

photobiologyInOut Version 0.4.1

User Guide

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1 Introduction

```
# this is needed as some Windows TZ strings are not recognized by R
Sys.setenv(TZ='UTC')
library(photobiology)
library(photobiologyWavebands)
library(photobiologyInOut)
library(lubridate)
library(ggplot2)
library(ggmap)
library(ggspectra)
```

```
options(dplyr.print_max = 5)
options(dplyr.print_min = 3)
options(photobiology.verbose = FALSE)
```

This package defines functions for importing spectral data from different instruments (Table 1) and simulation models (Table 2).

2 Examples

Reading a file generated by Ocean Optics' Jaz spectrometer.

```
jaz.spct <- read_oo_jazirrad(file = "spectrum.JazIrrad")
```

R function	Instrument	Program
read_ooss_file()	Ocean Optics spectrometers	SpectraSuite
read_oojaz_file()	Ocean Optics Jaz	<i>instrument</i>
read_macam_file()	Macam	<i>instrument</i>
read_licor_file()	LI-COR LI-1800	PC1800 (MS-DOS)

Table 1: Functions for importing measured spectral emission data

R function	Simulation model	version
read_tuv_file()	TUV (Sasha Madronich)	version 5.0 (modified)
read_tuv_file()	TUV (Sasha Madronich)	edited output

Table 2: Functions for importing simulated spectral data from models

```
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimum s.e.irrad = -0.032

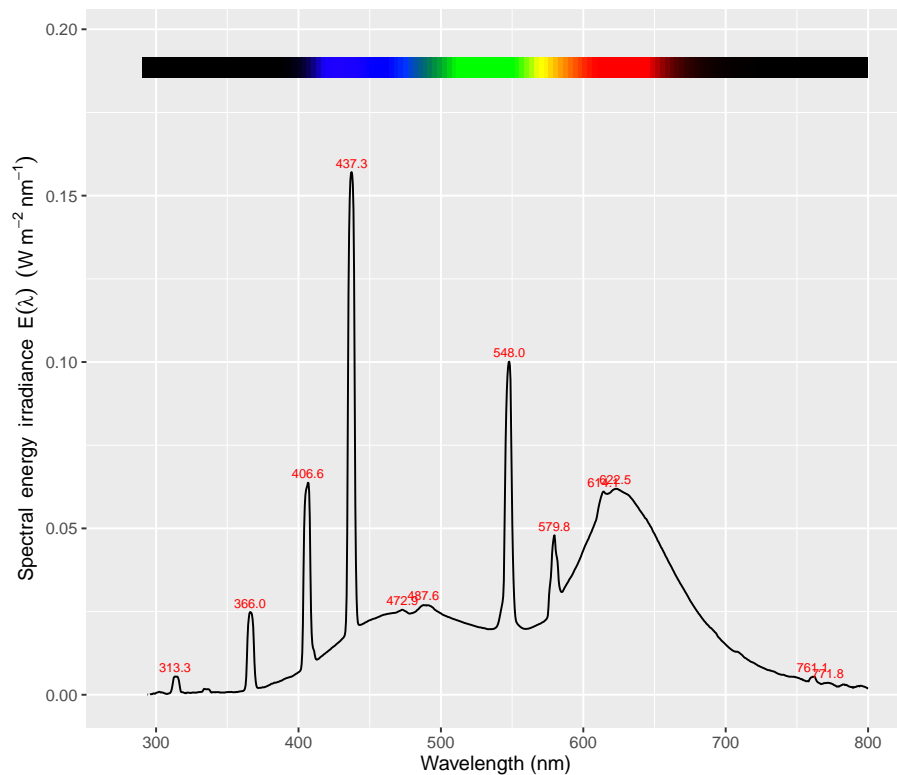
jaz0.spct <- jaz.spct
jaz.spct <- trim_wl(jaz.spct, range = c(290, 800))

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimum s.e.irrad = -0.032
```

Plotting the spectrum.

```
plot(jaz.spct)

## Warning: Removed 9 rows containing non-finite values
## (stat.peaks).
## Warning: Removed 2 rows containing missing values (geom.path).
```



We can see that the data have problems. We get a warning because the data contains negative values for spectral irradiance. We will use some methods from package photobiology to correct the problem. As the data are noisy we cannot just shift the scale so that the most negative value becomes zero. Neither can we replace all negative values with zeros, as this would create bias.

