Solar Dynamics Observatory (SDO)
Extreme Ultraviolet Variability Experiment (EVE):
Version 8 science data product Release Notes

Level 4 Lines Fit Science Data Product README
08/17/2025

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Introduction

The Laboratory for Atmospheric and Space Physics in Boulder, Colorado created Level 4 Lines Fit data files for the NASA Solar Dynamics Observatory (SDO) Extreme Ultraviolet Variability Experiment (EVE). The Science Processing and Operations Center (SPOC) is responsible for maintaining access to all

EVE products. To learn more about the EVE instrumentation, visit this link: https://lasp.colorado.edu/home/eve/science/instrument/.

The new EVE level 4 lines fit data product provides line-profile-fit results for intensity, wavelength shift, and line width for several emission features. It also contains flare fits that have the pre-flare background removed. There is one file per day, with line fits for each one-minute EVE spectrum.

This release of EVE data products replaces all previous versions, and every effort has been made for verification and validation. If you have any questions or encounter any problems with the data, please do not hesitate to inform us.

For access and data product issues please contact Don.Woodraska at lasp.colorado.edu.

For science issues please contact Tom.Woods at lasp.colorado.edu.

Responsible Data Usage

Please refer to the Goddard Space Flight Center SDO web page for data rights and rules for use: https://sdo.gsfc.nasa.gov/data/rules.php

Reference Publications

The EVE level 4 lines fit data product is described in the preprint paper.

Woods, T. N., Chamberlin, P. C., Jones, A., Mason, J. P., Qian, L., Warren, H. P., Woodraska, D., Borelli, R., Eparvier, F. G., & Gonzalez, G. (2025, July 25). *Revealing flare energetics and dynamics with SDO EVE solar extreme ultraviolet spectral irradiance observations* (arXiv:2507.19681) [Preprint]. arXiv. https://doi.org/10.48550/arXiv.2507.19681

More information about the general 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, 275*, 115-143, doi: 10.1007/s11207-009-9487-6, 2012. https://lasp.colorado.edu/home/eve/files/2011/06/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, 275*, 145-178, doi: 10.1007/s11207-010-9520-9, 2012. https://lasp.colorado.edu/home/eve/files/2011/06/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, 275*, 179-205, doi: 10.1007/s11207-009-9485-8, 2012.

Level 4 Lines Fit Science Products

The new EVE level 4 lines fit data product provides line-profile-fit results for 70 solar EUV lines observed by EVE MEGS. For each line, Gaussian fits are performed to provide results for intensity, wavelength center, and spectral width for these emission features. It also contains additional fits for "flare spectra" that have the pre-flare background removed when flares are detected in the GOES XRS data (and indicated in the level 4 lines fit data product by the "FLARE_FLAG"). The line profiles are fit using three Gaussians for each emission feature—one for the feature of interest, and two additional Gaussians for the lines to the left and right of the line of interest. The wavelength and Gaussian width parameters are fixed for the left- and right-wing Gaussians. This dataset provides a valuable resource for the study of flare events. However, it is less suitable for investigations focused on solar cycle minimum for hotter coronal emission lines.

The MEGS-A detector experienced a capacitor short on May 26, 2014 (day 146) that prevents the detector from working. Since no solar spectra are measured for wavelengths shorter than 33 nm after that anomaly, line fits cannot be performed for emission lines in that range, so fill values will be present.

For an in-depth discussion of EVE instrumentation please visit:
https://lasp.colorado.edu/home/eve/science/instrument/

Naming Convention

Level 4 products follow this naming convention

`EVE_LINESFIT_L4_YYYYDDD_vvv_rr.fit` where:
`EVE_LINESFIT` designates this as an SDO EVE lines fit data product
`L4` designates this as a level 4 product
`YYYY` is the year
`DDD` is the day of year (001-366)
`vvv` is the version number (008)
`rr` is the revision number (01-99)

Note that this is distinct from the level 4 spectra, which use the `EVE_L4_YYYYDDD_vvv_rr.fit` filename convention. The version number only increments after major software changes or after major calibration updates. These are expected to change after incorporation of suborbital rocket instrument information is available.

