Ground-based SO_2 Measurements

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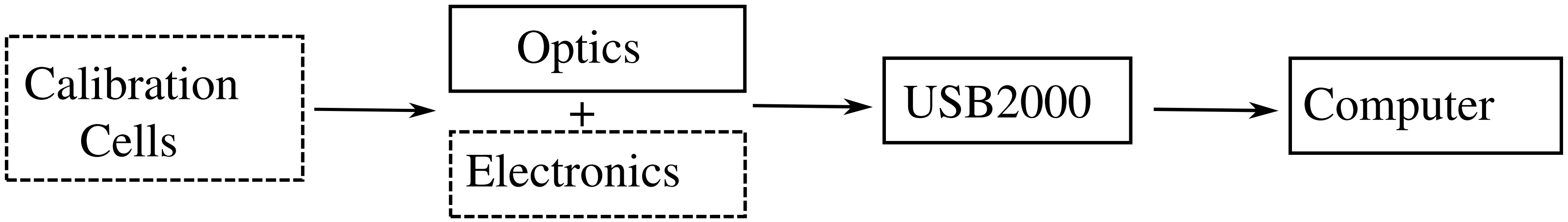
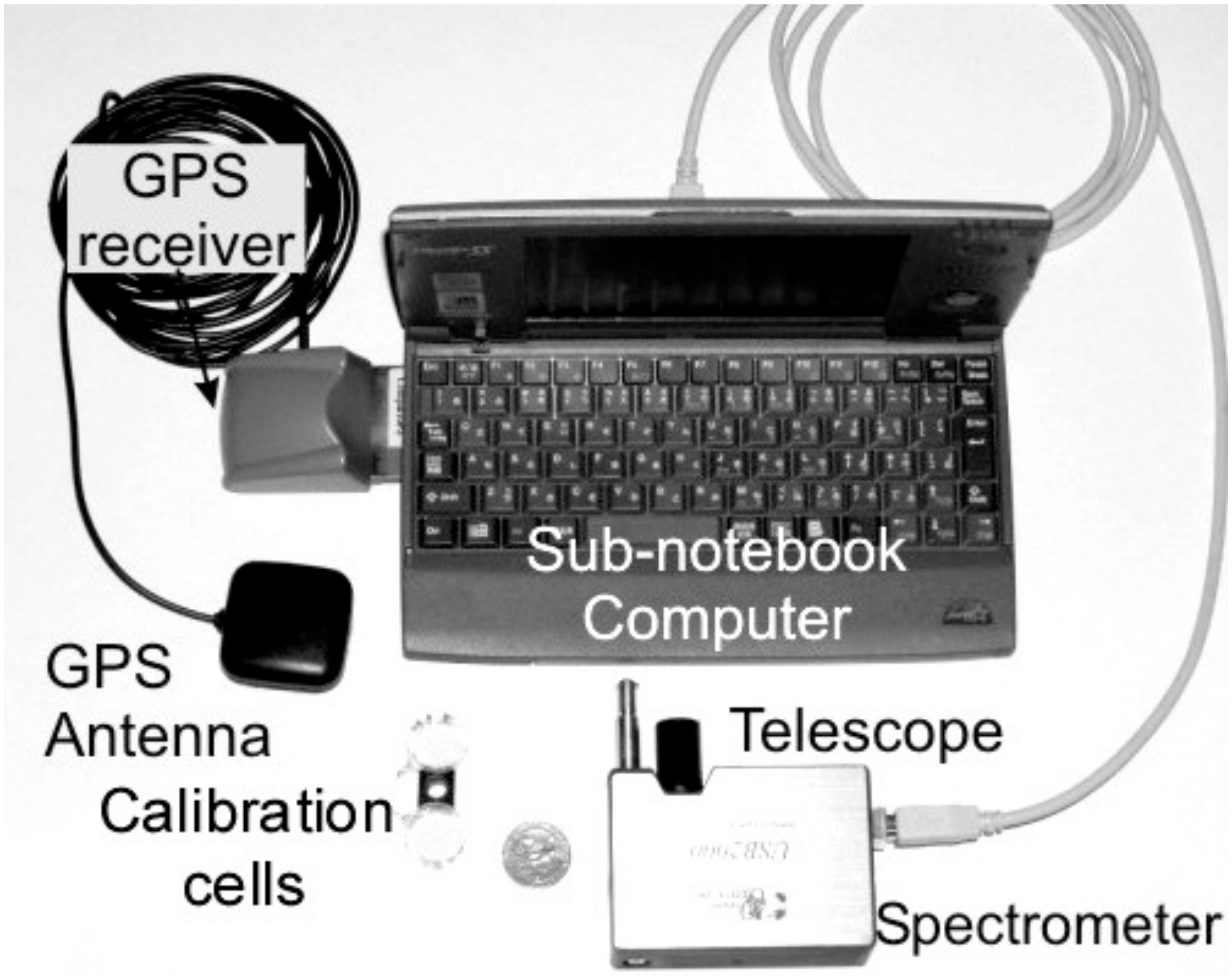
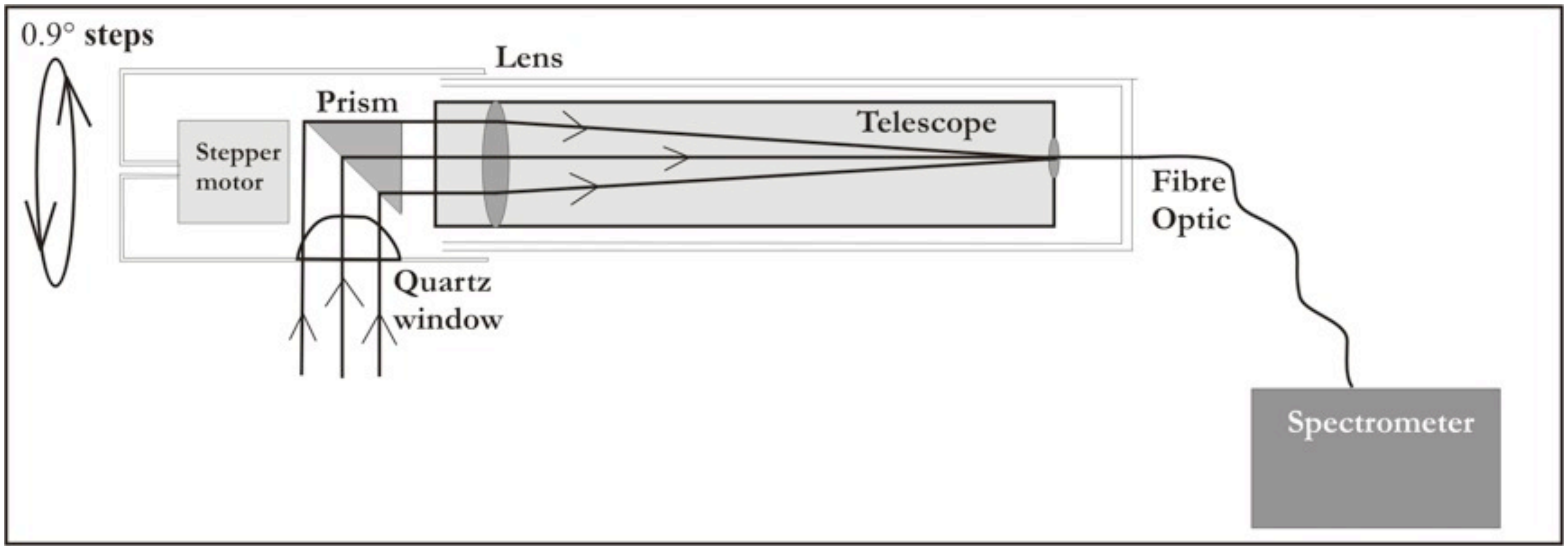
Measuring SO_2 emissions