In the following code chunk we will use a region of the spectrum in which spectral irradiance is known to be equal to zero as reference to shift the scale zero.

```
jaz.spct <- fshift(jaz0.spct, range = c(255, 290), f = "mean")

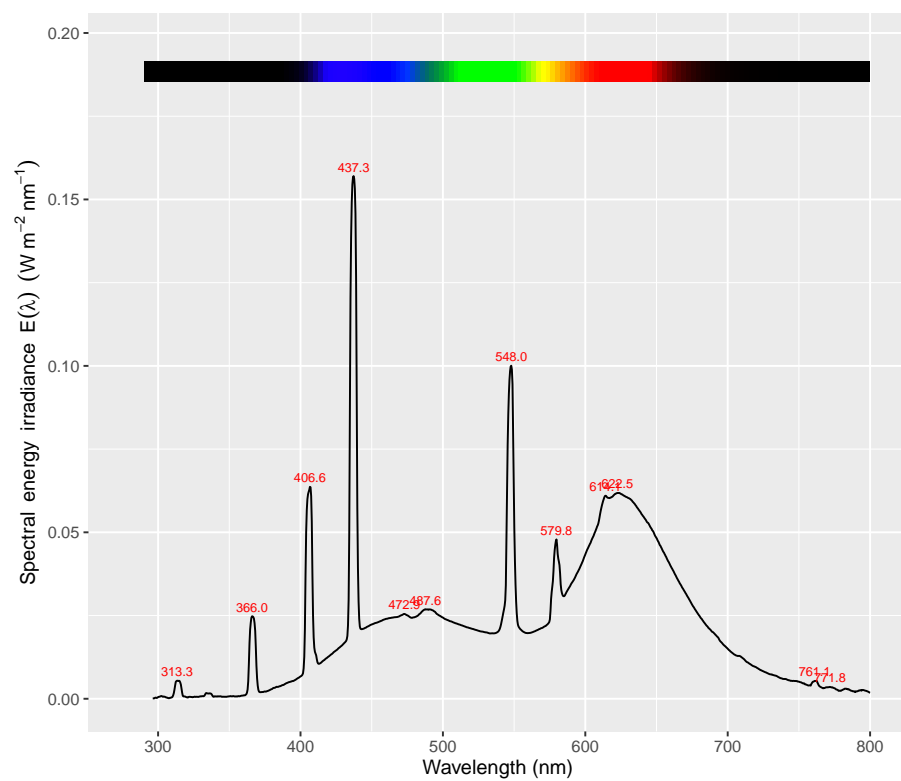
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimum s.e.irrad = -0.032
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimum s.e.irrad = -0.00035

jaz.spct <- trim_wl(jaz.spct, range = c(290, 800))

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimum s.e.irrad = -0.032

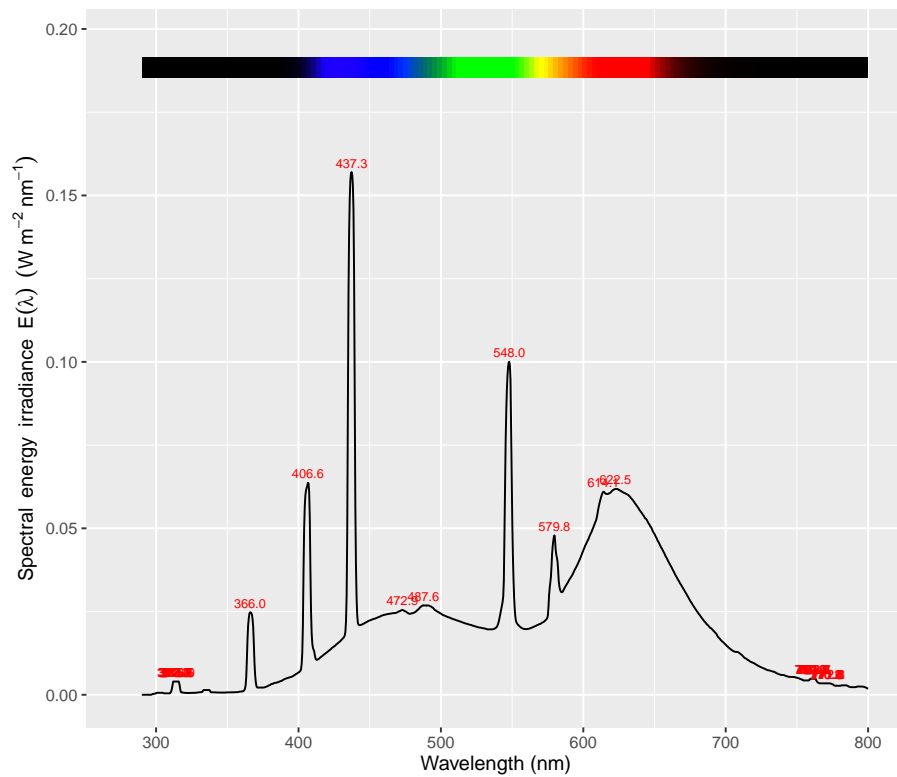
plot(jaz.spct)

## Warning: Removed 13 rows containing non-finite values
## (stat_peaks).
## Warning: Removed 9 rows containing missing values (geom_path).
```



We can next try to smooth the spectrum as it is very noisy outside the visible region.

```
jaz.spct <- smooth_spct(jaz.spct)
plot(jaz.spct)
```



Photon and energy irradiances.

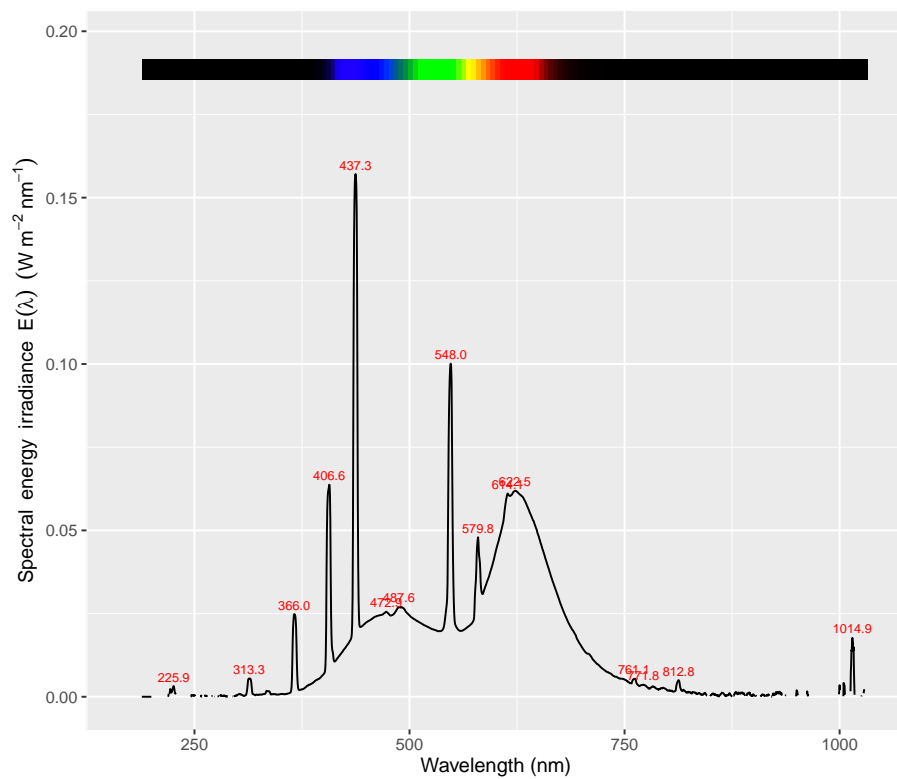
```
e_irrad(jaz.spct, PAR()) # W m-2

##      PAR
## 10.10675
## attr(,"time.unit")
## [1] "second"
## attr(,"radiation.unit")
## [1] "energy irradiance total"
```

