems	________ Date
Concurred:	____________________ Janet De Ponte ASC Data Systems Group Leader, L1.5 Pipelines	________ Date
Concurred:	____________________ Martin Elvis Manager, ASC Science Data Systems	________ Date

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Date	**Version**	**Section**	**Status**
15 July 98	0.5	all	re-formatted earlier draft and added new sections.

Unresolved Issues

The following is a list of unresolved, un-reviewed, or un-implemented items:

1. Section 1-3 introductory text needs updating – only the stuff describing the spectroscopy database is up to date. This document will eventually become a chapter in the larger ARD document, so the introductory text will be finalized at that time.

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1 Introduction

This document describes the interface to be employed in transferring the Analysis Reference Data (ARD) used in the ASC processing pipelines and analysis tools to or from the ASC Data Archive, according to the requirements stipulated in the "ASC Data System Requirements" (Applicable Document 2). The products described here are those used in Exposure Map, Instrument Map, or Grating Level 1.5–2 processing.

The ARD are typically derived calibration products or parameters used in Level 2 processing pipelines or in interactive analysis. ARD are in turn derived from Calibration Interface Products (CIP[1]) ARD may be identical to CIP, may be derived by re-formatting (e.g., ASCII table to FITS BINTABLE), or many-to-one processing. The primary distinction is that the ARD are necessary or convenient for *analysis*, and are a subset of the CIP, which define the detailed *calibration*.

Together with pipeline and interactive processing data products, the ARD form a Data Dictionary.

Formatting NOTE: Text formatted between horizontal rules (like this block) provide some historical context regarding alternative choices considered, which may still be debated.

Items boxed in the right margin (like this) are questions to be answered or TBD's to be replaced.

1.1 Purpose

AXAF processing, described in Applicable Document 2, consists of event processing of HRC or ACIS Level 1 products (which are described in Applicable Documents 6 and 7) to derive new products, such as images, spectra, light-curves, or exposure-maps. This document describes the structure and content of the reference data required for a subset of this processing and for further analysis, either via pipeline or interactive processing.

1.2 Scope

This interface shall apply to all data products that are used by ASC Level 2 pipelines and distributed to the ASC Data Archive (see Applicable Document 2 and the "ASC Data System Software Design," Applicable Document 3) during the course of the AXAF mission.

2 Applicable Documents

The Applicable Documents required for background and detail on grating Level 1.5 products are as follows:

1. AXAF Data Products Guide
   `http://hea-www.harvard.edu/asclocal/sds/CDR2/dp.ps`
2. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)

[1] See `http://space.mit.edu/HETG/xrcf_cal/cal_prods.html#Overview` for a definition.

3. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)

4. HEASARC FITS CALDB Standards:
   `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/caldb_intro.html`
   (and references therein.)

5. ASC FITS File Designers' Guide
   `http://hea-www.harvard.edu/ãrots/asc/fits/ascfits.ps` (and references therein).

6. HRC Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   `http://hea-www.harvard.edu/asclocal/sds/ICD/l1icd.ps.gz`

7. ACIS Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   Link to be on: `http://space.mit.edu/ASC/docs/docs.html`

8. Grating Data Products:
   Level 1.5 to ASC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/ICD_L1.5.ps.gz`

9. Grating Data Products:
   Level 2 to ASC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/ICD_L2.ps.gz`

10. "Response Matrix Tool: Design Specification and Data Product ICD"
    `http://space.mit.edu/ASC/docs/TBD`

11. ARF ICD and Tools:
    TBD to ASC Archive Interface Control Document
    `http://space.mit.edu/ASC/docs/TBD`

3 Functional Description

3.1 Data Content Summary

Data sets read by the processing pipelines shall consist of data files conforming to the FITS format (See the "ASC FITS File Designers' Guide", Document 5) and references therein.) These files contain header keyword entries and binary table (BINTABLE) extensions. Following rules outlined in Applicable Document 5, all these files will contain a possibly null primary header followed by a main binary table (the "principal HDU") and auxiliary extensions ("auxiliary HDU"). Furthermore, FITS ARD files will conform to the HEASARC CALDB conventions (4).

