Spectroscopic observation of Stars and planetary atmospheres

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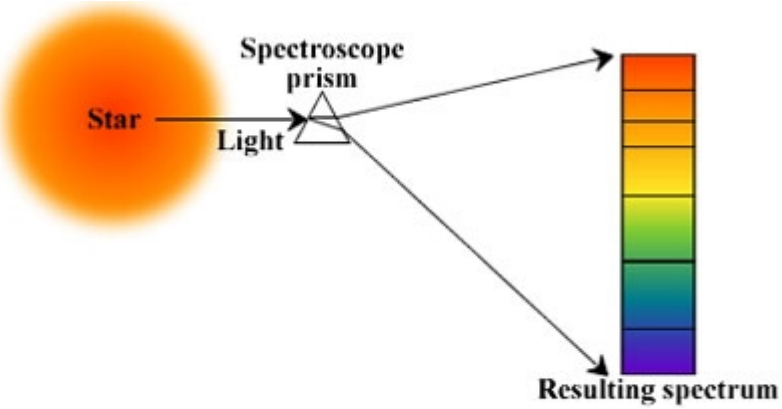
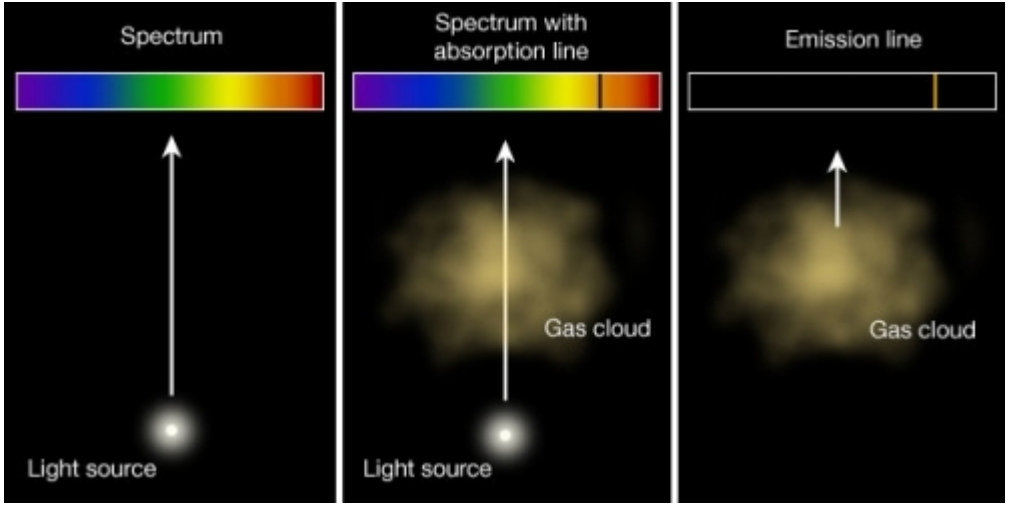
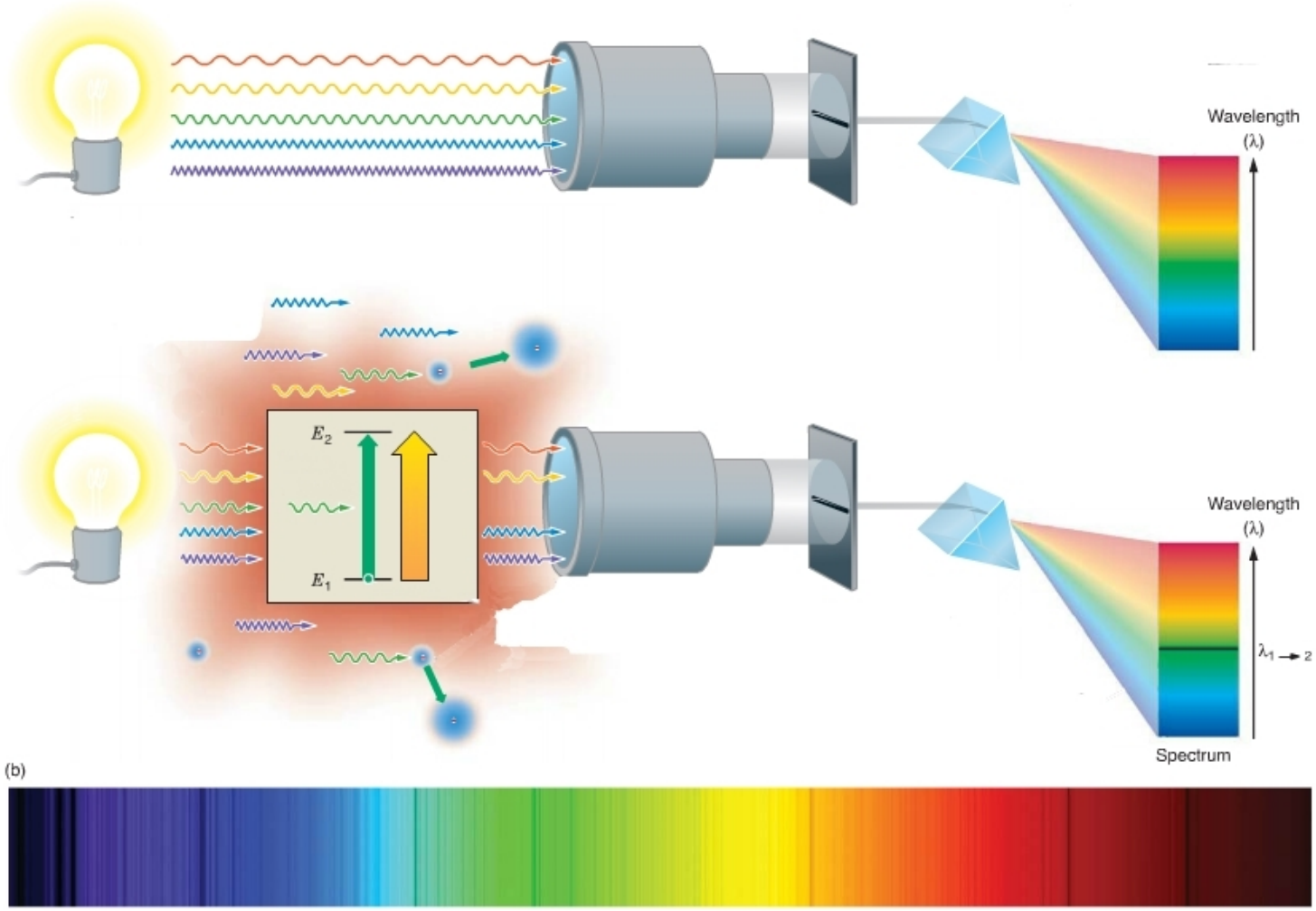
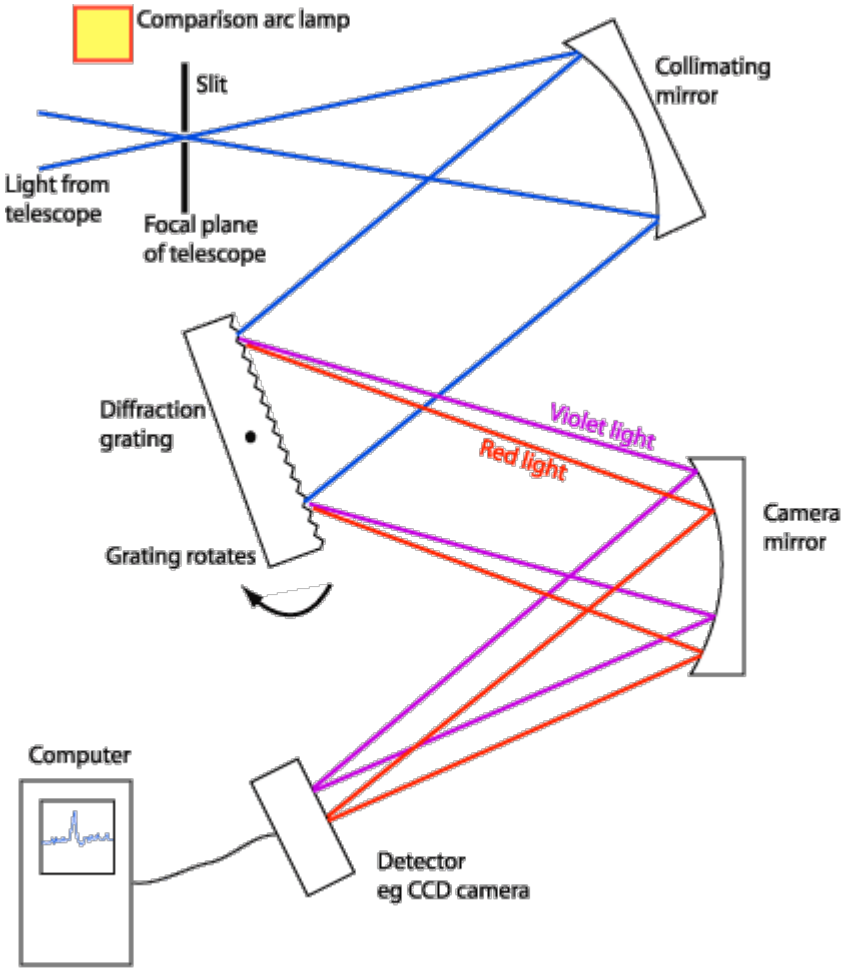
Optical spectroscopy: absorption & emission