All in one statement.

```
plot(read_oo_jazirrad(file = "spectrum.JazIrrad"))

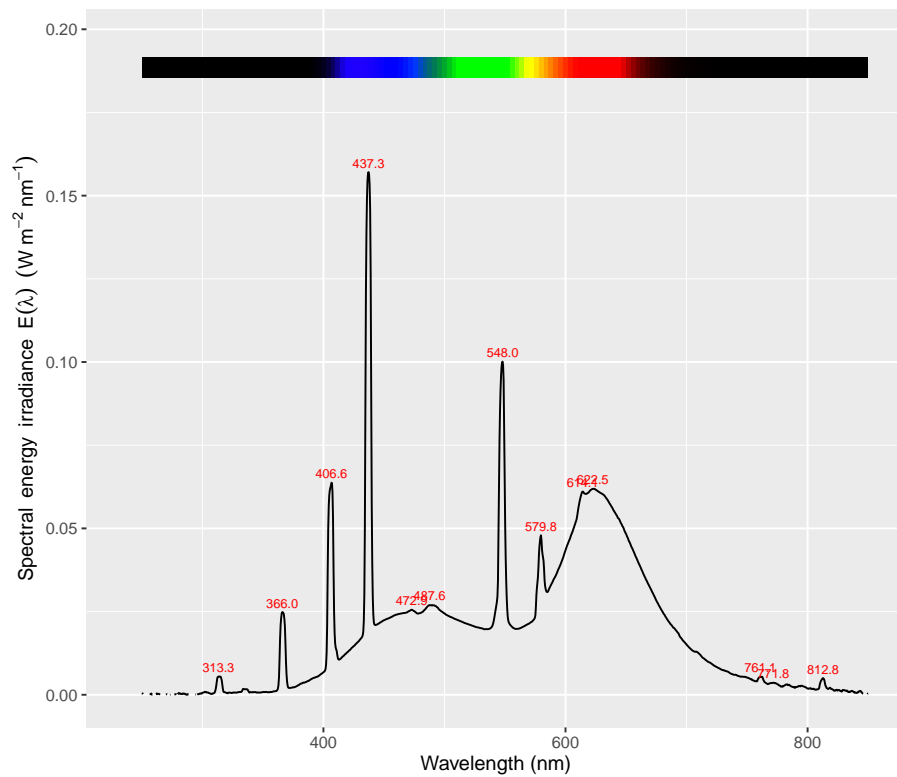
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032
## Warning: Removed 378 rows containing non-finite values
## (stat_peaks).
## Warning: Removed 1 rows containing missing values (geom_path).
```



As above but limiting the wavelength range plotted.

```
plot(read_oo_jazirrad(file = "spectrum.JazIrrad"), range = c(250,850))

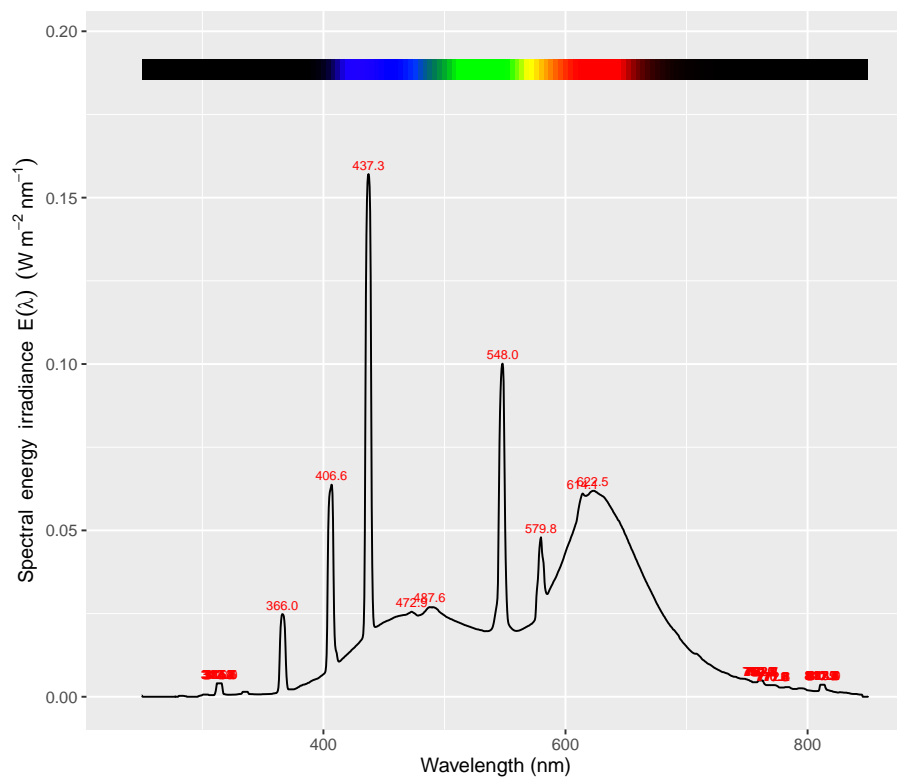
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning: Removed 52 rows containing non-finite values
## (stat.peaks).
```



Adding our custom “adaptive” smoothing.