Any other types of files will either be of types in common use (e.g., PostScript), or fully described here (e.g., ASCII region files of IRAF/PROS), or parameter files conforming to the SAO parameter interface.

Get param i/f ref.

3.2 Recipients and Utilization

The primary recipients of reference data products, via distribution from the archive, are AXAF observers, who will utilize these data products for scientific data analysis.

3.3 Pertinent Relationships with Other Interfaces

Changes to the definition of HRC, ACIS, or HRMA Calibration Interface Products, as described in Applicable Documents **??**TBD, may affect the data products described in the current document.

TBD: CIP doc reference.

3.4 Assumptions and Constraints

It is assumed that ASC pipeline processing uses ARD applicable to the time of the observations, and that the ARD is updated as necessary when CIP are revised. It is also assumed that these products are extracted from the ASC archive and placed into an exportable calibration database (CALDB) for users.

3.5 Products Not Covered

Products that are used for maintenance and diagnostic purposes (those that are not supplied to the user for scientific data analysis) are not currently included within the interface defined by this document.

3.6 Substructure Definition and Format

The "ASC FITS Designers' Guide" (Applicable Document 5) defines and lists header components for the primary header and for all binary table extensions. These will be used with appropriate modifications for non-flight data (e.g., many Observation and Timing Components' keywords are irrelevant). The modified components are listed in Appendix **??**. These will be used in accordance with Table 6 in the "ASC FITS Designers' Guide."

In general, when FITS headers are shown, column or row numbers are arbitrary unless otherwise indicated. It is the *column name and its attributes* specify the requirement. Additional columns or extensions not specified here are permitted in the file without violating the interface. Processing software can ignore them, pass them through, or use them if they are "known" quantities. (Example usage of this are columns derived from simulation containing *a priori* known values, to be directly compared with specified columns containing derived values.) Likewise, HDU order is arbitrary, except for the primary HDU. HDU are intended to be referenced by name, not position.

4 Spectroscopy Database

Unresolved issues

The following is the list of the most important unresolved issues:

1. The emissivity tables may be split up into smaller files if the format described here is too unwieldy.
2. Need format to store collision strength data?
3. Need format to store level CIE population values?
4. Many CONTENT and EXTNAME keywords are TBD as are TLMIN and TLMAX values in many of the bintables.
5. Format for file containing full literature references.
6. Need format for file containing collisional bound-bound transition rates or any other bound-bound rates (DR, inner shell processes, etc.)?
7. Format for file containing rates for continuum coupling to particular levels (or will these come from a subroutine which evaluates analytic fits?). minor issue.

4.1 Database Summary

This database contains atomic data for elements with relatively high solar/cosmic abundances and, for selected ionization states, includes tables of energy levels, wavelengths and radiative transition probabilities. The database also includes tables of ionization balance and line and continuum emissivities as a function of electron temperature and electron density for a plasma in collisional ionization equilibrium (CIE). Note that the atomic data is independent of the state of the plasma and is therefore useful for analysis of plasma emission under fairly general conditions. While the CIE ionization balance and emissivities are based on a more narrow set of assumptions about the state of the plasma, they still provide a useful starting point for the analysis of emission from more complex plasmas.

The data files shall be assigned external names as shown in Table 1. The names obey the following conventions:

```
sdb_content.fits
sdb_content_id.fits
sdb_content_element.fits
sdb_content_element_id.fits
```

where *element* indicates that the file contains data for a particular chemical element, and *content* indicates the contents of the file (see Table 1). The *element* string is the 2 character chemical abbreviation. Valid content strings are listed in the table below. The optional *id* field may be used to indicate different versions of a given file. For example, if several different ionization balance files are available, this field may be used to make the file names unique.

This database will be used by various tools including *line_examine_feature, line_identify_feature.*

File name	Contents
`sdb_abund.fits`	Relative elemental abundances by number
`sdb_cieionbal_`*`id`*`.fits`	Ion fractions in collisional ionization equilibrium
`sdb_level_`*`element`*`.fits`	Excitation states of each ion
`sdb_line_`*`element`*`.fits`	Emission lines from each ion
`sdb_cielemis_`*`id`*`.fits`	Line emissivity tables
`sdb_ciecemis_`*`id`*`.fits`	Continuum emissivity tables

Table 1: Spectroscopy Database Filenames

4.2 Abundance Table

Data Product Summary

Analysis Reference Data Product	Abundance Table
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

This file contains the solar/cosmic abundances of abundant chemical elements by number, relative to Hydrogen. For each element, the tables give the base-10 logarithm of the number of atoms of that element per 10^{12} Hydrogen atoms. Several abundance values, taken from different literature references, are listed for each element.

