README file for Level 2 version 2 release (02/17/11)

Files in this directory were created at the Laboratory for Atmospheric and Space Physics in Boulder, Colorado for the NASA Solar Dynamics Observatory (SDO) Extreme Ultraviolet Variability Experiment (EVE). The Science Processing and Operations Center (SPOC) is responsible for creating and maintaining access to all EVE products.

This is the second public release of EVE Level 2 data products. We have made every effort at verification and validation, but if you have any questions or encounter any problems with the data, please let us know about them. For access and data product issues please contact Don.Woodraska@lasp.colorado.edu. For science issues please contact Frank.Eparvier@lasp.colorado.edu.

EVE Overview

EVE spectrographs measured the solar extreme ultraviolet (EUV) radiation spectrum from 6-105 nm with a resolution of approximately 0.1 nm and a cadence of 10 seconds from geosynchronous orbit. A series of photometers are used to also provide broadband measurements at a 4 Hz cadence.

More information about the EVE instrument measurements, and calibrations can be found in these references:

Woods, T. N., F. G. Eparvier, R. Hock, A. R. Jones, D. Woodraska, D. Judge, L. Didkovsky, J. Lean, J. Mariska, H. Warren, D. McMullin, P. Chamberlin, G. Berthiaume, S. Bailey, T. Fuller-Rowell, J. Sojka, W. K. Tobiska, and R. Viereck, "Extreme Ultraviolet Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO): Overview of Science Objectives, Instrument Design, Data Products, and Model Developments", Solar Physics, p. 3, doi: 10.1007/s11207-009-9487-6, Jan. 2010. http://lasp.colorado.edu/eve/docs/EVE_Overview_SolarPhys.pdf

Hock, R. A., P. C. Chamberlin, T. N. Woods, D. Crotser, F. G. Eparvier, D. L. Woodraska, and E. C. Woods, "Extreme Ultraviolet Variability Experiment (EVE) Multiple EUV Grating Spectrographs (MEGS): Radiometric Calibrations and Results", Solar Physics, doi: 10.1007/s11207-010-9520-9, Feb. 2010. http://lasp.colorado.edu/eve/docs/Final_Sol_Phy_Hock_1April_2010.pdf

Didkovsky, L., D. Judge, S. Wieman, T. Woods, and A. Jones, "EUV SpectroPhotometer (ESP) in Extreme Ultraviolet Variability Experiment (EVE): Algorithms and Calibrations", Solar Physics, p. 182, doi: 10.1007/s11207-009-9485-8, Dec. 2009.

Daily activities are performed to maintain calibration; otherwise EVE has nearly continuous solar observing capability.

Data Availability/Gaps

Daily calibrations are performed that last a total of about 30 minutes; however, the channel calibrations are staggered so that one of the science channels is always observing the sun during the daily calibration. These daily calibrations allow for EVE to directly measure dark signals on the detectors to track changes. For the CCDs, the flatfield LEDs are also used. On Sundays, a slightly longer calibration is performed to increase statistics.

Two annual eclipse outage periods of about 3 weeks occur as the spacecraft orbit aligns with the earth and sun. These can last up to 72 minutes each day. After longer eclipses (10+ minutes), some thermal settling causes a wavelength shift on MEGS-A that is not yet corrected. Around the 2 eclipse seasons, additional off-pointing maneuvers are performed including EVE cruciform scans (9 hours), EVE FOV maps(~2 hours), plus maneuvers for the other instruments and the guide telescopes. In 2010, the late eclipse season lasted from Sept 15-Oct 8, and the early season in 2011 will begin on March 11.

The spacecraft is also subject to being blocked by the moon, but this is infrequent. Other infrequent activities include momentum management, and station-keeping thruster firings.