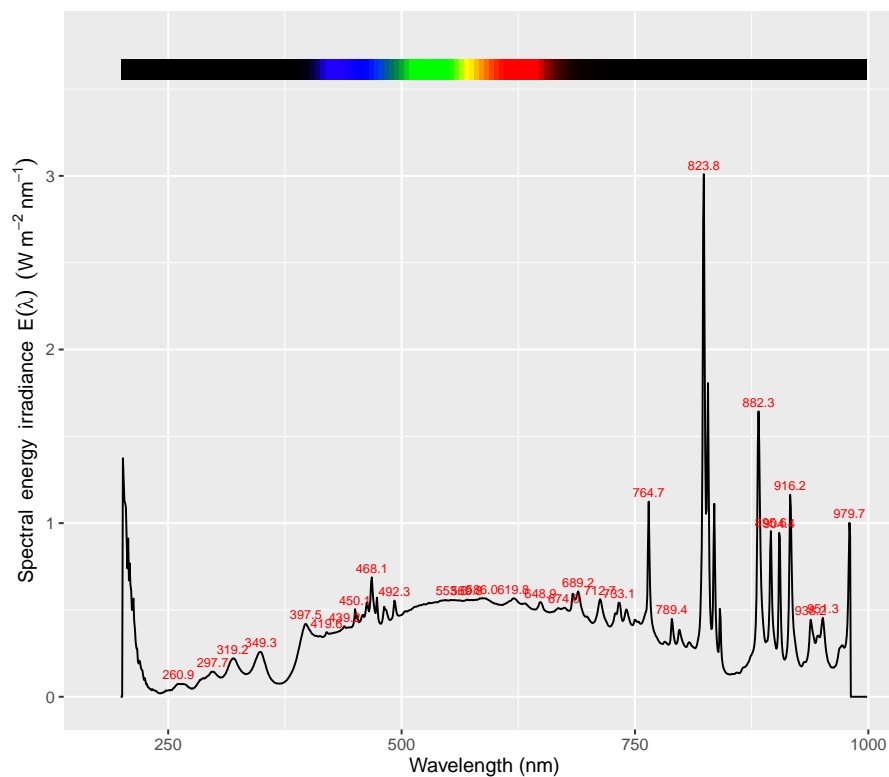
```
plot(smooth_spct(read_oo_jazirrad(file = "spectrum.JazIrrad")), range = c(250,850))

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in smooth_spct.source_spct(read_oo_jazirrad(file = "spectrum.JazIrrad")):
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
```



Now a file from an Ocean Optics' Q6500? spectrometer.

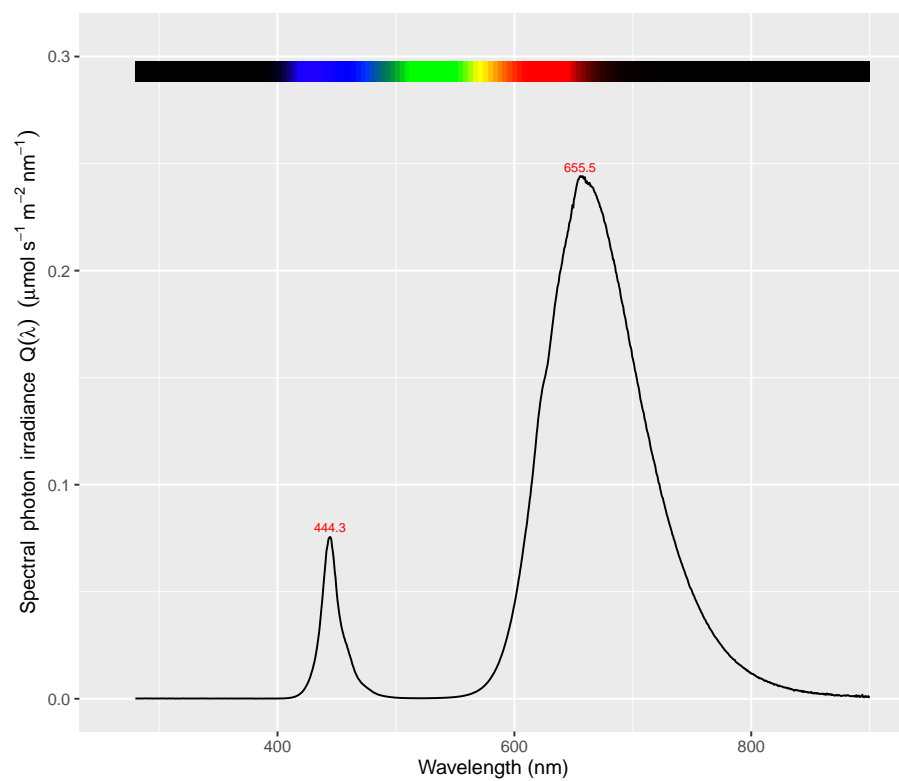
```
plot(read_oo_sstxt(file = "spectrum.SSIrrad"))
```

Avantes' two column .csv files can also be imported.

