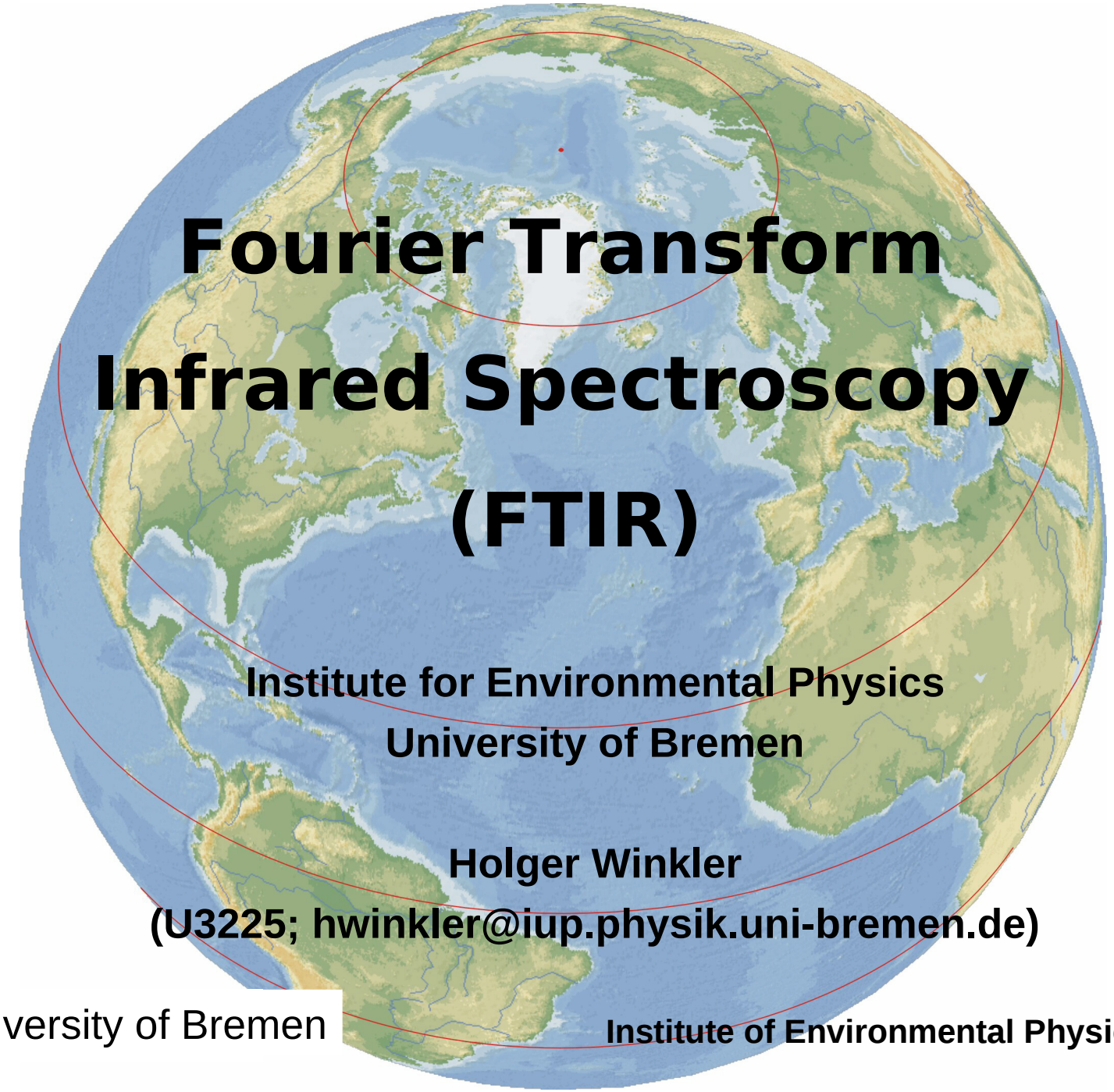

Fourier Transform Infrared Spectroscopy (FTIR)

Institute for Environmental Physics
University of Bremen

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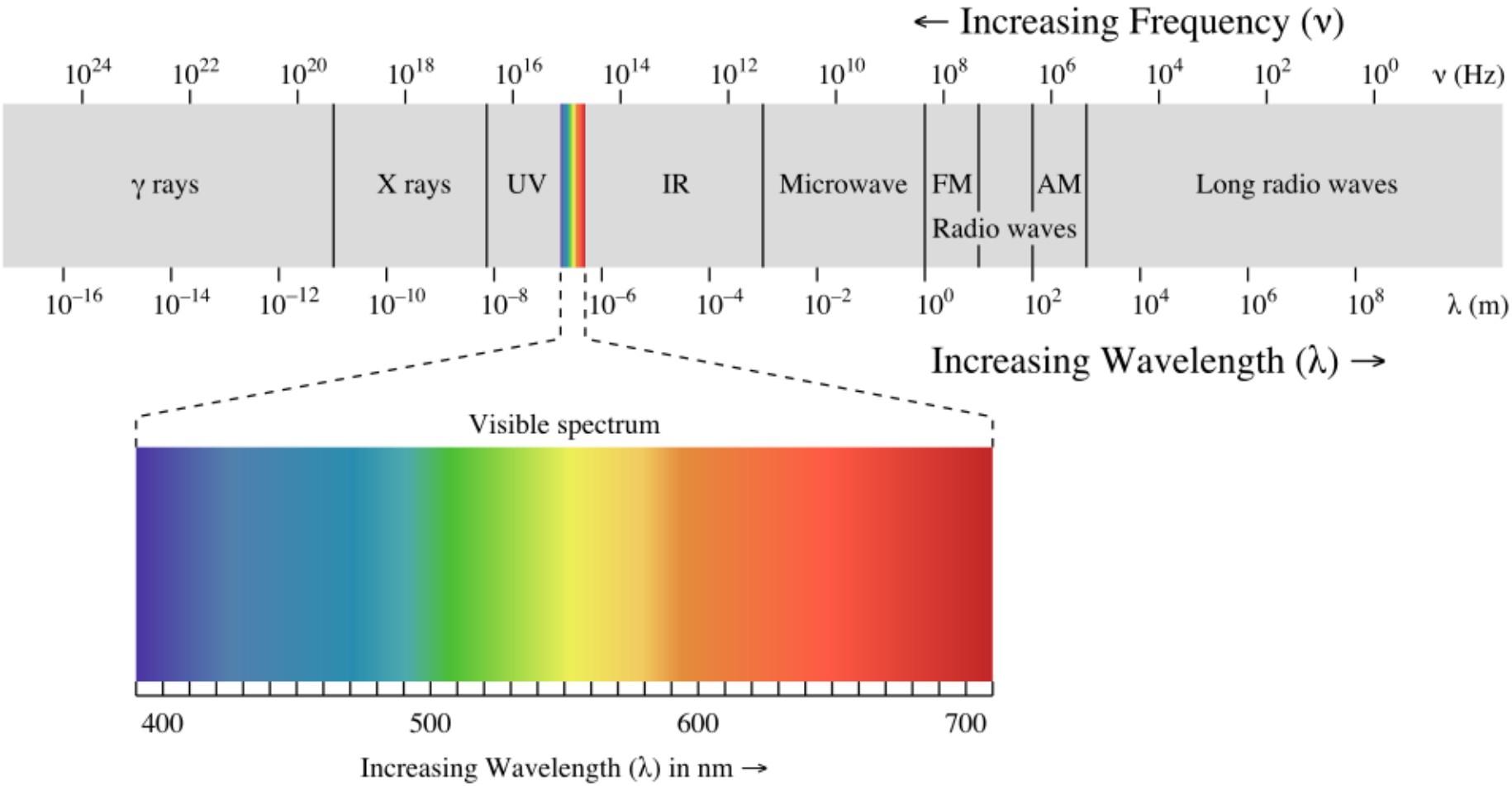
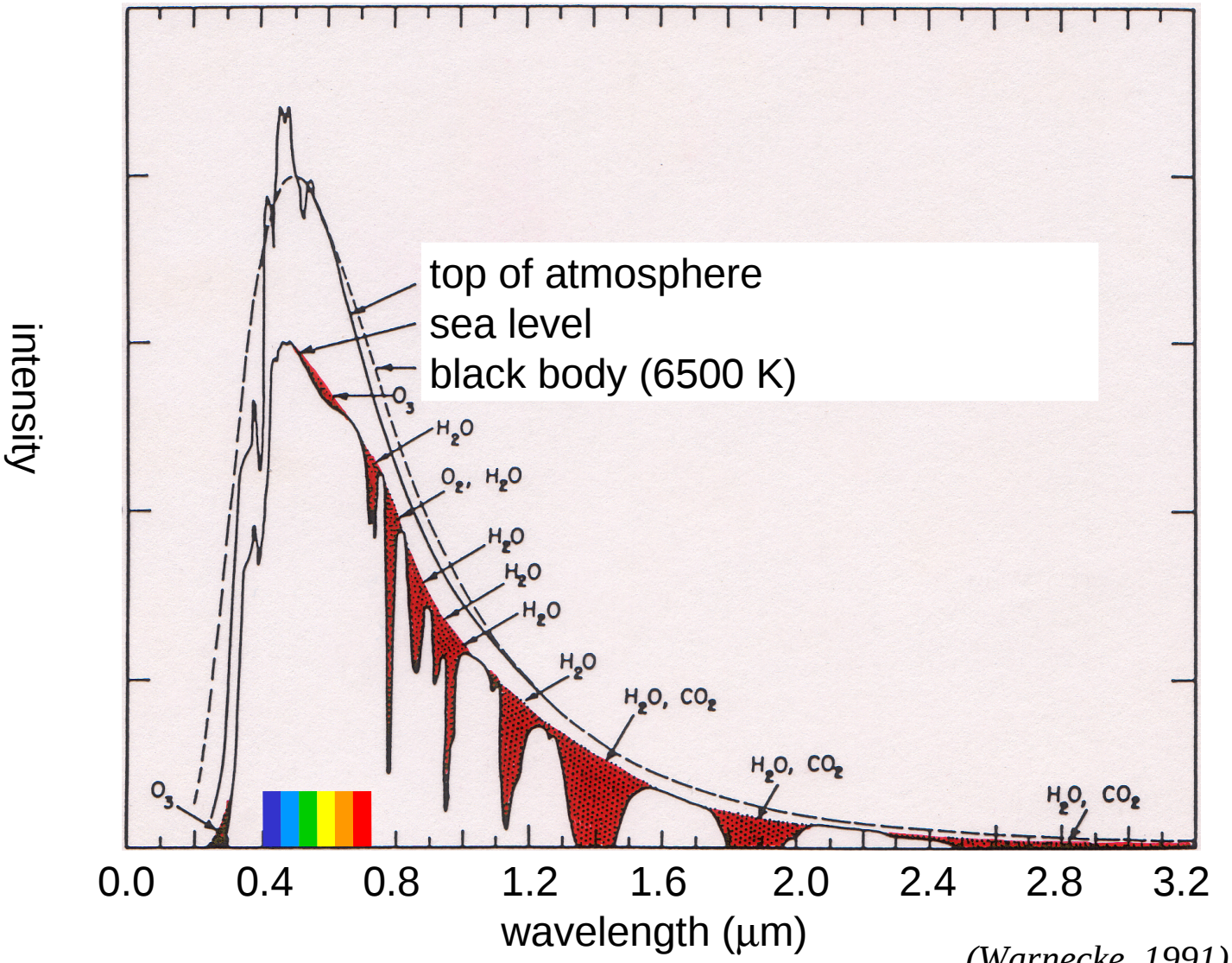
Outline