CCD bakeouts may occur as needed to maintain instrument sensitivity. The first bakeout started on June 16 (day 167), 2010 and continued through June 18 (day 169), 2010. The second CCD bakeout was much longer lasting from September 23 (day 266) through September 28 (day 271), 2010. After each bakeout, there is a period of several days where the detectors change rapidly, and this is not corrected in version 2.

Detailed daily information is provided in the Science Operations Mission Log and is available at this location:

http://lasp.colorado.edu/eve/data_access/evewebdata/EVE_sciopslog.html

Product Overview

The following sections describe the level 2 data products available in the version 2 release.

Level 2 Products

Two types of EVE level 2 products are routinely created: **Spectra** (EVS) and **Lines** (EVL).

Level 2 spectra are the merged spectral measurements from the two spectrographs, A and B. The A detector is designed to measure from 6-17 nm, and 16-38 nm using two filters, while the B detector is designed to measure 35-105 nm. Level 2 processing stitches these pieces to form one spectrum. In version 2, the MEGS-B region is only included from 37-65 nm. A future version may include the longer wavelength data. All level 2 irradiances are adjusted to 1-AU.

Lines are integrated from low to high bounds, and the 4 Hz photometer data are averaged down to the same time scale as the spectrum. No continuum is subtracted from the line irradiances.

There are two sets of flags included. One is EVE-specific flags, the other is Spacecraft flags.

Values in the FLAGS field are the bitwise OR of these values.
Bit 0 (value 1) - MEGS-A data is missing
Bit 1 (value 2) - MEGS-B data is missing
Bit 2 (value 4) - ESP data is missing
Bit 3 (value 8) - MEGS-P data is missing
Bit 4 (value 16) - Possible clock adjust in MEGS-A
Bit 5 (value 32) - Possible clock adjust in MEGS-B
Bit 6 (value 64) - Possible clock adjust in ESP
Bit 7 (value 128) - Possible clock adjust in MEGS-P

Values in the SC_FLAGS field are the bitwise OR of these values.
Bit 0 (value 1) - 4-bit obstruction indicator (0 is no obstruction)
Bit 1 (value 2) - 4-bit obstruction indicator (0 is no obstruction)
Bit 2 (value 4) - 4-bit obstruction indicator (0 is no obstruction)
Bit 3 (value 8) - 4-bit obstruction indicator (0 is no obstruction)
Bit 4 (value 16) - Observatory is off-pointed by more than 1 arcmin

Obstruction flag values:
Value 0 No obstruction
Value 1 Warmup from Earth eclipse
Value 2 Atmosphere penumbra
Value 3 Atmosphere umbra
Value 4 Penumbra of Mercury
Value 5 Umbra of Mercury
Value 6 Penumbra of Venus
Value 7 Umbra of Venus
Value 8 Penumbra of Moon
Value 9 Umbra of Moon
Value 10 Penumbra of solid Earth
Value 11 Umbra of solid Earth

If more than one obstruction is taking place, only the highest-numbered one will be indicated.

Generally, any flags being set mean some data are missing or possibly suspect.

Version 2 Data Notes:

Missing or corrupted data is replaced using the "fill" value of -1.0. Fill values should be discarded since these are not science measurements.

MEGS-B is included in this product release for wavelengths spanning 37-65 nm. We have elected to release these Version 2 products without the longer wavelengths since the shorter part is fairly well understood. The longer wavelength portion of MEGS-B not yet ready to support scientific studies, like the other channels. The investigation into MEGS-B is ongoing.
MEGS-B has a reduced-exposure operation where the detector is exposed for 3 hours each day, and additionally for another 5 minutes each hour. This began on August 16, 2010 (day 228).

MEGS-B is also used to support flare campaign operations. Each flare campaign lasts 24 hours and starts at 16:00 UT. The flare campaigns to date are summarized below.