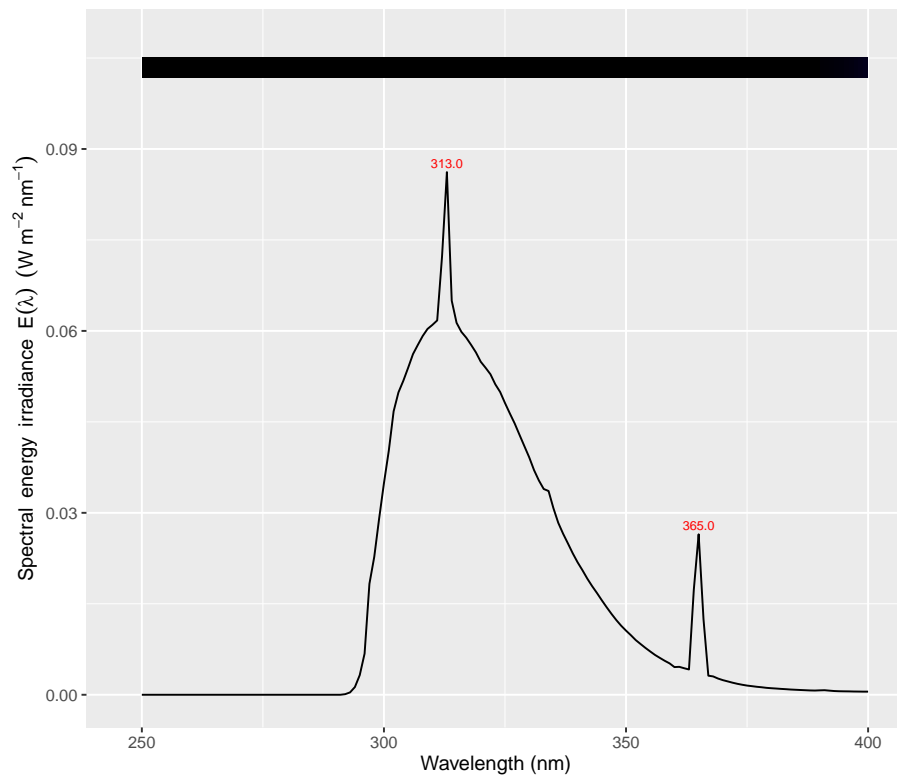
```
plot(read_avaspec_csv(file = "spectrum-avaspec.csv"),
     range = c(280, 900), unit.out = "photon")

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## Warning in range_check(x, strict.range = strict.range): Negative spectral photon
## Warning in range_check(x, strict.range = strict.range): Negative spectral photon
```



Macam's single column DTA files can also be imported.

```
plot(read_macam_dta(file = "spectrum.DTA"))
```



And a file generated by LI-COR's PC1800 program for the LI-1800 septro-radiometer.

```
licor.spct <- read_licor_prn(file = "spectrum.PRN")
```

In all cases as much information as possible is decoed, and the data file headers are preserved as comments in the source.spct objects.

```
licor.spct

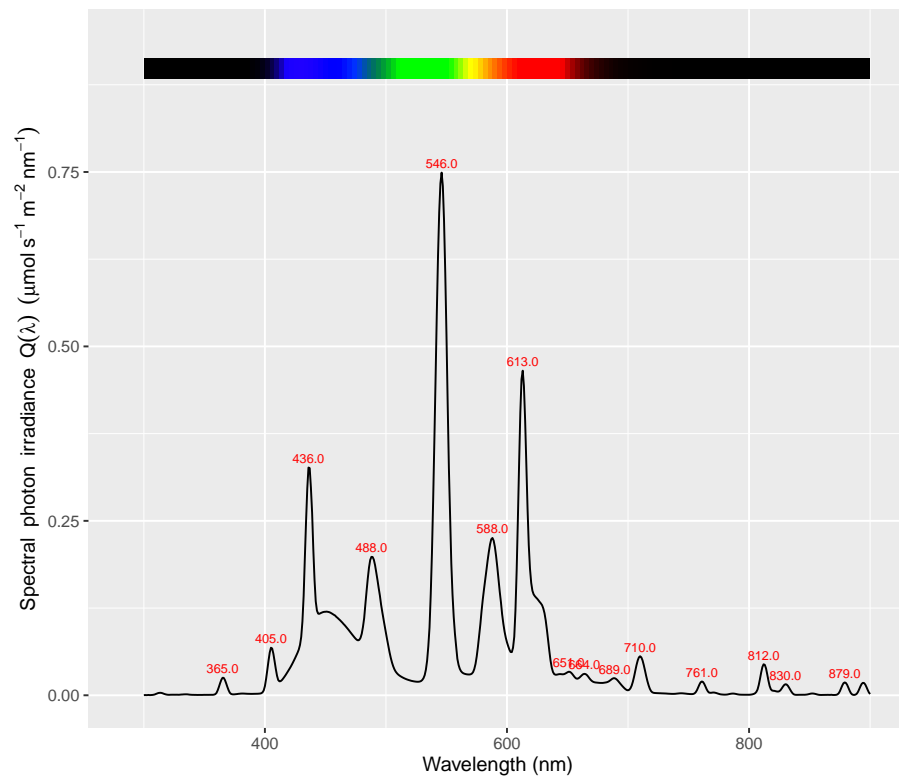
## Object: source_spct [601 x 2]
## Wavelength (nm): range 300 to 900, step 1
## Measured on: 0000-08-23 16:32:00 UTC
## Time unit: 1s
##
##   w.length s.q.irrad
##   (dbl)    (dbl)
## 1      300 1.518e-10
## 2      301 3.355e-10
## 3      302 2.197e-10
## ..      ...      ...

cat(comment(licor.spct))

## LICOR LI-1800:
```

```
## "FILE:FL2"
## "REM: TLD 36W/865      (QNTM)"
## "LIMS: 300- 900NM"
## "INT:  1NM"
## "DATE:08/23 16:32"
## "MIN:  300NM 1.518E-04"
## "MAX:  546NM 7.491E-01"

plot(licor.spct, unit.out = "photon")
```



