EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

EURAMET
European Association of National Metrology Institutes

Post processing of data from array spectroradiometer

«*Workshop-Tutorial*»

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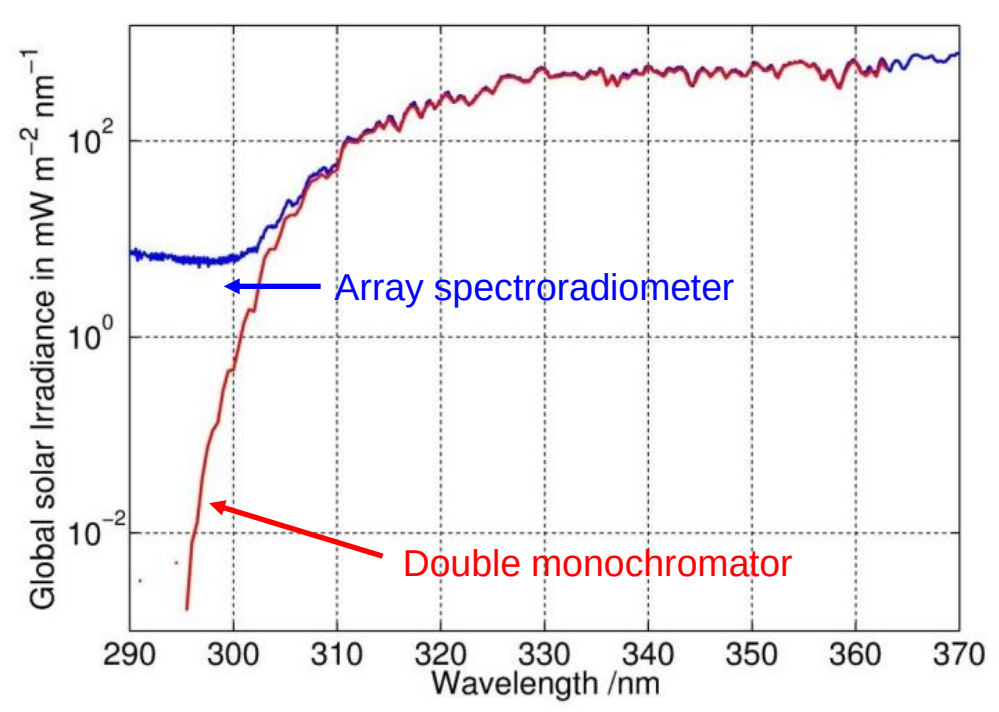
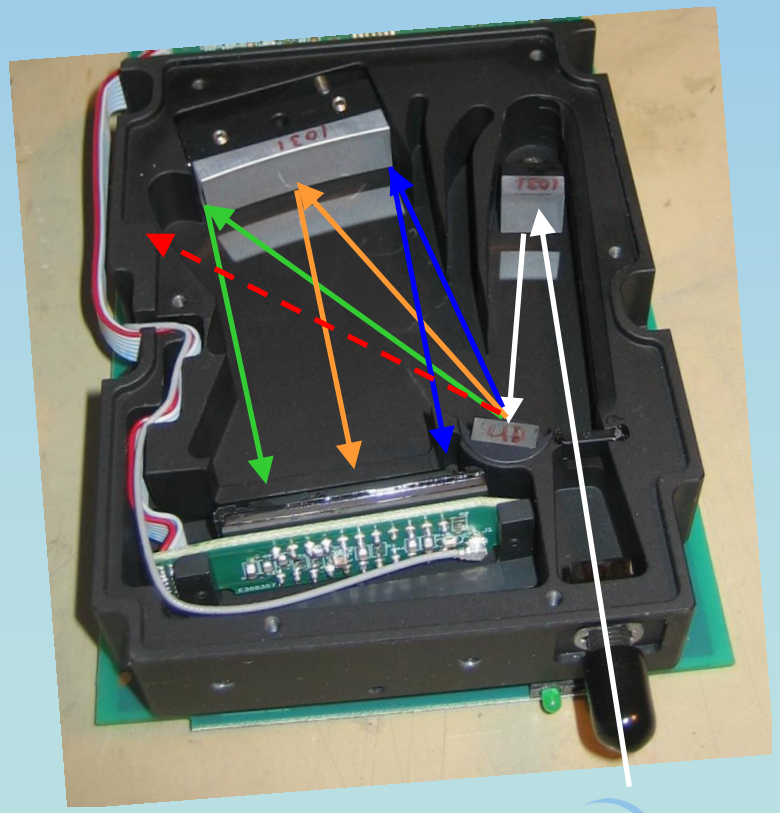
PMOD Intrument «AVOS»

Avantes AvaSpec ULS2048 /CCD Hamamatsu back illuminated

Wavelength: 280 – 390 nm **(<u>irregular grid</u>)**





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Adressing Data Post Processing

1. Data Acquisition
2. Linearity correction
3. Dark Measurements
4. Handling several integration times
5. Stray Light Corrrection
4. Bandwidth and wavelength correction / homogenization

   “Matshic”
5. Discussion of experience of users of other array

   spectroradiometers

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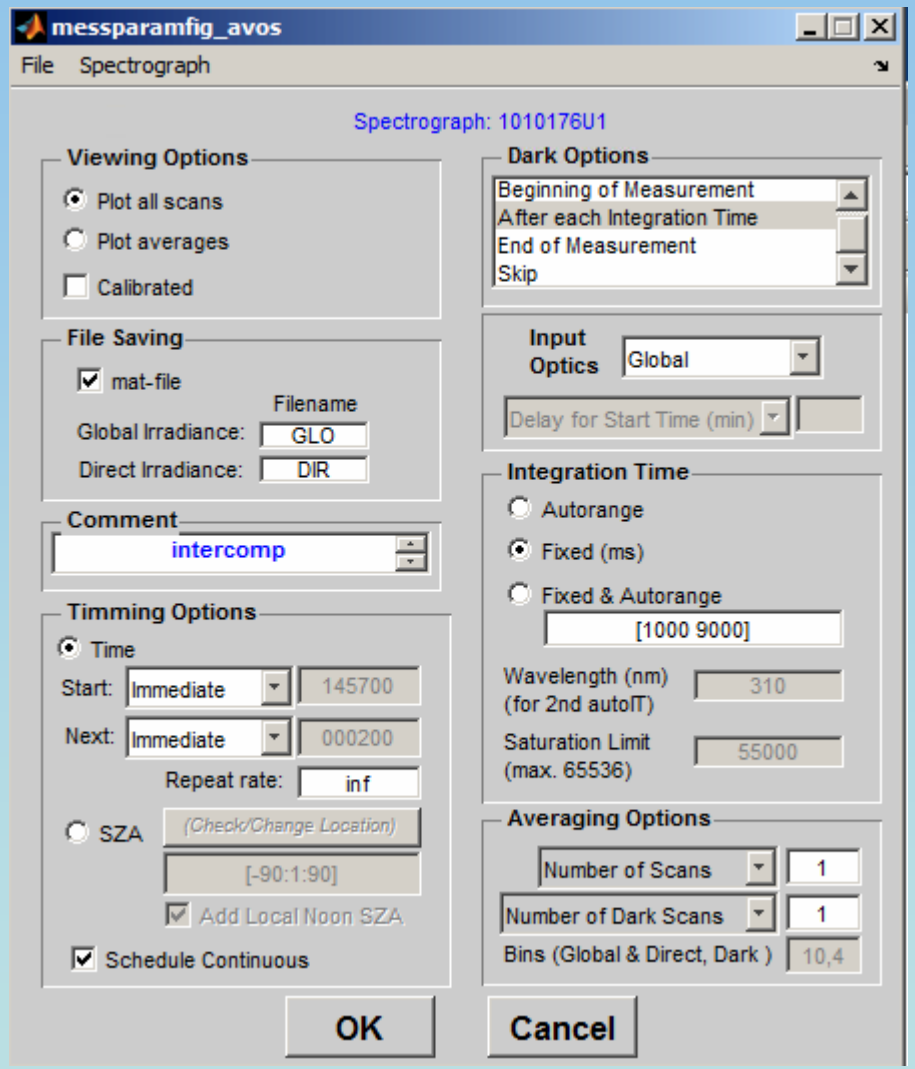
Data Acquisition

- Setting **integration** time and **dark measurement**



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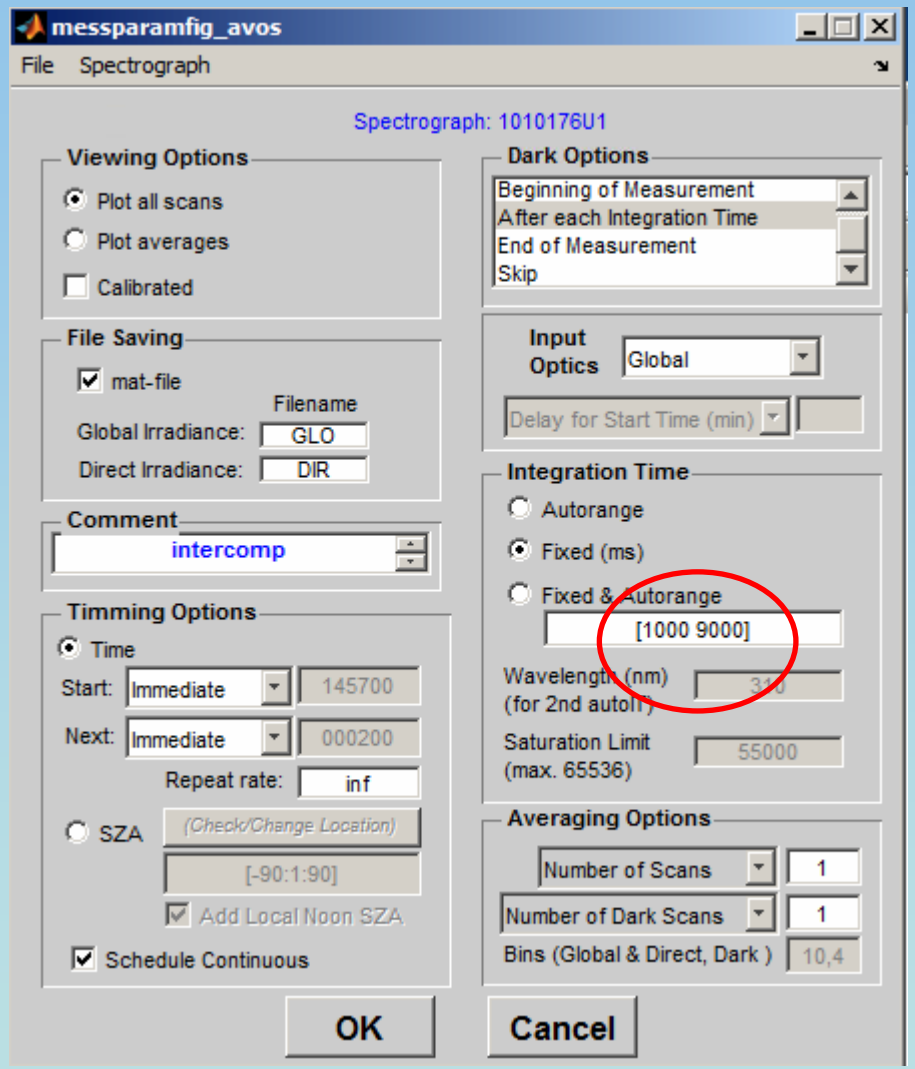
Data Acquisition

- Setting **integration** time



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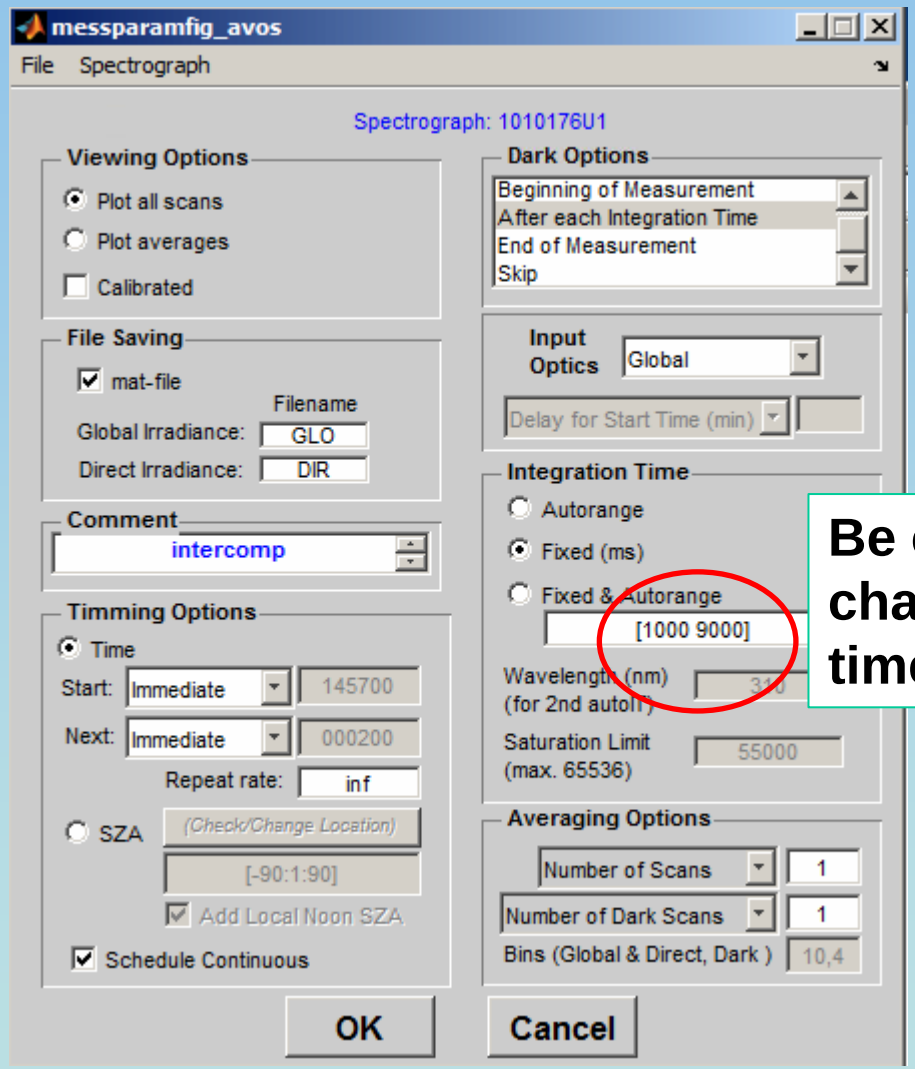
Data Acquisition

- Setting **integration** time



Be careful in changing Integration times !!