Level 4 Lines Fit Data

Each daily file spans one UT day. The EVE level 4 lines fit files contain one FITS header-data unit (HDU) that contains the metadata for the emission lines that are fit, one HDU with the fit parameters for a Gaussian fit, another HDU that contains the fit parameters for the flare fit, an HDU with accuracy for the line fits, and an HDU with irradiance as calculated by the line fit parameters. The first HDU#0 is null for compatibility with other FITS software.

LinesMeta HDU

The LinesMeta header data unit contains information about the emission lines for which fits are performed. It contains wavelength information describing the line, line temperature, the minimum and maximum temperature of the emission line, the wavelength shift attributed to line blends, the primary element of the line and the approximate purity, and the primary ions in the line. Table 2 lists the emission lines that are included in the level 4 lines data products.

Table 1: LinesMeta Description

Column Name	Data Type	Units	Description
LINE_WAVELENGTH	Float	nm	Nominal center or peak of the emission line
LINE_TEMP_MK	Float	Log(K)	Log (base 10) temperature of the emission line
LINE_TEMP_MIN	Float	Log(K)	Log (base 10) minimum temperature of the emission line
LINE_TEMP_MAX	Float	Log(K)	Log (base 10) maximum temperature of the emission line
BLEND_ERROR	Float	km/s	Wavelength shift from line blends
LINE_ELEMENTS	String	NA	The primary element and approximate purity
LINE_IONS	String	NA	The primary ions in this line

Table 2: LinesMeta Enumerated Values

LINE_ WAVELENGTH	LINE_ TEMP_MK	LINE_ TEMP_MIN	LINE_ TEMP_MAX	BLEND_ ERROR	LINE_ ELEMENTS	LINE_ IONS
9.393	8.00	4.00	12.00	16	Fe (98%)	Fe XVIII
10.395	6.30	4.00	10.00	861	Fe (98%)	Fe XVIII
11.723	10.00	10.00	20.00	636	Fe (92%)	Fe XXII / Fe XXI
12.875	12.00	6.30	20.00	316	Fe (99%)	Fe XXI
13.113	0.63	0.40	1.00	27	Fe (95%)	Fe VIII
13.288	12.00	6.30	12.00	715	Fe (99%)	Fe XX / Fe XXIII
13.419	1.00	1.00	1.50	1668	Fe (91%)	Fe IX, Fe XI
14.837	1.50	1.00	1.50	2655	Ni (91%)	Ni XI
17.107	0.63	0.40	1.50	22	Fe (98%)	Fe IX
17.459	1.00	0.63	1.00	114	Fe (100%)	Fe X
17.723	1.00	1.00	1.50	106	Fe (99%)	Fe X / Fe IX, Fe XI
18.038	1.50	1.00	1.50	97	Fe (99%)	Fe XI / Fe X, Mg IV
19.513	1.50	1.00	2.50	63	Fe (89%)	Fe XII
20.176	1.50	1.00	1.50	9	Fe (97%)	Fe XIII
20.381	1.50	1.50	2.50	315	Fe (99%)	Fe XIII
21.137	1.50	1.50	2.50	4	Fe (96%)	Fe XIV
21.516	0.25	0.25	0.40	277	O (80%)	O V / Ne V
21.912	2.50	2.50	4.00	1871	Fe (94%)	Fe XIV
23.39	2.50	2.50	4.00	120	Fe (79%)	Fe XV / Ni XVIII
24.171	0.63	0.63	1.00	169	Fe (98%)	Fe IX / Fe VIII
24.919	2.50	2.50	8.00	12	Ni (98%)	Ni XVII
25.632	0.08	0.04	0.15	121	He (99%)	He II
26.474	1.50	1.50	2.50	673	Fe (94%)	Fe XIV / Fe XVI
27.039	0.40	0.40	0.63	27	Mg (96%)	Mg VI / Fe XIV
27.660	0.40	0.25	0.40	135	Mg (94%)	Mg V
28.416	2.50	1.50	8.00	4	Fe (98%)	Fe XV