A variable with the user supplied date and time data, or the date read from the header (the text itself) not the file date as the file date may not reflect the creation date and time.

```
jaz1.spct <- read_oo_jazirrad(file = "spectrum.JazIrrad", date = NULL)

## Warning in range.check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032

jaz1.spct

## Object: source_spct [2,048 x 2]
## Wavelength (nm): range 188.82523 to 1033.1483, step 0.357056 to 0.459625
## Measured on: 2015-02-03 09:44:41 UTC
## Time unit: 1s
```

```
##
##      w.length s.e.irrad
##      (dbl)      (dbl)
## 1  188.8252      0
## 2  189.2849      0
## 3  189.7444      0
## ..      ...      ...
```

```
jaz.spct <- read_oo_jazirrad(file = "spectrum.JazIrrad",
                             date = ymd_hms("2015-11-15 12:00:00"))

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032

jaz.spct

## Object: source_spct [2,048 x 2]
## Wavelength (nm): range 188.82523 to 1033.1483, step 0.357056 to 0.459625
## Measured on: 2015-11-15 12:00:00 UTC
## Time unit: 1s
##
##      w.length s.e.irrad
##      (dbl)      (dbl)
## 1  188.8252      0
## 2  189.2849      0
## 3  189.7444      0
## ..      ...      ...
```

```
jaz.spct <- read_oo_jazirrad(file = "spectrum.JazIrrad", date = now())

## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
## irradiance values; minimum s.e.irrad = -0.032

jaz.spct

## Object: source_spct [2,048 x 2]
## Wavelength (nm): range 188.82523 to 1033.1483, step 0.357056 to 0.459625
## Measured on: 2015-12-21 19:31:28 UTC
## Time unit: 1s
##
##      w.length s.e.irrad
##      (dbl)      (dbl)
## 1  188.8252      0
## 2  189.2849      0
## 3  189.7444      0
## ..      ...      ...
```

3 Output from solar spectrum simulation models

The output from the TUV model can be imported either by editing it before import, or by making a simple edit to the output routine of TUV. This function

is known to work with TUV version 5.0 output. The output from TUV can contain a variable number of spectra in “parallel” columns, which are *melted* into a single column, with a factor with letter as levels, a numeric variable with the zenith angle and a POSIXct column with times. A date needs to be always supplied as the output file from TUV has only time of day information.

```
tuv.spct <- read_tuv_usrout(file = "usrout.txt", date = ymd("2014-03-21"))
summary(subset(tuv.spct, spct.idx == "A"))

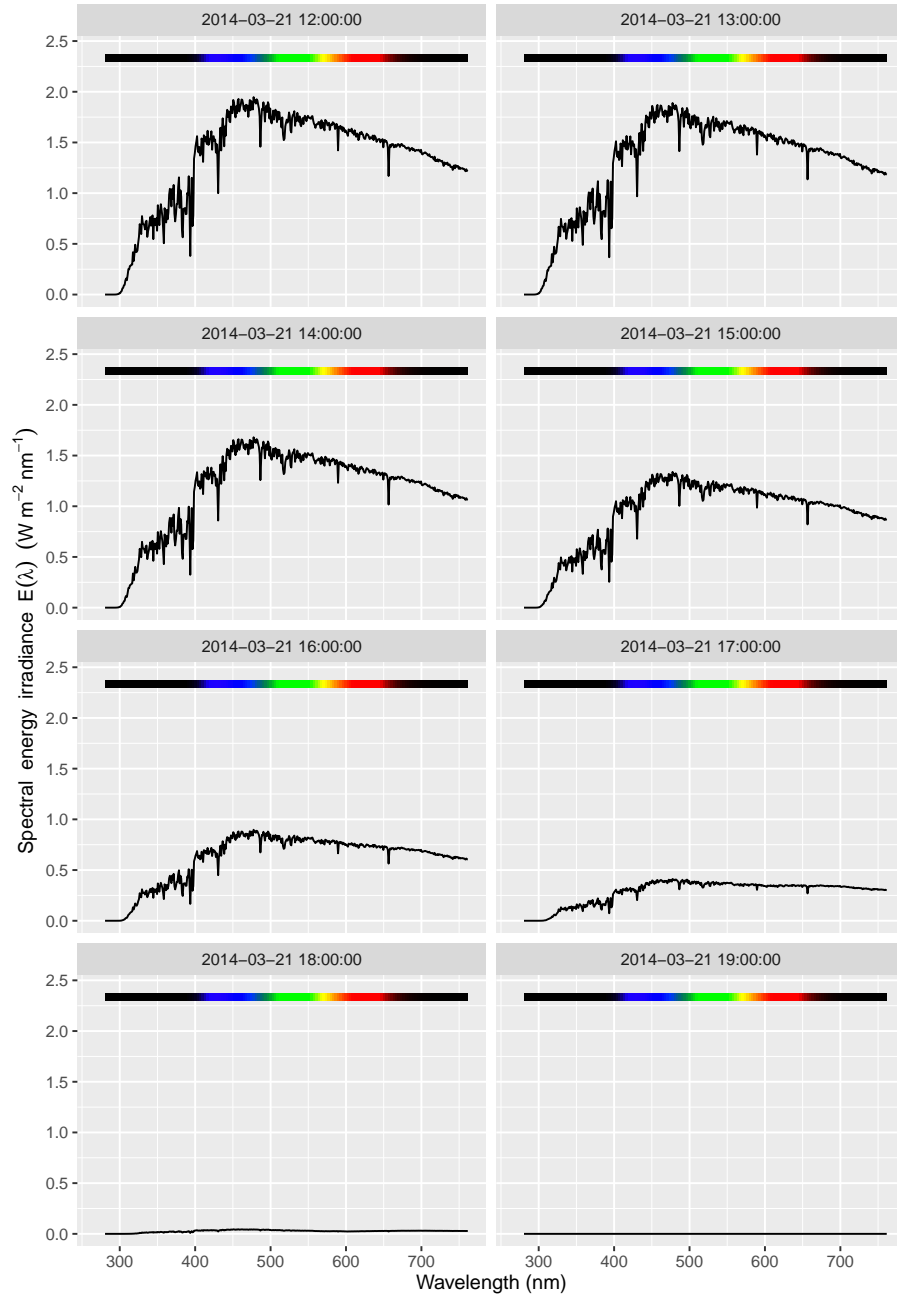
## Summary of object: source_spct [482 x 5]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length      spct.idx      s.e.irrad
## Min.      :280.5    A      :482    Min.      :0.000
## 1st Qu.:400.8    B      : 0    1st Qu.:1.216
## Median :521.0    C      : 0    Median :1.483
## Mean   :521.0    D      : 0    Mean   :1.322
## 3rd Qu.:641.2    E      : 0    3rd Qu.:1.680
## Max.    :761.5    F      : 0    Max.    :1.947
##
##      (Other): 0
##      angle      date
## Min.      :1.829 Min.      :2014-03-21 12:00:00
## 1st Qu.:1.829 1st Qu.:2014-03-21 12:00:00
## Median :1.829 Median :2014-03-21 12:00:00
## Mean   :1.829 Mean   :2014-03-21 12:00:00
## 3rd Qu.:1.829 3rd Qu.:2014-03-21 12:00:00
## Max.    :1.829 Max.    :2014-03-21 12:00:00
##

tuv.spct

## Object: source_spct [3,856 x 5]
## Wavelength (nm): range 280.5 to 761.5, step -481 to 1
## Time unit: 1s
##
##      w.length spct.idx s.e.irrad angle
##      (dbl)   (fctr)   (dbl) (dbl)
## 1      280.5      A 3.041e-15 1.829
## 2      281.5      A 1.164e-13 1.829
## 3      282.5      A 1.824e-12 1.829
## ..      ...      ...      ...    ...
## Variables not shown: date (time)
```