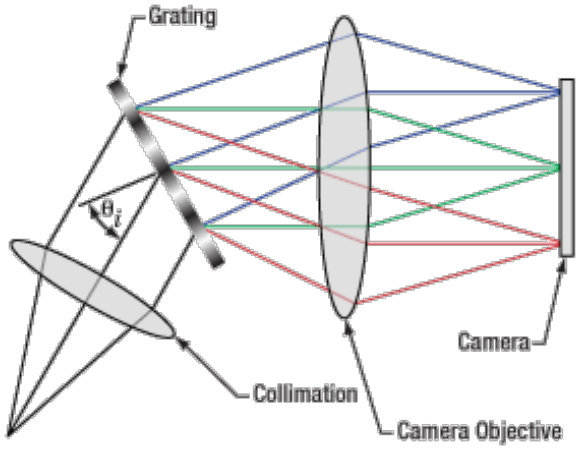


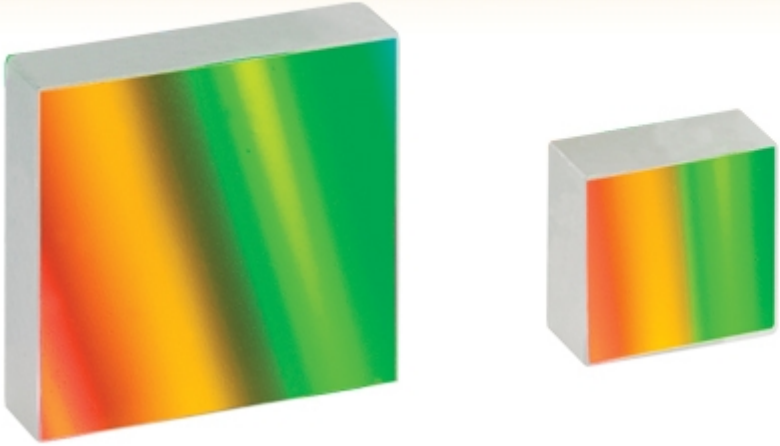

Wavelength
(λ)
E_2
E_1
Wavelength
(λ)
$\lambda_{1 \to 2}$
Spectrum
(b)