FLYSPEC

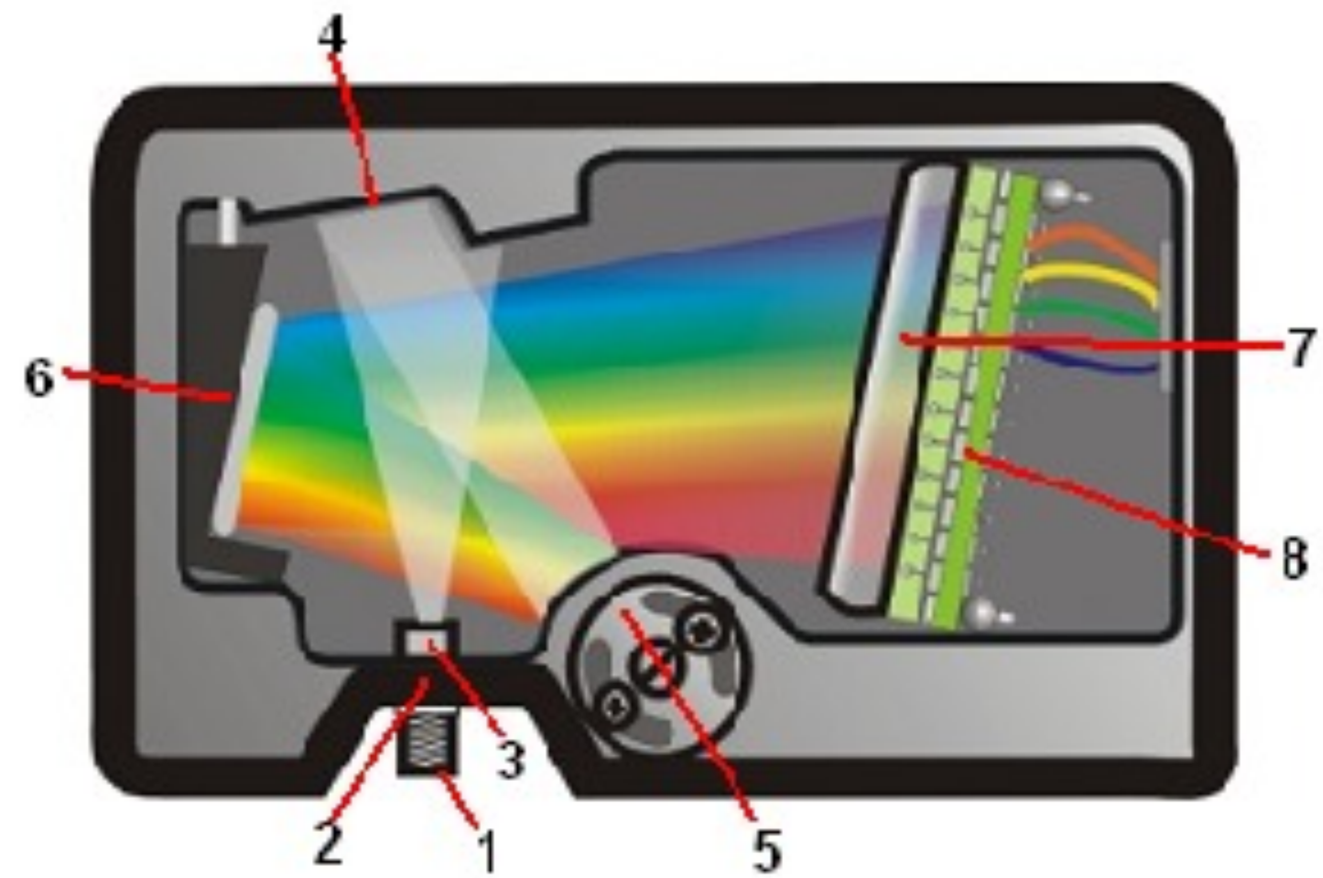

Calibration Cells
Optics
+
Electronics
USB2000
Computer


GPS receiver
Sub-notebook Computer
GPS Antenna
Calibration cells
Telescope
Spectrometer