It is possible to extract individual spectra with subset, or as done here plot them in different panels.

```
plot(tuv.spct, annotations = c("colour_guide")) +
  facet_wrap(~date, ncol = 2)
```



The output is a single `source_spect` object that can be easily converted into a `source_mspect` object containing the individual spectra as members of the collection.

```

tuv.mspect <- subset2mspect(tuv.spct)
tuv.mspect

## Object: source_mspect [8 x 1]
## --- Member: A ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad angle          date
##      (dbl)    (dbl) (dbl)          (time)
## 1      280.5 3.041e-15 1.829 2014-03-21 12:00:00
## 2      281.5 1.164e-13 1.829 2014-03-21 12:00:00
## 3      282.5 1.824e-12 1.829 2014-03-21 12:00:00
## ..      ...      ...      ...
## --- Member: B ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad angle          date
##      (dbl)    (dbl) (dbl)          (time)
## 1      280.5 1.314e-15 13.198 2014-03-21 13:00:00
## 2      281.5 5.415e-14 13.198 2014-03-21 13:00:00
## 3      282.5 9.039e-13 13.198 2014-03-21 13:00:00
## ..      ...      ...      ...
## --- Member: C ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad angle          date
##      (dbl)    (dbl) (dbl)          (time)
## 1      280.5 4.521e-17 28.2 2014-03-21 14:00:00
## 2      281.5 2.510e-15 28.2 2014-03-21 14:00:00
## 3      282.5 5.413e-14 28.2 2014-03-21 14:00:00
## ..      ...      ...      ...
## --- Member: D ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad angle          date
##      (dbl)    (dbl) (dbl)          (time)
## 1      280.5 3.075e-20 43.202 2014-03-21 15:00:00
## 2      281.5 3.273e-18 43.202 2014-03-21 15:00:00
## 3      282.5 1.234e-16 43.202 2014-03-21 15:00:00
## ..      ...      ...      ...
## --- Member: E ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad angle          date
##      (dbl)    (dbl) (dbl)          (time)
## 1      280.5 2.253e-26 58.205 2014-03-21 16:00:00
## 2      281.5 7.751e-24 58.205 2014-03-21 16:00:00

```



```
## 3      282.5 8.148e-22 58.205 2014-03-21 16:00:00
## ..      ...      ...      ...      ...
## --- Member: F ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad  angle          date
##      (dbl)    (dbl)    (dbl)        (time)
## 1      280.5 1.929e-27 73.208 2014-03-21 17:00:00
## 2      281.5 5.710e-25 73.208 2014-03-21 17:00:00
## 3      282.5 5.202e-23 73.208 2014-03-21 17:00:00
## ..      ...      ...      ...
## --- Member: G ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad  angle          date
##      (dbl)    (dbl)    (dbl)        (time)
## 1      280.5 4.721e-28 88.211 2014-03-21 18:00:00
## 2      281.5 1.385e-25 88.211 2014-03-21 18:00:00
## 3      282.5 1.250e-23 88.211 2014-03-21 18:00:00
## ..      ...      ...      ...
## --- Member: H ---
## Object: source_spct [482 x 4]
## Wavelength (nm): range 280.5 to 761.5, step 1
## Time unit: 1s
##
##      w.length s.e.irrad  angle          date
##      (dbl)    (dbl)    (dbl)        (time)
## 1      280.5          0 103.213 2014-03-21 19:00:00
## 2      281.5          0 103.213 2014-03-21 19:00:00
## 3      282.5          0 103.213 2014-03-21 19:00:00
## ..      ...      ...      ...
## --- END ---
```

With the default of `lubridate::today()` for date times are ‘mapped’ to the current local date using the time zone of the computer as visible to R.

```
tuv_nd.spct <- read_tuv_usrout(file = "usrout.txt")
tuv_nd.spct

## Object: source_spct [3,856 x 5]
## Wavelength (nm): range 280.5 to 761.5, step -481 to 1
## Time unit: 1s
##
##      w.length spct.idx s.e.irrad angle
##      (dbl)    (fctr)    (dbl) (dbl)
## 1      280.5          A 3.041e-15 1.829
## 2      281.5          A 1.164e-13 1.829
## 3      282.5          A 1.824e-12 1.829
## ..      ...      ...      ...
## Variables not shown: date (time)
```

Functions `read_fmi_cum` and `read_m_fmi_cum` can be used to read text files output by a simulation model of solar spectral irradiance. The model was de-

veloped at the Finnish Meteorological Institute (FMI) by Dr. Anders Lindfors and collaborators.