Dates	NOAA flare classifications
2010/291-292 (Oct 18-19)	C2.5, C1.2, B7.3, C1.3, C1.1, B2.6, B5.1, B5.8
2011/021-022 (Jan 21-22)	C2.2, C1.1, C1.3, B3.2, B1.7, B1.5, B1.4, C2.4, B3.7, B4.3
2011/045-047 (Feb 14-16) extended 48-hours	C7.0, M2.2, C6.6, C2.7, C2.7, X2.2, C4.8, C4.8, C6.6, C2.0, M1.0, C2.2, C5.9, C2.1, M1.1, C9.9, C3.2, M1.6, C7.7

The spectrum bins should not be used individually for analysis due to the possibility of small-scale wavelength shifts. Rather, users should integrate over the features of interest. MEGS-A (5-37 nm) is the most sensitive to these small wavelength shifts.

The Lyman-alpha diode measurement is susceptible to low energy particles. Our initial attempt to remove the low energy particle noise using the dark diode needs refinement. Rather than exclude this measurement, we filter it based on those periods of increased particle noise. Therefore, the MEGS-P Lyman-alpha measurement is sometimes very complete, and sometimes only available from about 6-12 UT each day. The Lyman-alpha measurement uses the same filter mechanism as MEGS-B, so it is also operating with the same reduced-exposure scenario.

Also, due to random large particle hits, the Lyman-alpha measurement is filtered using a 10-second Kalman smoothing technique. Additional filtering was implemented for version 2 where data are pre-filtered using a median technique. Unfortunately, the Lyman-alpha measurement is very noisy, and therefore most useful after averaging to a daily value. Except for flare campaign days, MEGS-P measures the sun for about 20% of a day.

Naming Convention:

Level 2 products follow this naming convention `EV?_L2_YYYYDDD_HH_vvv_rr.fit` where:

EV designates this as an EVE product
? is either S (spectrum) or L (lines/bands)
L2 designates this as a level 2 product
YYYY is the year
DDD is the day of year (001-366)
HH is the UT hour of day (00-23)
vvv is the version number (002)
rr is the revision number (01-99)

Each Level 2 data file spans one hour.

The version number only increments after major software changes or after major calibration updates. These are expected to change after the incorporation of each suborbital rocket calibration flight. When referencing EVE data in scientific papers, users agree to mention this version number.

The revision increments whenever updated information are available. Generally, revision 1 is considered "preliminary". After 30 days, products become "definitive" since no new telemetry can be delivered after this period of time due to finite storage capacity of the SDO ground station. For most days, revision 2 will be the final revision.

Level 2 Spectra Products:

Level 2 products are stored in the scientific format called FITS as binary tables. FITS was first introduced in 1979. As one of the oldest scientific data formats, it continues to be widely used and expanded.

FITS reference: FITS: A Flexible Image Transport System, Wells, D. C., Greisen, E. W., and Harten, R. H., *Astronomy & Astrophysics Supplement Series*, 44, 363-370, 1981.
http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1981A%26AS...44..363W&db_key=AST&high=3db47576cf05627

FITS Binary table reference: Binary Table Extension to FITS, Cotton, W. D., Tody, D. B., and Pence, W. D., *Astronomy & Astrophysics Supplement Series*, 113, 159-166, 1995.
http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1995A%26AS..113..159C&db_key=AST&high=3db47576cf06210

Additional detailed documentation is available on-line.
http://fits.gsfc.nasa.gov/fits_documentation.html

Standard reader software is available from GSFC for many different languages. A graphical program called "fv" is useful for browsing the contents without writing any programs.
http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/

For IDL, we use mrdfits.pro.
http://idlastro.gsfc.nasa.gov/mrdfits.html
http://idlastro.gsfc.nasa.gov/fitsio.html

An example of using mrdfits directly follows:

```
IDL> data1 = mrdfits( 'EVS_L2_2010151_20_001_01.fit.gz', 1 ,hdr, /unsigned
)
```

This reads HDU #1 and returns an array of structures called "data1". Note that HDU #0 is reserved for image data, so it is NULL.