0.9° steps
Lens
Prism
Telescope
Stepper
motor
Fibre
Optic
Quartz
window
Spectrometer

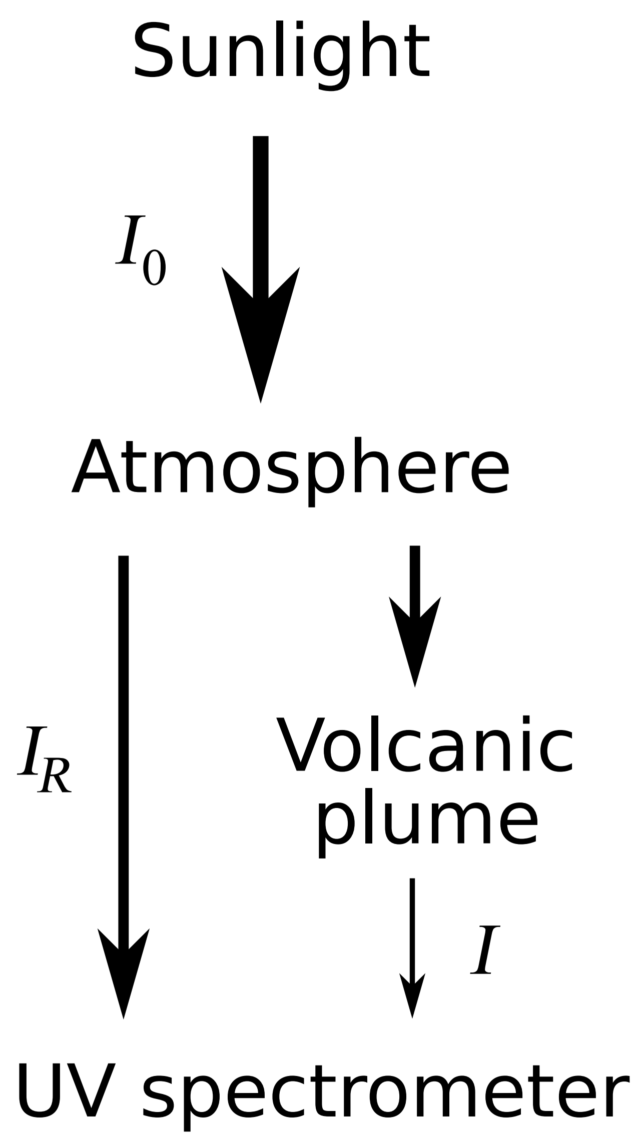
USB2000 Spectrometer

The USB2000 incorporates a monochromator based on an asymmetric crossed Czerny-Turner configuration, and a 2048-element charge coupled device (CCD) linear silicon array



Ocean Optics USB2000 Fiber Optic Spectrometer.
Spectrometer's components: 1=SMA connector, 2=slit, 3=filter, 4=collimating mirror, 5=grating, 6=focusing mirror, 7=Optional L2 detector collection lens, 8=CCD detector.