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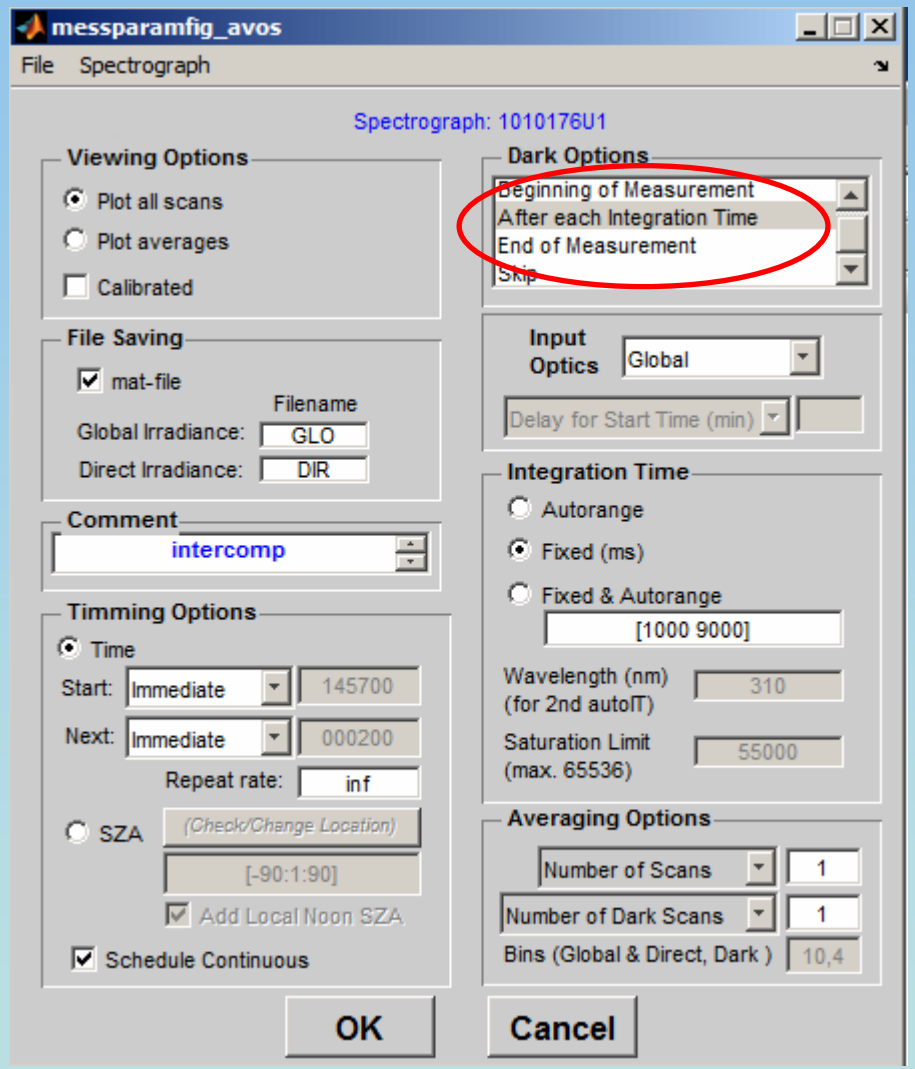
Data Acquisition

- Setting **dark measurement**



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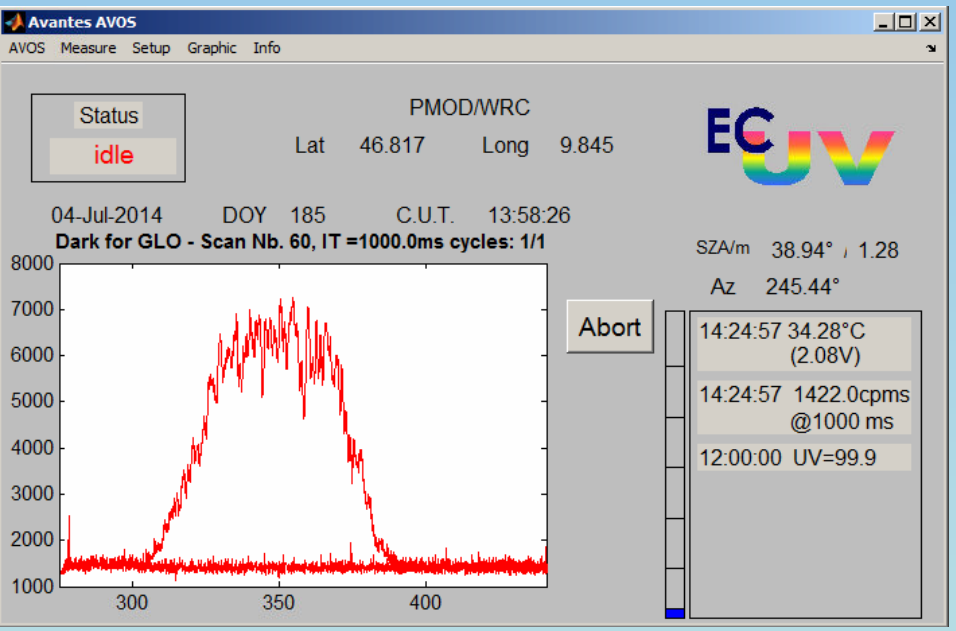
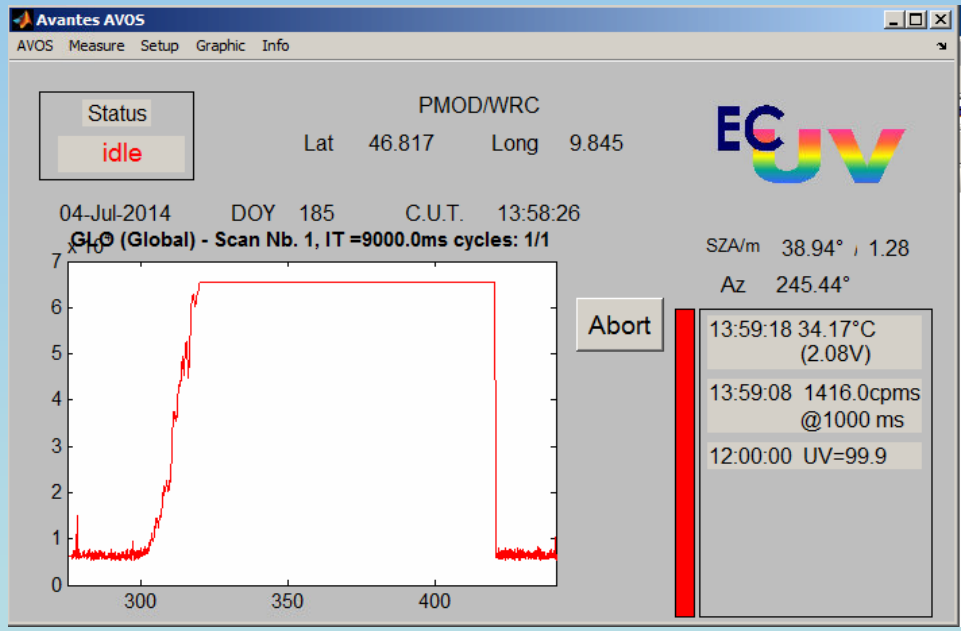
Data Acquisition

- Monitoring schedule

1000 ms



9000 ms



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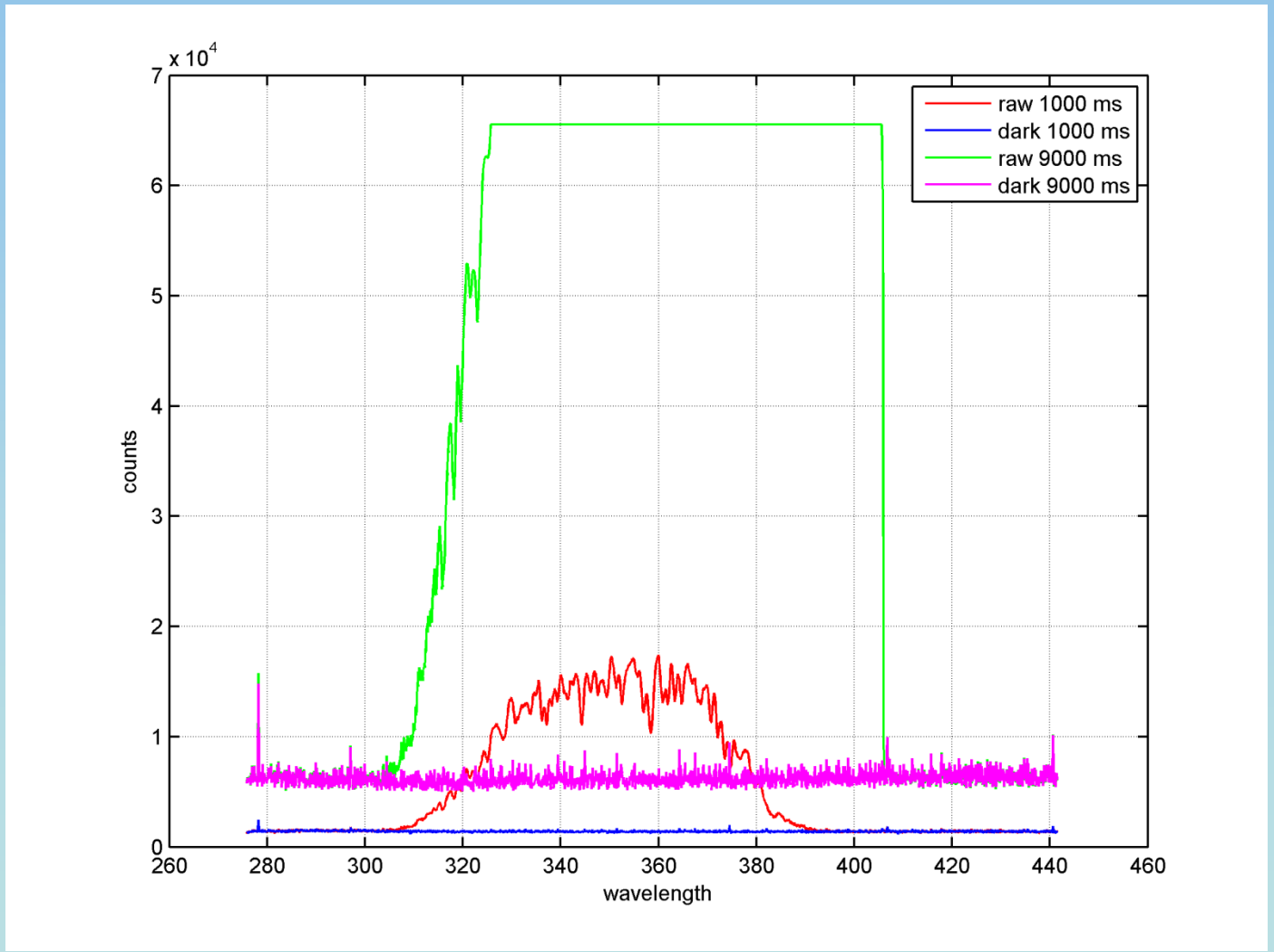
After Linearity correction: **Dark Measurements**

- Subtracting dark measurements for each scan and integration time



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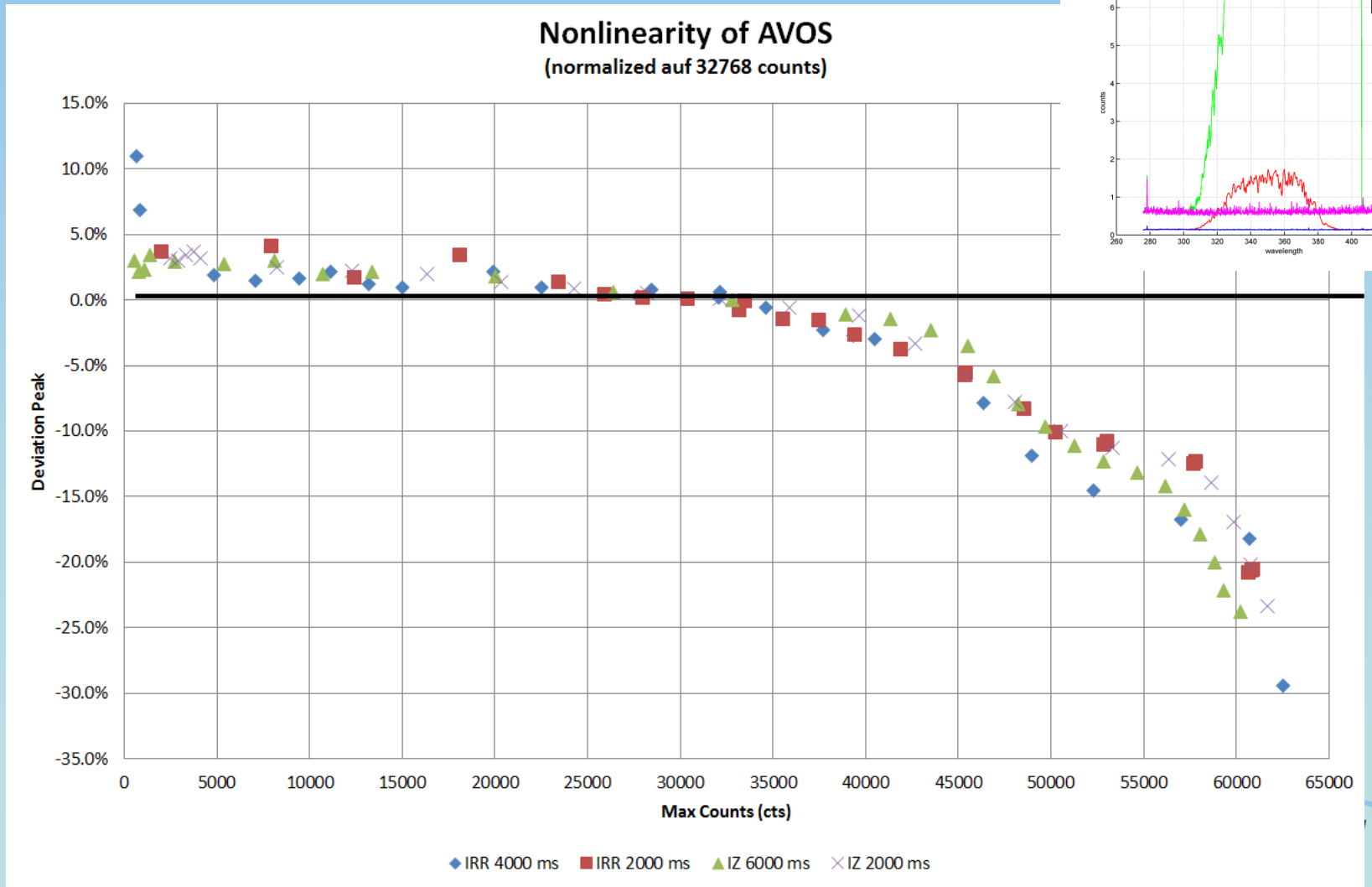
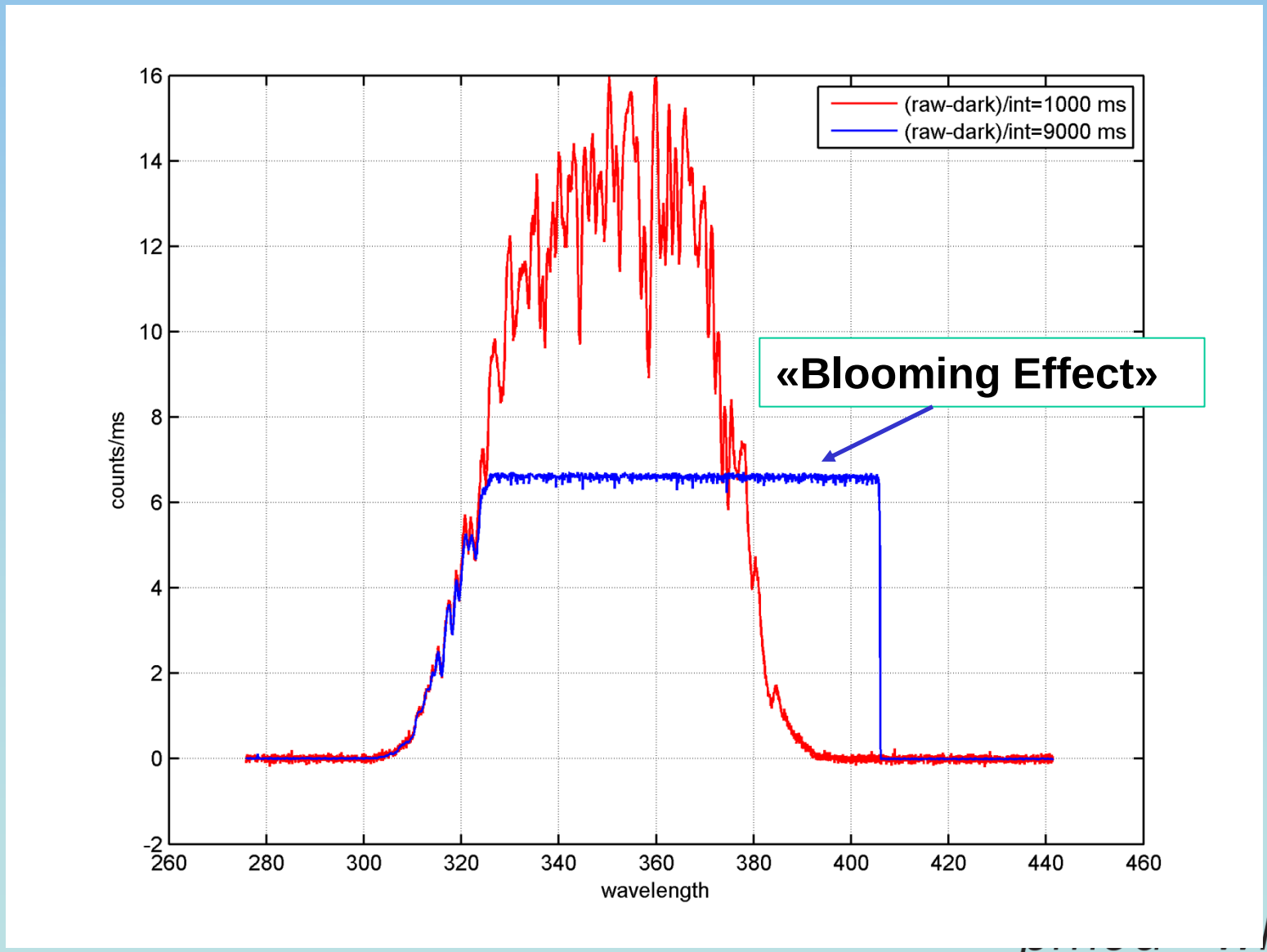
Linearity correction