- Infrared radiation
- Fourier Transform Infrared (FTIR) Spectroscopy
- FTIR spectroscopy as a remote sensing method
- FTIR measurements in Bremen

The electromagnetic spectrum



Solar spectrum + atmospheric absorption



(Warnecke, 1991)

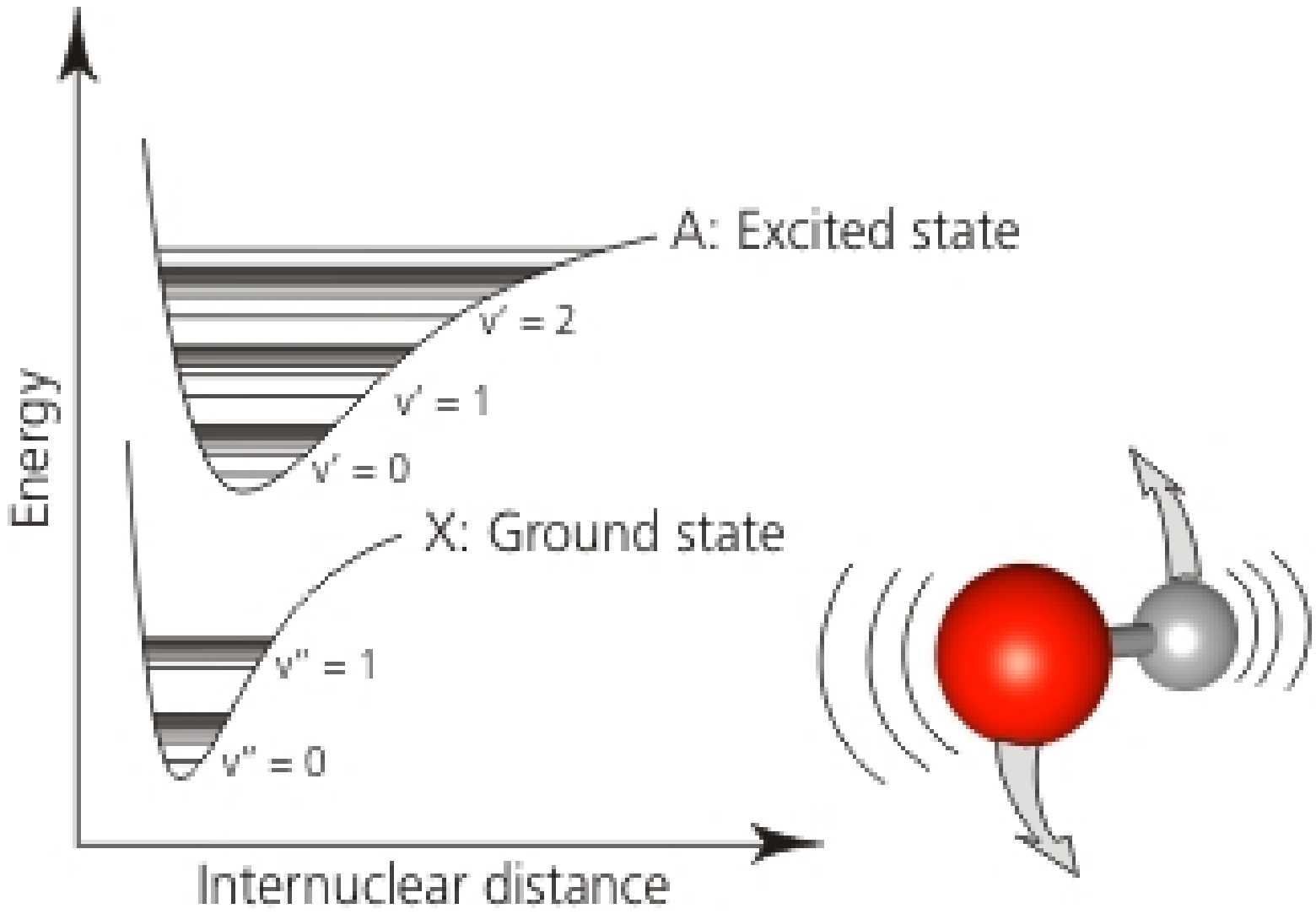
Infrared

Designation	Abbreviation	Wavelength [μm]	Wavenumber [1/cm]
Near Infrared	NIR	0.78 - 3	12800 - 3333
Mid Infrared	MIR	3 - 50	3333 - 200
Far Infrared	FIR	50 - 1000	200 - 10