Intensity and Transmittance

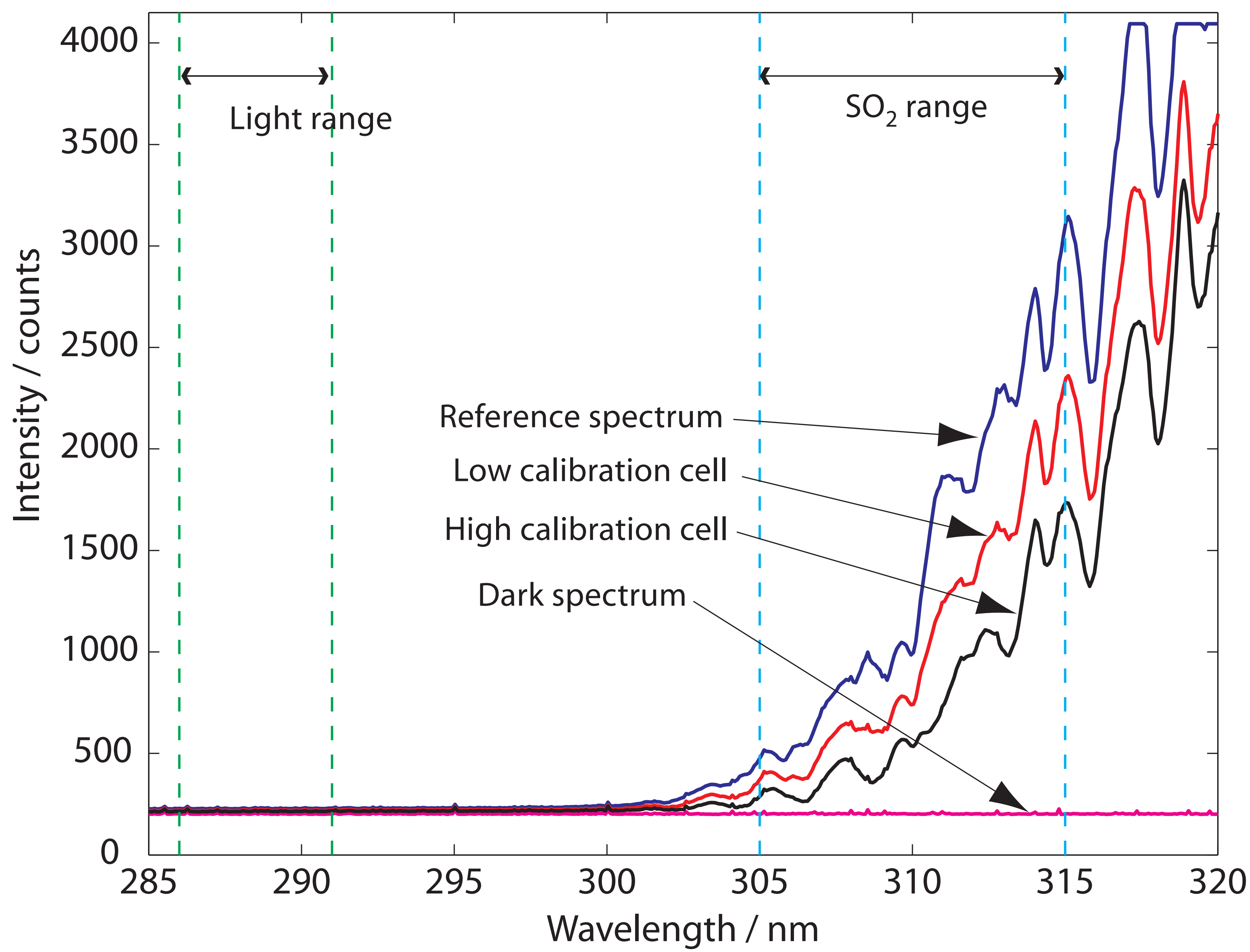


$$I(\lambda) = I_0(\lambda)e^{-L[\Omega_S(\lambda)+\Omega_{RM}(\lambda)]}$$

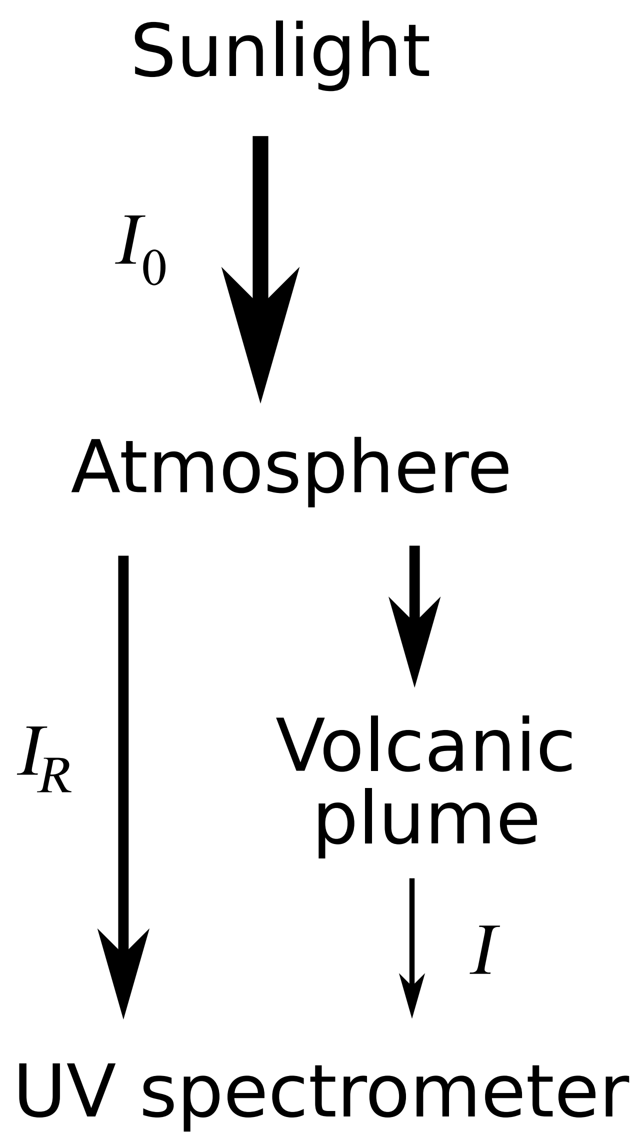
$$T = I/I_0$$

$$A = -\ln(T) = -\ln(I/I_0)$$