- Correcting **raw signal (in counts)** for linearity



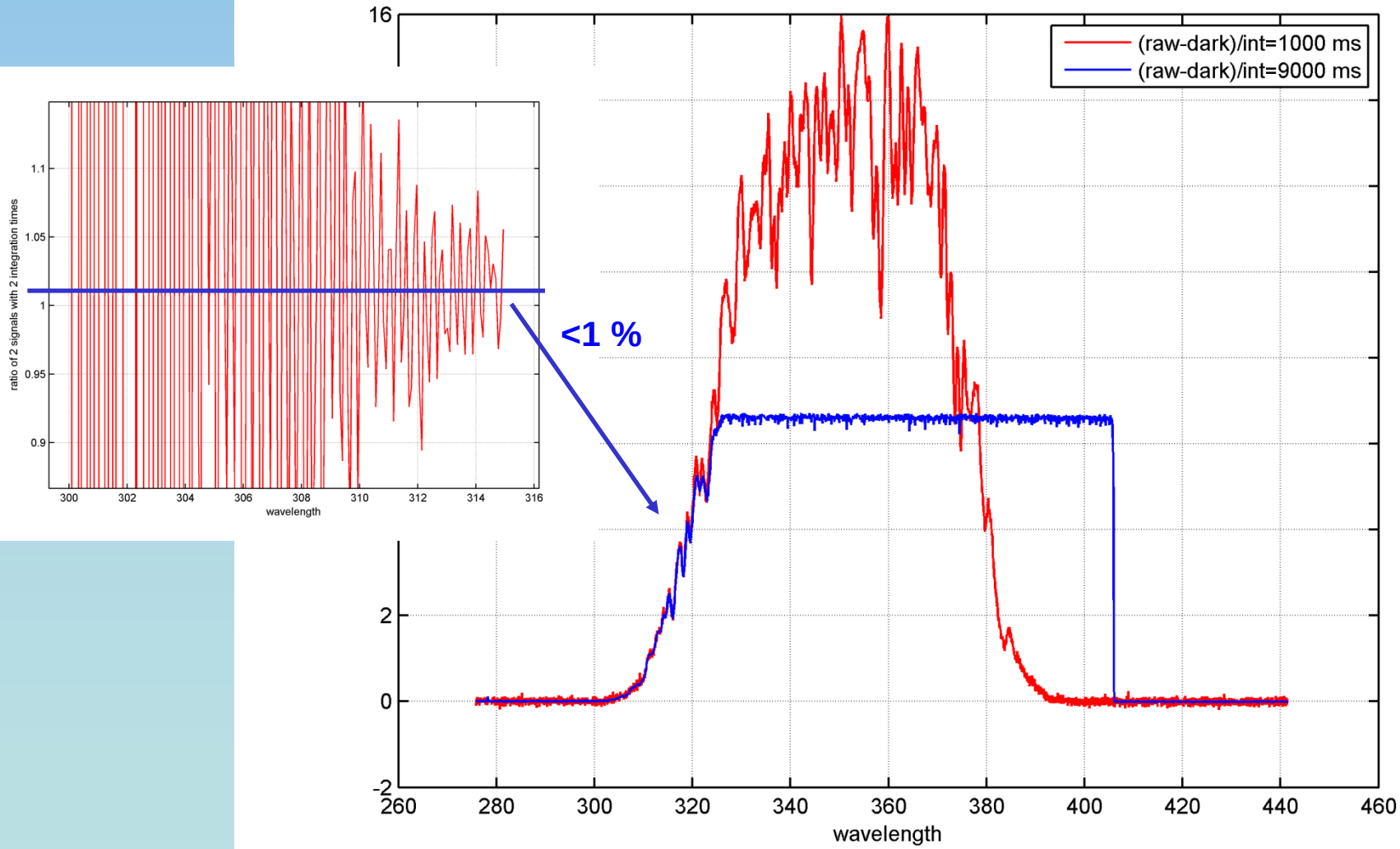
Normalized Signal

- Dividing to integration time **[counts/ms]**



Compariosn of normalized signal

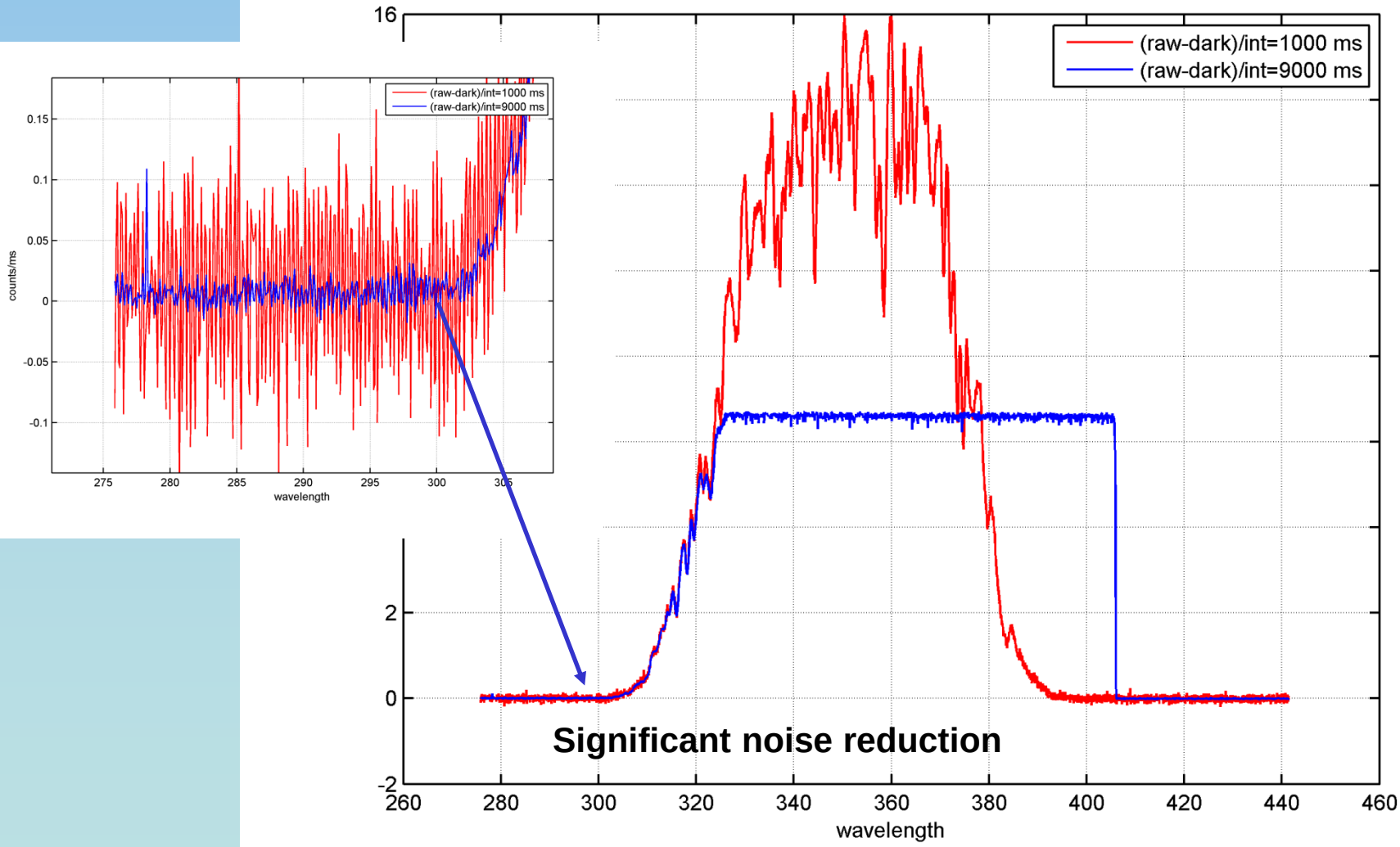
- Dividing to integration time **[counts/ms]**



Noise reduction

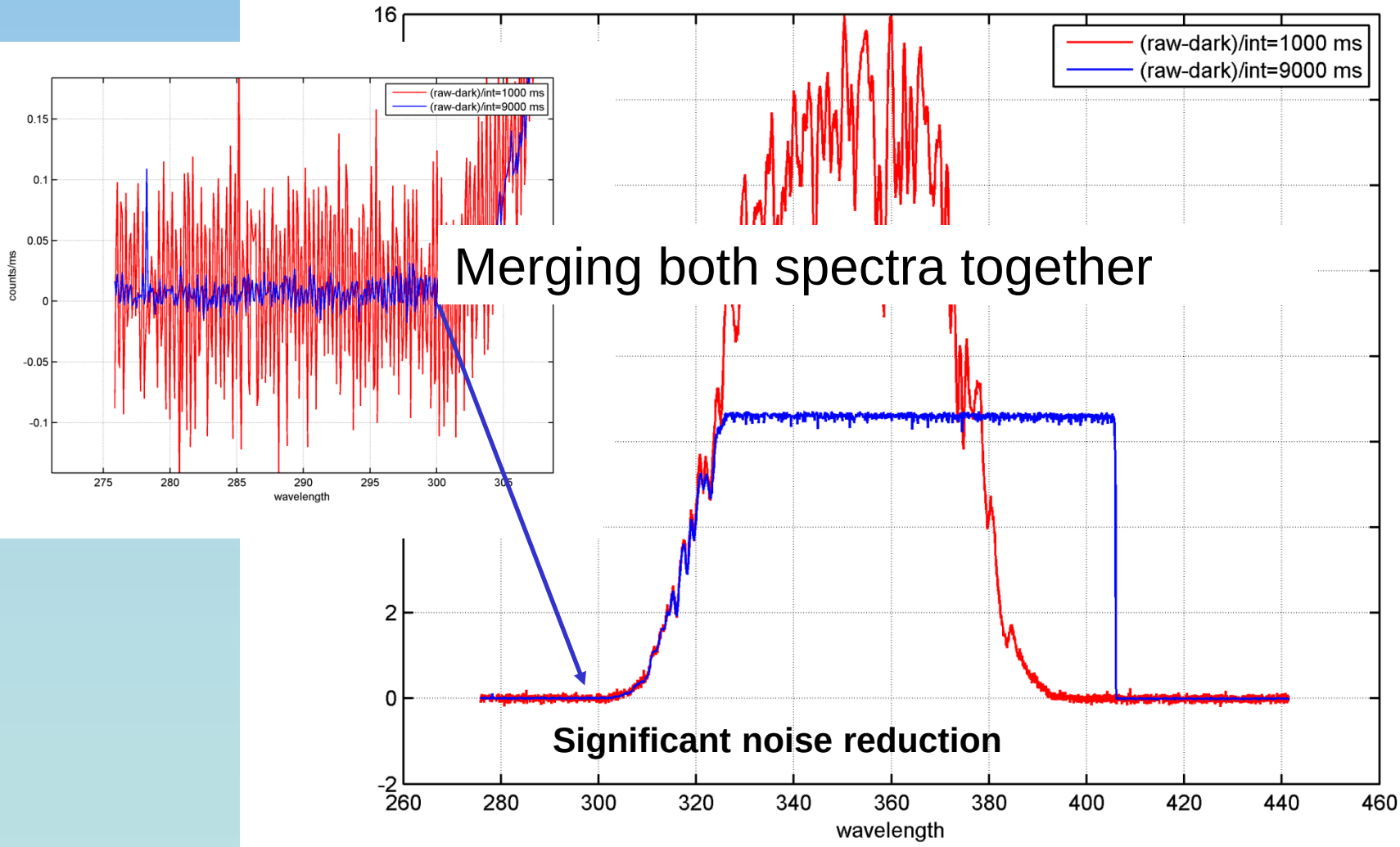
- Effect of longer integration time

Longer integration time reduce noise more than averaging several spectra!

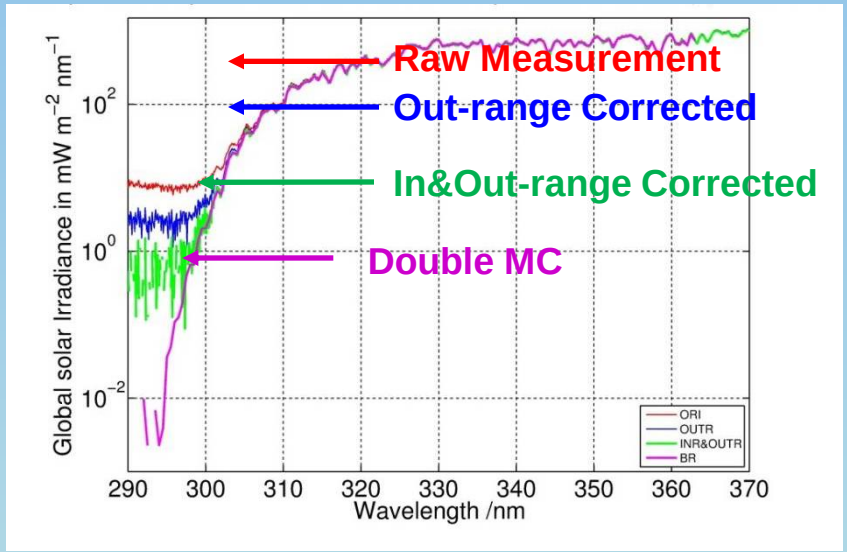


Merging

- Selecting best parts of the normalized signal

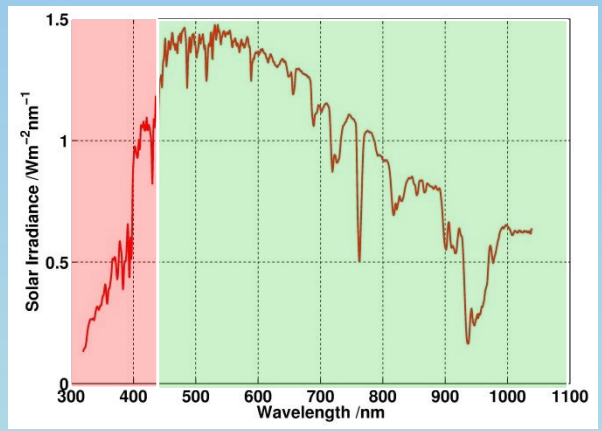


Stray Light Correction



This Array Spectroradiometer

- Nominal Sensitivity: **280 – 440 nm**
- Out-range Radiation from 440 nm to ~1100 (Silicon) nm