4.2.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2	BINTABLE	TBD	ABUNDANCE	ABUNDANCE	Solar/Cosmic Abundances in log form with H=12.00

4.2.2 Column Descriptions

Columns for Abundance Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Element		2A	N/A	N/A	N/A	NONE	Element name
Z		1J	0	100	N/A	999	proton number
Atomic_wt	g	1E	0.0	1.e-20	N/A	NaN	Atomic_wt
Allen		D	-100.0	100.0	N/A	NaN	Elemental abundances from Allen (1973)
AG89		D	-100.0	100.0	N/A	NaN	Elemental abundances from Anders & Grevesse (1989)
GA88		D	-100.0	100.0	N/A	NaN	Elemental abundances from Grevesse & Anders (1988)
Feldman		D	-100.0	100.0	N/A	NaN	Elemental abundances from Feldman (1992)

The literature references cited here are also listed in the HDU.

- Allen, C. W. "Astrophysical Quantities", 3rd Ed., 1973 (London: Athlone Press)
- Anders, E. & Grevesse, N. 1989, Geochimica et Cosmochimica Acta, 53, 197
- Grevesse, N, & Anders, E. 1988, "Cosmic abundances of matter", ed. C. J. Waddington, AIP Conference #193, Minneapolis, MN
- Feldman, U. 1992, Physica Scripta 46, 202

4.2.3 Size Estimate

At this writing, the file lists the abundance of elements with nuclear charge $Z \leq 28$. Four abundance tables are provided, so the table contains $4 \times 28 = 96$ 64 bit floating point abundance values. Only one such table is necessary although further abundance tables may be included, thus increasing the table size.

4.2.4 Unresolved Issues

4.3 Ionization Balance Table

Data Product Summary

Analysis Reference Data Product	Ionization Balance Table
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

This file gives the ionization balance of the plasma as a function of temperature and electron density in collisional ionization equilibrium. For each element, the ion fractions are normalized so that

$$\sum_{k=0}^{Z} X_k^Z(T,n) = 1 \tag{1}$$

where $X_k^Z(T,n)$ is the fraction of atoms with nuclear charge Z and k bound electrons at temperature T and electron density n. In the table, `Z_ELEMENT` is the nuclear charge Z and `X_IONPOP` is the ion fraction $X_k^Z(T,n)$.

4.3.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	ION_BAL	ASC ION_BAL	
2	BINTABLE	PARAMETERS	ION_BAL	ASC ION_BAL PARAMETERS	Ionization balance table

4.3.2 Column Descriptions

At each temperature and electron density, the ion fraction of all ions is listed in a single vector, ordered by element and ion charge. For example, in the case where only 2 elements (H, He) are listed, the ions are listed in order H^0, H^{1+}, He^0, He^{1+}, He^{2+}.

Columns for Ionization Balance Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Temperature	K	E	0.0	1.0e8	N/A	NaN	Electron temperature
Density	cm**(-3)	E	0.0	TBD	N/A	NaN	Electron density
Z_ELEMENT		13J	0	200	N/A	NaN	List of element proton numbers
X_IONPOP		181E	0	1.0	N/A	NaN	Ion fraction list