Alternatively, we provide an IDL function called read_generic_fits.pro that is available from the EVE web site to read all of the HDUs in the EVE FITS files. It iterates over the HDUs and builds a structure containing all of the HDU data. It is really a wrapper for the mrdfits.pro functions. This may be more useful for users that wish to read all of the data with one function call.

```
IDL> d=read_generic_fits('EVS_L2_2010120_00_002_01.fit.gz')
% Compiled module: READ_GENERIC_FITS.
% Compiled module: STRSPLIT.
% Compiled module: REVERSE.
% Compiled module: PATH_SEP.
% Compiled module: MRDFITS.
% Compiled module: FXMOVE.
% Compiled module: MRD_HREAD.
% Compiled module: FXPAR.
% Compiled module: GETTOK.
% Compiled module: VALID_NUM.
% Compiled module: MATCH.
% Compiled module: MRD_STRUCT.
% Compiled module: MRD_SKIP.
MRDFITS: Extension past EOF
IDL> help,d
D               STRUCT    = -> <Anonymous> Array[1]
IDL> help,d,/str
** Structure <18daa08>, 8 tags, length=16906744, data length=16903138,
refs=1:
   PRIMARY          INT              0
   PRIMARY_HEAD     STRING    Array[5]
   SPECTRUMMETA     STRUCT    -> <Anonymous> Array[5200]
   SPECTRUMMETA_HEADER
                    STRING    Array[27]
   SPECTRUMUNITS    STRUCT    -> <Anonymous> Array[1]
   SPECTRUMUNITS_HEADER
                    STRING    Array[39]
   SPECTRUM         STRUCT    -> <Anonymous> Array[360]
   SPECTRUM_HEADER  STRING    Array[91]
```

The primary data unit is null for the level 2 spectrum file, but there is a standard 5 line header that is returned in PRIMARY_HEAD. The next substructure contains metadata for the spectrum (SPECTRUMMETA) with an array of strings created from the header. The next structure contains the units with brief descriptions (SPECTRUMUNITS). The data is in the SPECTRUM substructure. The tags in the SPECTRUM and SPECTRUMUNITS structures match for easier use. The SPECTRUM also has associated keyword that are returned in the SPECTRUM_HEADER string array.

The SPECTRUMMETA array of structures contains 5200 elements, with one of the structure tags corresponding to the wavelength. Accuracy is not yet implemented.