We can read an individual file into a `source_spct` object while adding some metadata.

```
z.spct <- read_fmi_cum("2014-08-21_cum.hel")

## Error in eval(expr, envir, enclos): could not find function "read_fmi_cum"

class_spct(z.spct)

## Error in class_spct(z.spct): object 'z.spct' not found

getWhenMeasured(z.spct)

## Error in getWhenMeasured(z.spct): object 'z.spct' not found

z.spct

## Error in eval(expr, envir, enclos): object 'z.spct' not found
```

```
z.mspect <- read_m_fmi_cum("2014-08-21_cum.hel")
class(z.mspect)

## [1] "source_mspect" "generic_mspect" "list"

getWhenMeasured(z.mspect)

## Source: local data frame [1 x 2]
##
##           spct.idx when.measured
##           (fctr)      (time)
## 1 2014_08_21_cum.hel 2014-08-21

z.mspect

## Object: source_mspect [1 x 1]
## --- Member: 2014_08_21_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-21 UTC
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)      (dbl)
## 1      290 0.000000e+00
## 2      291 2.931322e-05
## 3      292 7.235264e-04
## ..      ...      ...
## --- END ---
```

```
z.mspect <- read_m_fmi_cum(c("2014-08-21_cum.hel",
                             "2014-08-22_cum.hel"))
class(z.mspect)
```

```
## [1] "source_mspct" "generic_mspct" "list"

getWhenMeasured(z.mspct)

## Source: local data frame [2 x 2]
##
##           spct.idx when.measured
##           (fctr)      (time)
## 1 2014_08_21_cum.hel 2014-08-21
## 2 2014_08_22_cum.hel 2014-08-22

z.mspct

## Object: source_mspct [2 x 1]
## --- Member: 2014_08_21_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-21 UTC
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)      (dbl)
## 1      290 0.000000e+00
## 2      291 2.931322e-05
## 3      292 7.235264e-04
## ..      ...      ...
## --- Member: 2014_08_22_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-22 UTC
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)      (dbl)
## 1      290 0.000000e+00
## 2      291 2.926634e-05
## 3      292 7.213022e-04
## ..      ...      ...
## --- END ---
```

```
files <- system("ls /*cum.hel", intern = TRUE)
z1.mspct <- read_m_fmi_cum(files)
class(z1.mspct)

## [1] "source_mspct" "generic_mspct" "list"

getWhenMeasured(z1.mspct)

## Source: local data frame [2 x 2]
##
##           spct.idx when.measured
##           (fctr)      (time)
## 1 2014_08_21_cum.hel 2014-08-21
## 2 2014_08_22_cum.hel 2014-08-22

z1.mspct
```

```
## Object: source_mspct [2 x 1]
## --- Member: 2014_08_21_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-21 UTC
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)        (dbl)
## 1      290 0.000000e+00
## 2      291 2.931322e-05
## 3      292 7.235264e-04
## ..      ...      ...
## --- Member: 2014_08_22_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-22 UTC
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)        (dbl)
## 1      290 0.000000e+00
## 2      291 2.926634e-05
## 3      292 7.213022e-04
## ..      ...      ...
## --- END ---
```

```
z2.mspct <-
  read_m_fmi_cum(files,
    geocode = geocode("Kumpula, Helsinki, Finland",
      source = "google"))

## Information from URL : http://maps.googleapis.com/maps/api/geocode/json?address=Kumpula,%20Helsinki,%20Finland&

class(z2.mspct)

## [1] "source_mspct" "generic_mspct" "list"

getWhenMeasured(z2.mspct)

## Source: local data frame [2 x 2]
##
##      spct.idx when.measured
##      (fctr)      (time)
## 1 2014_08_21_cum.hel 2014-08-21
## 2 2014_08_22_cum.hel 2014-08-22

getWhereMeasured(z2.mspct)

## Source: local data frame [2 x 3]
##
##      spct.idx      lon      lat
##      (fctr)      (dbl)      (dbl)
## 1 2014_08_21_cum.hel 24.96474 60.20911
## 2 2014_08_22_cum.hel 24.96474 60.20911

z2.mspct
```

```

## Object: source_mspct [2 x 1]
## --- Member: 2014_08_21_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-21 UTC
## Measured at: 60.20911 N, 24.96474 E
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)        (dbl)
## 1      290 0.000000e+00
## 2      291 2.931322e-05
## 3      292 7.235264e-04
## ..      ...      ...
## --- Member: 2014_08_22_cum.hel ---
## Object: source_spct [511 x 2]
## Wavelength (nm): range 290 to 800, step 1
## Measured on: 2014-08-22 UTC
## Measured at: 60.20911 N, 24.96474 E
## Time unit: 86400s (~1 days)
##
##      w.length      s.e.irrad
##      (dbl)        (dbl)
## 1      290 0.000000e+00
## 2      291 2.926634e-05
## 3      292 7.213022e-04
## ..      ...      ...
## --- END ---

```