Acquisition of Light Spectra



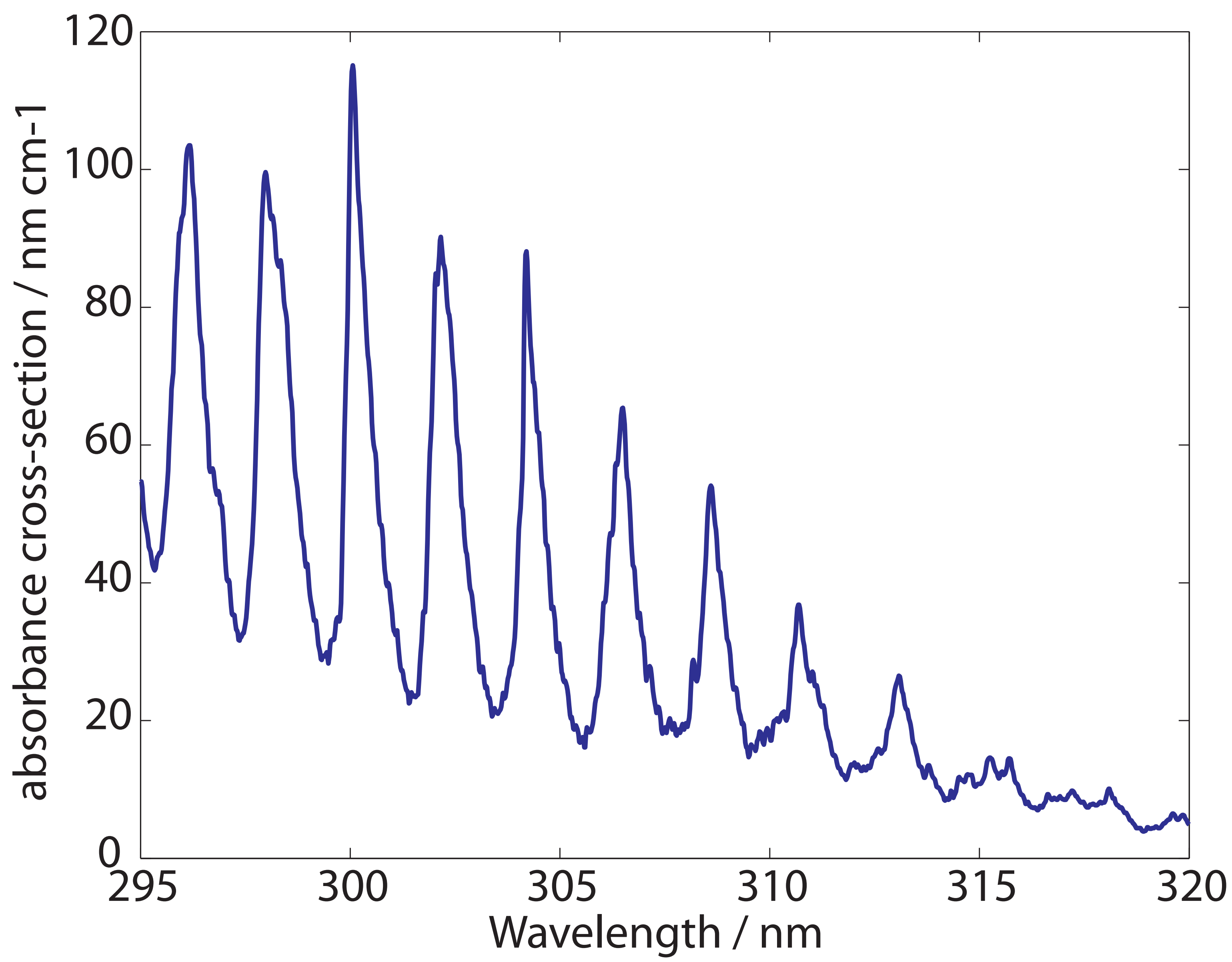
Absorption



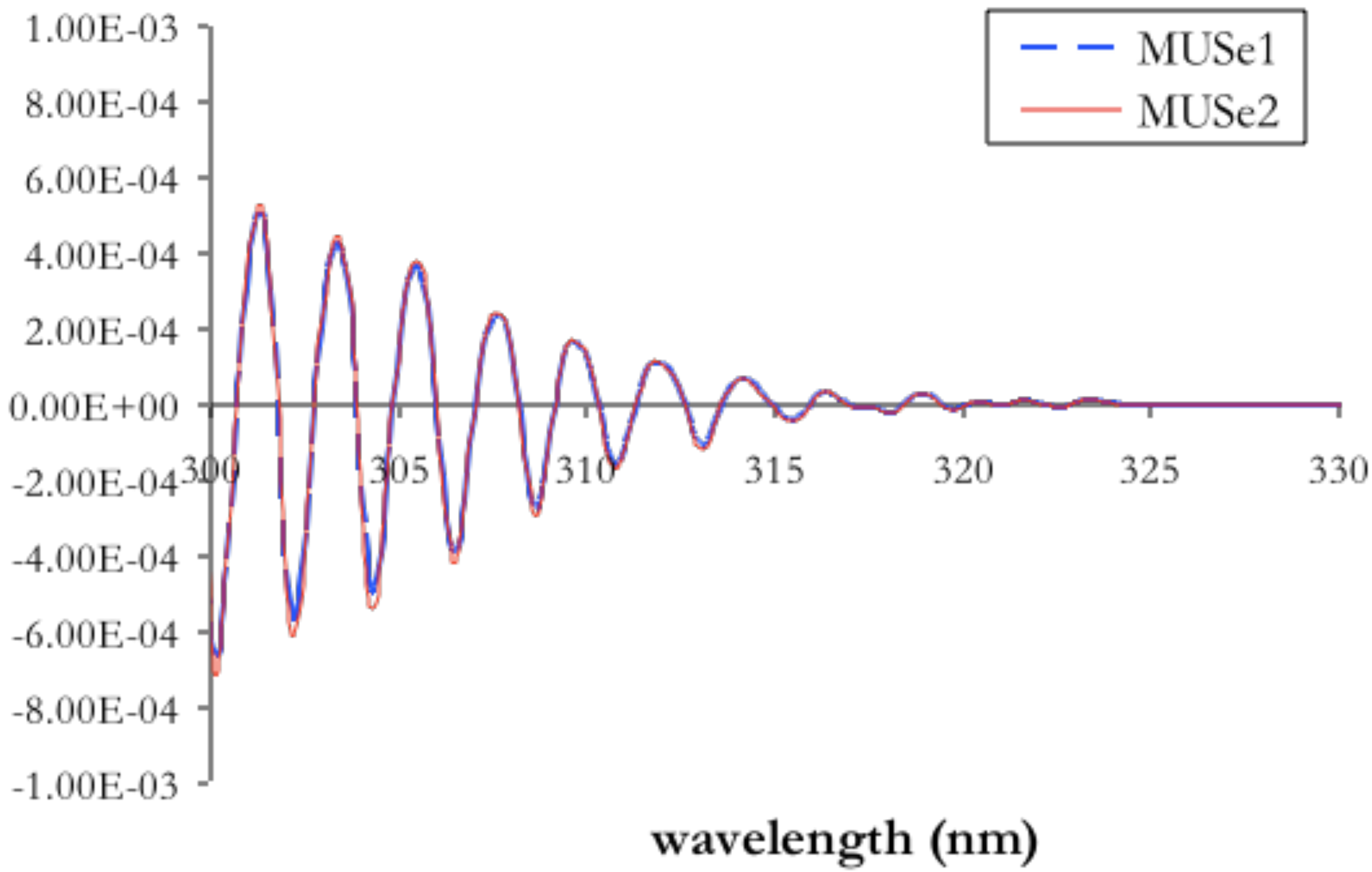
$$A_{plume}(\lambda) = -\ln\left(\frac{I(\lambda)}{I_R(\lambda)}\right) = l\ \Omega_p$$