30.378	0.08	0.04	0.63	248	He (97%)	He II / Si XI
33.540	2.50	2.50	10.00	24	Fe (100%)	Fe XVI / Mg VIII, Fe XXI
35.385	4.00	0.63	20.00	77	Ar (60%) / Fe	Ar XVI / Fe XIV
36.076	2.50	2.50	12.00	14	Fe (98%)	Fe XVI
36.812	1.50	1.50	2.50	10	Mg (31%) / Fe	Mg VII / Mg IX / Fe XIII
38.903	0.10	0.06	20.00	292	C (48%) / Ar Cr Fe	C III / Ar XVI / Cr XIV / Fe X
41.755	4.00	0.63	4.00	125	S (36%) / Na Fe	S XIV / Na VI / Fe XV
44.570	4.00	4.00	20.00	3	S (100%)	S XIV
46.525	0.63	0.40	0.63	1	Ne (98%)	Ne VII
46.985	0.15	0.10	0.40	3	Ne (98%)	Ne IV
49.941	2.50	1.50	20.00	0	Si (100%)	Si XII
50.800	0.10	0.04	0.25	1	O (98%)	O III
52.066	2.50	1.50	20.00	1	Si (99%)	Si XII
52.579	0.10	0.06	0.25	1	O (100%)	O III
53.824	0.10	0.08	0.15	8	C (88%)	C III
54.199	0.15	0.10	0.40	9	Ne (99%)	Ne IV, Ca IX / Fe XII
54.389	0.15	0.08	0.25	23	Ne (93%)	Ne IV, Ca VII / Fe XIV
55.002	1.50	1.00	12.00	2	Al (99%)	Al XI
55.445	0.15	0.08	0.25	1	O (98%)	O IV
56.813	1.50	1.50	4.00	132	Al (98%) / Ne / Fe	Al XI / Ne V / Fe XX
57.230	0.25	0.15	0.63	2	Ne (99%)	Ne V
57.430	0.08	0.06	0.08	77	C (65%) / O / Ca	C III / O III / Ca X
58.433	0.04	0.02	0.08	1	He (99%)	He I
59.223	8.00	4.00	16.00	162	Fe (99%)	Fe XII / Fe XIX
59.959	0.10	0.06	0.25	1	O (100%)	O III
60.982	0.15	0.08	20.00	9	O (61%) / Mg Ni	O IV / O III / Mg X / Ni XXIV
62.493	1.00	1.00	12.00	7	Mg (98%)	Mg X
62.973	0.25	0.10	1.50	0	O (95%)	O V
76.040	0.25	0.15	0.40	49	O (100%)	O V
76.515	0.15	0.10	0.40	22	N (98%)	N IV / Fe VII
77.043	0.63	0.40	8.00	4	Ne (99%)	Ne VIII
78.769	0.15	0.06	0.25	7	O (98%)	O IV / S X
79.019	0.15	0.08	0.40	0	O (99%)	O IV
83.525	0.10	0.08	0.25	83	O (100%)	O III
90.409	0.04	0.02	0.10	11	C (100%)	C II

92.320	0.15	0.06	0.25	6	N (89%)	N IV / Fe III
93.338	0.25	0.10	1.00	8	S (99%)	S VI
94.974	0.02	0.01	0.40	0	H (93%)	H I / Si IX
97.254	0.02	0.01	2.50	0	H (99%)	H I
97.702	0.08	0.02	0.25	0	C (98%)	C III
102.572	0.02	0.01	4.00	0	H (99%)	H I
103.191	0.25	0.15	6.30	0	O (100%)	O VI
103.689	0.04	0.02	0.10	19	C (100%)	C II
103.761	0.25	0.25	4.00	34	O (100%)	O VI

LinesFitParams HDU

The LinesFitParams HDU contains an array of structures with line-profile-fit results for intensity, wavelength shift, and line width for each of the emission features. Note that there is no error field for the Gaussian width or wavelength on the left and right wings as these parameters are held constant. There is one structure with the fields described in Table 3 for each minute of the day, and each field has an array for each of the emission lines that are identified in the LinesMeta HDU. The LEFT_WAVELENGTH, LEFT_GAUSS_WIDTH, RIGHT_WAVELENGTH, and RIGHT_GAUSS_WIDTH parameters are fixed during the fits.