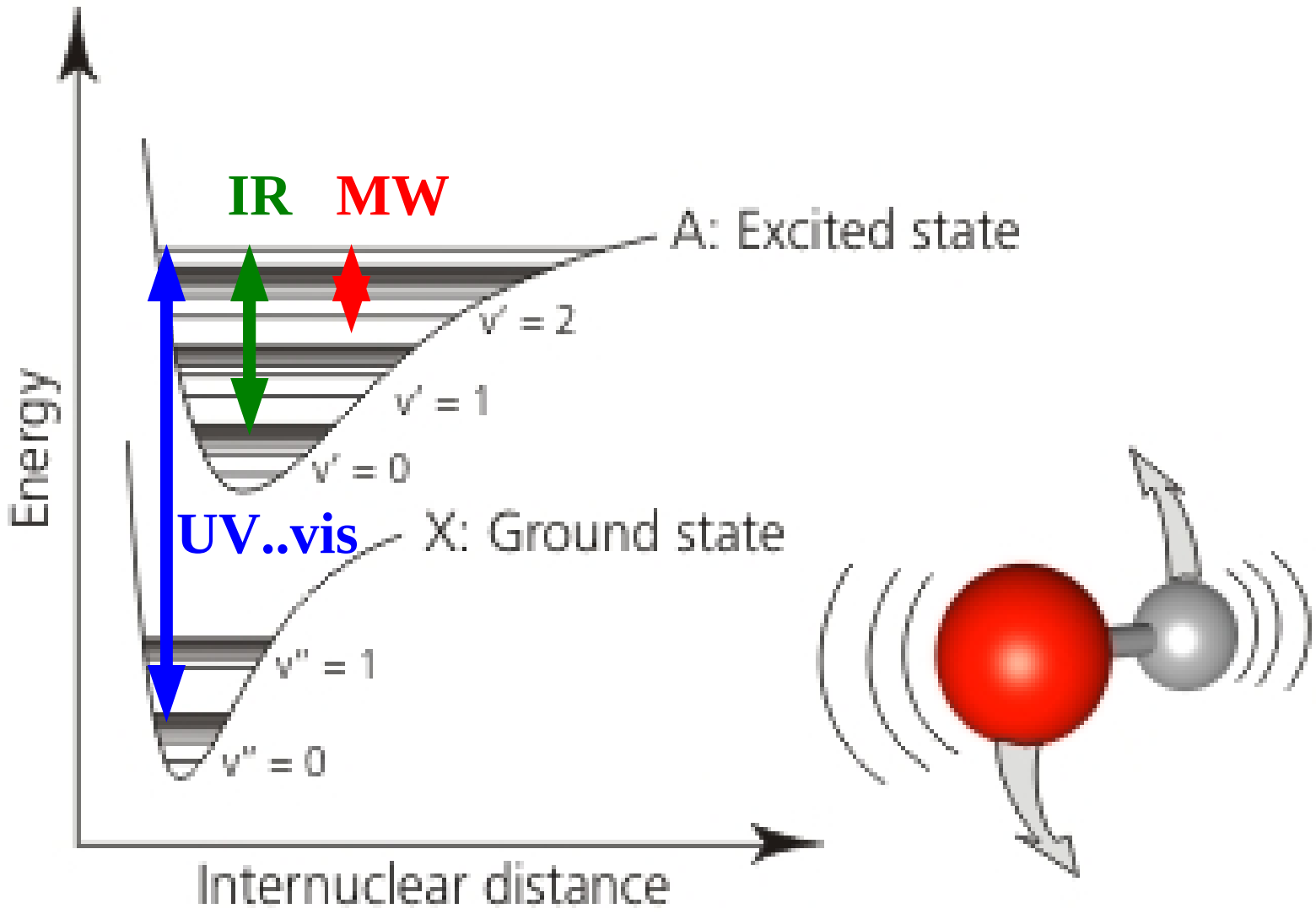
Wavenumber

$$\tilde{\nu} = 1/\lambda$$

Molecular transitions

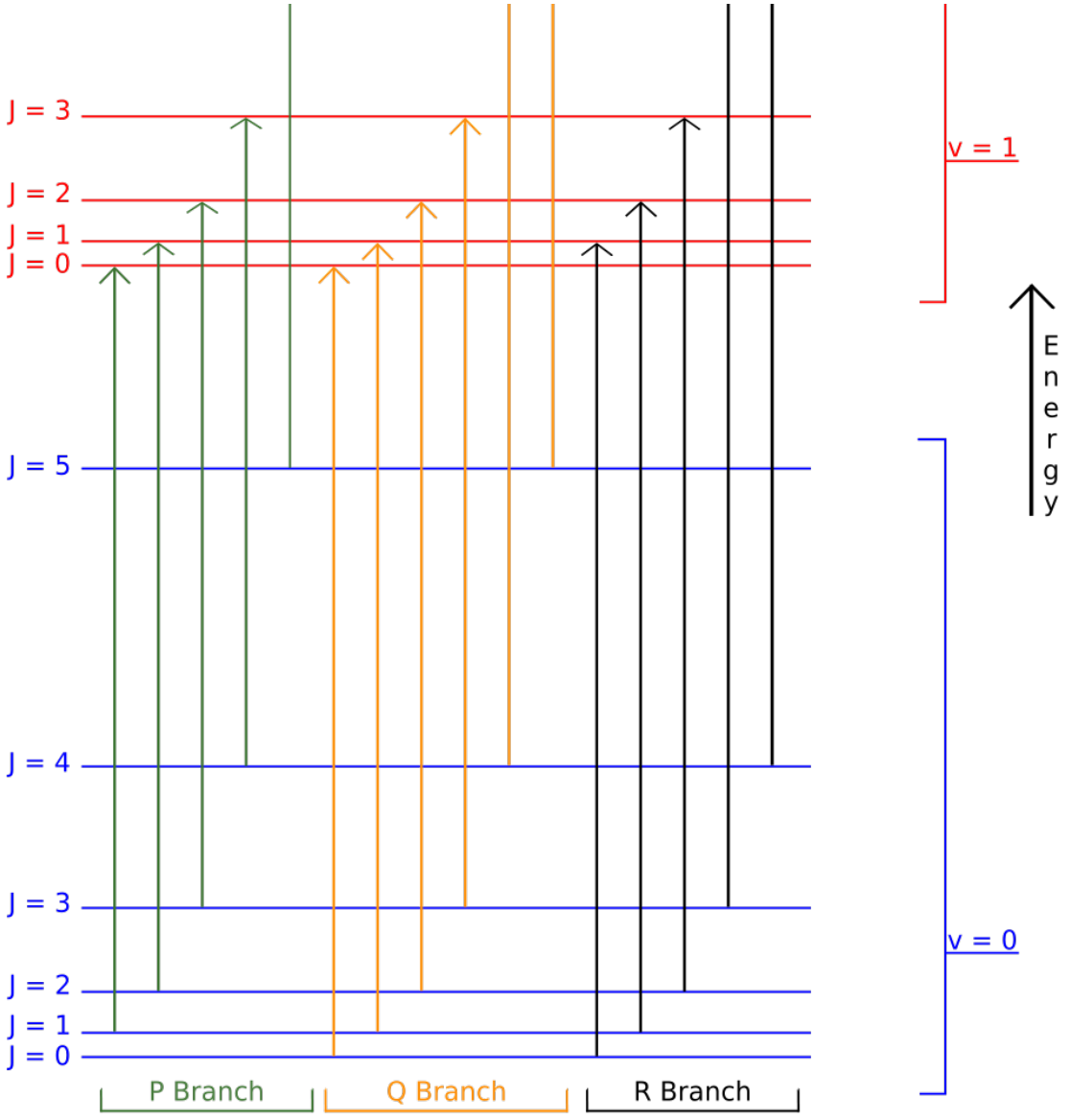


Molecular transitions

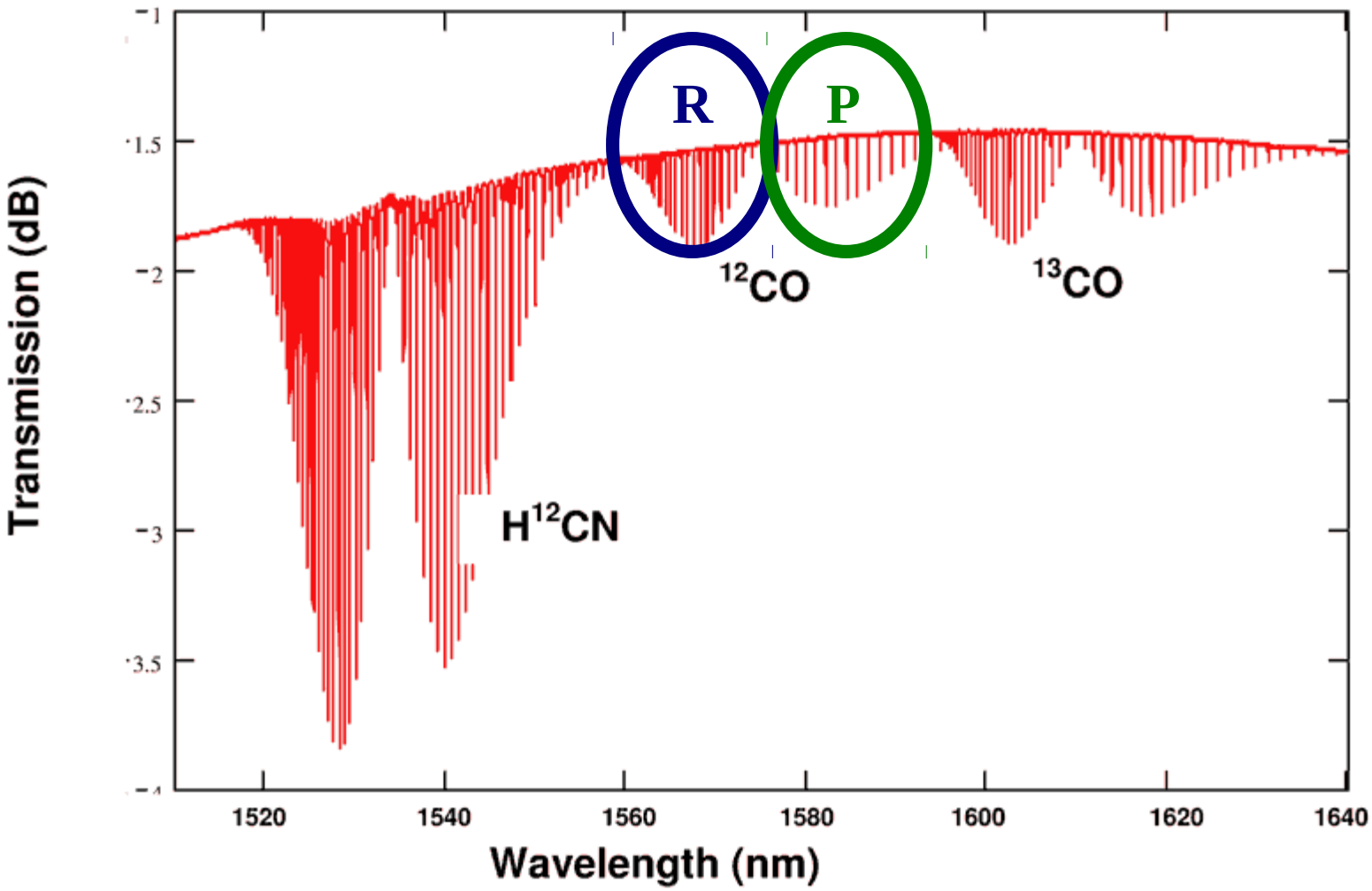


Vibrational-rotational transition (absorption)

