# photobiologyInOut Version 0.4.0
# User Guide

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## Contents



## 1 Introduction

```
library(photobiology)
library(photobiologyWavebands)
library(photobiologygg)
library(photobiologyInOut)
library(lubridate)
library(ggplot2)
library(ggmap)
```

```
options(dplyr.print_max = 5)
options(dplyr.print_min = 3)
```

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

| R function | Instrument | Program |
|---|---|---|
| read_ooss_file() | Ocean Optics spectrometers | SpectraSuite |
| read_oojaz_file() | Ocean Optics Jaz | *instrument* |
| read_macam_file() | Macam | *instrument* |
| 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 simualted spectral data from models

## 2 Examples

Reading a file geenrated by Ocean Optics' Jaz spectrometer.

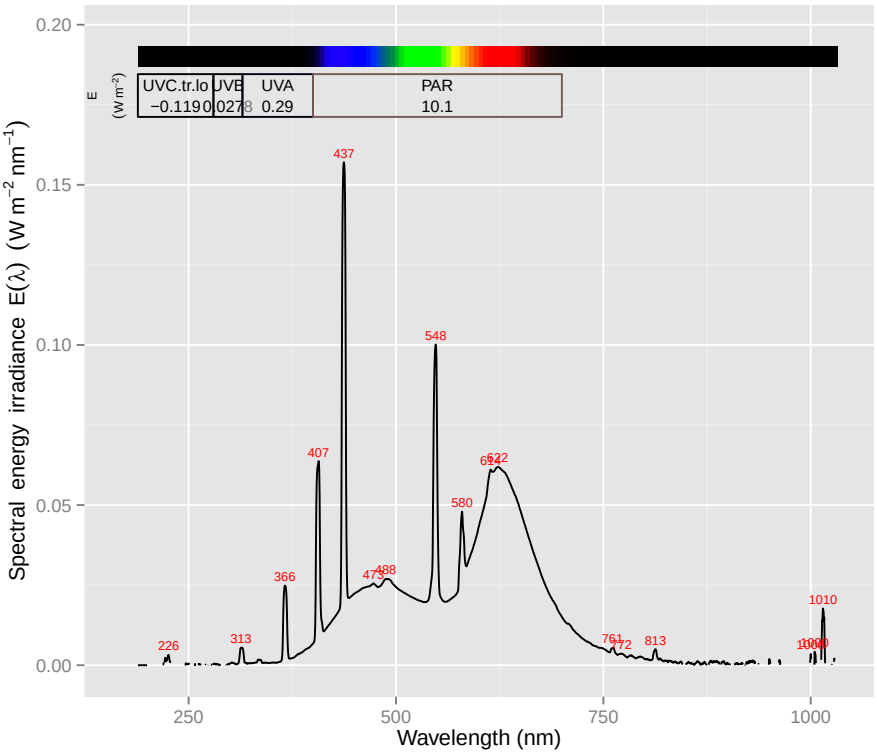
```
jaz.spct <- read_oo_jazirrad(file = "spectrum.JazIrrad")

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

Photon and energy irradiances.

```
q_irrad(jaz.spct, PAR()) * 1e6 # umol m-2 s-1

##      PAR
## 47.43464
## attr(,"time.unit")
## [1] "second"
## attr(,"radiation.unit")
## [1] "photon irradiance total"