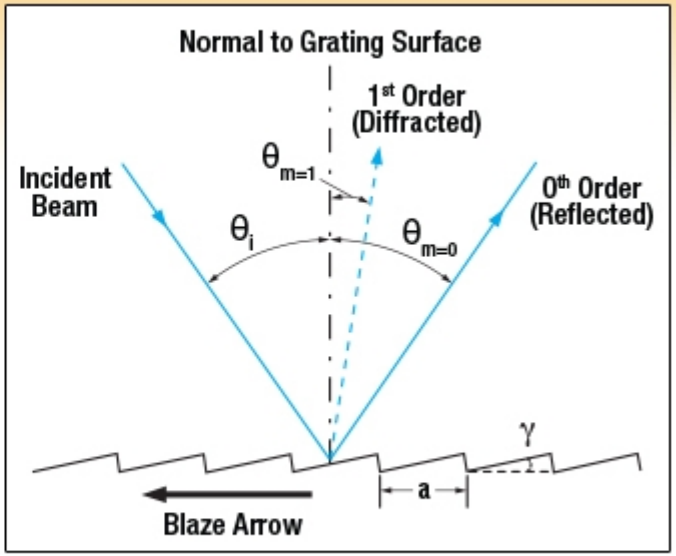
Transmission grating spectrometer



A Schematic Diagram of a Slit Spectrograph

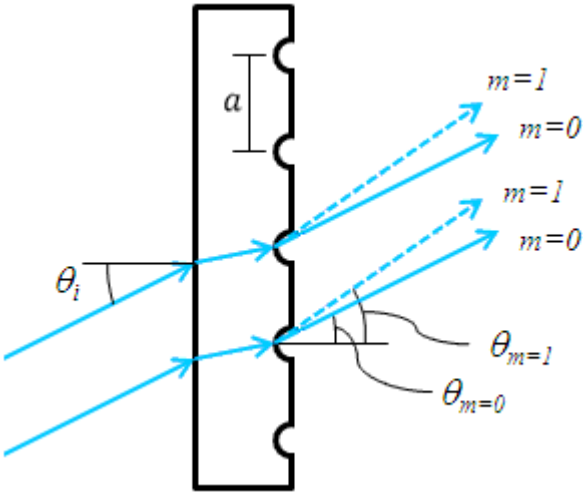






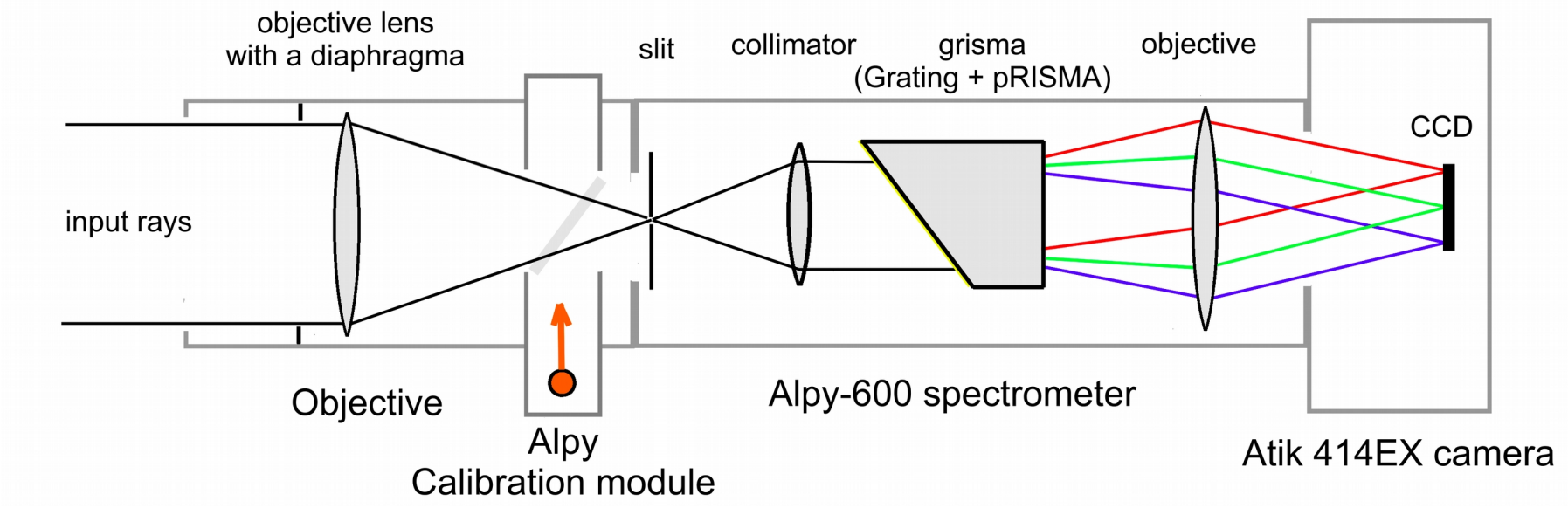
$$a\,[\sin(\theta_m) + \sin(\theta_i)] = m\lambda$$