v = vib. QN
J = rot. QN

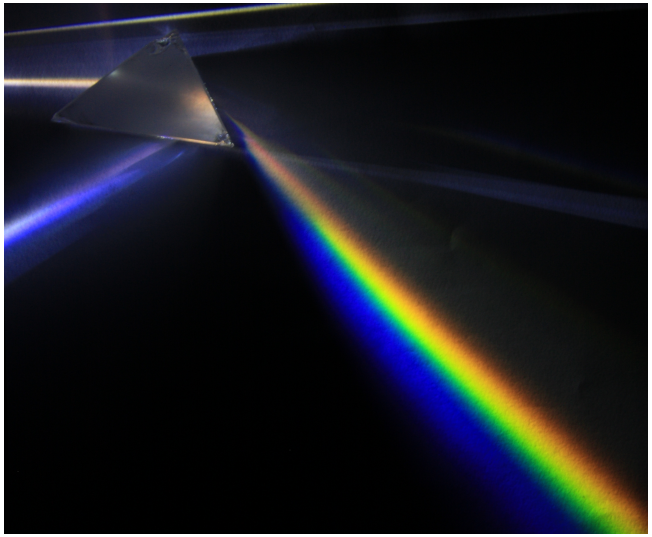


Molecules' fingerprints

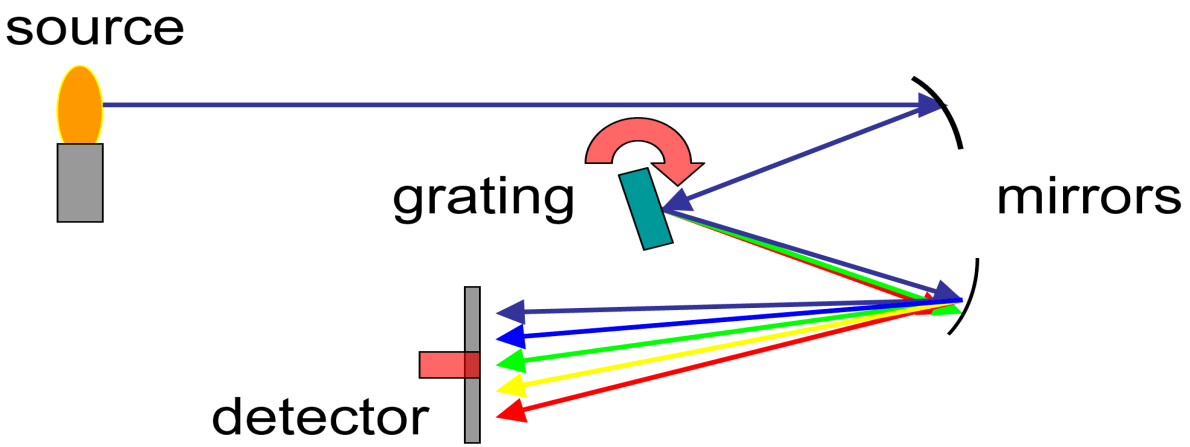


Spectroscopy

… prism

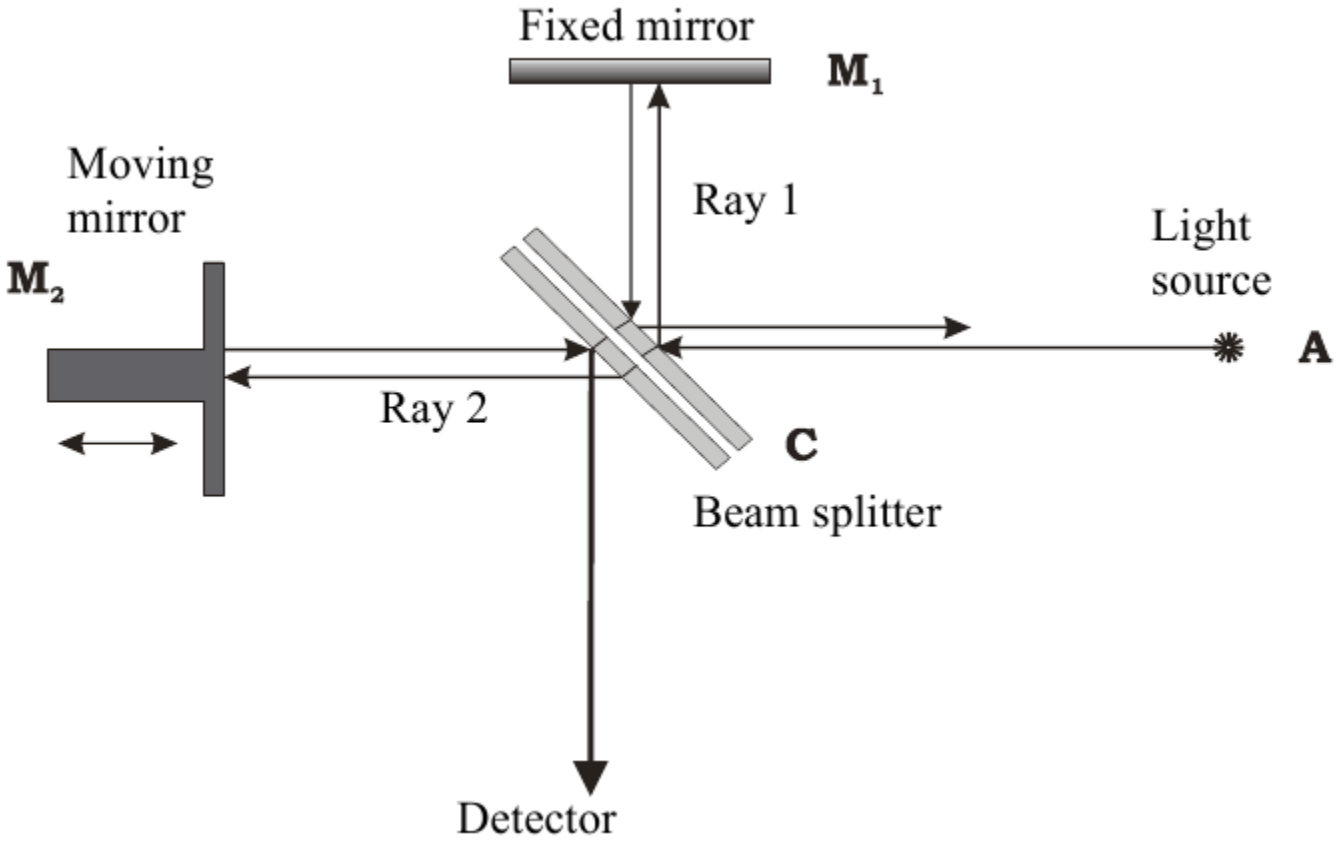


… grating



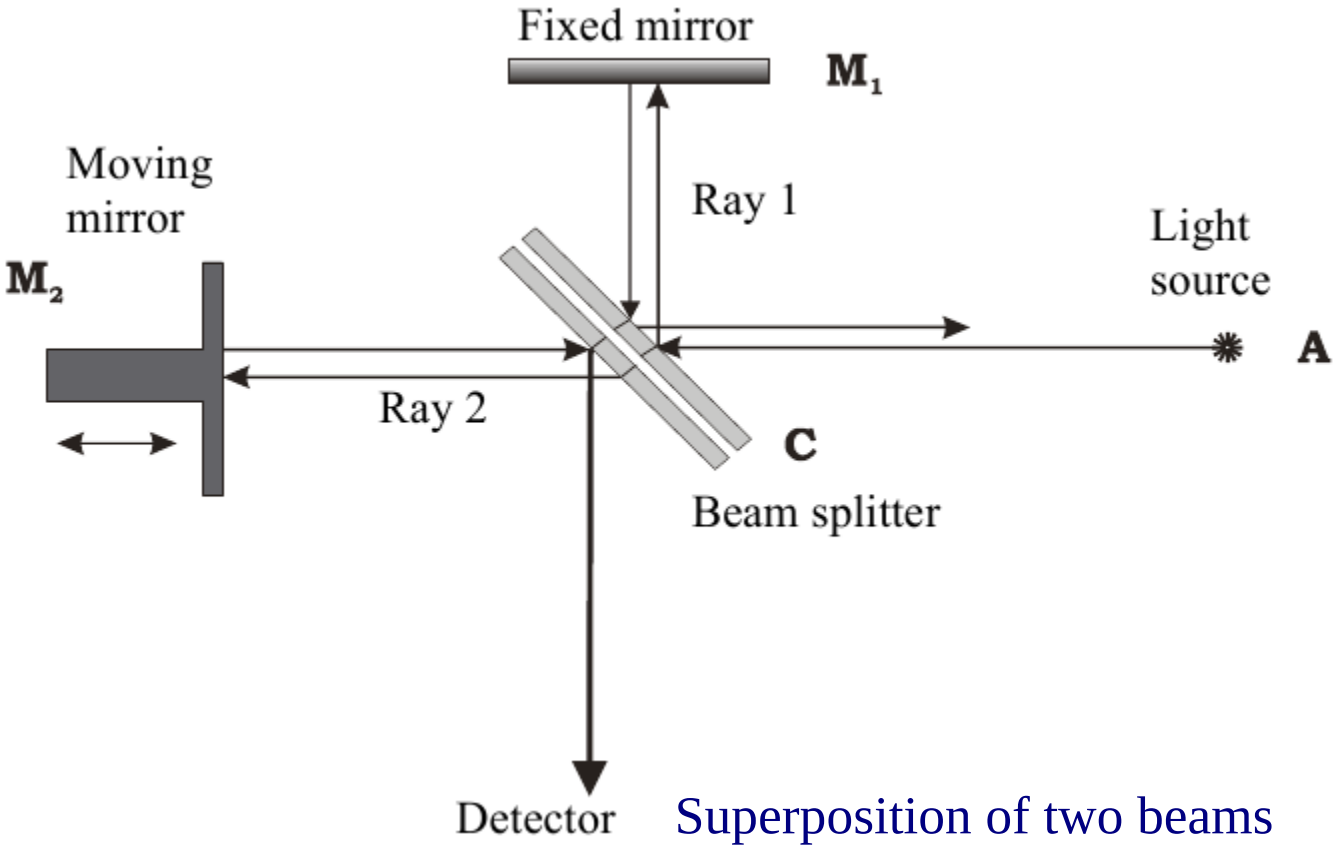
Fourier-Transform Infrared Spectroscopy

Michelson spectrograph



Fourier-Transform Infrared Spectroscopy

Michelson spectrograph



Superposition of two beams
→ Interference

Fourier-Transform Infrared Spectroscopy