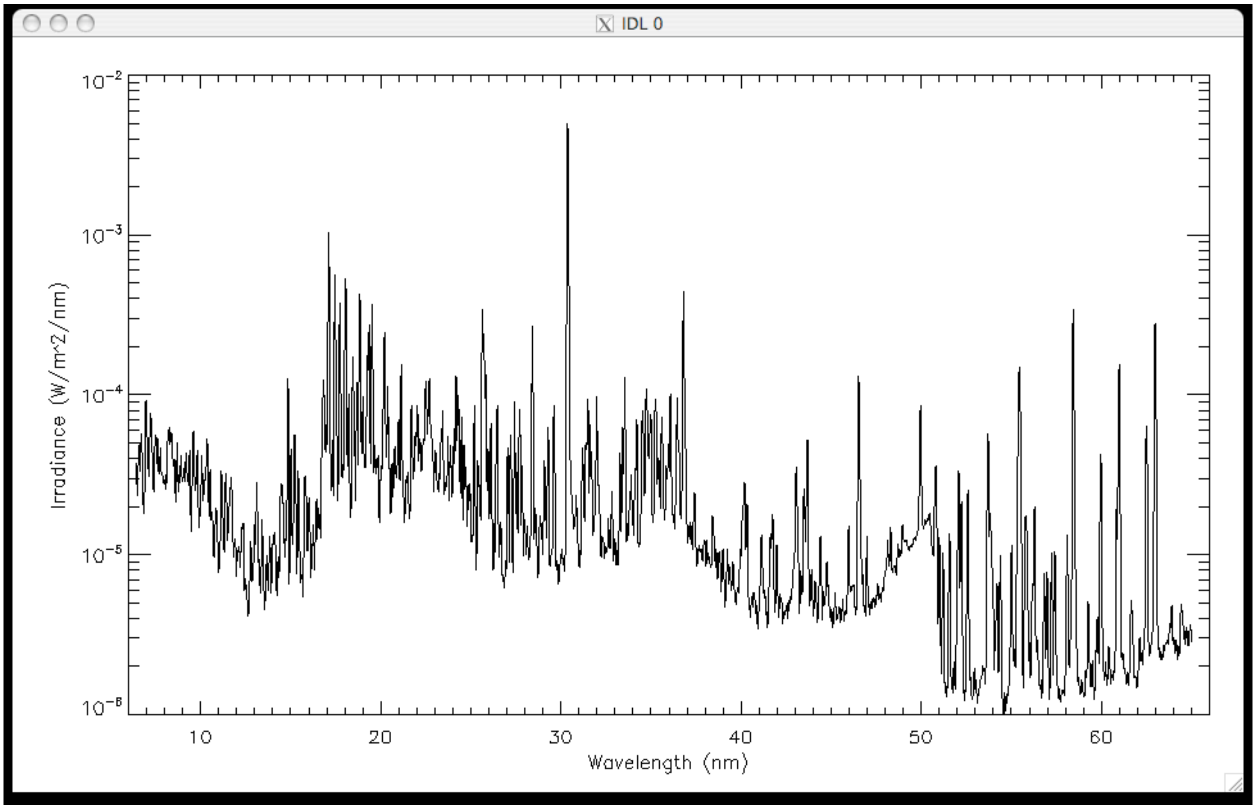
```
IDL> help,d.spectrummeta,/str
** Structure <153ecc8>, 2 tags, length=8, data length=8, refs=2:
   WAVELENGTH      FLOAT           3.01000
   ACCURACY        FLOAT          -1.00000

IDL> help,d.spectrumunits,/str
** Structure <156c518>, 9 tags, length=144, data length=144, refs=2:
   TAI             STRING    'seconds // International Atomic Time seco'...
   YYYYDOY         STRING    'NA // 4-digit year and 3-digit day of yea'...
   SOD             STRING    'seconds // seconds of the UT day at the c'...
   FLAGS           STRING    'NA // 0=good, other values indicate data '...
   SC_FLAGS        STRING    'NA // 0=good, other value indicate spacec'...
   INT_TIME        STRING    'seconds // the duration of the exposure'
   IRRADIANCE      STRING    'W m^-2 nm^-1 // Spectral power per unit a'...
   PRECISION       STRING    'NA // VERSION 2 HAS JUST FILL VALUES, rel'...
   BIN_FLAGS       STRING    'NA // flag for each spectral bin, 0=good,'...


IDL> help,d.spectrum,/str
** Structure <18da608>, 9 tags, length=46840, data length=46830, refs=2:
   TAI             DOUBLE       1.6512768e+09
   YYYYDOY         LONG           2010120
   SOD             DOUBLE           10.265536
   FLAGS           BYTE         0
   SC_FLAGS        BYTE         0
   INT_TIME        DOUBLE           10.000000
   IRRADIANCE      FLOAT     Array[5200]
   PRECISION       FLOAT     Array[5200]
   BIN_FLAGS       BYTE      Array[5200]
```

To plot one integration from this file of 360 spectral measurements, this IDL command could be used. The plot is shown below.

```
IDL> plot, d.spectrummeta.wavelength, d.spectrum[0].irradiance, /ylog, $
       yr=[1e-6,1e-2], xr=[6,66], xs=1, $
       xtitle='Wavelength (nm)', ytitle='Irradiance (W/m^2/nm)'
```



TAI is the number of seconds elapsed since the TAI epoch (Jan 1, 1958).
YYYYDOY is the year and day of year.
SOD is the seconds of day.
FLAGS contain 32-bit fields that are used to indicate validity.
INT_TIME is the integration time in seconds.
IRRADIANCE is the irradiance in Watts / meter^2 / nanometer at 1-AU.
PRECISION is the relative uncertainty based on counting statistics (0-1).
BIN_FLAGS is a byte flag for each spectral bin (0=good).