$$A_{plume}(\lambda) = \sigma_{SO_2}(\lambda)\ c_{SO_2}\ l$$

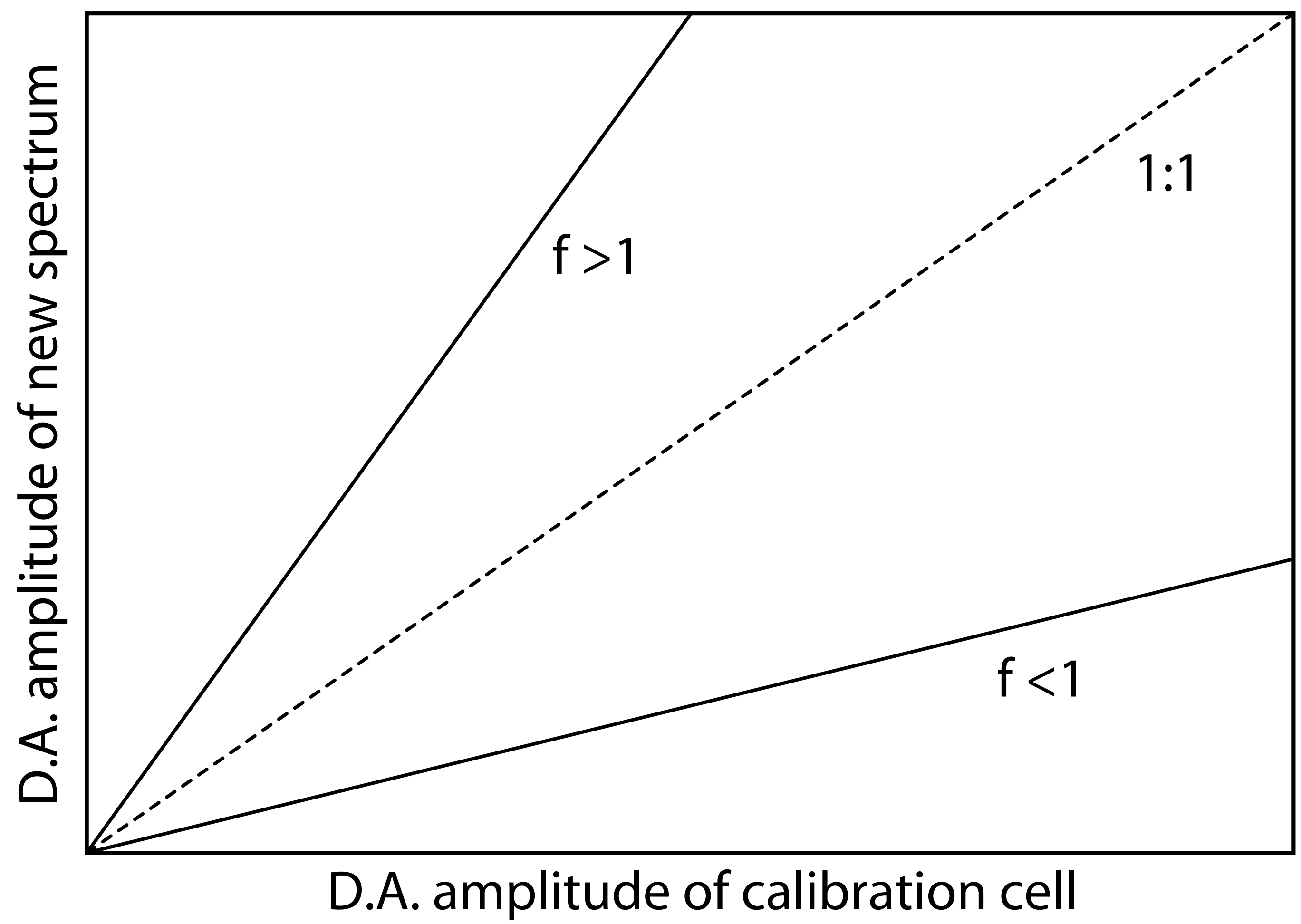
SO_2 absorption



Differential absorbance

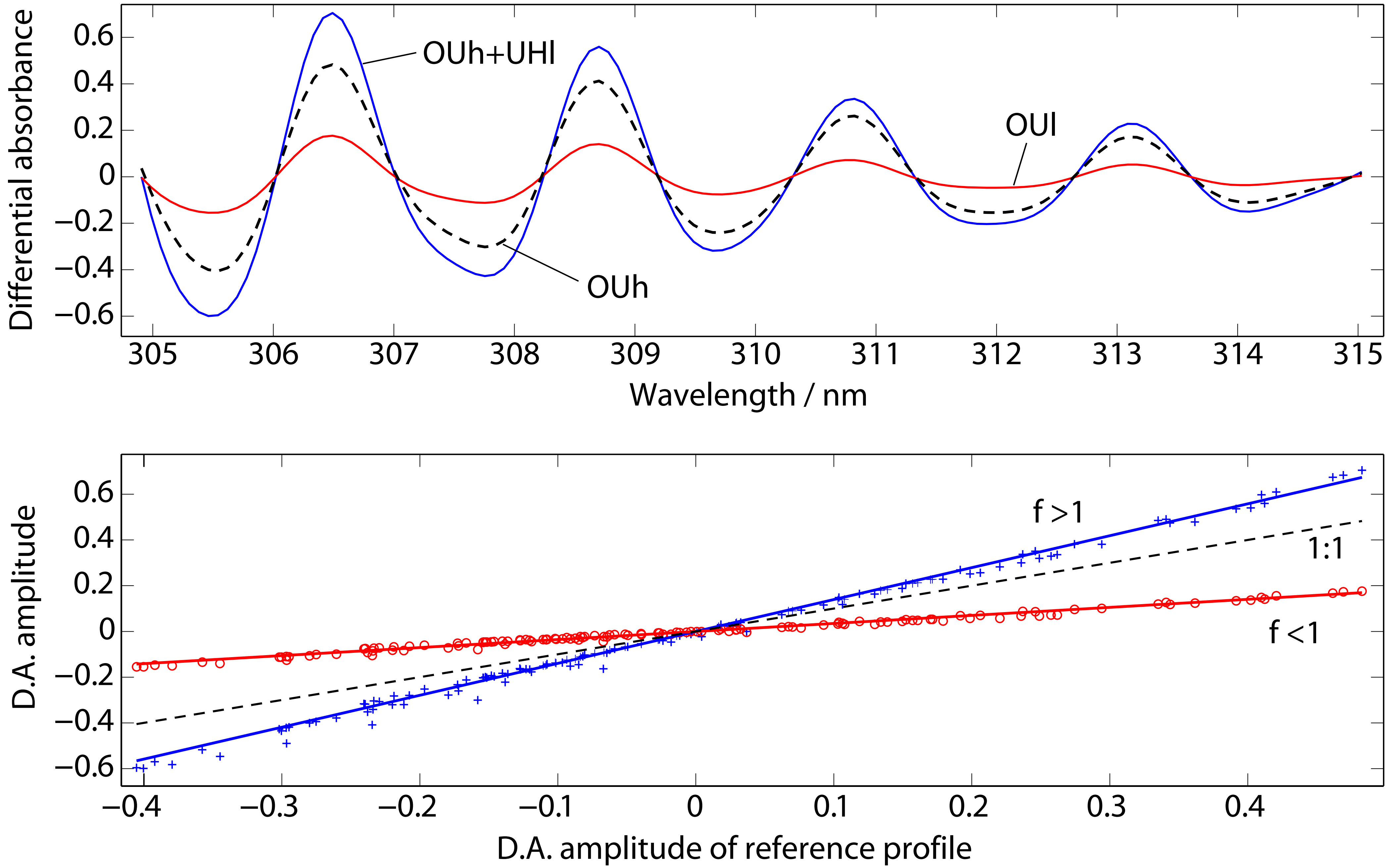


DA Correlation

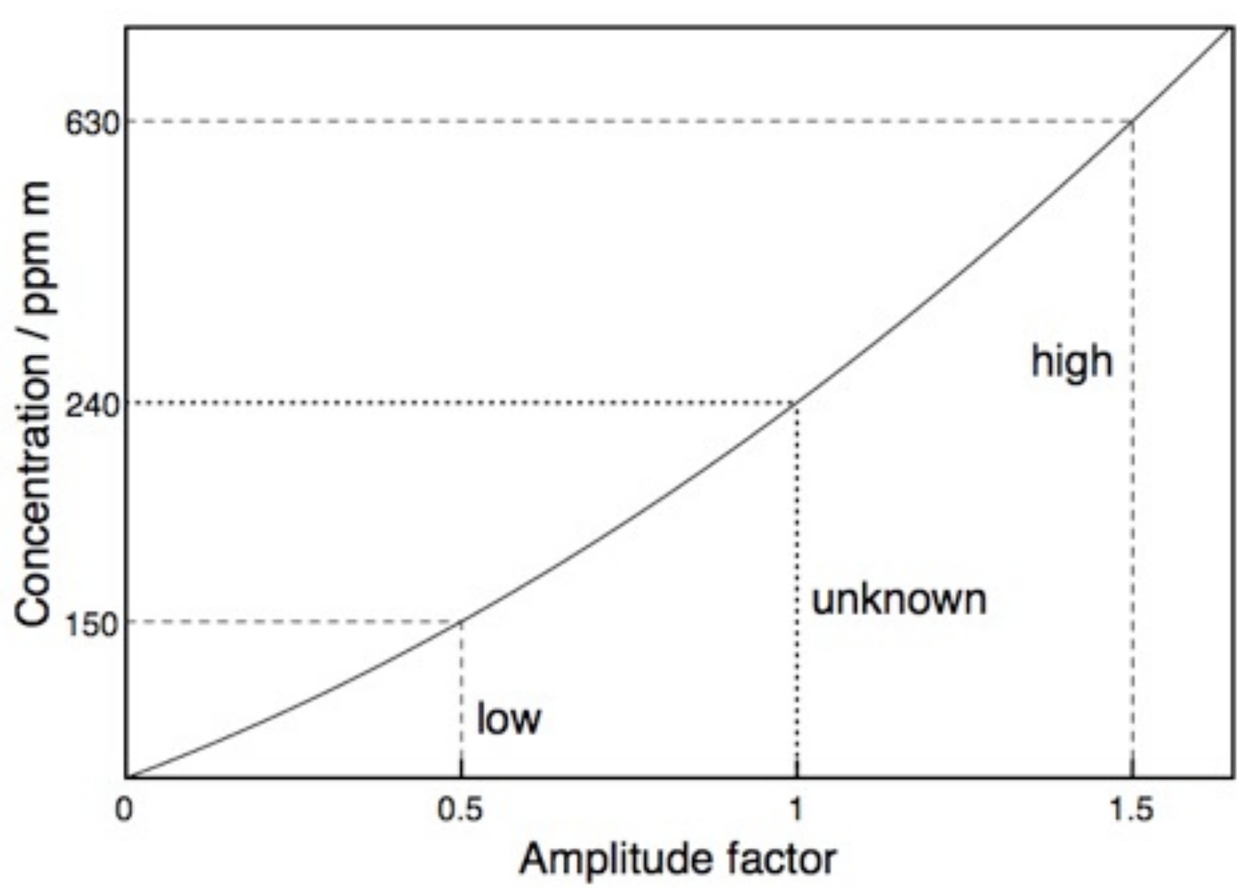


$$DA_h(\lambda) = f \cdot DA_l(\lambda) \qquad f > 1$$

DA Correlation



Calculate P-L Concentration



$$DA_{new} = f_h \cdot DA_{high} \quad f_h < 1$$

$$DA_{new} = f_l \cdot DA_{low} \quad f_l > 1$$

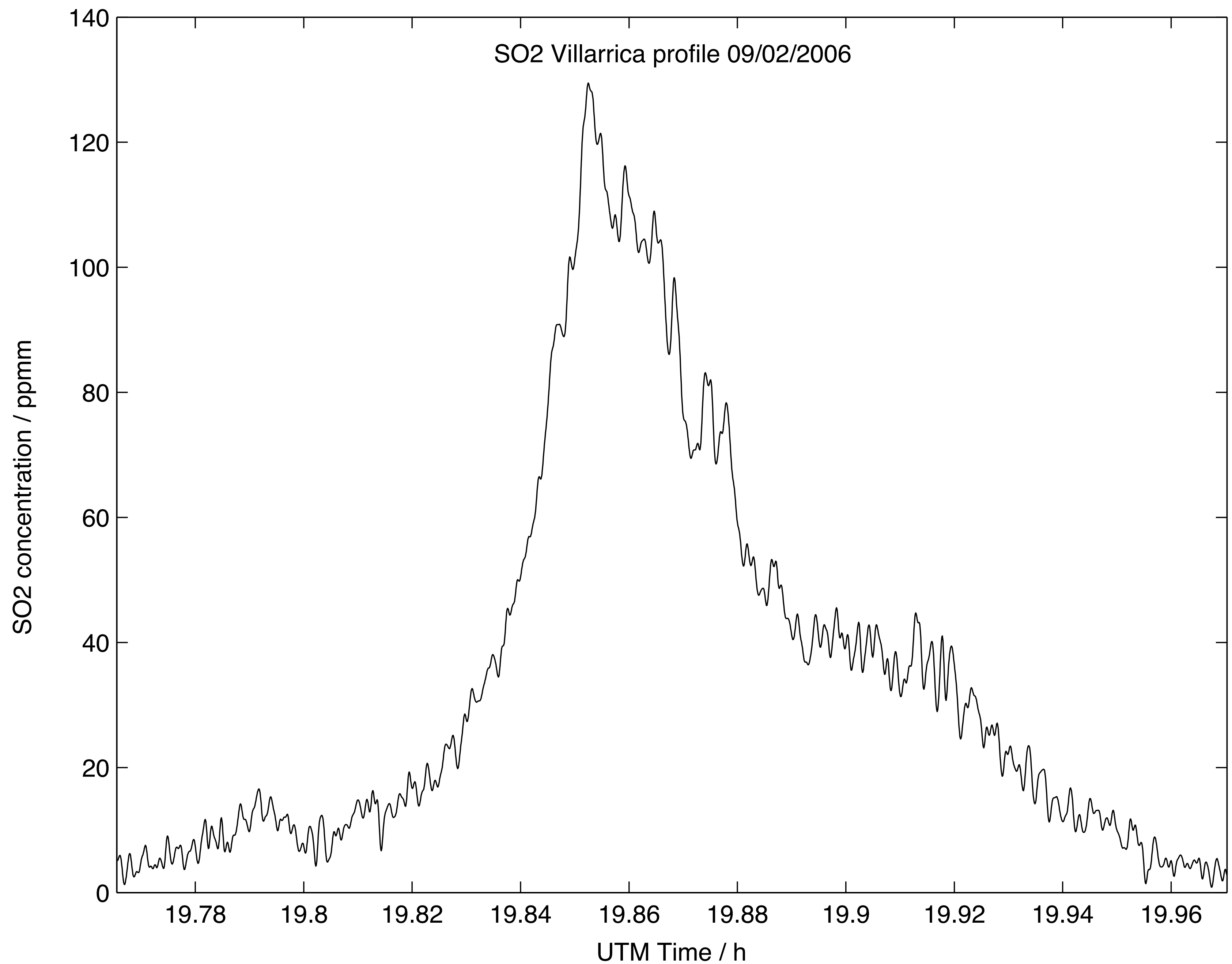
$$C_i = a \cdot \tilde{f}_i^2 + b \cdot \tilde{f}_i$$

$$\tilde{f}_i = 1/f_i$$

$$C_i \cdot f_i = a\frac{1}{f_i} + b$$

$$C_{new} = a + b$$

Example of Measurements



Procedure for calculation of the SO_2 path-length concentration from raw light spectra data

1. Set parameters of the spectrometer (light correction and fitting ranges) and calculations.
2. Set the calibration
    (a) Read reference (background) and dark (instrument offset) files
    (b) Read spectra and get concentrations of calibration cells
    (c) Calculate and store the differential absorbance of the calibration cells
3. Read files with new measurements
    (a) Read dark and reference files if they are different to the corresponding calibration files
    (b) Open the file with new measurements
4. Loop over the spectra in the new scan file
    (a) Read a single spectrum
    (b) Get the differential absorbance of the new spectrum
    (c) Correlate the differential absorbances of the calibration cells with the new spectrum, and calculate the concentration of SO2
5. (Optional) Identify and label spikes
6. Plot and save the results