Detected intensity

for a monocromatic signal: $I(p) \sim [1 + \cos(2\pi\, p\, \tilde{\nu})]$

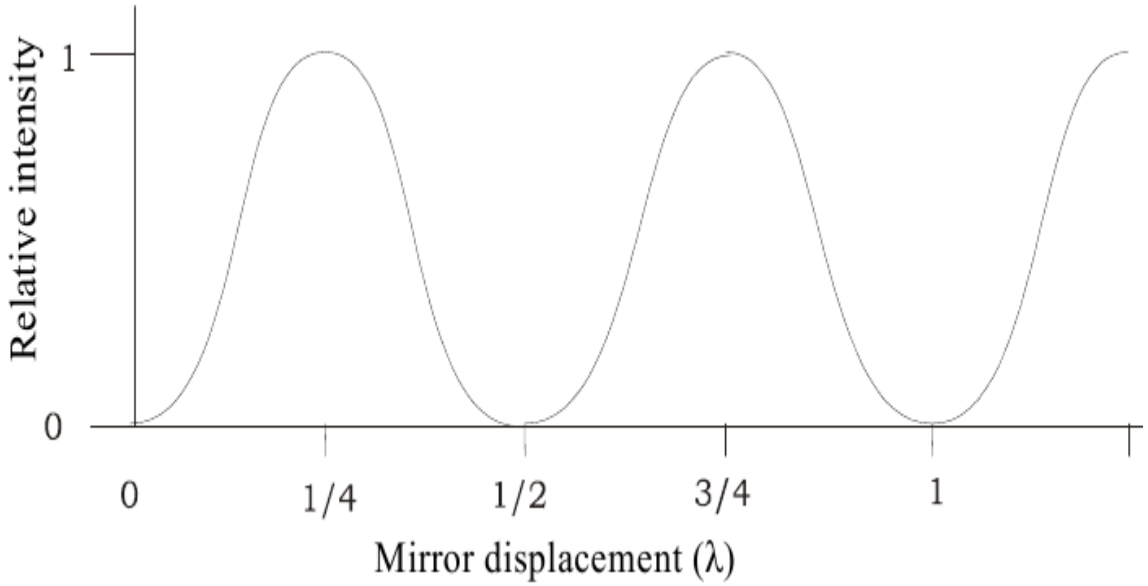
path difference

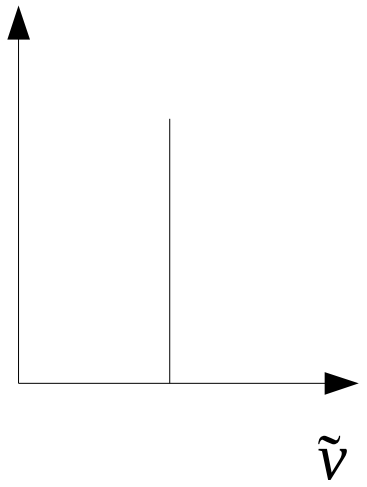
Fourier-Transform Infrared Spectroscopy

Detected intensity

for a monocromatic signal: $I(p) \sim [1 + \cos(2\pi\, p\, \tilde{\nu})]$

path difference





Fourier-Transform Infrared Spectroscopy

Detected intensity

the modulated part for a polychromatic signal:

$$I(p) = \int B(\tilde{\nu}) \cos(2\pi\, p\, \tilde{\nu})\, d\tilde{\nu}$$

spectrum

Fourier-Transform Infrared Spectroscopy

Detected intensity

the modulated part for a polychromatic signal:

$$I(p) = \int B(\tilde{\nu}) \cos(2\pi\, p\tilde{\nu})\, d\tilde{\nu}$$

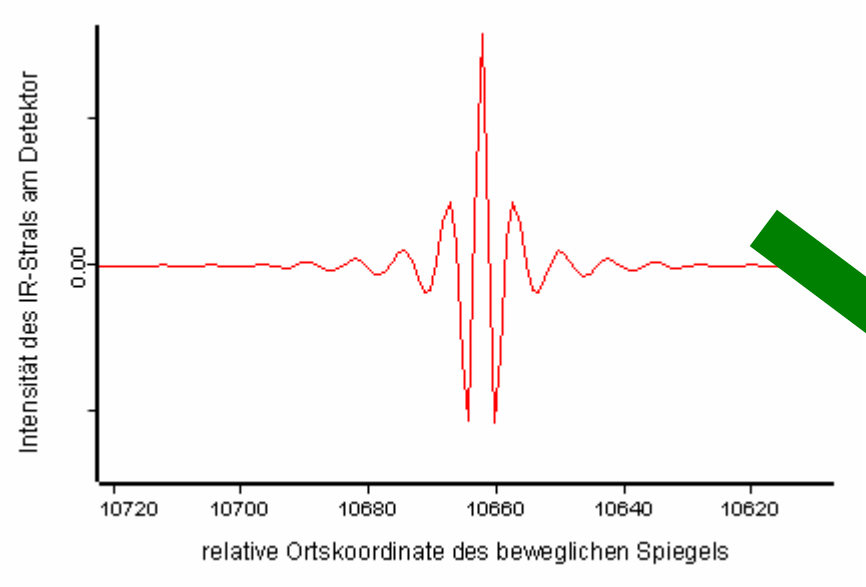
spectrum

Fourier transformation

$$B(\tilde{\nu}) = \int I(p) \cos(2\pi\, p\tilde{\nu})\, dp$$

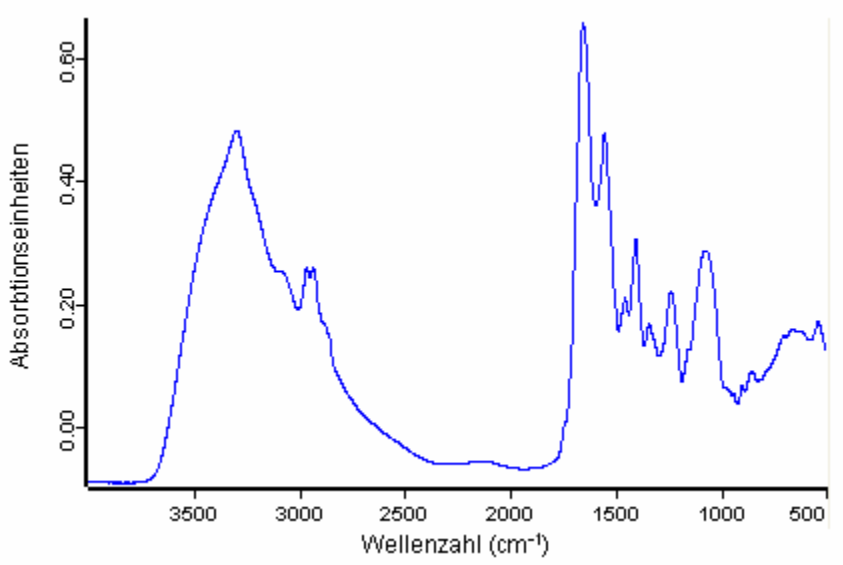
Fourier-Transform Infrared Spectroscopy

Interferogram

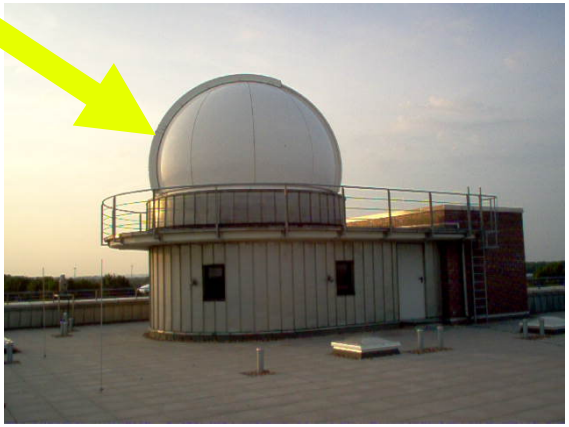


Fourier transformation

spectrum

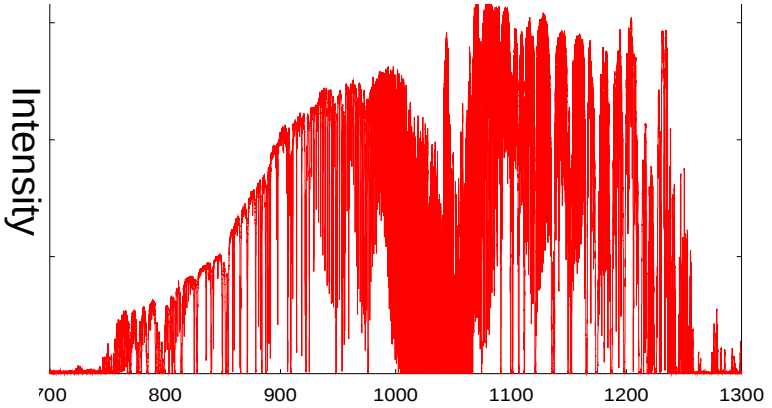


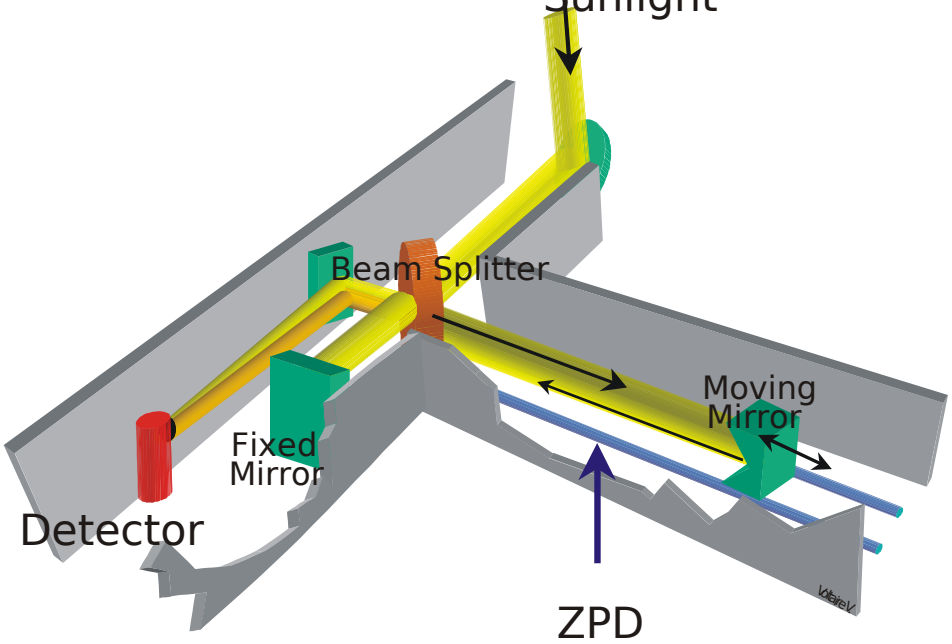
FTIR spectroscopy as a ground based passive remote sensing method