4.3.3 Special Header Keywords

Although the temperature and electron density values are explicitly given in the table, the parameters used to generate these grids are given in header keywords. The keyword `T_LINEAR` indicates whether the temperature grid is linear or logarithmic. If a logarithmic grid is used, the temperature values should be interpreted as base-10 logarithms of the electron temperature in Kelvin. The electron density values should be interpreted similarly. The total number of elements and ion stages represented in the table are given by the keywords `N_ELEMEN` and `N_IONS` respectively.

```
T_FIRST = 4.00000000000000E+00 / [K] First temperature
T_DELTA = 1.00000000000000E-01 / [K] Delta temperature
T_LINEAR=                    F / Linear (or log) temperature spacing
T_NUMBER=                   51 / Number of temperature grid points
N_FIRST = 1.00000000000000E+00 / [cm**(-3)] First electron density
N_DELTA = 1.00000000000000E+00 / [cm**(-3)] Delta electron density
N_LINEAR=                    T / Linear (or log) electron density spacing
N_NUMBER=                    1 / Number of electron density grid points
N_ELEMEN=                   13 / Number of elements
N_IONS  =                  181 / Total number of ion stages
```

4.3.4 Size Estimate

The file size is proportional to the product `N_IONS` $\times$ `T_NUMBER` $\times$ `N_NUMBER`. The sample file containing the Raymond-Smith (1993) ionization balance table for 181 ions of 13 elements on a grid of 51 temperatures at a single electron density occupies 46 kb. Newer ionization balance tables containing data for more elements and including electron density dependence may be significantly larger. Only a few such files are likely to be available.

4.3.5 Unresolved Issues

4.4 Energy Level Table

Data Product Summary

Analysis Reference Data Product	Energy Level Table
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

This file contains the excitation state structure of the ions of a particular element. The excitation states of each ion are listed in a separate FITS file extension, so the maximum number of such extensions is equal to the nuclear charge of the element (`Z_ELEMENT`). For each excitation state, the table gives the configuration of bound electrons (or a unique label), the excitation energy, the degeneracy of the level (its statistical weight) and a literature reference indicating the source of the data.

Note that a relatively familiar LS coupling label describing the configuration of bound electrons for a given level is not always available, because LS coupling does not always accurately describe the angular momentum coupling conditions in the ion of interest. While LS coupling is usually appropriate for low Z ions, jj coupling predominates among high Z ions. This means that the wavefunctions of energy levels in high Z ions such as Fe often have significant configuration mixing between LS coupling states so that an LS coupling label cannot accurately describe the state. For example, the wavefunction describing an energy level may be a mixture of 30% ^1P and 70% ^3P so that neither individual label is accurate.

4.4.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	E_LEVELS	ATOMIC E_LEVELS	
2	BINTABLE	PARAMETERS	E_LEVELS	ATOMIC E_LEVEL ION_STATE	Ion energy level table
...	...	...	...	...	...
Z_ELEMENT	BINTABLE	PARAMETERS	E_LEVELS	ATOMIC E_LEVEL ION_STATE	Ion energy level table

4.4.2 Column Descriptions

Columns for Ion Energy Level Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Elec_Config		40A	N/A	N/A	N/A	NONE	Electron Configuration (or other unique label)
Energy	eV	1E	0.0	1.e6	N/A	NaN	Excitation energy
Lev_Deg		1J	0	100	N/A	999	Level Degeneracy
Source		40A	N/A	N/A	N/A	NONE	Literature Source

4.4.3 Special Header Keywords

The number of elements and ions represented in the file is given by the keywords `N_ELEMEN` and `N_IONS` respectively. These keywords are normally found in the null primary HDU.

Each extension carries the energy level structure of a single ion of a single element. The element is specified by its proton number using the keyword `ELEMENT` and the ion is specified by the net ion charge using the keyword `ION_STAT`. The keyword `ION_NAME` holds a string containing the name of the ion while `N_LEVELS` gives the number of energy levels for which data is listed.

```
N_ELEMEN=                        1 / Number of elements
N_IONS  =                       26 / Total number of ion stages
ELEMENT =                       26 / Z of element
ION_STAT=                       13 / Ion state (0 = neutral)
ION_NAME= 'FeXIV   '               / Ion name
N_LEVELS=                       12 / Number of energy levels
```

4.4.4 Size Estimate

Normally, a file contains all the energy level data for all ions of a single element. The size of the file depends on the number of ions (ie the proton number of the element) and the number of energy levels per ion. A typical energy level file is smaller than 1 Mb and one such file is needed for each element of interest.

4.4.5 Unresolved Issues

The exact form of the level identifiers is unresolved. Electron configurations will be used where available.