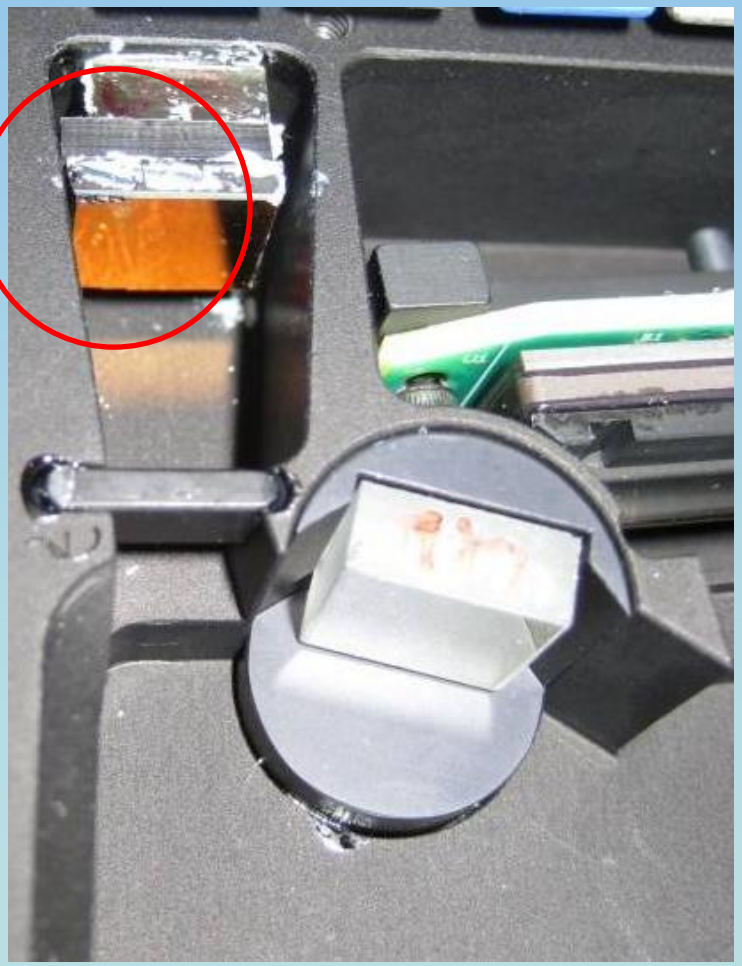


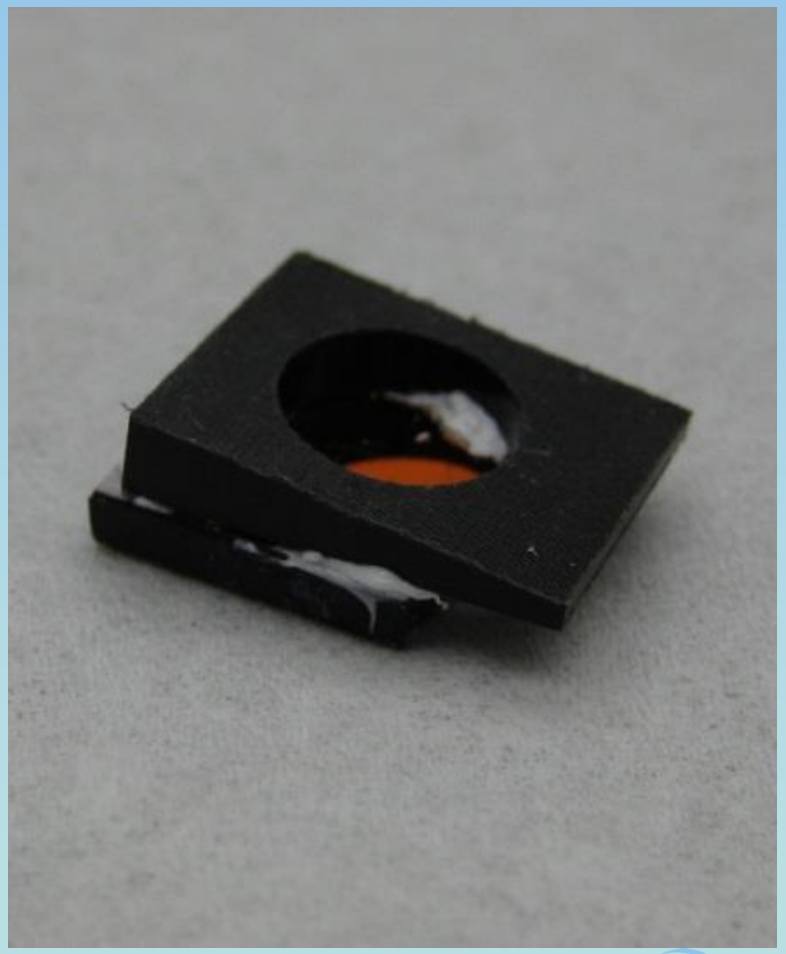
This instrument only In-Range stray light correction

pmod wrc

Modification of array spectroradiometer to suppress out-range radiation

We placed a **DUG11X solarblind filter** in the beam path to suppress out-range radiation in the sensi-tivity range of the silicon CCD detector (390-1100 nm).





pmod wrc

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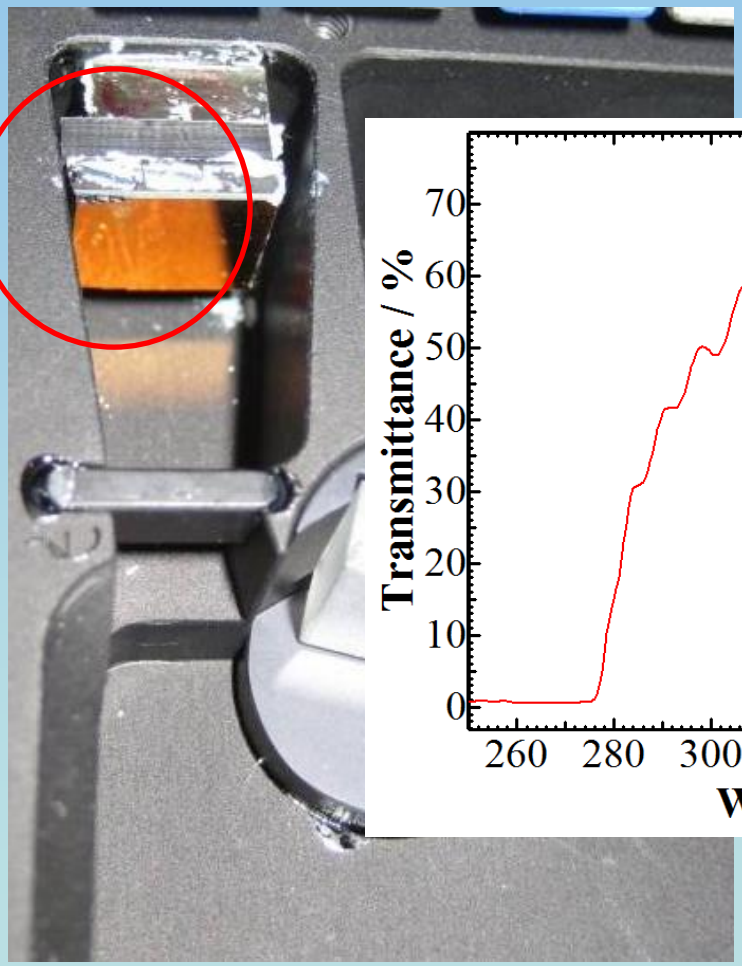
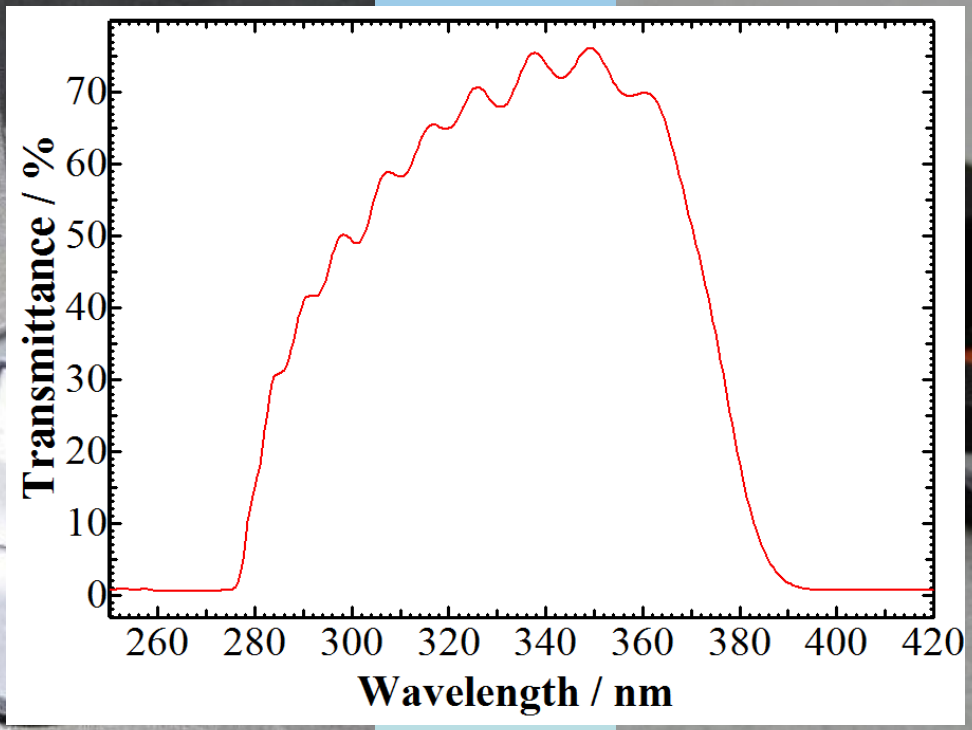
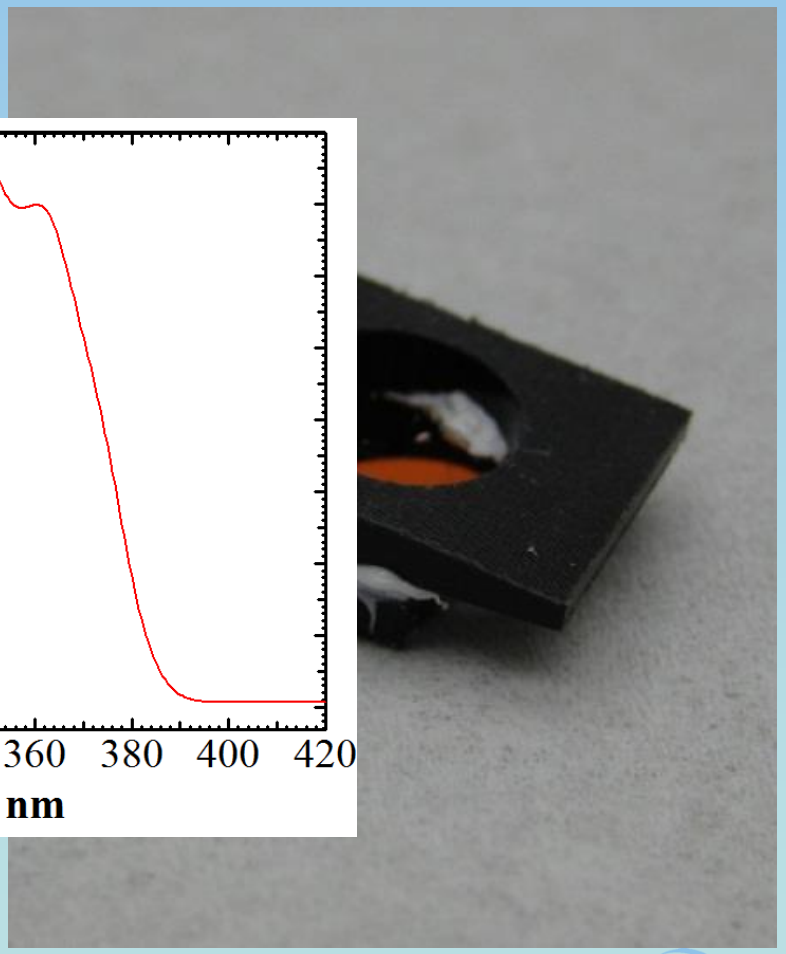
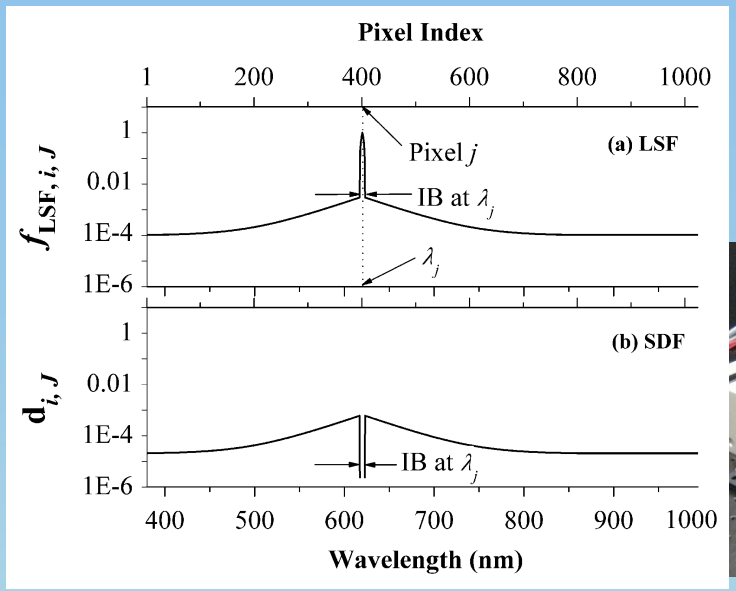






pmod wrc

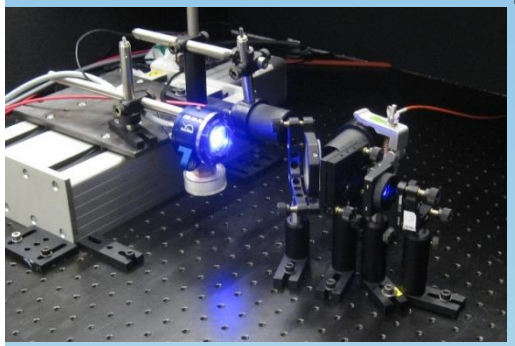
Stray light correction procedure for array spectroradiometer



$$\boldsymbol{Y}_{\mathrm{IB}} = \boldsymbol{A}^{-1} \cdot \boldsymbol{Y}_{\mathrm{meas}} = \boldsymbol{C} \cdot \boldsymbol{Y}_{\mathrm{meas}}$$

from Zong et al, 2006

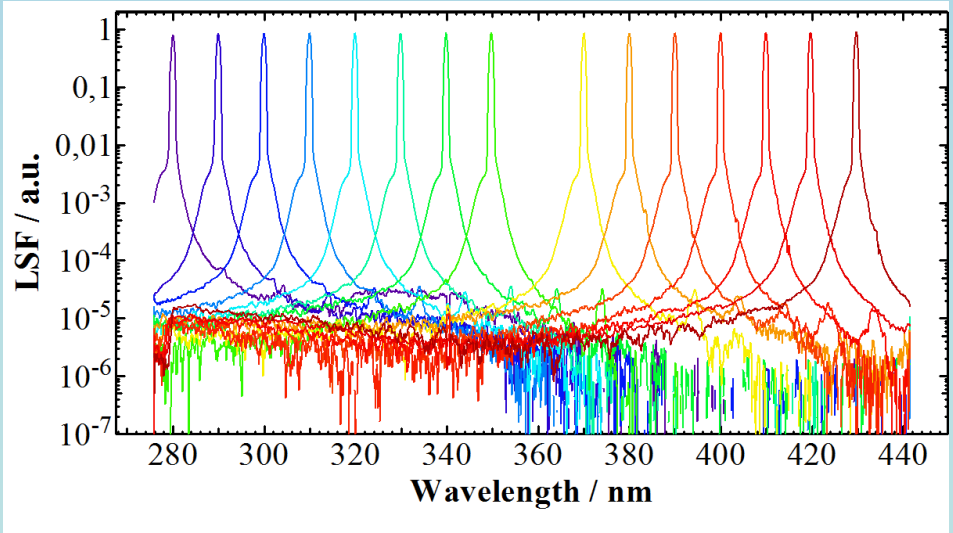
In-range straylight matrix



$$\boldsymbol{\Delta} = \mathbf{s}_{\mathrm{OoR}} \cdot \mathbf{E}_{\mathrm{OoR}} \cdot \delta\lambda\,,$$

OoR straylight (Nevas et al. 2012)

Slit Functions obtained from tunable laser setup (PLACOS-PTB) - > **creating matrix**