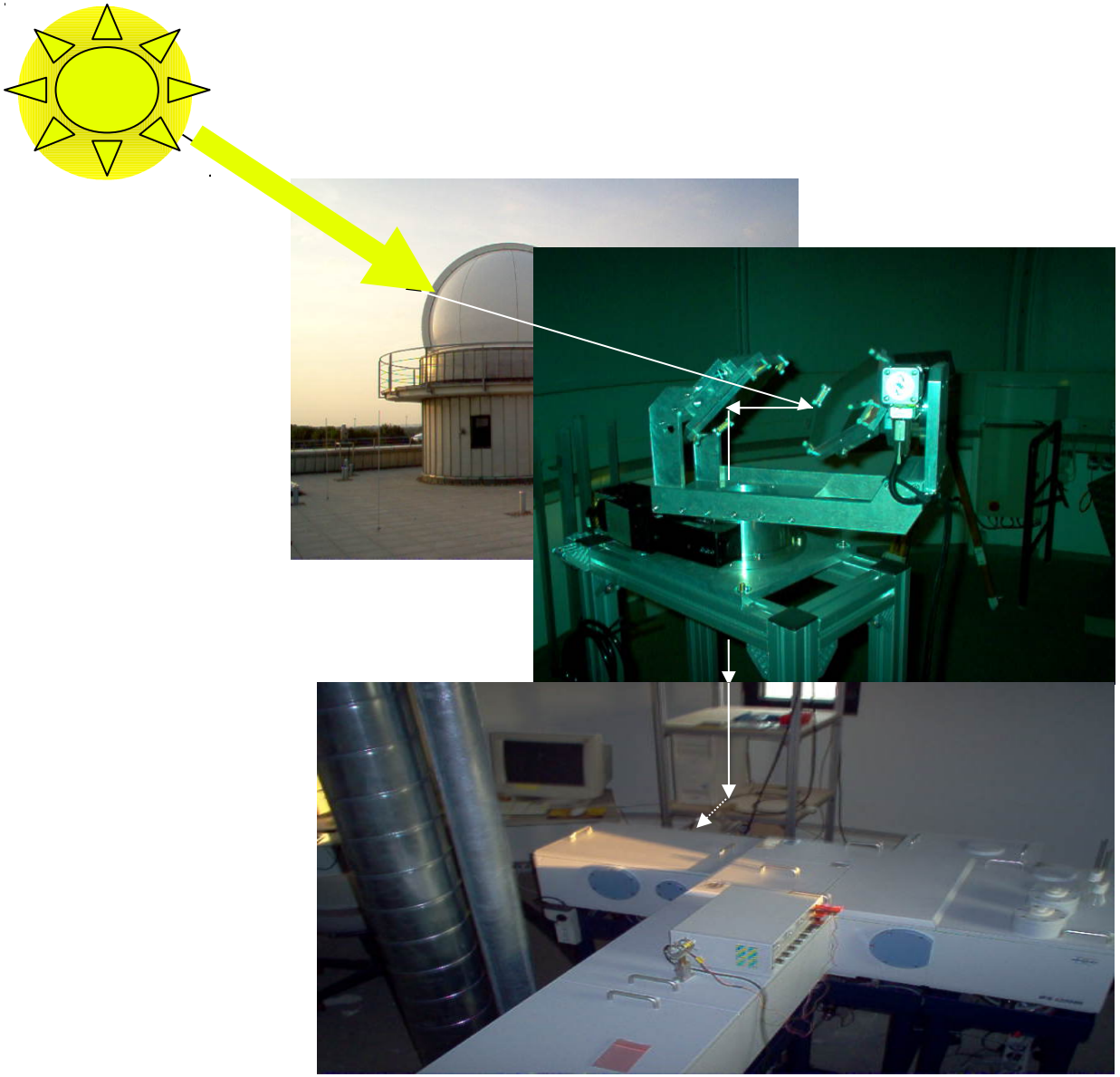
Sunlight

Fourier transformation

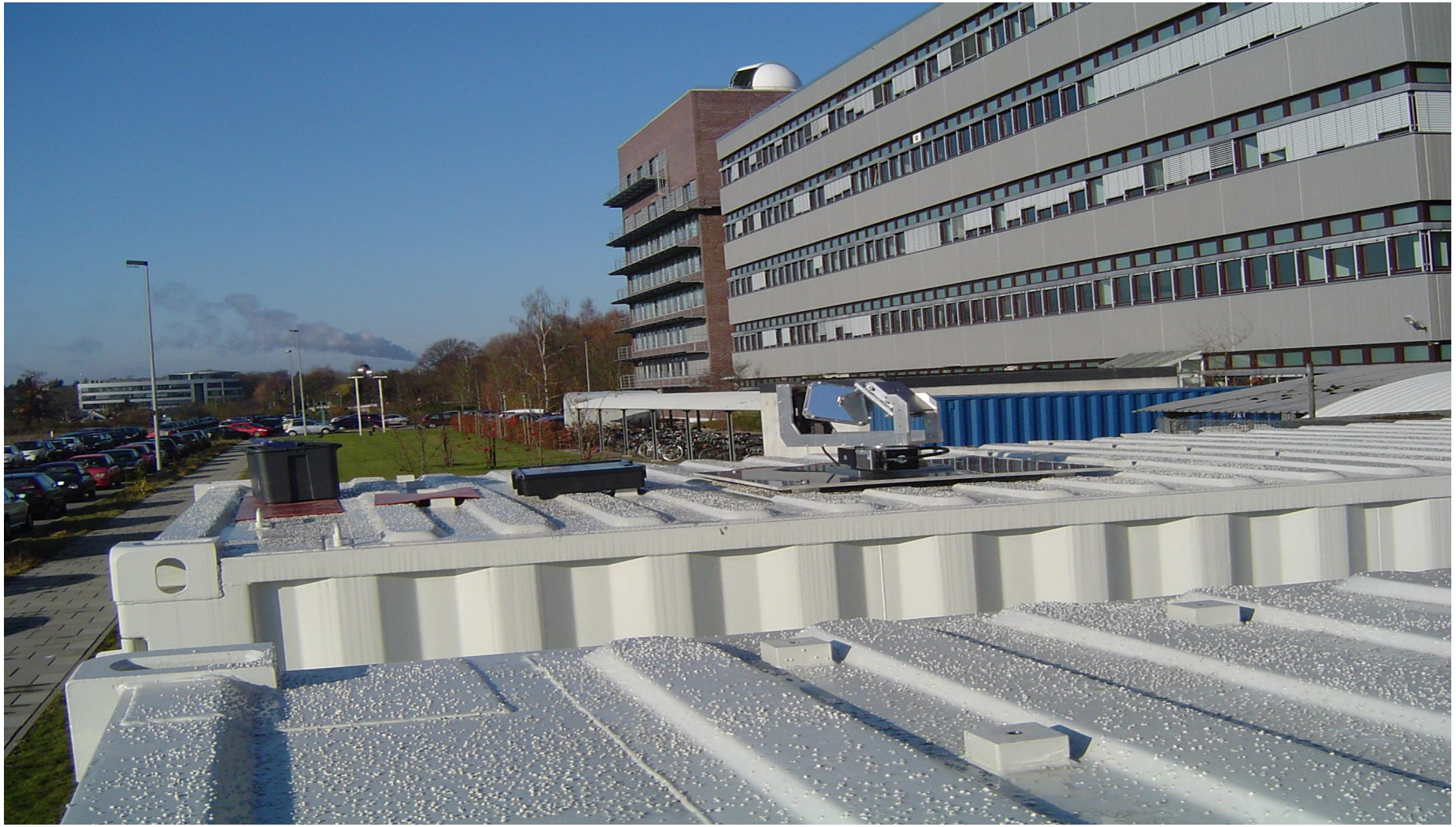




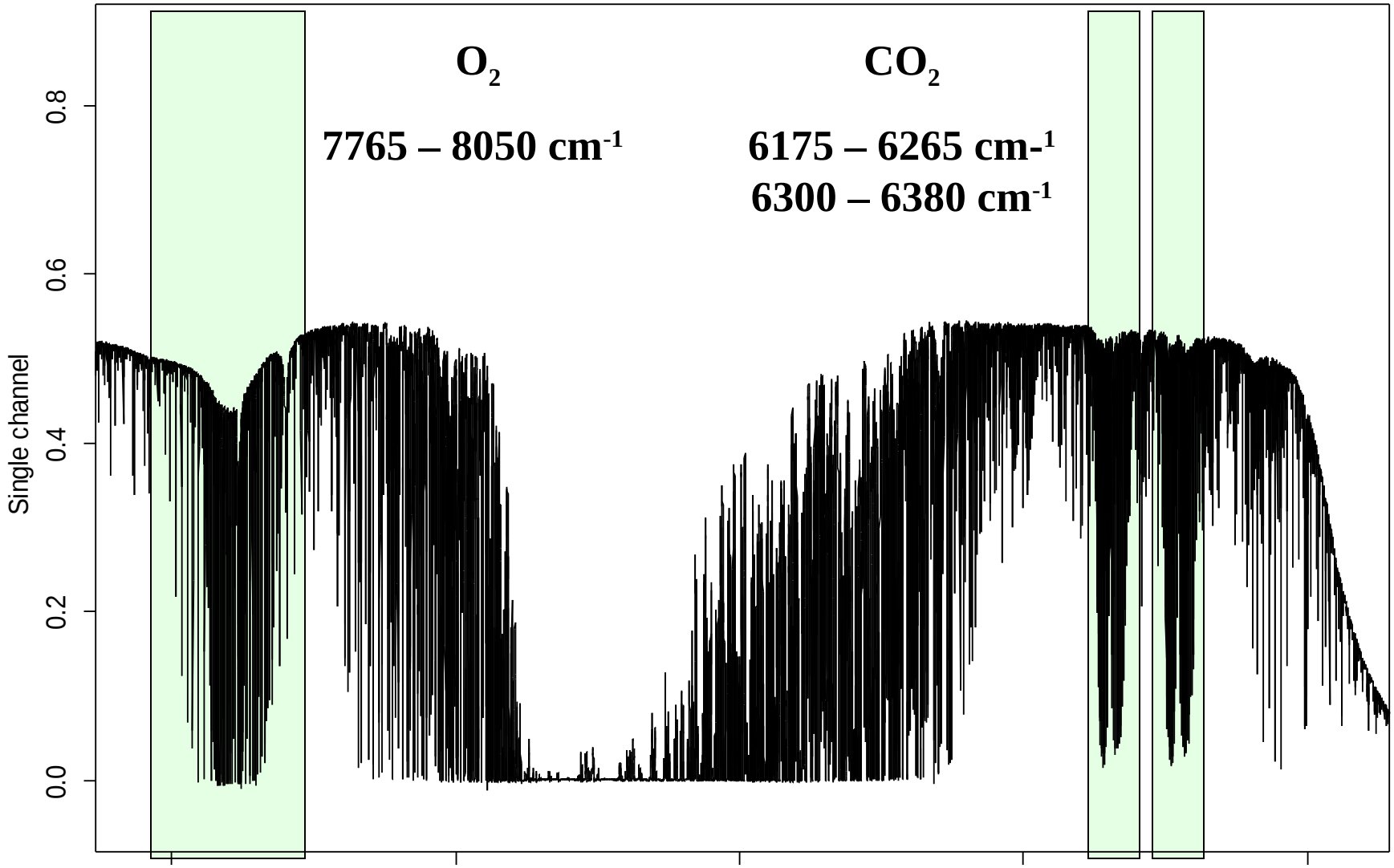
FTIR measurements in Bremen



FTIR measurements in Bremen



Example


O2
7765 – 8050 cm-1
CO2
6175 – 6265 cm-1
6300 – 6380 cm-1
Single channel
0.0
0.2
0.4
0.6
0.8

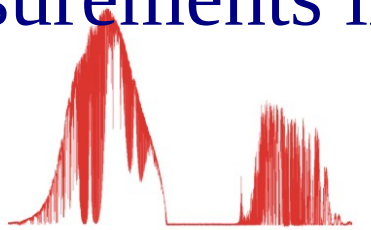
Information from the spectra

- **Aera of an absorption line**
  + absorption cross section → total number of absorbers (column)

- **Strength of rotational emission lines**
  → population of rotational states → temperature