4.5 Wavelength Table

Data Product Summary

Analysis Reference Data Product	Wavelength Table
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

This file gives a list of selected emission lines produced by the ions of an element. The emission lines from each ion are listed in separate FITS extensions, so the maximum number of such extensions is equal to the nuclear charge of the element (`Z_ELEMENT`). For each emission line transition, the table lists the indices of the upper and lower energy levels and the wavelength of the transition along with an estimate of its accuracy. The table also lists the transition rate (Einstein A coefficient), an estimate of its accuracy and gives a literature reference indicating the source of the data. The full literature references are contained in a separate file. Each transition also has a code indicating the transition type.

4.5.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	NULL	EM_LINES	ATOMIC EM_LINES	
2	BINTABLE	PARAMETERS	EM_LINES	ATOMIC EM_LINES ION_STATE	Ion Wavelength Table
...	...	...	...	...	...
Z_ELEMENT	BINTABLE	PARAMETERS	EM_LINES	ATOMIC EM_LINES ION_STATE	Ion Wavelength table

4.5.2 Column Descriptions

Columns for Wavelength Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Upper_Lev		1J	1	TBD	N/A	0	Upper energy level of transition
Lower_Lev		1J	1	TBD	N/A	0	Lower energy level of transition
Wavelen	angstrom	1E	0.0	1.e10	N/A	NaN	Wavelength of emission line
Wave_Err	angstrom	1E	0.0	1.e10	N/A	NaN	Uncertainty in wavelength of emission line
Source_index		1J	1	TBD	N/A	NONE	Literature source index
Trans_Type_index		1J	1	TBD	N/A	NONE	Transition type index
Einstein_A	s**(-1)	1E	0.0	1.e38	N/A	NaN	Einstein A coefficient
Ein_A_Err	s**(-1)	1E	0.0	1.e38	N/A	NaN	Uncertainty in Einstein A coefficient

4.5.3 Special Header Keywords

Each FITS extension contains a list of emission lines from a particular ion. The identity of the ion and the number of emission lines listed are specified by these keywords.

```
ELEMENT =                    26 / Z of element
ION_STAT=                     0 / Ion state (0 = neutral)
ION_NAME= 'FeI     '            / Ion name
N_LINES =                     0 / Number of emission lines
```

4.5.4 Size Estimate

Each file contains a list of selected emission lines from all the ions of a given element. The size of the file depends very strongly on the available atomic data. For well known ions, the number of available emission lines may be very large (ie tens of thousands of lines or more). Typical files are probably a few Mb or less, although much larger files are possible. One wavelength table is needed for each element of interest.

4.5.5 Unresolved Issues

Labelling of satellite lines is TBR.

4.6 Line Emissivity Tables

Data Product Summary

Analysis Reference Data Product	Line Emissivity Tables
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

For a selection of "bright" emission lines, the line emissivity per ion will be stored as a function of electron density and temperature. For ease of use in typical applications, each electron density point will stored in a separate file. An emissivity grid with ND electron density points and NT temperature points will therefore contain ND FITS files each with NT extensions. Each FITS extension will contain emissivities for a list of "bright" emission lines for a single temperature. Users not interested in electron density dependence will generally make use of the low electron density case contained in the single emissivity file representing the lowest tabulated electron density.

If uncertainty information is absent for all lines in an extension, the uncertainty columns can be left out.

Continuum emissivities are stored separately, in a similar format (see section 4.7 below). The continuum emissivities will include emission from all emission lines not explicitly listed in the line emissivity tables.

4.6.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	TBD	SPECTRUM	SPECTRAL EMISSIVITY	
2	BINTABLE	TBD	SPECTRAL	SPECTRAL EMISSIVITY EMIS_LINES	Line Emissivity per Ion
3	...	...	...	...	...
N_TEMP	BINTABLE	TBD	SPECTRAL	SPECTRAL EMISSIVITY EMIS_LINES	Line Emissivity per Ion