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

##      PAR
## 10.12685
## attr(,"time.unit")
## [1] "second"
## attr(,"radiation.unit")
## [1] "energy irradiance total"
```

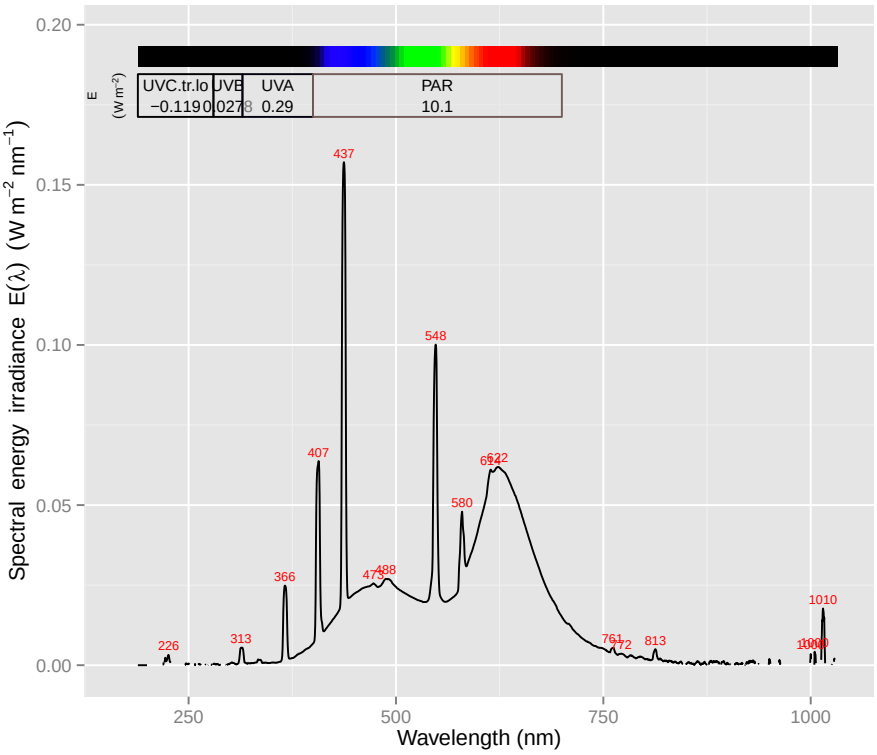
Plotting the spectrum.

```
plot(jaz.spct)

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



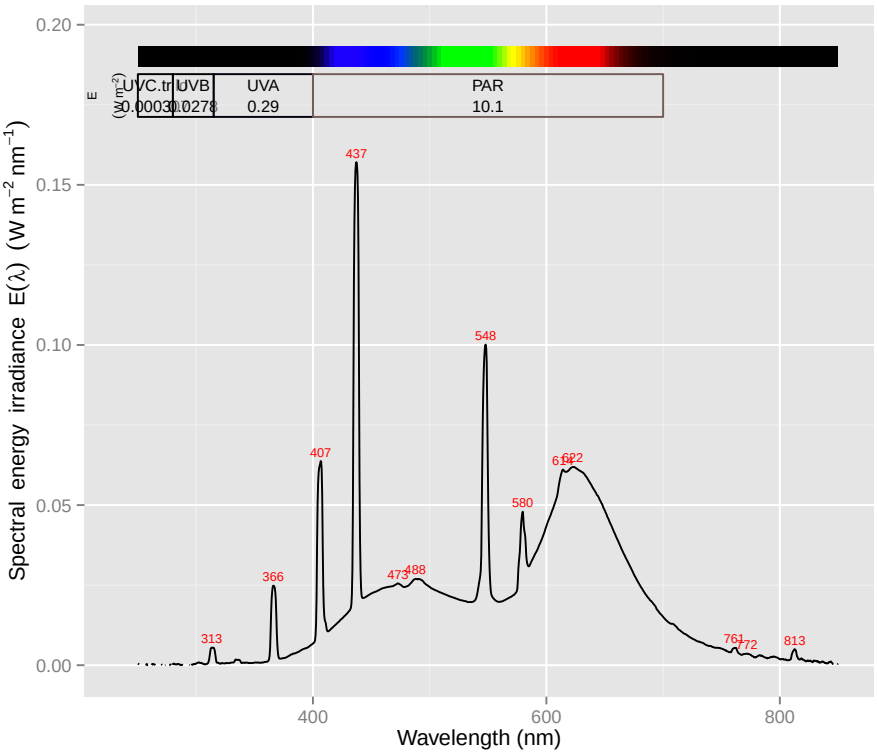

All in one statement.