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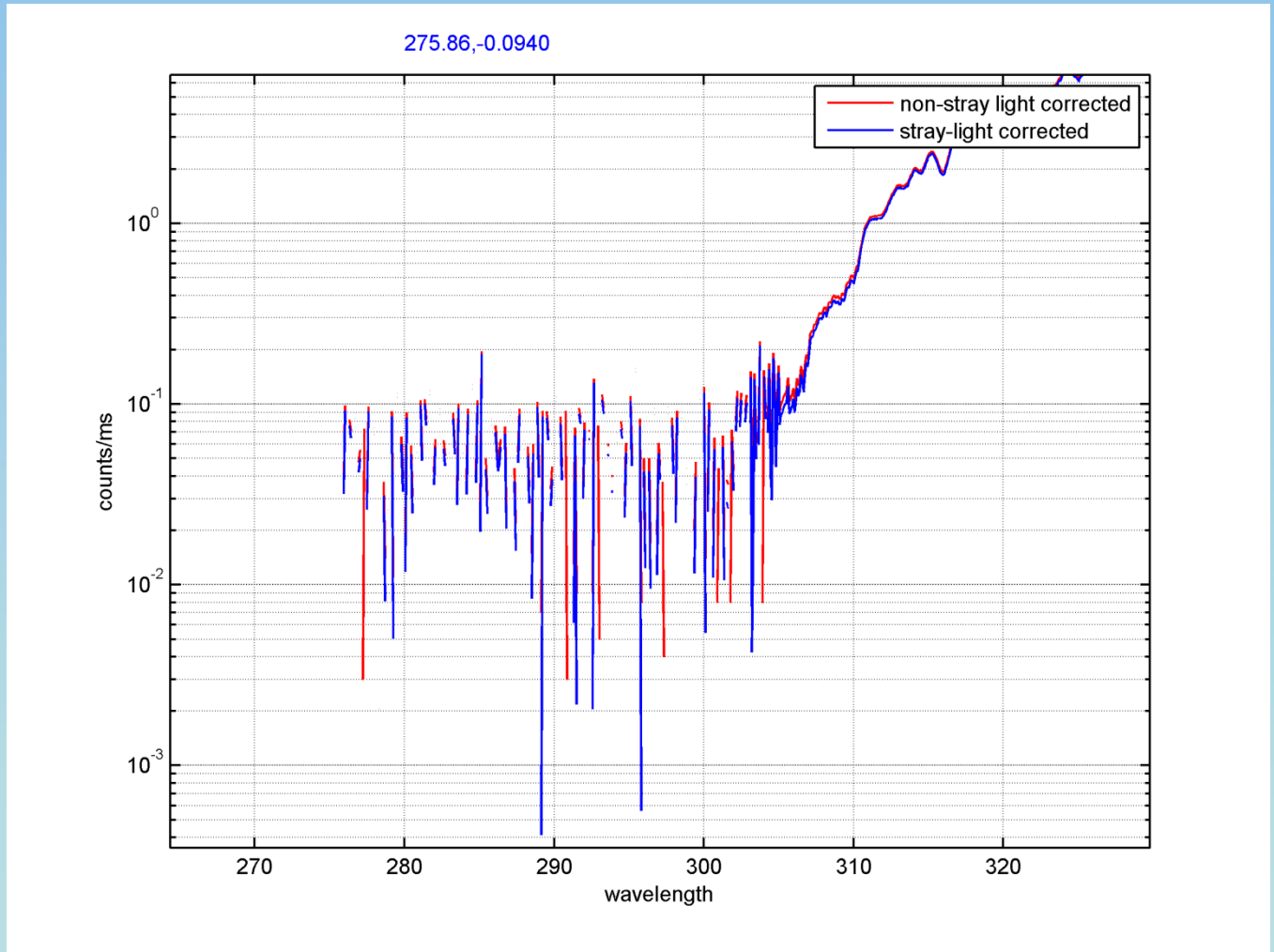
Applying Stray Light Correction

- Linear corrected and normalized signal **[counts/ms]**

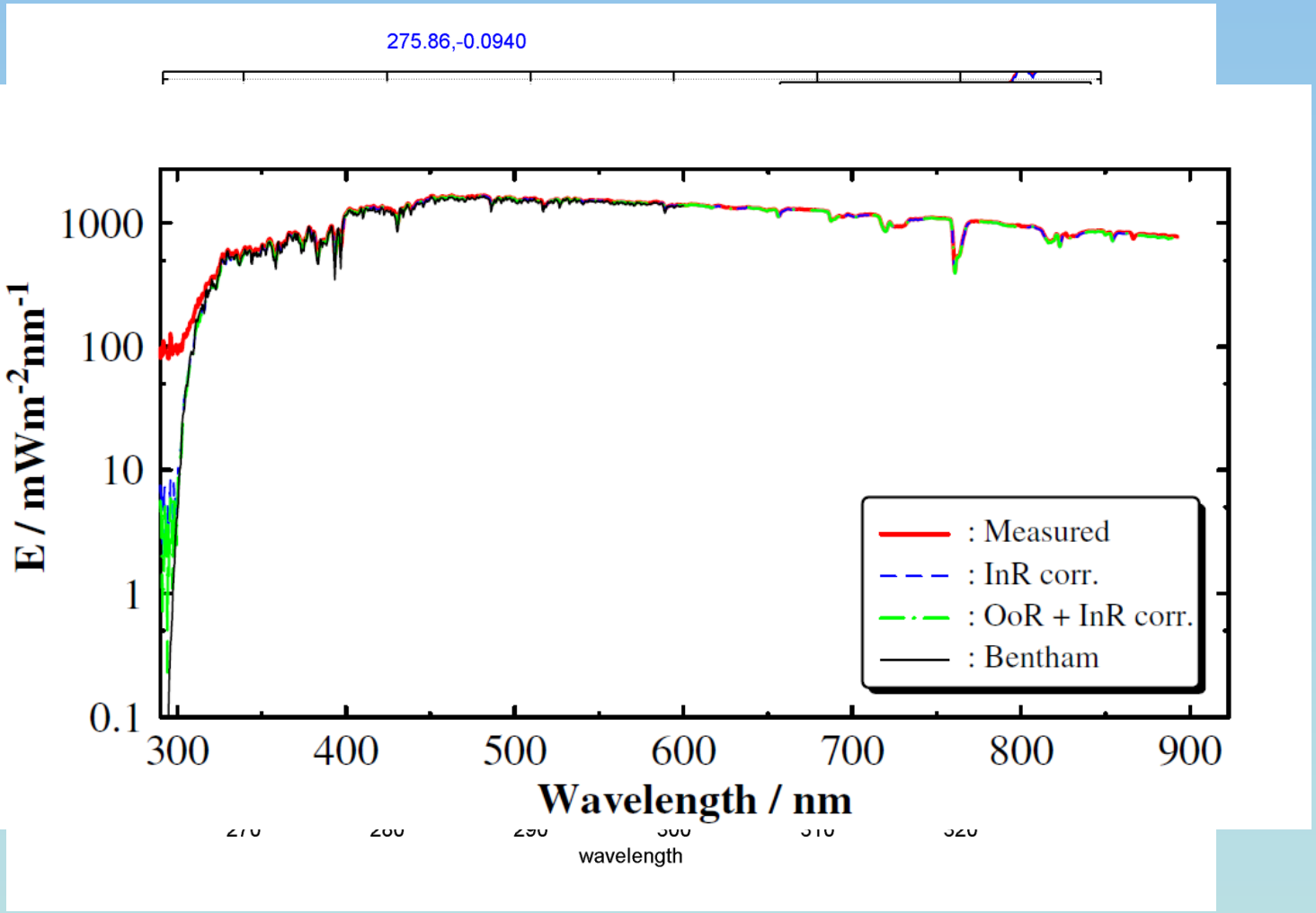


This instrument only In-Range stray light correction between 280 and 390 nm

pmod wrc

Applying Stray Light Correction

- Linear corrected and normalized signal **[counts/ms]**



This instrument only In-Range stray light correction between 280 and 390 nm

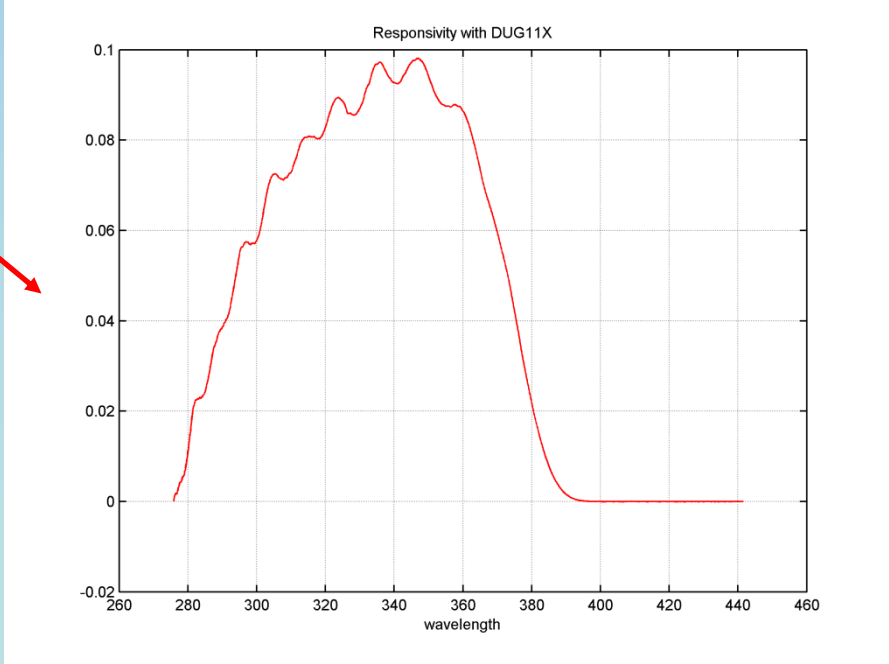
pmod wrc

Responsitity

- Measuring standard lamp

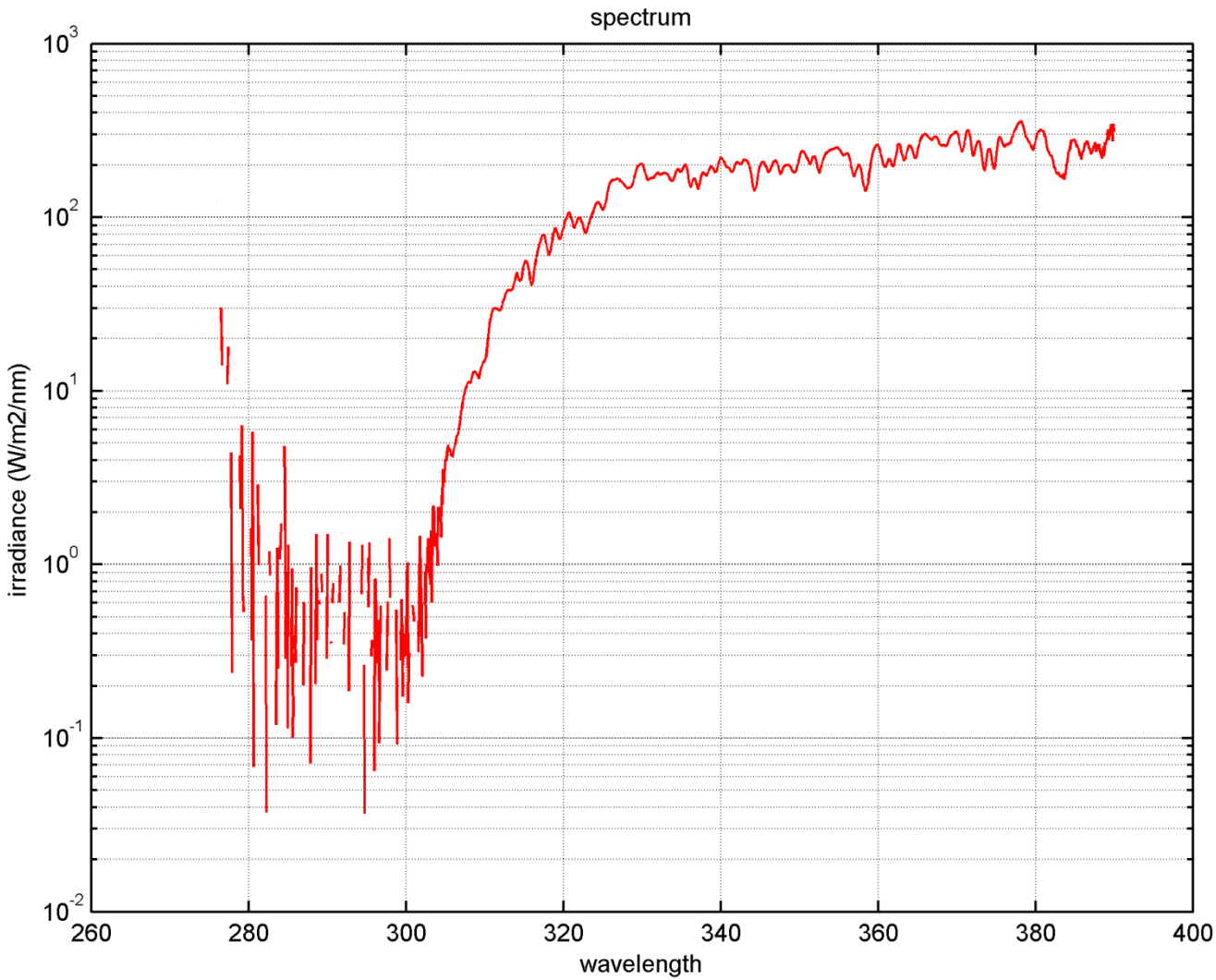
- Using same procedure as above:
  - **Linear correction of raw signal and dark measurements**
  - **Stray light correction**

- Calculate **responsivity** in **[counts/ms** -> measured **/ (W/m² /nm)** -> known lamp**]**



Final spectrum

- Measurements (**counts/ms**) divided by responsivity



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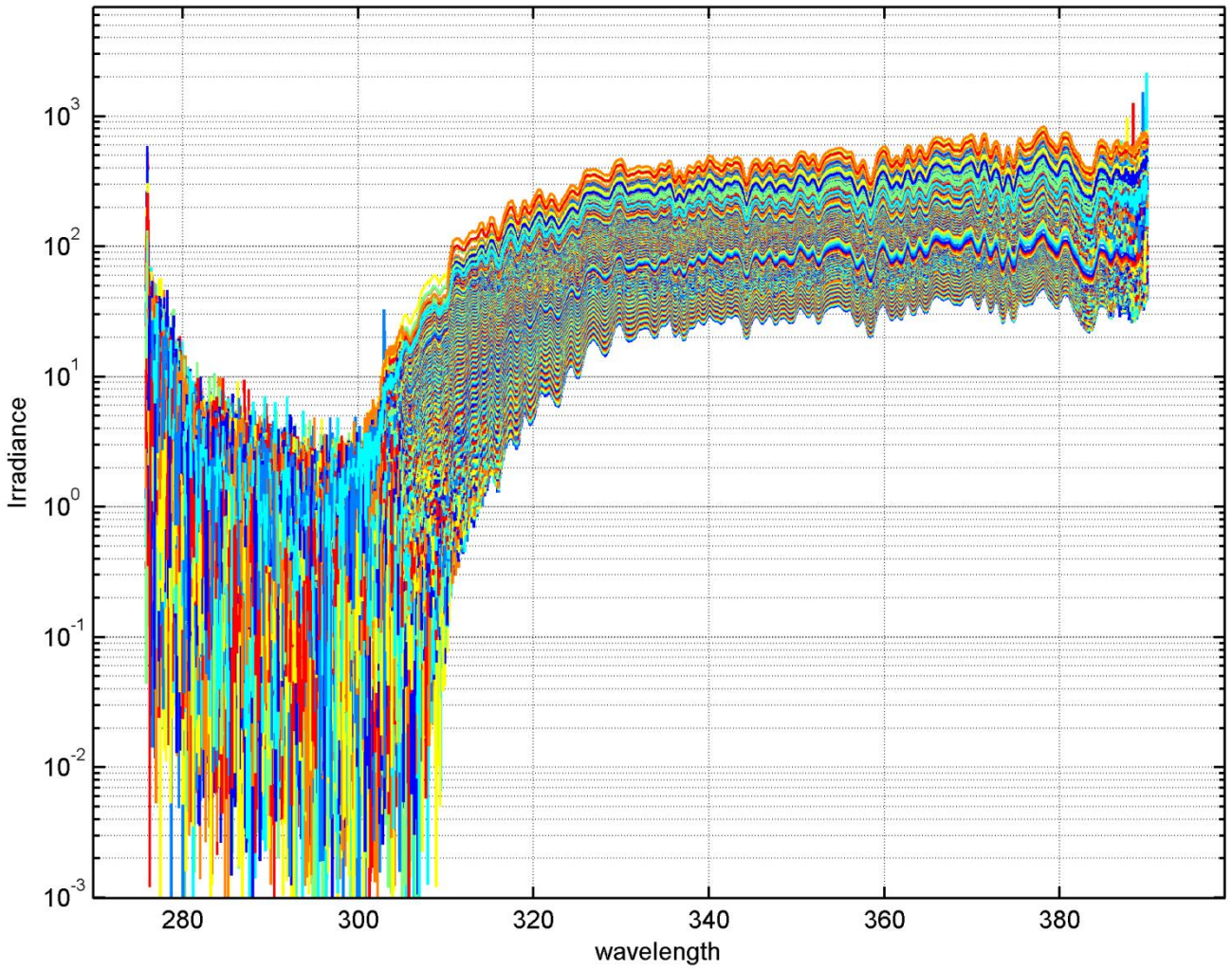
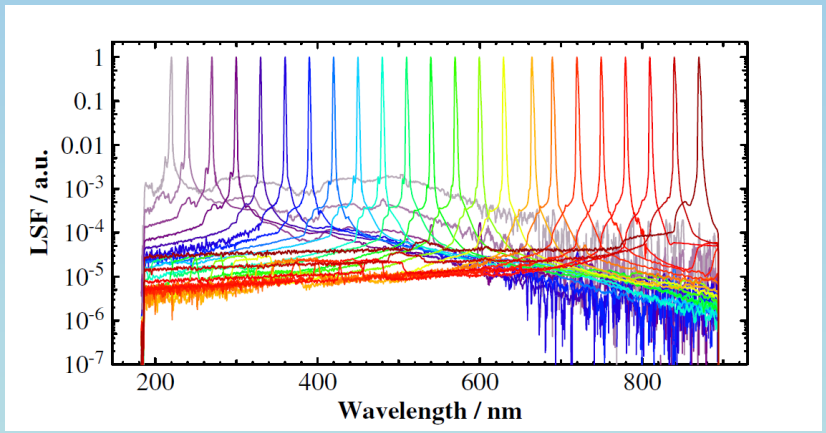