4.6.2 Column Descriptions

Columns for Line Emissivity Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Lambda	angstrom	1E	0.0	1.e10	N/A	NaN	Emission line wavelength
Lambda_Err	angstrom	1E	0.0	1.e10	N/A	NaN	Emission line wavelength uncertainty
Plambda	erg cm**3 /s	1E	0.0	TBD	N/A	NaN	Line emissivity per ion
Plambda_Err	erg cm**3 /s	1E	0.0	TBD	N/A	NaN	Uncertainty in line emissivity per ion
Element		1J	0	100	N/A	999	Proton number
Ion		1J	0	100	N/A	999	Ion charge
Upper_level		1J	0	TBD	N/A	999	Upper excited state index
Lower_level		1J	0	TBD	N/A	999	Lower excited state index

4.6.3 Special Header Keywords

Special header keywords specify the electron temperature and electron density for each FITS extension as well as the number of bright emission lines listed.

```
TEMPERAT=         1.584892E+04 / Electron temperature
DENSITY =         1.000000E+09 / Electron density
N_LINES =                  145 / Number of emission lines
```

4.6.4 Size Estimate

File sizes are TBD

The size of each file is TBD; it depends on the number of bright lines selected and the number of temperature points in the grid. There will be one such line emissivity file for each electron density point. The number of electron density points is TBD.

4.6.5 Unresolved Issues

Is it better to store the emissivities as photons instead of ergs?

4.7 Continuum Emissivity Tables

Data Product Summary

Analysis Reference Data Product	Continuum Emissivity Tables
Instrument(s)	
Level	2
Scientist/SDS	J. Houck
Scientist/Cal	
Filetype	FITS
Created by tool	
Used by tool(s)	various
Sample file	TBS

The continuum emissivity per ion will be stored as a function of electron density and temperature. For ease of use in typical applications, each electron density point will stored in a separate file. An emissivity grid with ND electron density points and NT temperature points will therefore contain ND FITS files each with NT extensions. Each FITS extension will contain continuum emissivities on a wavelength grid defined within that extension. Users not interested in electron density dependence will generally make use of the low electron density case contained in the single emissivity file representing the lowest tabulated electron density.

When uncertainty values are unknown, these columns should be omitted.

Line emissivities are stored separately, in a similar format (see section 4.6 above).

4.7.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	TBD	SPECTRUM	SPECTRAL EMISSIVITY	
2	BINTABLE	TBD	SPECTRAL	SPECTRAL EMISSIVITY EMIS_CONT	Continuum Emissivity Table
3	...	...	...	...	...
N_TEMP	BINTABLE	TBD	SPECTRAL	SPECTRAL EMISSIVITY EMIS_CONT	Continuum Emissivity Table

4.7.2 Column Descriptions

Columns for Continuum Emissivity Table HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
Binhi	angstrom	1E	0.0	1.e10	N/A	NaN	High bin coordinate
Pseudo	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Blended weak line emissivity per ion per bin
Pseudo_Err	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Uncertainty in blended weak line emissivity per ion per bin
Brems	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Bremsstrahlung emissivity per bin
Brems_Err	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Uncertainty in bremsstrahlung emissivity per bin
Two_Photon	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Two-photon emissivity per ion per bin
TwPh_Err	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Uncertainty in two-photon emissivity per ion per bin
Rad_Rec	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Radiative recombination emissivity per ion per bin
Rad_Rec_Err	photon cm**3 /s	1E	TBD	TBD	N/A	NaN	Uncertainty in radiative recombination emissivity per ion per bin

4.7.3 Special Header Keywords

To save space, we store only the upper edges of the bins in the continuum wavelength grid and assume the grid has no gaps. To make sure we don't lose the edge of the lowest bin, that value is stored in header keyword MINBIN. The electron temperature and electron density values for each extension are also stored as keywords as is the total number of wavelength bins.

```
TEMPERAT=         1.584892E+04 / [K] Electron temperature
DENSITY =         1.000000E+09 / [cm**(-3)] Electron density
N_BIN   =                10000 / Number of wavelength bins
MINBIN  =         1.000000E+00 / Low edge of lowest bin
```

4.7.4 Size Estimate

File sizes are TBD

The size of each file is TBD; it depends on the resolution of the wavelength grids and the number of points in the temperature grid. One such file is necessary for each electron density point. The number of electron density points is TBD.

4.7.5 Unresolved Issues