- **Line broadening**
  Doppler broadening (thermal speed)
  Pressure broadening (pressure)

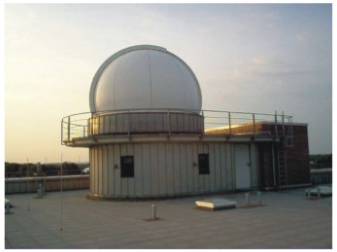
FTIR measurements in Bremen



Experiment

Spectrum

Retrieval



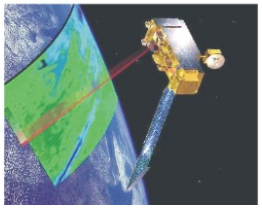
Vmr

Comparison

In situ

Model

Satellite



FTIR measurements in Bremen

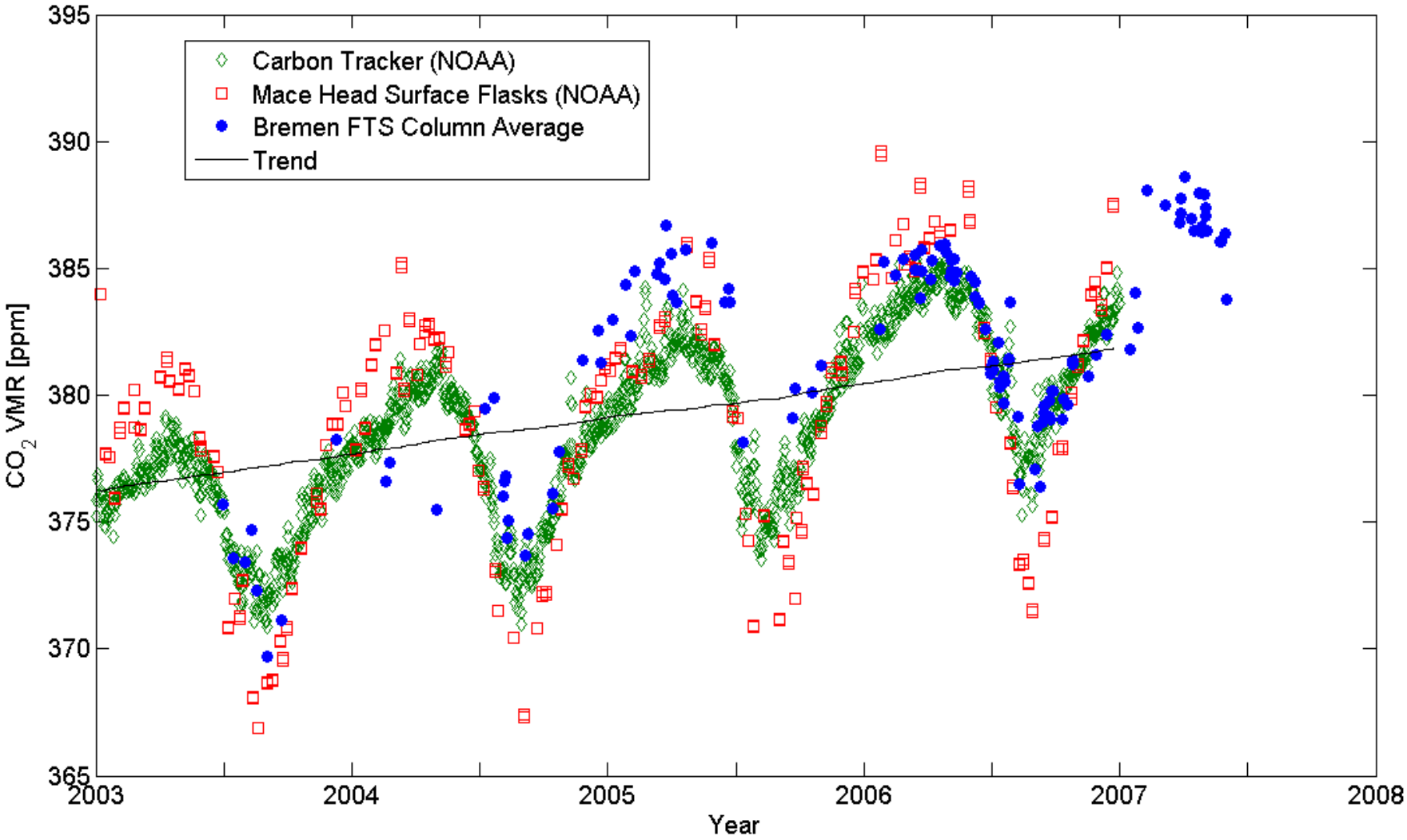


Figure by courtesy of Ronald Macatangay

Thanks for your attention

and

Have fun with the FTIR experiment !

(1. absorption measurements in the laboratory
2. atmospheric emission measurements)