Bandwith and Wavelength Homegenization

- **Problem:**

  - **Irregular grid** of wavelength from array spectroradiometer
  - **Shift of wavelength** (non ideal characterization pixel – wavelength)
  - **Variable slit functions** on array spectroradiometer depending on wavelength



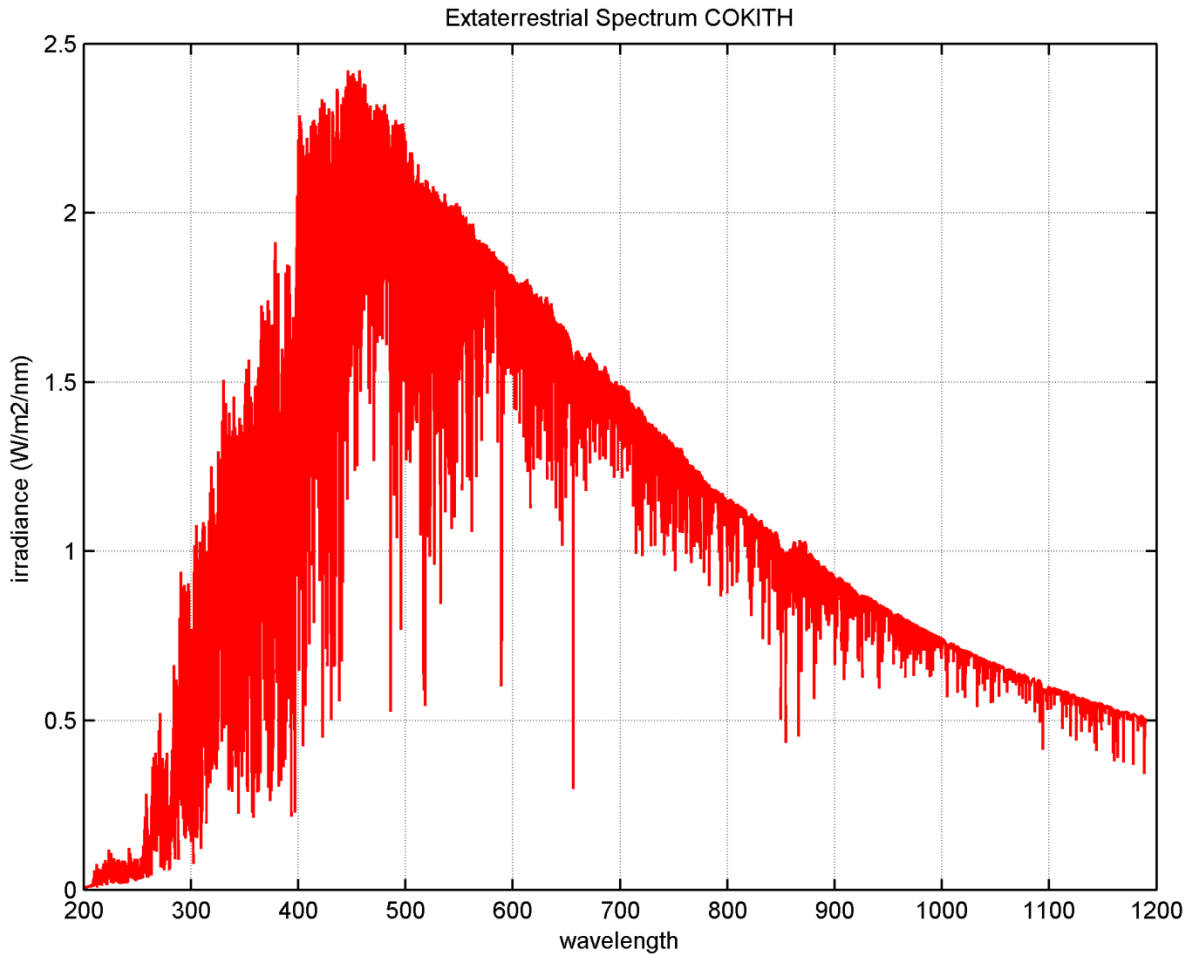
- **Objective:**

  - **Regular grid** of wavelengths (no splining!)
  - Correction for **Wavelength-Shift**
  - Nominal slit function for all wavelengths instead of **variable slit functions** from array spectroradiometer

pmod wrc

Matshic

- **1. Extra-Terrestrial Spectrum ET (MHP-COKITH)**
  - wavelength step 0.01 nm, bandwidth 0.05 nm (Validated from 290 – 500 nm)



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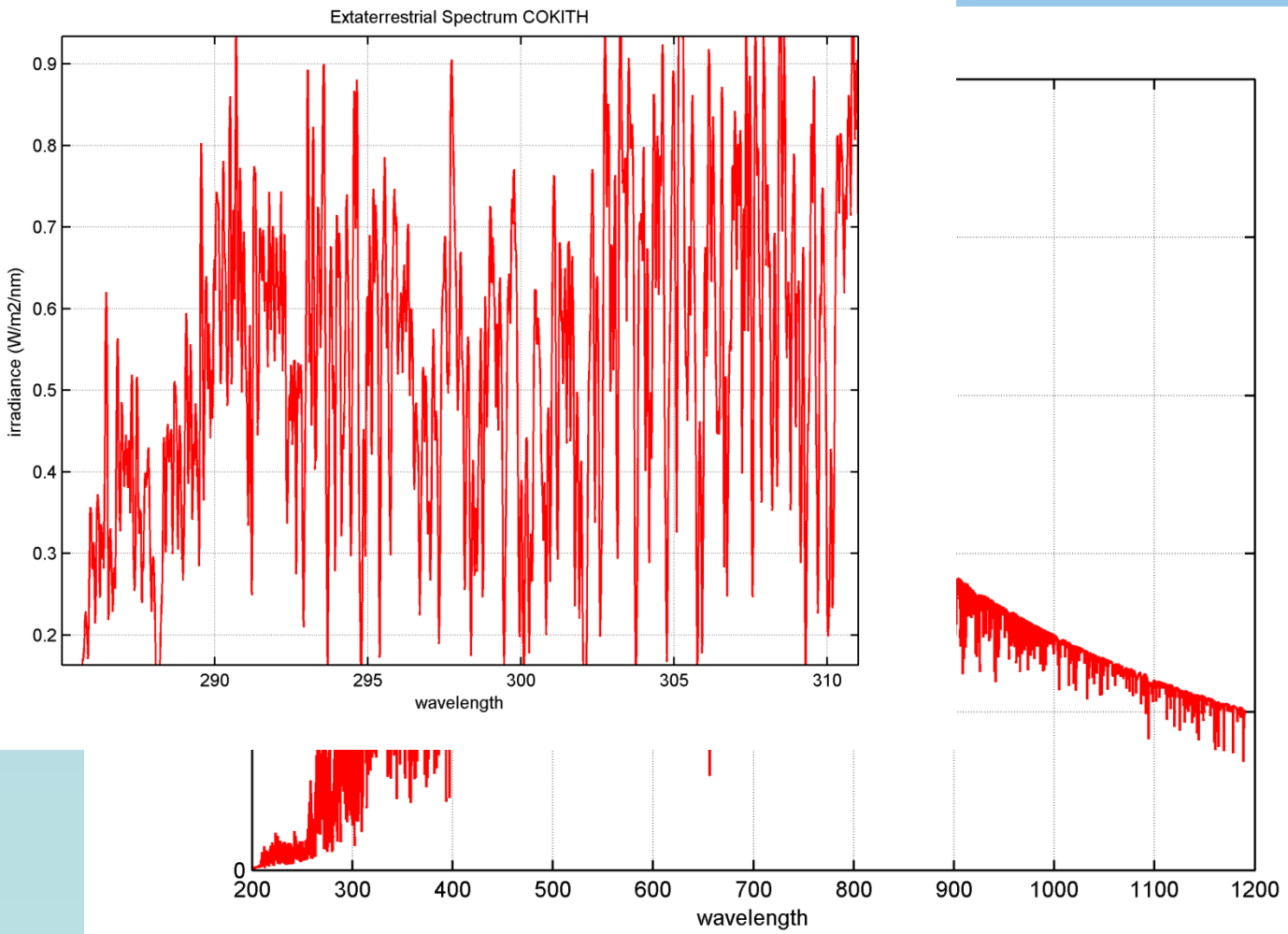
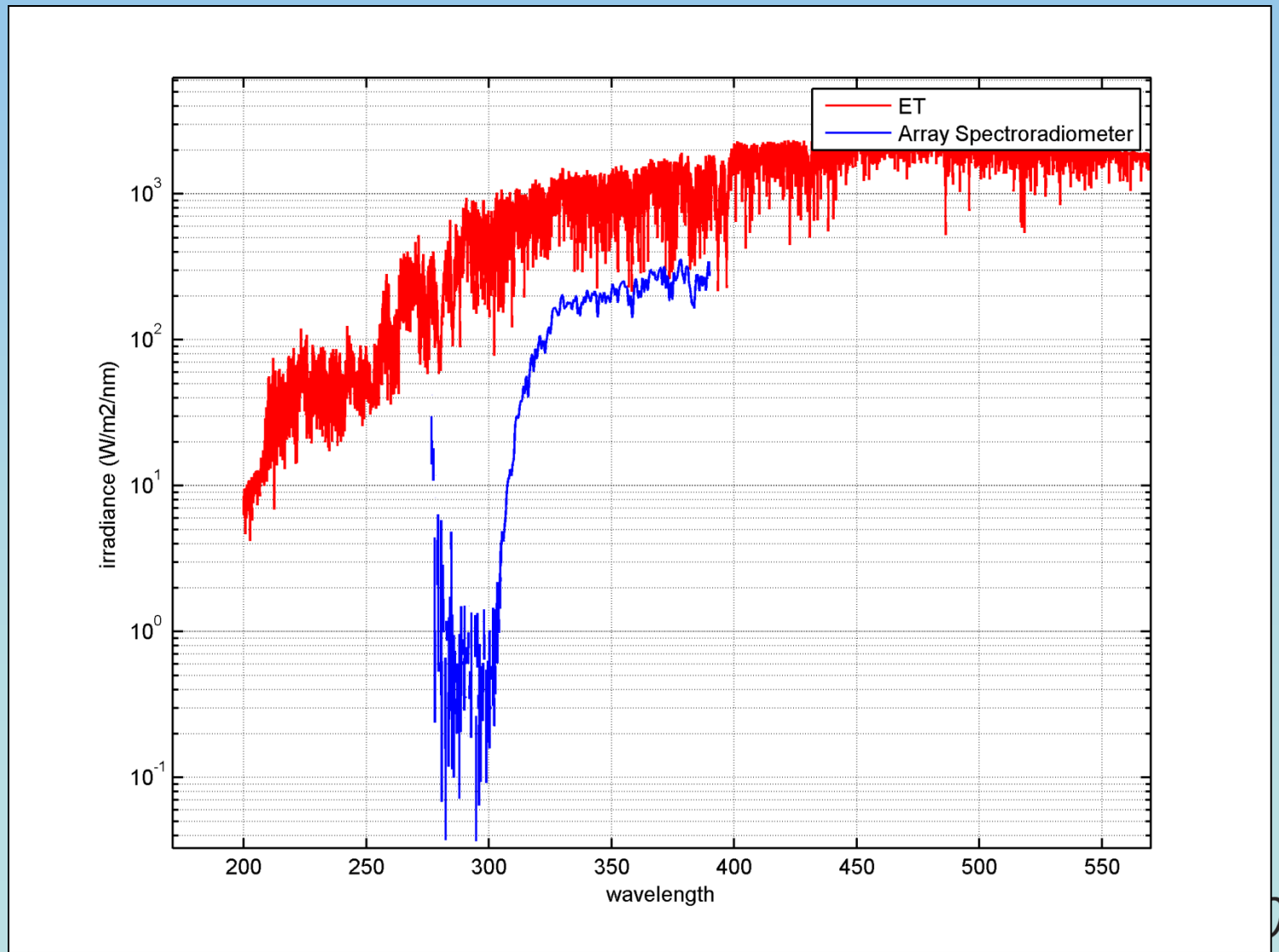