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

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



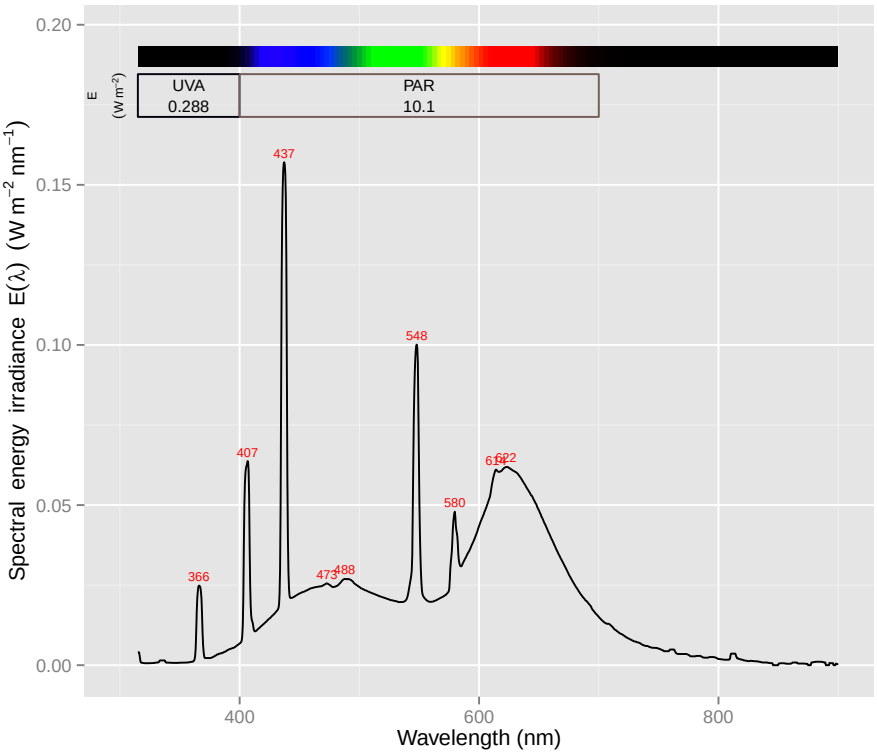

As above but limiting the wavelength range plotted.

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

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



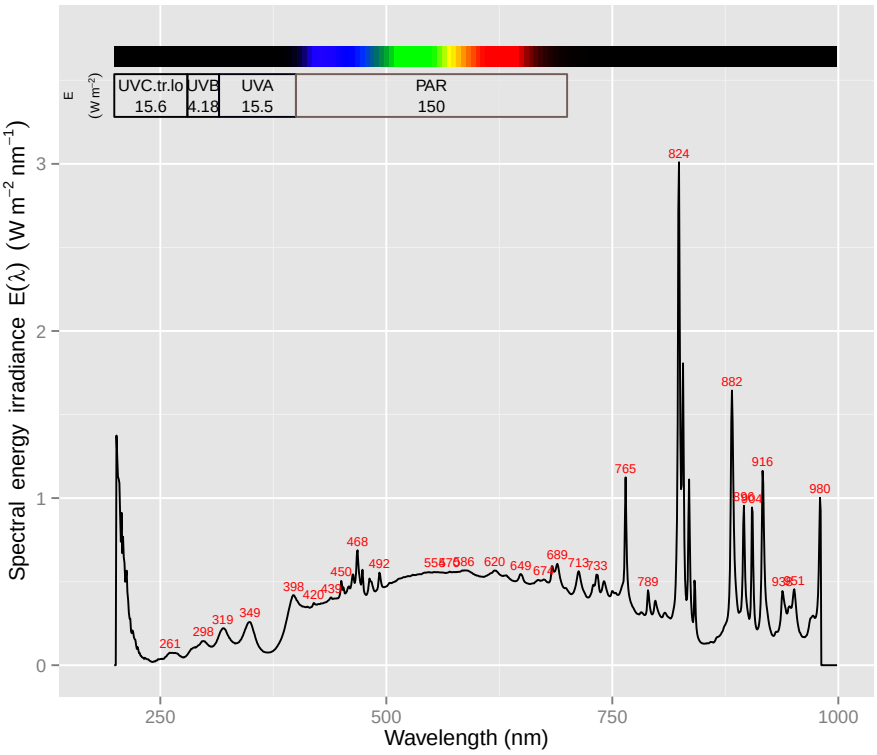

Adding our custom "adaptive" smoothing.

```
plot(smooth_spct(read_oo_jazirrad(file = "spectrum.JazIrrad")), range = c(315,900))

## Warning in range_check(x, strict.range = strict.range):  Negative spectral energy
irradiance values; minimun s.e.irrad = -0.032
## Warning in smooth_spct.source_spct(read_oo_jazirrad(file = "spectrum.JazIrrad")):
89 'bad' estimates in spectral irradiance
## Warning in range_check(x, strict.range = strict.range):  Negative spectral energy
irradiance values; minimun s.e.irrad = -0.027
## Warning in range_check(x, strict.range = strict.range):  Negative spectral energy
irradiance values; minimun s.e.irrad = -0.027
```