Table 3: LinesFitParams Description

Column Name	Data Type	Units	Description
WAVELENGTH	Float	nm	Center or peak of the emission line
AMPLITUDE	Float	W m^-2	Amplitude of the Gaussian fit to the line
GAUSS_WIDTH	Float	nm	Width of the Gaussian fit to the line
BACKGROUND	Float	W m^-2	Coefficients for a line fit to the background level (c_0, c_1 where $y = c_0 + c_1 x$); note the units given are for the line evaluated at a particular wavelength (but the units of c_1 are W m^-2 nm^-1)
FIT_CHI2	Float	NA	Chi-square value of the fit
ERR_WAVELENGTH	Float	NA	Relative error in the wavelength of the Gaussian
ERR_AMPLITUDE	Float	NA	Relative error in the amplitude of the Gaussian
ERR_GAUSS_WIDTH	Float	NA	Relative error in the width of the Gaussian
ERR_BACKGROUND	Float	NA	Error in the coefficients for the line fit to the background level
LEFT_WAVELENGTH	Float	nm	Center or peak of the emission line on the left wing of the line of interest
LEFT_AMPLITUDE	Float	W m^-2	Amplitude of the Gaussian fit to the line on the left wing of the line of interest
LEFT_GAUSS_WIDTH	Float	nm	Width of the Gaussian fit to the line on the left of the line of interest
ERR_LEFT_AMPLITUDE	Float	NA	Relative error in the amplitude of the Gaussian fit for the line on the left wing of the line of interest
RIGHT_WAVELENGTH	Float	nm	Center or peak of the emission line on the right wing of the line of interest
RIGHT_AMPLITUDE	Float	W m^-2	Amplitude of the Gaussian fit to the line on the right wing of the line of interest

RIGHT_GAUSS_WIDTH	Float	nm	Width of the Gaussian fit to the line on the right wing of the line of interest
ERR_RIGHT_AMPLITUDE	Float	NA	Relative error in the amplitude of the Gaussian fit for the line on the right wing of the line of interest
FIT_VALID	Byte	NA	Indicates whether the fit is valid (1) or not (0)

FlareFitParams HDU

The FlareFitParams HDU is similar to the LinesFitParams HDU. It contains line-profile-fit parameters for each emission line, but the preflare background is subtracted before fitting. This structure also reports the GOES XRS irradiance, and flare flags indicate whether a flare is occurring.

Column Name	Data Type	Units	Description
GOES_XRSA	Float	W m^-2	GOES XRS-A irradiance
GOES_XRSB	Float	W m^-2	GOES XRS-B irradiance
GOES_TEMP_MK	Float	Log(K)	Log (base 10) temperature
FLARE_FLAG	Int	NA	Indicates the flare mode: FLARE_MODE_NOT_IN_SUN = 0 FLARE_MODE_HISTORY_FILLING = 1 FLARE_MODE_NOT_IN_FLARE = 2 FLARE_MODE_FLARE_LIKELY = 4 FLARE_MODE_FLARE_STARTED = 8 FLARE_MODE_FLARE_DECREASING = 16 FLARE_MODE_FLARE_INCREASING = 32
PREFLARE_TIME_JD	Float	Days	Julian day for the preflare background
FLARE_IRRADIANCE	Float	W m^-2	Irradiance of the flare
FLARE_WAVELENGTH	Float	nm	Center or peak wavelength of the flare fit
FLARE_AMPLITUDE	Float	W m^-2	Amplitude of the Gaussian fit to the line
FLARE_BACKGROUND	Float	W m^-2	Coefficients for a line fit to the background level (c_0, c_1 where $y = c_0 + c_1 x$); note the units given are for the line evaluated at a particular wavelength (but the units of c_1 are W m^-2 nm^-1)
FLARE_FIT_CHI2	Float	NA	Chi-square value of the fit
ERR_WAVELENGTH	Float	NA	Relative error in the wavelength of the Gaussian
ERR_AMPLITUDE	Float	NA	Relative error in the amplitude of the Gaussian
ERR_BACKGROUND	Float	NA	Error in the coefficients for the line fit to the background level
FIT_VALID	Byte	NA	Indicates whether the fit is valid (1) or not (0)

LinesFitAccuracy HDU

The LinesFitAccuracy HDU contains one structure with a 2D array (FIT_ACCURACY). This array represents the root-mean-square of the relative errors for the Gaussian fit parameters. The first dimension is the line index (lines are defined in the LinesMeta HDU), and the second dimension is the time dimension, representing each minute of the day.