Additional information is in the string array hdr.

Level 2 Lines/Bands Products:

These products are read the same way as the spectra products, except there are 6 non-null HDUs available to read.

Reading the data directly with mrdfits is one option.

```
IDL> data1 = mrdfits( 'EVL_L2_2010151_20_001_01.fit.gz', 1, hdr,
/unsigned)
```

Another is to read the whole file with read_generic_fits.pro. The mrdfits library of tools will still need to be in the IDL path.

```
IDL> d=read_generic_fits('EVL_L2_2010120_00_002_01.fit.gz',/unsigned)
% Compiled module: READ_GENERIC_FITS.
% Compiled module: STRSPLIT.
% Compiled module: REVERSE.
% Compiled module: PATH_SEP.
% Compiled module: MRDFITS.
% Compiled module: FXMOVE.
% Compiled module: MRD_HREAD.
% Compiled module: FXPAR.
% Compiled module: GETTOK.
% Compiled module: VALID_NUM.
% Compiled module: MATCH.
% Compiled module: MRD_STRUCT.
% Compiled module: MRD_SKIP.
MRDFITS: Extension past EOF

IDL> help,d
D               STRUCT    = -> <Anonymous> Array[1]

IDL> help,d,/str
** Structure <18bd808>, 14 tags, length=278760, data length=275154, refs=1:
   PRIMARY         INT              0
   PRIMARY_HEAD    STRING    Array[5]
   LINESMETA       STRUCT    -> <Anonymous> Array[30]
   LINESMETA_HEADER
                   STRING    Array[46]
   BANDSMETA       STRUCT    -> <Anonymous> Array[20]
   BANDSMETA_HEADER
                   STRING    Array[28]
   DIODEMETA       STRUCT    -> <Anonymous> Array[6]
   DIODEMETA_HEADER
                   STRING    Array[27]
   QUADMETA        STRUCT    -> <Anonymous> Array[4]
   QUADMETA_HEADER STRING    Array[27]
   LINESDATA       STRUCT    -> <Anonymous> Array[360]
   LINESDATA_HEADER
                   STRING    Array[117]
   LINESDATAUNITS  STRUCT    -> <Anonymous> Array[1]
   LINESDATAUNITS_HEADER
                   STRING    Array[55]

IDL> help,d.linesmeta,/str
** Structure <15661b8>, 7 tags, length=64, data length=64, refs=2:
   WAVE_CENTER     FLOAT           9.39260
   WAVE_MIN        FLOAT           9.33000
   WAVE_MAX        FLOAT           9.43000
   LOGT            FLOAT           6.81000
   NAME            STRING    'Fe XVIII'
   TYPE            STRING    'F '
   BLENDS          STRING    '              '
```

The LINESMETA tag is from HDU #1. It contains the binary table of information related to the extracted solar emission lines. Currently there are 30 lines, and the first is Fe XVIII.

```
IDL> help,d.bandsmeta,/str
** Structure <1565078>, 2 tags, length=32, data length=32, refs=2:
   NAME            STRING    'AIA_A94       '
   TYPE            STRING    'AIA '
```