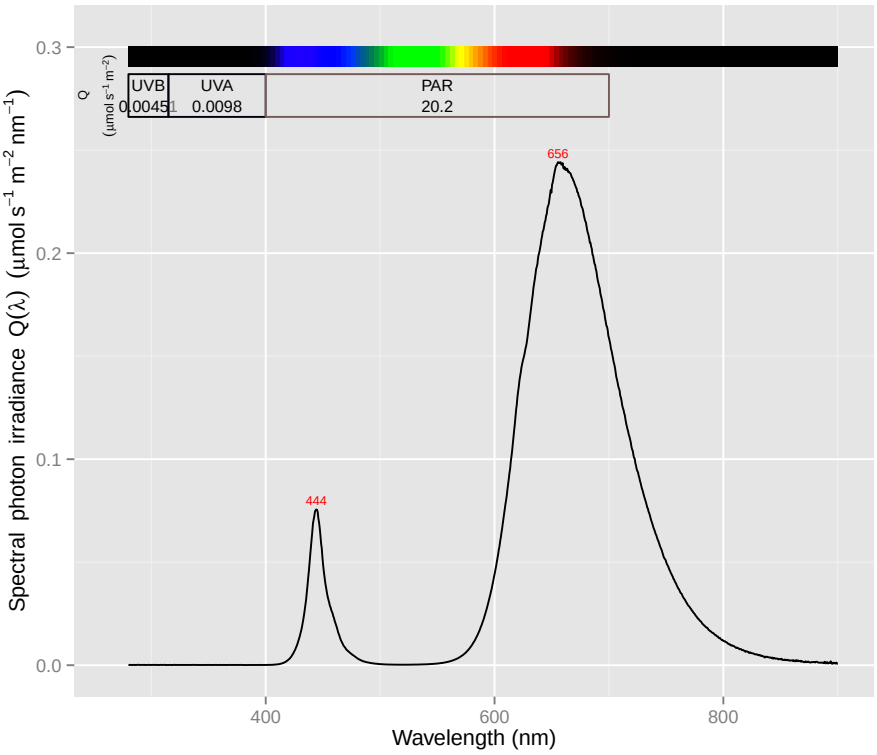

Now a file from an Ocean Optics' Q6500? spectrometer.

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



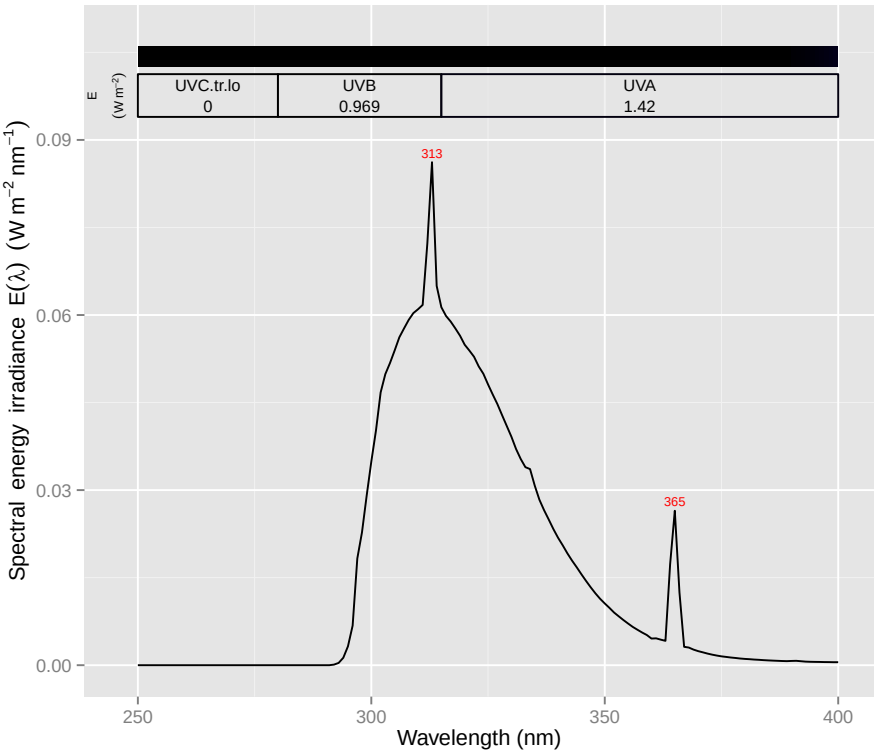

Avantes' two column .csv files can also be imported.

```
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
irradiance values; minimun s.e.irrad = -0.0017
## Warning in range_check(x, strict.range = strict.range): Negative spectral energy
irradiance values; minimun s.e.irrad = -0.0017
## Warning in range_check(x, strict.range = strict.range): Negative spectral photon
irradiance values; minimun s.q.irrad = -1.5e-08
```