Matshic

- 2. **Relation** between ET and measured Spectrum



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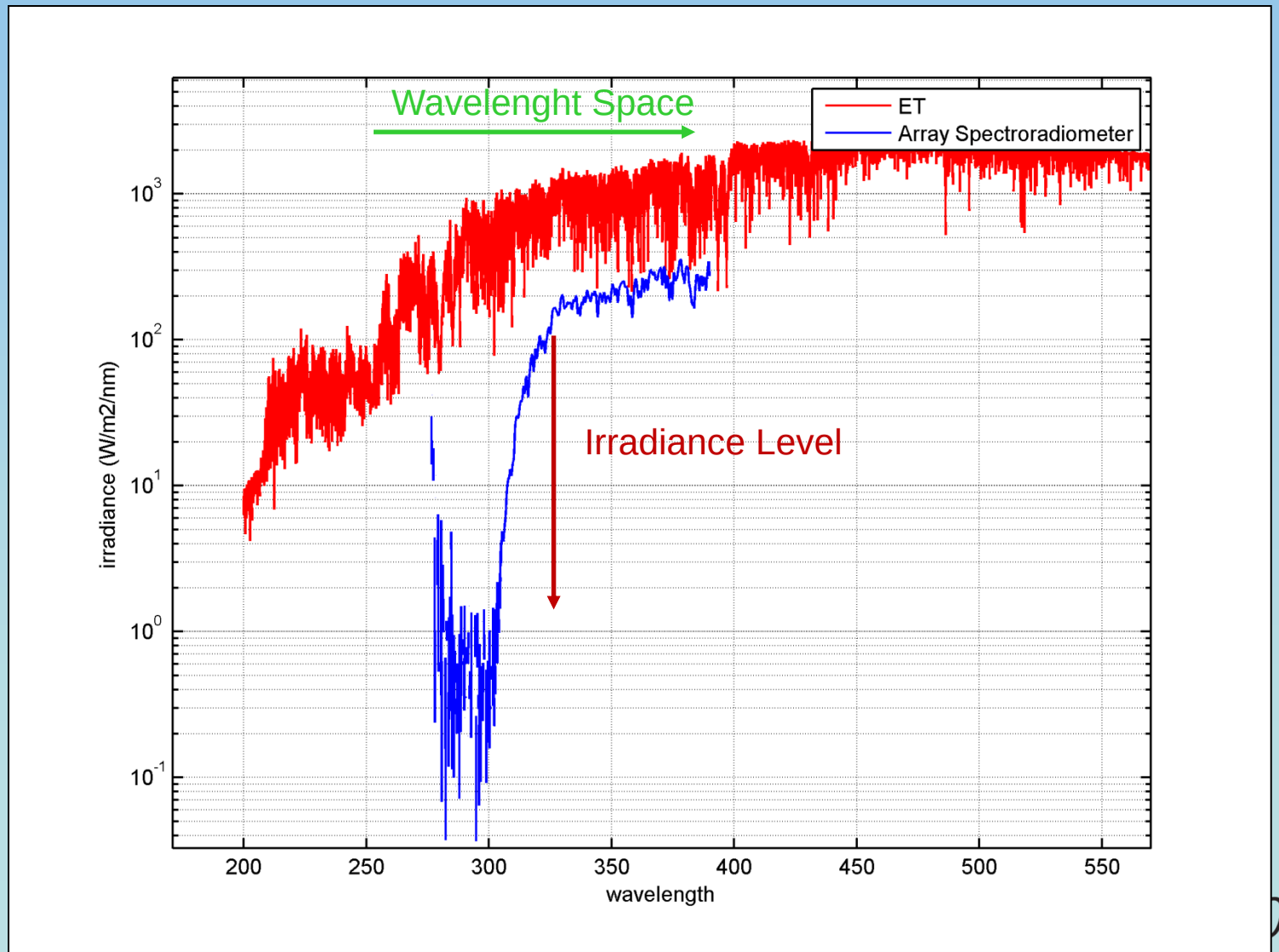
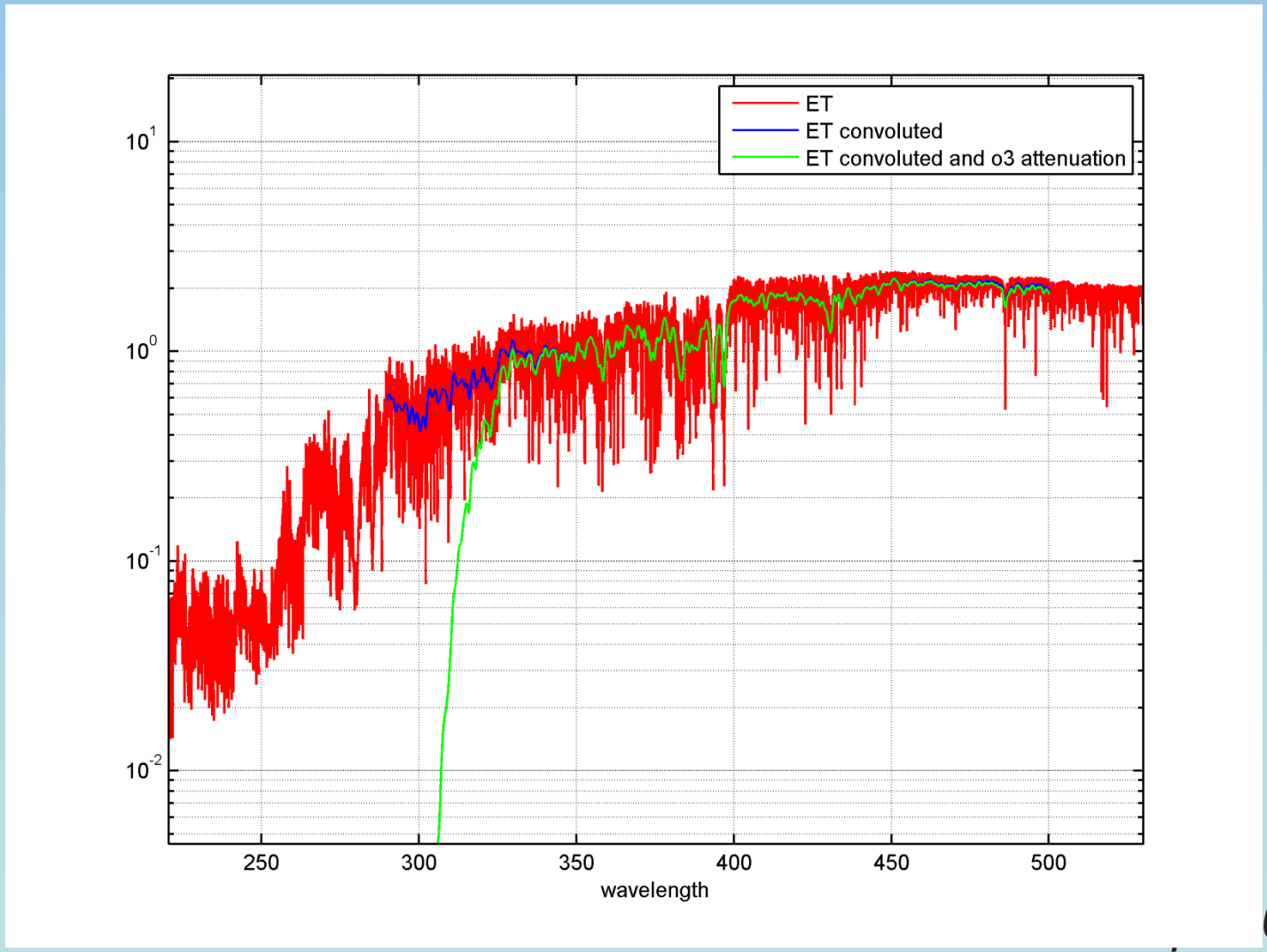


Matshic - Procedure

a) convoluting ET - using the instruments (variable) slit function

b) determine O3 attenuation



Matshic - Procedure

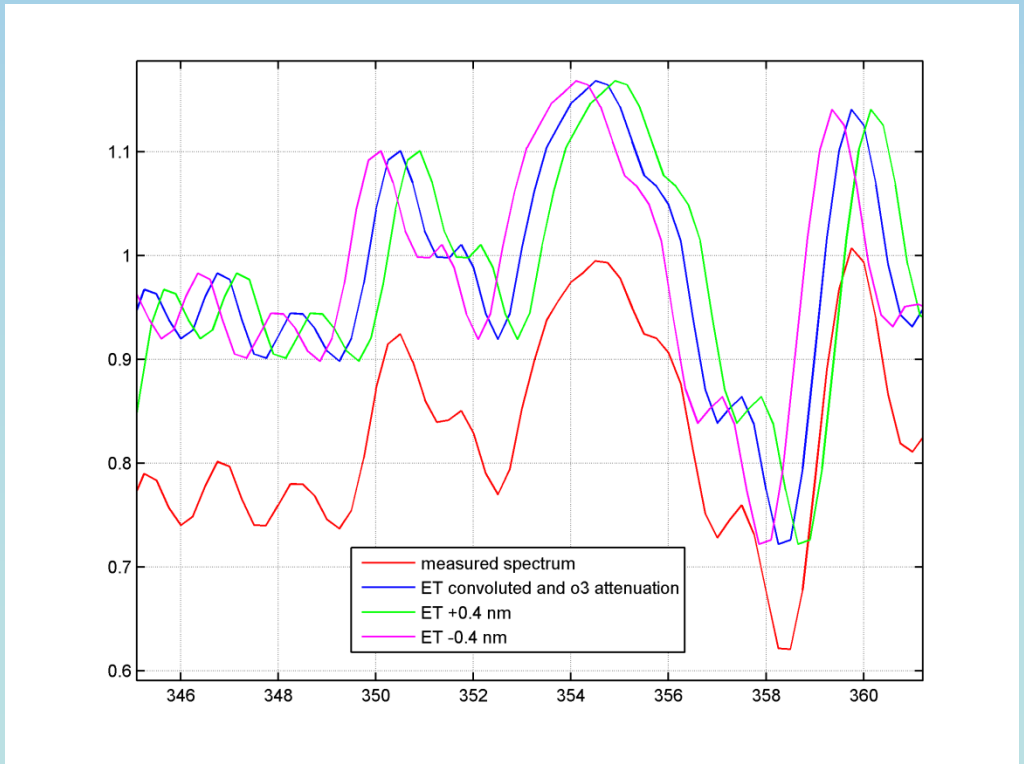
a) comparison of measured spectrum with processed ET

b) shift the ET for wavelength in 0.005 nm step.

c) determine the best congruence of measurements with ET for all **wavelengths-steps** and **all wavelength** of the array spectroradiometer

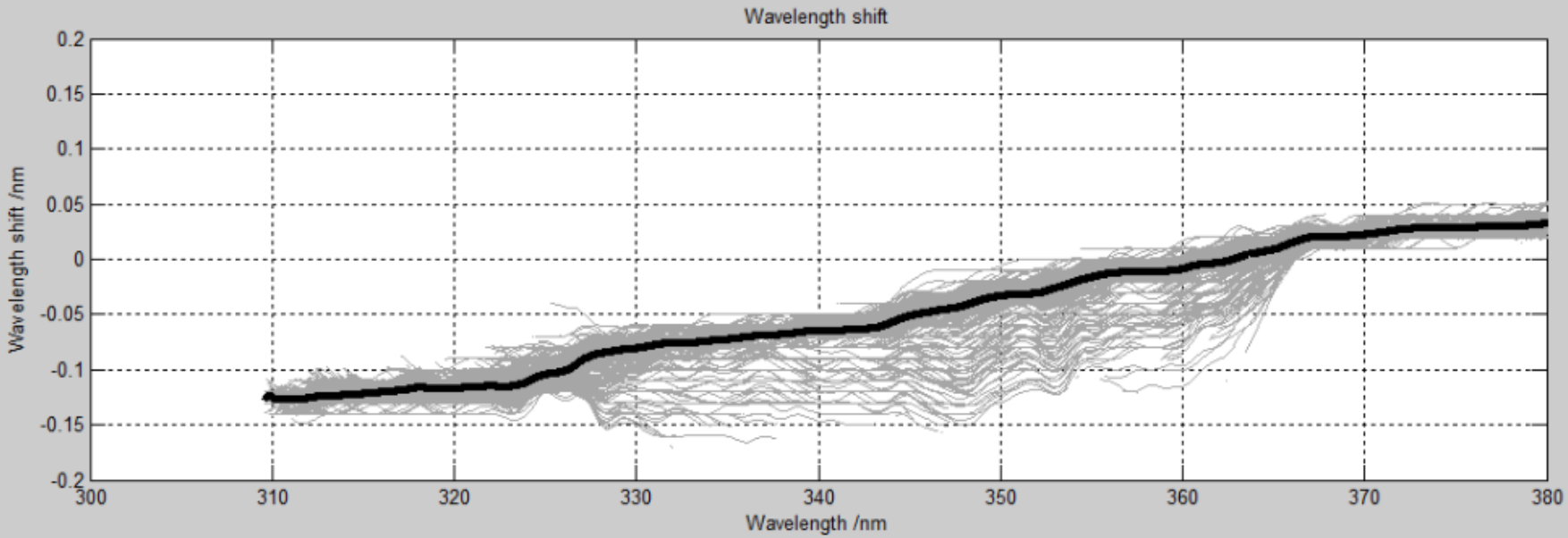
d) applying the best wavelength shift to the ET

e) applying measured irradiance scale to the ET with selectable:
bandwidth & wavelength grid