The BANDSMETA tag is another binary table of the extracted bands corresponding to the AIA spectral bands, two GOES-14 bands, 4 MEGS bands corresponding to ESP diodes, two very broad bands used for creating Q_{EUV} proxy, two MEGS-A broad bands, and 3 MEGS-B bands . The band names are printed here.

```
IDL> print,d.bandsmeta.name
AIA_A94       AIA_A131      AIA_A171      AIA_A193
AIA_A211      AIA_A304      AIA_A335      GOES-14 EUV-A
GOES-14 EUV-B MA171         MA257         MA304
MA366         E7-37         E37-45        MEGS-A1
MEGS-A2       MEGS-B short  MEGS-B both   MEGS-B long
```

The diode measurements (ESP and MEGS-P) are averaged down to the 10-second spectrum cadence from the 4 Hz measurements to create a more convenient way to compare the data to other measurements.

```
IDL> help,d.diodemeta,/str
** Structure <1568368>, 2 tags, length=32, data length=32, refs=2:
   NAME            STRING    'ESPQ     '
   TYPE            STRING    'ESP   '
```

The ESP central quad diode contains information about the center of brightness for the 0.1-7 nm bandpass. These are normalized to provide a relative measure of the distribution of irradiance. During flare periods, the difference of flare and pre-flare measurements indicates the flare position.

```
IDL> help,d.quadmeta,/str
** Structure <15642d8>, 2 tags, length=32, data length=32, refs=2:
   NAME            STRING    'Q0'
   TYPE            STRING    'ESP'
```

The actual science measurements are all contained in LINESDATA.

```
IDL> help,d.linesdata,/str
** Structure <191f608>, 17 tags, length=752, data length=742, refs=2:
   TAI             DOUBLE       1.6512768e+09
   YYYYDOY         LONG           2010120
   SOD             DOUBLE           10.265536
   FLAGS           BYTE         0
   SC_FLAGS        BYTE         0
   LINE_IRRADIANCE FLOAT     Array[30]
   LINE_PRECISION  FLOAT     Array[30]
   LINE_ACCURACY   FLOAT     Array[30]
   BAND_IRRADIANCE FLOAT     Array[20]
   BAND_PRECISION  FLOAT     Array[20]
   BAND_ACCURACY   FLOAT     Array[20]
   DIODE_IRRADIANCE
                   FLOAT     Array[6]
   DIODE_STDEV     FLOAT     Array[6]
   DIODE_PRECISION FLOAT     Array[6]
   QUAD_FRACTION   FLOAT     Array[4]
   QUAD_STDEV      FLOAT     Array[4]
   QUAD_PRECISION  FLOAT     Array[4]

IDL> help,d.linesdataunits,/str
** Structure <191ec08>, 17 tags, length=272, data length=272, refs=2:
   TAI             STRING    'seconds // International Atomic Time seco'...
   YYYYDOY         STRING    'NA // 4-digit year and 3-digit day of yea'...
   SOD             STRING    'seconds // seconds of the UT day at the c'...
   FLAGS           STRING    'NA // 0=good, other values indicate data '...
   SC_FLAGS        STRING    'NA // 0=good, other value indicate spacec'...
   LINE_IRRADIANCE STRING    'W m^-2 // Power per unit area at 1-AU ove'...
   LINE_PRECISION  STRING    'NA // relative precision'
```

```
LINE_ACCURACY   STRING    'NA // relative accuracy'
BAND_IRRADIANCE STRING    'Mixed: W m^-2 or avg counts AIApixel^-1 s'...
BAND_PRECISION  STRING    'NA // relative precision'
BAND_ACCURACY   STRING    'NA // relative accuracy'
DIODE_IRRADIANCE
                STRING    'W m^-2 // Power per unit area at 1-AU mea'...
DIODE_STDEV     STRING    'W m^-2 // one-sigma spread of 4 hz integr'...
DIODE_PRECISION STRING    'NA // relative precision'
QUAD_FRACTION   STRING    'NA // fraction of the 0.1-7 nm irradiance'...
QUAD_STDEV      STRING    'NA // one-sigma spread of 4 Hz integratio'...
QUAD_PRECISION  STRING    'NA // relative precision of quadrant diod'...
```