Transmission grating

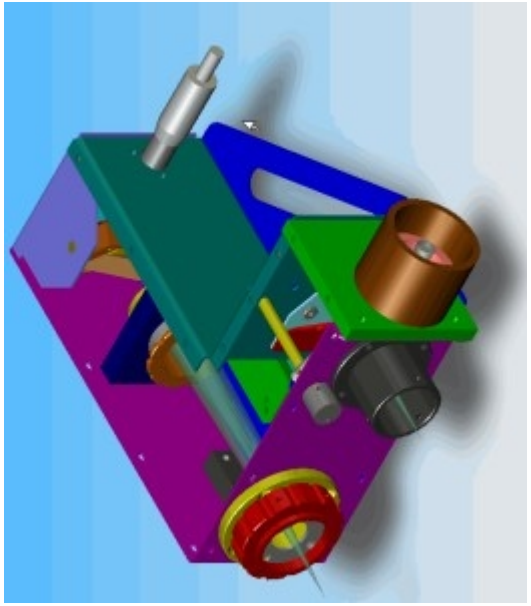


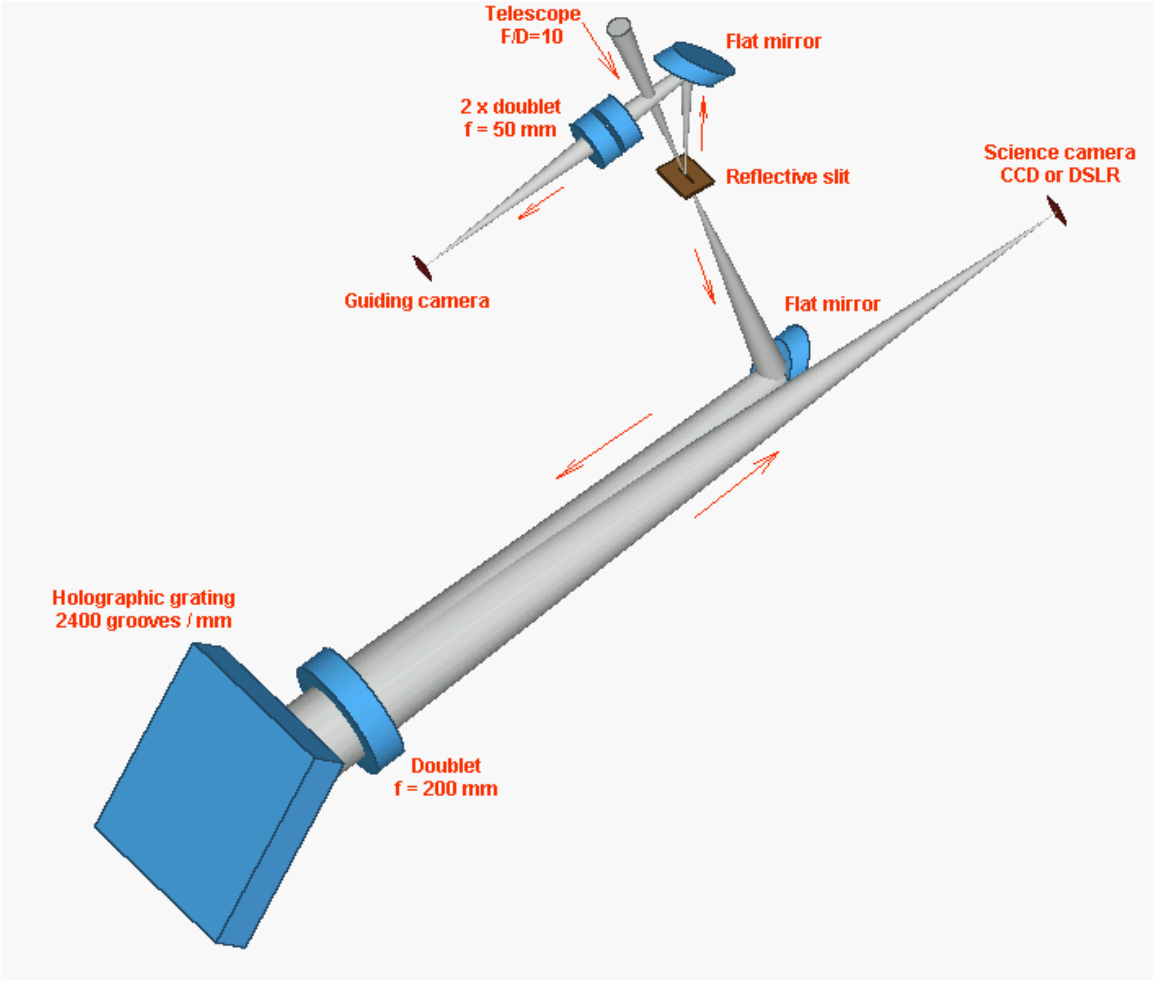
$$a\,[\sin(\theta_m) - \sin(\theta_i)] = m\lambda$$