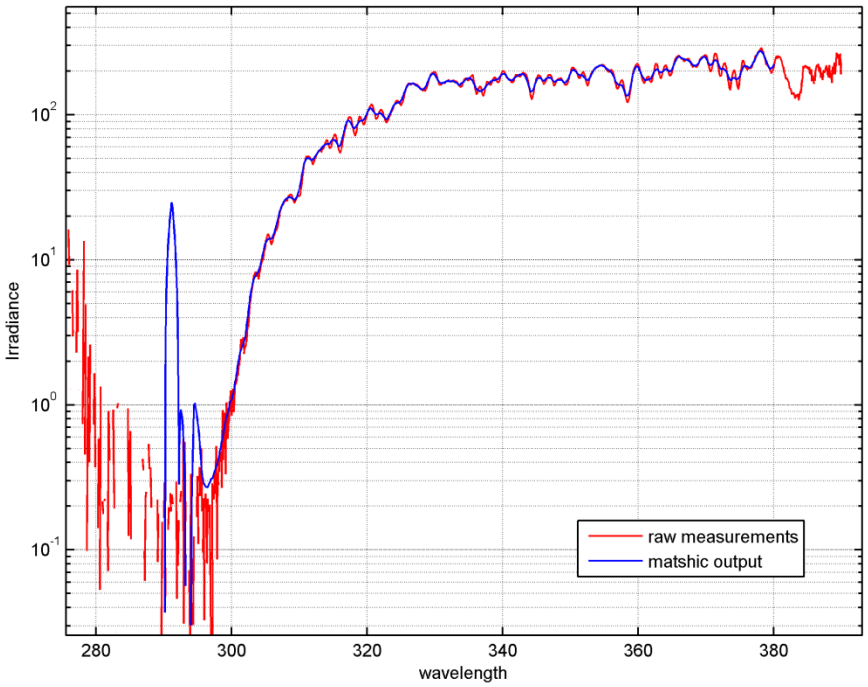
pmod wrc

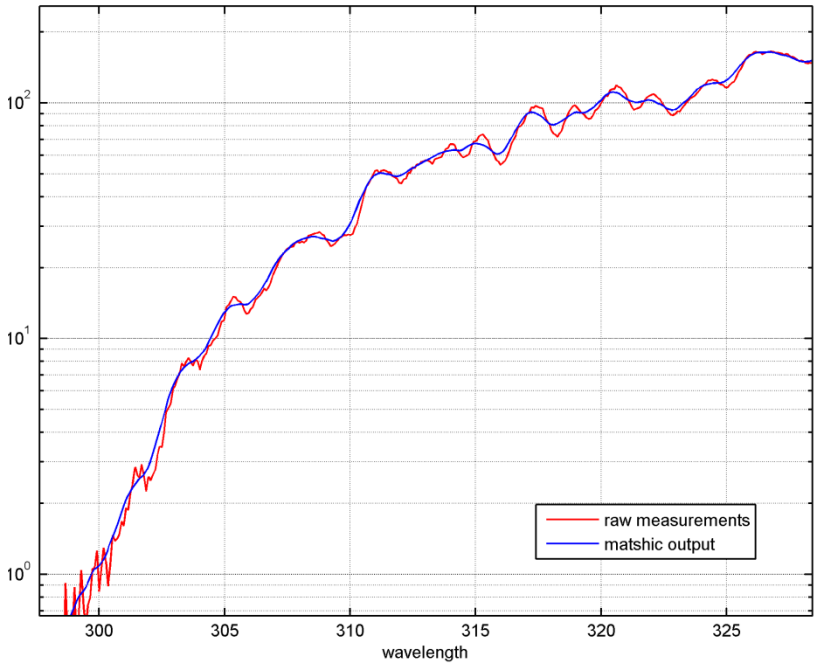
Matshic Results



pmod wrc

Matshic Result

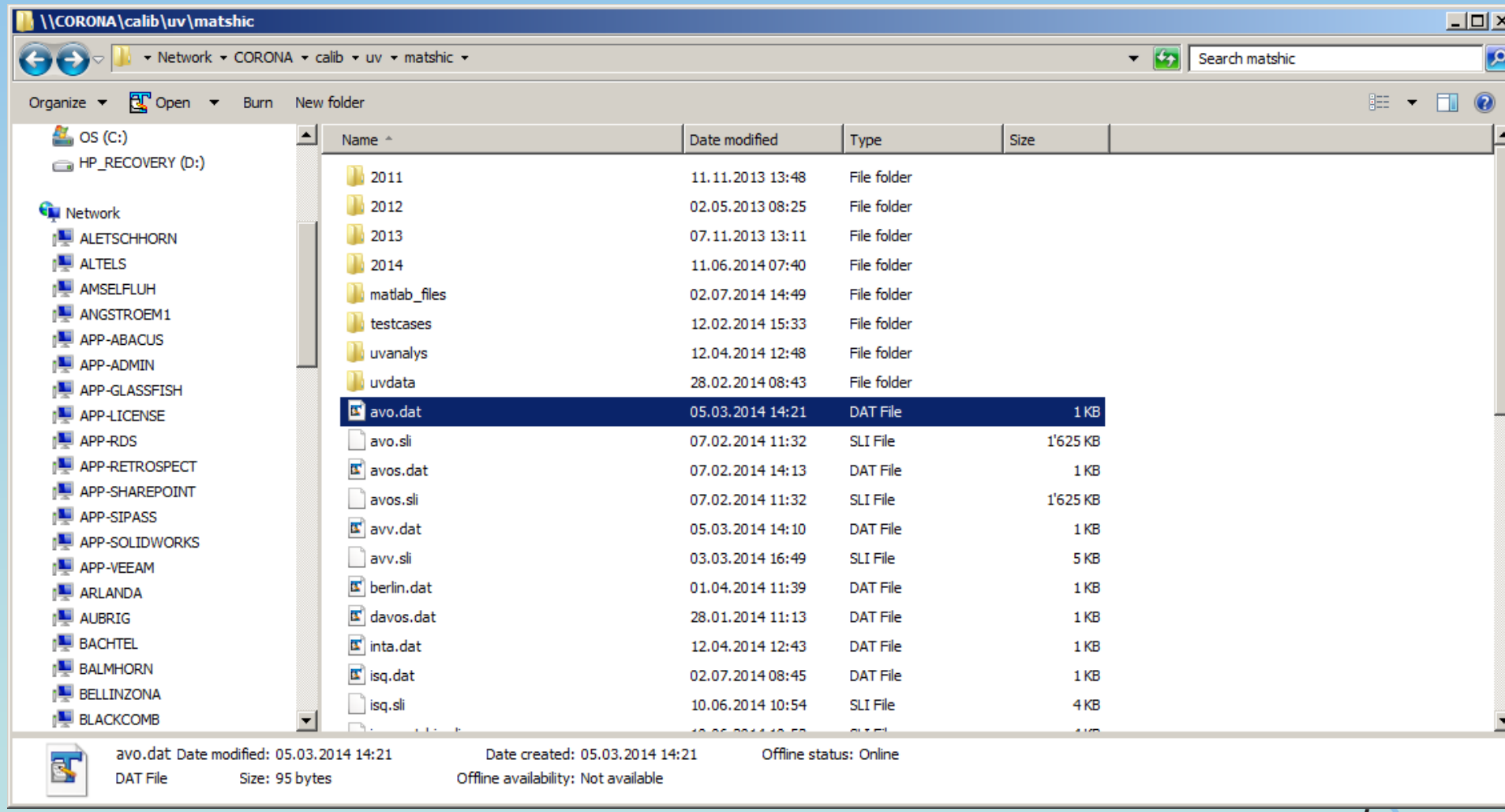




pmod wrc

Matshic in Matlab

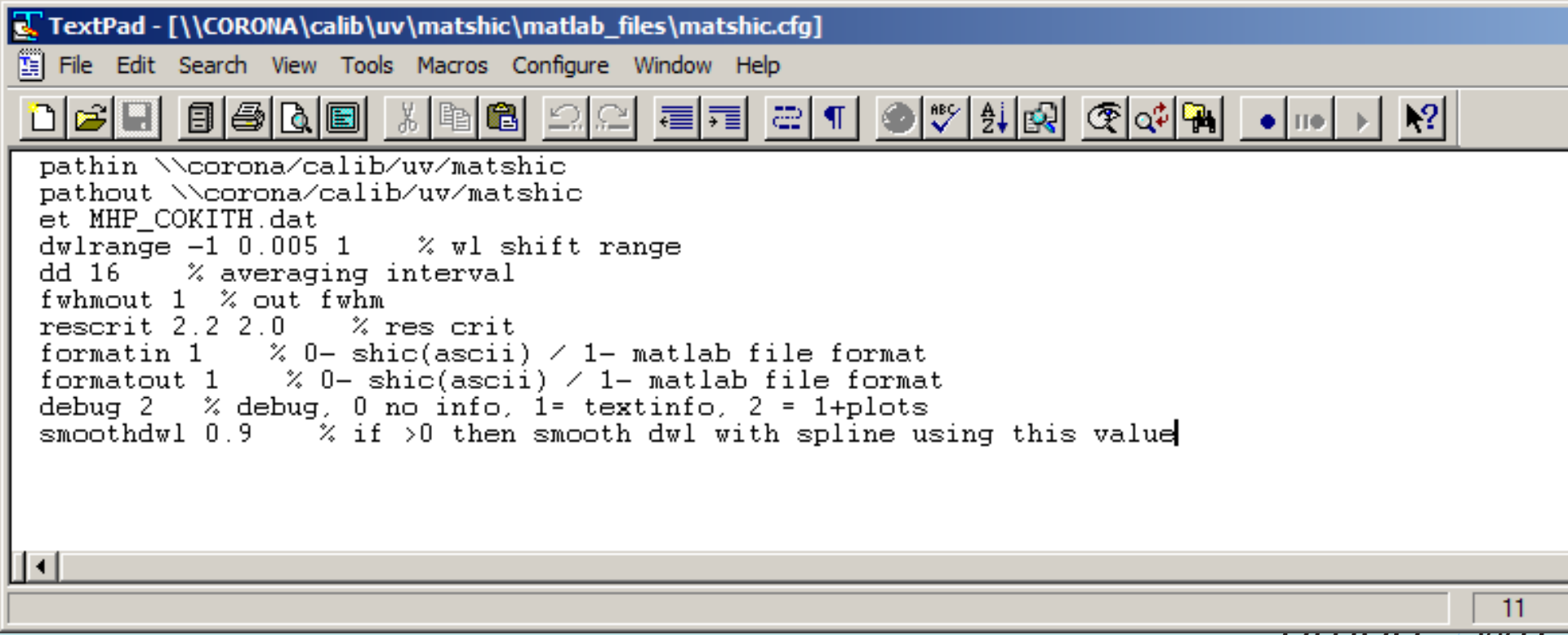
- Data-In: Matlab Matrix or ASCII (in uvdata)
- Slit- function (variable or single slit)



pmod wrc

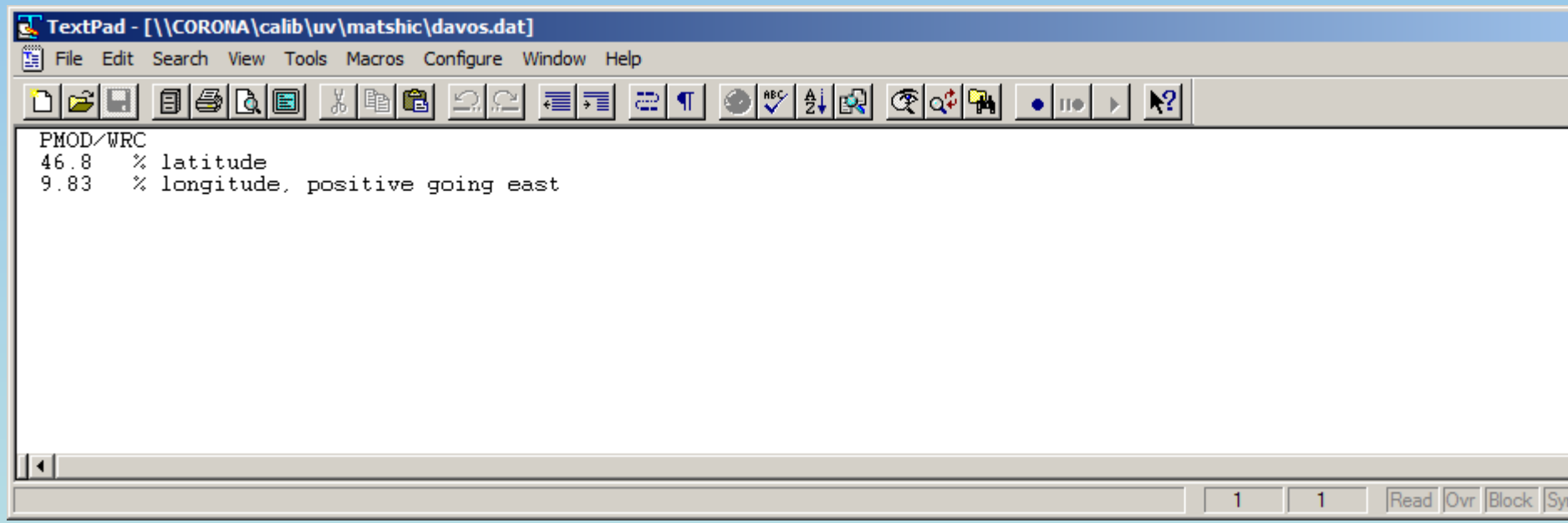
Matshic in Matlab

- Main -Configuration:
  - ET
  - WL-shift-range
  - Analysing window for WL-Shift
  - Bandwidth of output spectrum
  - Format in and out (ASCII or Matlab)



Matshic in Matlab

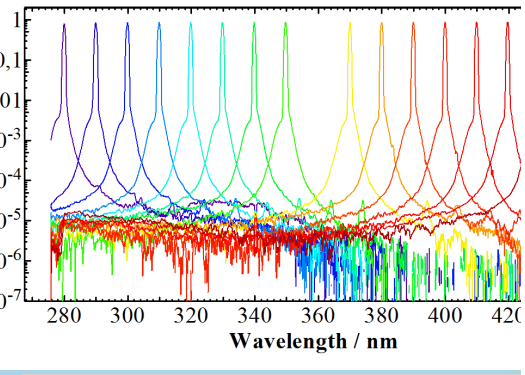
- Location -Configuration:
  - Latitude and Longitude

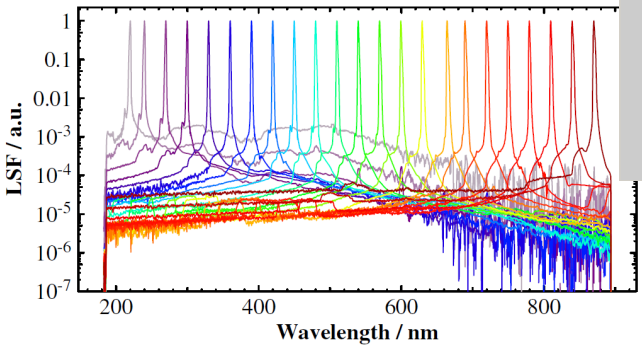


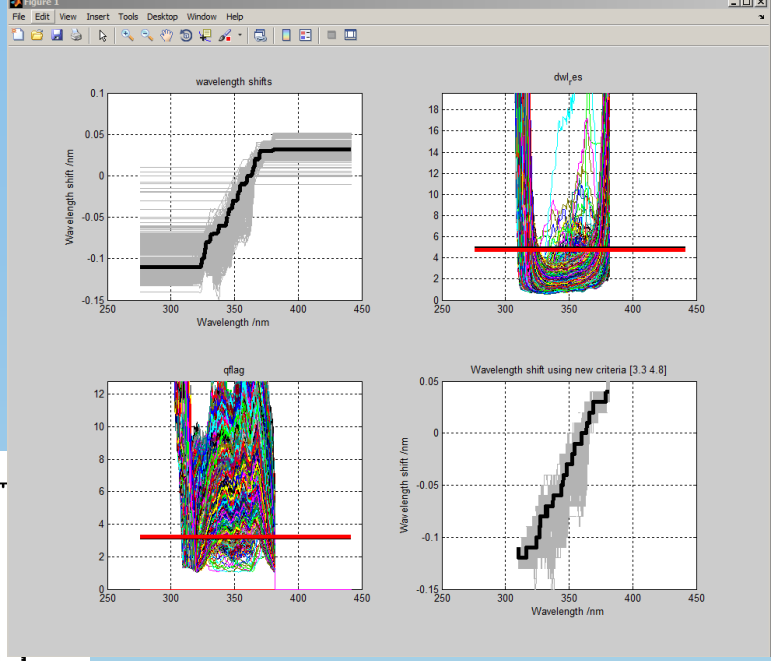
pmod wrc

Matshic in Matlab

- Instrument-Configuration:
  - criteria individually for each inst. (-debug 2)
  - wl-range of output spectrum
  - using single slit (if variable is available)







TextPad - [\\CORONA\calib\uv\matshic\avo.dat]

File Edit Search View Tools Macros Configure Window Help

```
rescrit 3.2 3.8
dwlrange -1 0.01 1
wlout 290 0.5 360
fileformat 1
debug 2
singleslit 320
```

1 1 Read Ovr Block Sync

Matshic in Matlab

- Running Matshic:

```
>>
>>
>> matshic('12-jul-2014','12-jul-2014','davos','jrc');
jrc : Center WL=-0.000 nm FWHM=0.824 nm
Processing 12-Jul-2014 : 32 spectra
-----------
\\corona/calib/uv/matshic/uvdata/2014/jrc/mat_uv1932014.jrc : scan Nb:1/32
12-Jul-2014 03:00:01 o3=   0 DU  sza=96.0  m=7.5
12-Jul-2014 03:00:01 o3= 254 DU  sza=96.0  m=7.5
Elapsed time for wlshift: 1.237772 sec
Elapsed time for shifted spec: 0.176548 sec
-----------
\\corona/calib/uv/matshic/uvdata/2014/jrc/mat_uv1932014.jrc : scan Nb:2/32
12-Jul-2014 03:30:01 o3=  95 DU  sza=92.0  m=11.1
Elapsed time for wlshift: 0.635063 sec
Elapsed time for shifted spec: 0.175998 sec
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\\corona/calib/uv/matshic/uvdata/2014/jrc/mat_uv1932014.jrc : scan Nb:3/32
12-Jul-2014 04:00:01 o3= 129 DU  sza=87.5  m=10.9
Elapsed time for wlshift: 0.638603 sec
Elapsed time for shifted spec: 0.174926 sec
-----------
\\corona/calib/uv/matshic/uvdata/2014/jrc/mat_uv1932014.jrc : scan Nb:4/32
12-Jul-2014 04:30:01 o3= 232 DU  sza=83.1  m=6.9
Elapsed time for wlshift: 0.636201 sec
Elapsed time for shifted spec: 0.175035 sec
-----------
\\corona/calib/uv/matshic/uvdata/2014/jrc/mat_uv1932014.jrc : scan Nb:5/32
12-Jul-2014 05:00:01 o3= 306 DU  sza=78.4  m=4.6
Elapsed time for wlshift: 0.639906 sec
Elapsed time for shifted spec: 0.174948 sec
```
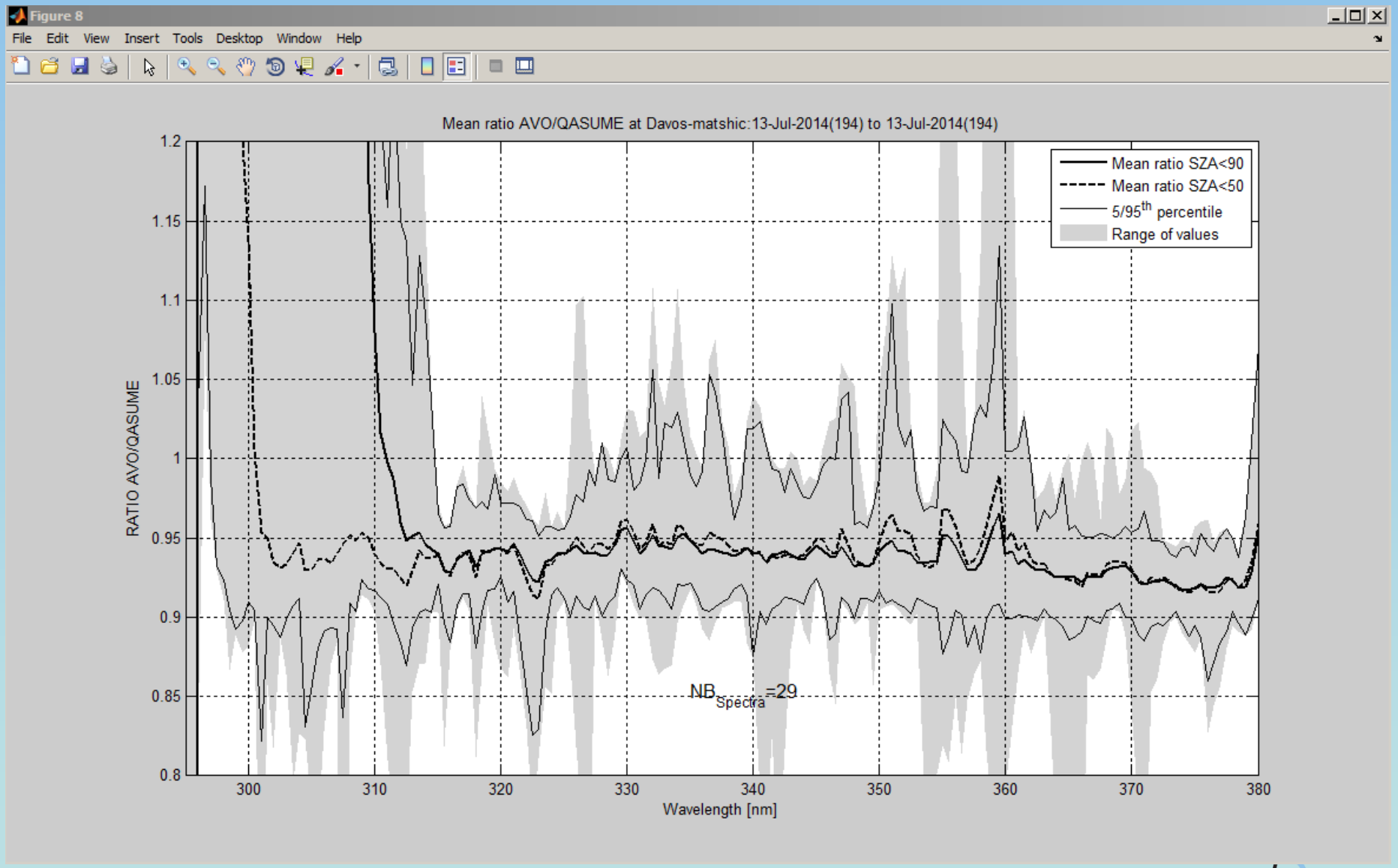

Result



pmod wrc

Conclusion

- For array spectroradiometer data post-processing is important and should **be tailored individually** to the specific instrument.

  - *integration times*
  - *linear correction*
  - *stray light correction*
  - *wavelength shift detection*

- Matshic provides **bandwidth and wavelength homogenized spectra** – to be compared with other instruments

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Discussion – Experience of othe Users

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