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

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



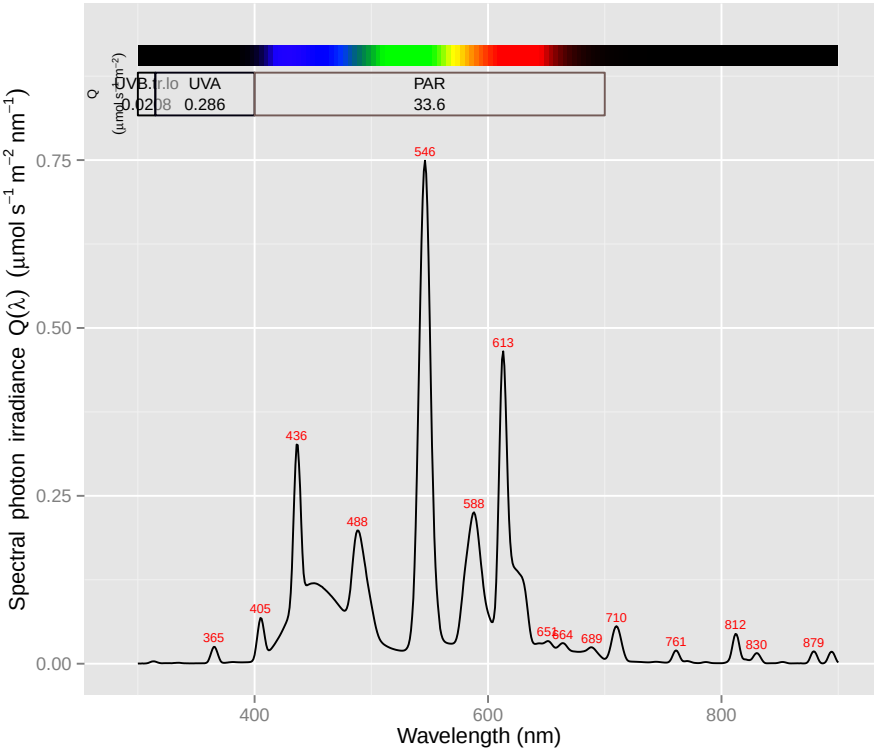

And a file generated by LI-COR's PC1800 program for the LI-1800 sepctroradiometer.

```
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 14:32:00 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 noy reflect the creation date and time.

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

## Warning in range_check(x, strict.range = strict.range):  Negative spectral energy
irradiance values; minimun 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: 2015-02-03 07:44:41 UTC
## Time unit: 1s
```