LinesData HDU

The LinesData data unit contains the irradiance as calculated from the line fits for each emission line. The other dimension corresponds to time, which is available in the variable SOD (seconds of UTC day) or TAI (International Atomic Time). SOD represents the center of the 1-minute time interval (30, 90, 150, and so on). The line irradiance for line *i* is calculated from the line fit parameters according to equation

$$\text{irradiance}_i = A \cdot w \cdot \sqrt{\pi}$$

where A is the amplitude of the Gaussian and w is the width.

User Guide and Examples in IDL

The level 4 lines data products are stored in FITS format and can be read using a variety of software. For more information, please refer to the documentation section on the following website: https://lasp.colorado.edu/eve/data_access/index.html.

LASP has provided an IDL function called eve_read_whole_fits.pro, which allows for easy reading of any EVE data product that is in FITS format. This software can be downloaded from the EVE website. https://lasp.colorado.edu/eve/data_access/eve_data/software/eve_read_whole_fits.pro

Reading a level 4 lines file

We will use the function eve_read_whole_fits in the following examples.

To read in a level 4 lines data product, download a file and call the function with the filename.

```
IDL> l4lines = eve_read_whole_fits( 'EVE_LINESFIT_L4_2011046_008_01.fit' )
```

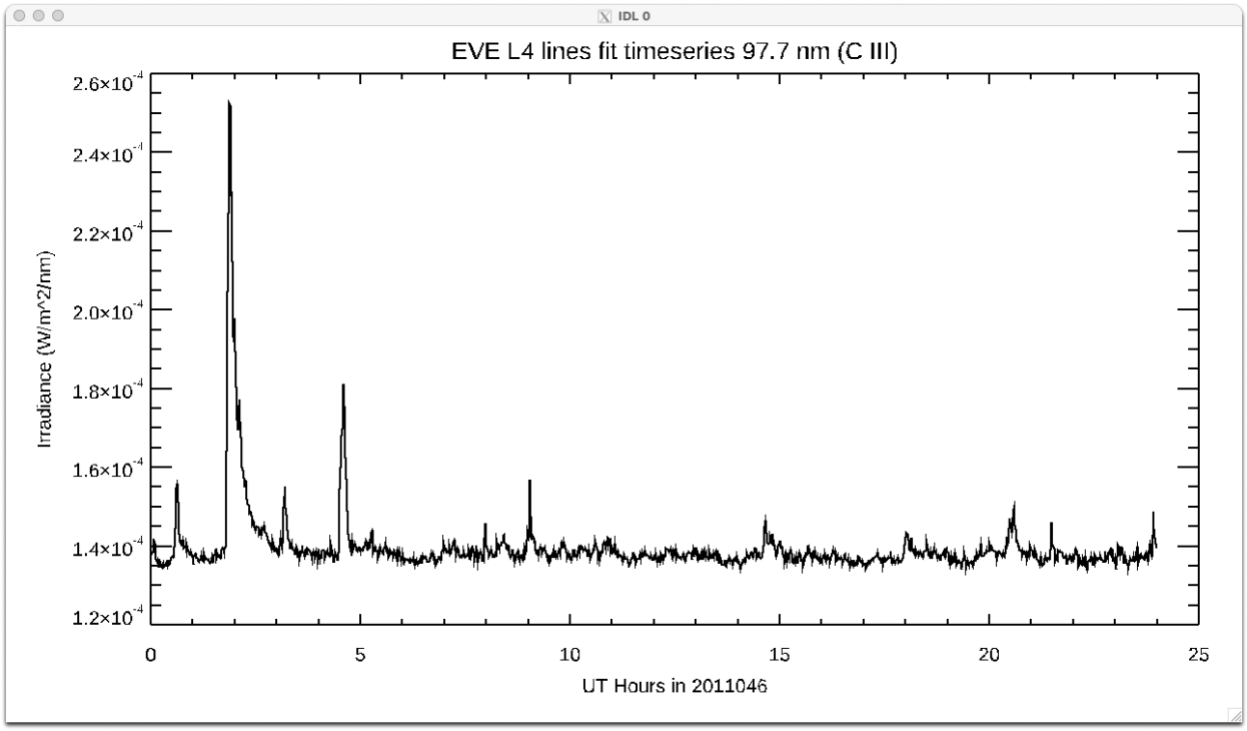
The reader software returns a structure of structures. The substructures correspond to each HDU in the FITS file. The 6 HDUs in the file are Primary (unused), LinesMeta, LinesFitParams, FlareFitParams, LinesFitAccuracy, and LinesData. The HDU #0 is left empty since it is convention to only include images in the first HDU. To see the structure contents, perform the following command:

```
IDL> help, l4lines, /structure
** Structure <1bdb948>, 12 tags, length=12784920, data length=12775996, refs=1:
   PRIMARY         LONG                 0
   PRIMARY_HEAD    STRING    Array[5]
   LINESMETA       STRUCT    -> <Anonymous> Array[70]
   LINESMETA_HEADER
                   STRING    Array[42]
   LINESFITPARAMS  STRUCT    -> <Anonymous> Array[1440]
   LINESFITPARAMS_HEADER
                   STRING    Array[85]
   FLAREFITPARAMS  STRUCT    -> <Anonymous> Array[1440]
   FLAREFITPARAMS_HEADER
                   STRING    Array[73]
   LINESFITACCURACY
                   STRUCT    -> <Anonymous> Array[1]
   LINESFITACCURACY_HEADER
                   STRING    Array[26]
   LINESDATA       STRUCT    -> <Anonymous> Array[1]
   LINESDATA_HEADER
                   STRING    Array[101]
```