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

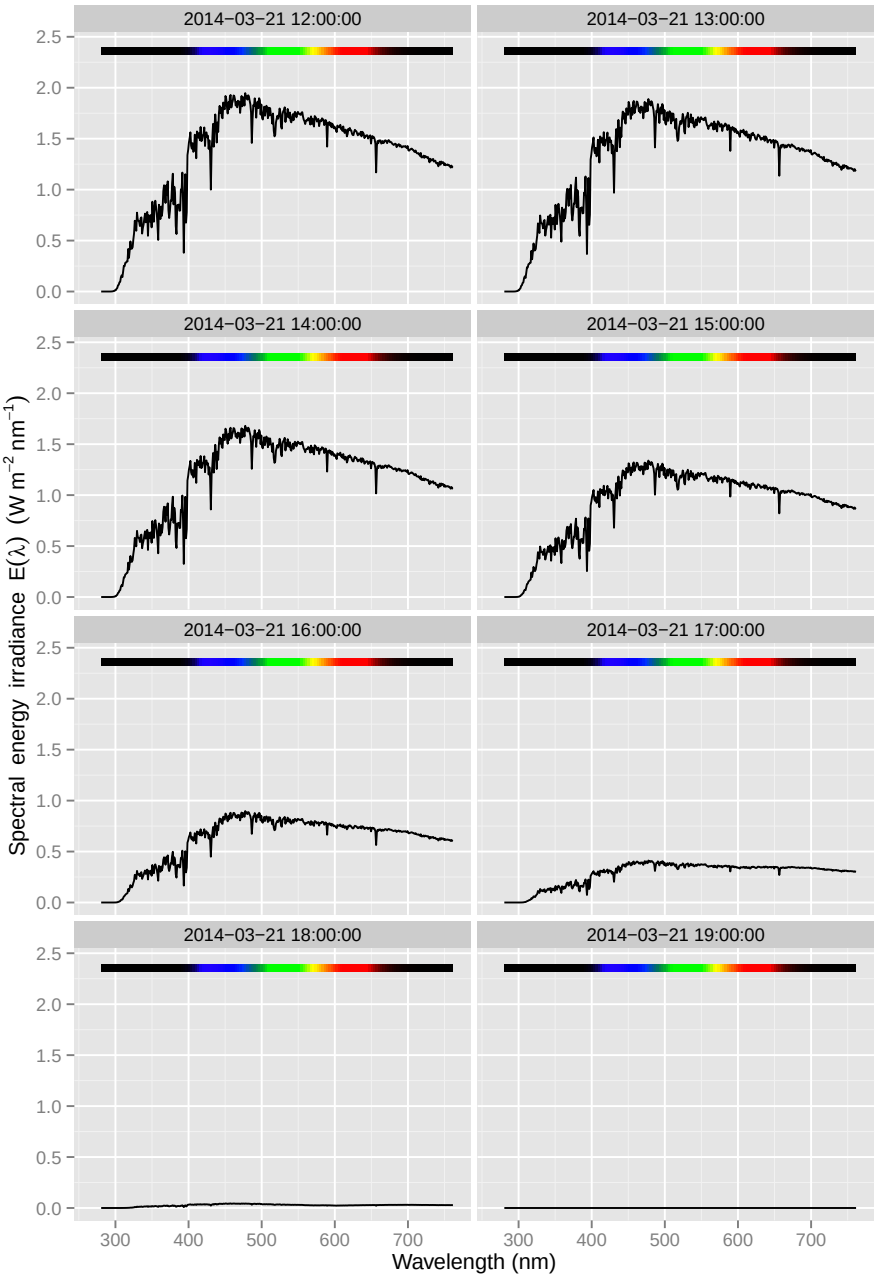
# 3 Output from solar spectrum simulation models

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"))

## wavelength ranges from 280.5 to 761.5 nm
## largest wavelength step size is 1 nm
## spectral irradiance ranges from 3.041e-15 to 1.947 W m-2 nm-1
## energy irradiance is 636.7 W m-2

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               date
##       (dbl)   (fctr)     (dbl) (dbl)             (time)
## 1     280.5        A 3.041e-15 1.829 2014-03-21 12:00:00
## 2     281.5        A 1.164e-13 1.829 2014-03-21 12:00:00
## 3     282.5        A 1.824e-12 1.829 2014-03-21 12:00:00
## ..      ...      ...       ...   ...                 ...
```

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_spct` object that can be easily converted into a `source_mspct` object containing the individual spectra as members of the collection.

```
tuv.mspct <- subset2mspct(tuv.spct)
tuv.mspct
```

```
## Object: source_mspct [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               date
##       (dbl)   (fctr)     (dbl) (dbl)             (time)
## 1     280.5        A 3.041e-15 1.829 2015-11-01 12:00:00
## 2     281.5        A 1.164e-13 1.829 2015-11-01 12:00:00
## 3     282.5        A 1.824e-12 1.829 2015-11-01 12:00:00
## ..      ...      ...       ...   ...                 ...
```

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 Meateorological 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")
class_spct(z.spct)

## [1] "source_spct"  "generic_spct"

getWhenMeasured(z.spct)

## [1] "2014-08-21 UTC"

z.spct

## 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
## ..      ...          ...
```

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

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

getWhenMeasured(z.mspct)

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

z.mspct

## Object: source_mspct [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.mspct <- read_m_fmi_cum(c("2014-08-21_cum.hel",
                            "2014-08-22_cum.hel"))
class(z.mspct)

## [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"))

## Information from URL : http://www.datasciencetoolkit.org/maps/api/geocode/json?address=Kumpula,%20Helsinki,%20F

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 24.96424 60.20942
## 2 2014_08_22_cum.hel 24.96424 60.20942
```

```
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: 60.20942 N, 24.96424 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: 60.20942 N, 24.96424 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 ---
```