In this example, we plot a time series of the irradiance for the C III line at 97.7 nm (line index 65).

```
IDL> line_index = 65
IDL> good = where(l4lines.linesfitparams.fit_valid[line_index] eq 1, ngood)
```

```
IDL> title = 'EVE L4 lines fit timeseries ' + $
     string(l4lines.linesmeta[line_index].line_wavelength, $
     format='(F4.1)') + ' nm (' + $ strtrim(l4lines.linesmeta[line_index].line_ions, 2)
     + ')'
IDL> plot, l4lines.linesdata.sod[good]/60./60., $
     l4lines.linesdata.line_irradiance[line_index,good], $
     /ynozero, xtitle='UT Hours in 2011046', ytitle='Irradiance (W/m^2/nm)', $
     title=title
```



User Guide and Examples in Python

The following example shows how to make a similar plot using Python using the astropy package to read the FITS file and matplotlib to plot the data.

```
>>> import matplotlib.pyplot as plt
>>> from astropy.io import fits
>>> import numpy as np
>>>
>>> l4_lines_file = "EVE_LINESFIT_L4_2011046_008_01.fit"
>>> line_index = 65
>>>
>>> with fits.open(l4_lines_file) as hdu_list:
...     # extract data
...     linesmeta = hdu_list["LINESMETA"].data
...     linesfitparams = hdu_list["LINESFITPARAMS"].data
...     linesdata = hdu_list["LINESDATA"].data
...     # FIT_VALID = 1 indicates good data
...     fit_valid = linesfitparams["FIT_VALID"][:, line_index]
...     good = np.where(fit_valid == 1)[0]
...     # irradiance for selected line
...     irradiance = linesdata["LINE_IRRADIANCE"][0][good, line_index]
...     # convert TAI seconds to datetime
...     tai_seconds = linesdata["TAI"].flatten()[good]
```

```
...     epoch = np.datetime64("1958-01-01T00:00:00")
...     times = epoch + tai_seconds.astype("timedelta64[s]")
...     # plot title
...     wavelength = linesmeta["LINE_WAVELENGTH"][line_index]
...     ions = linesmeta["LINE_IONS"][line_index].strip()
...     title = f"EVE L4 lines fit timeseries {wavelength:.1f} nm ({ions})"
...     # plot
...     plt.figure(figsize=(10, 6))
...     plt.plot(times, irradiance, 'k-', linewidth=0.8)
...     plt.autoscale(enable=True, axis='x', tight=True)
...     plt.xlabel("Time (UTC)")
...     plt.ylabel("Irradiance (W/m²/nm)")
...     plt.title(title)
...     plt.grid(True, color='lightgray', zorder=0)
...     plt.tight_layout()
...     plt.show()
...
```