ALPY 600 spectrometer

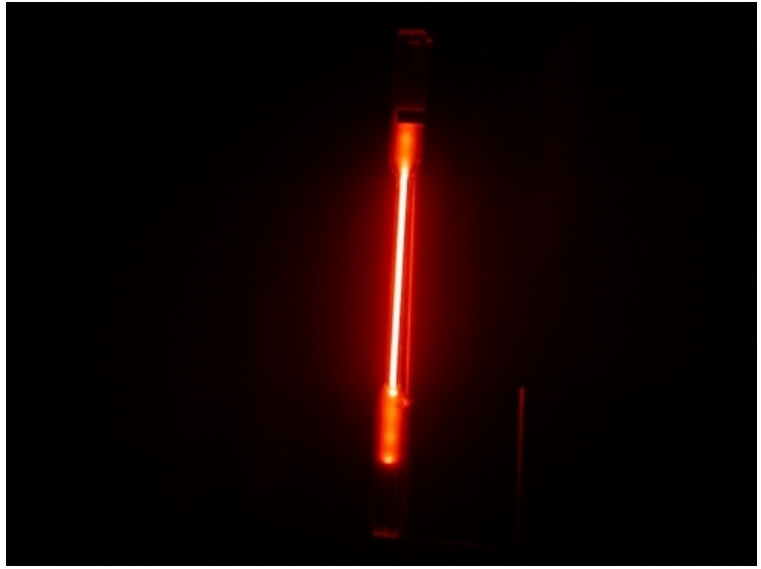

objective lens
with a diaphragma
slit
collimator
grisma
(Grating + pRISMA)
objective
CCD
input rays
Objective
Alpy
Calibration module
Alpy-600 spectrometer
Atik 414EX camera

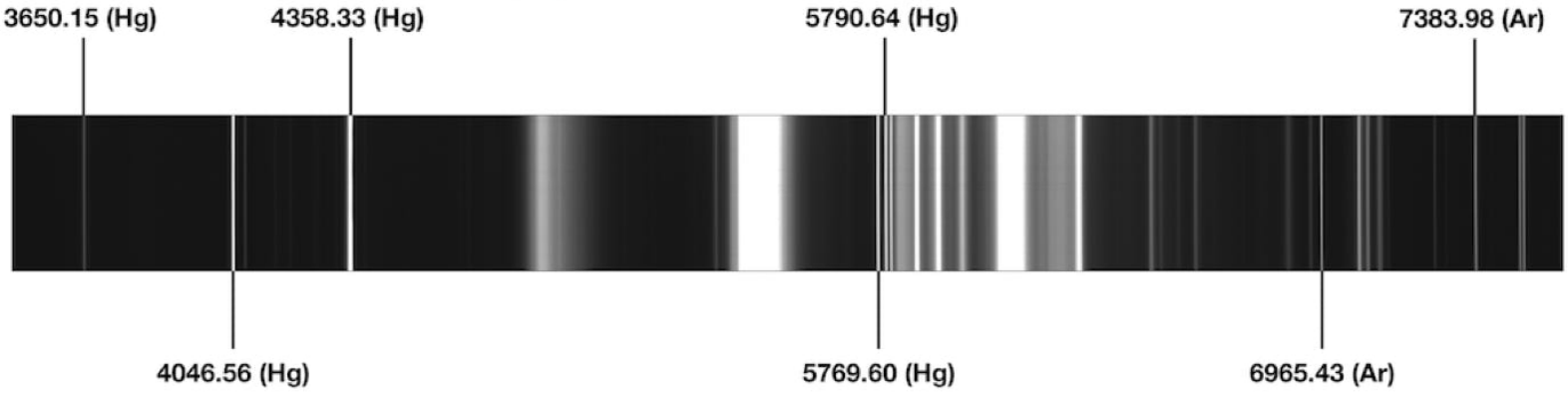
LHIRES III spectrograph

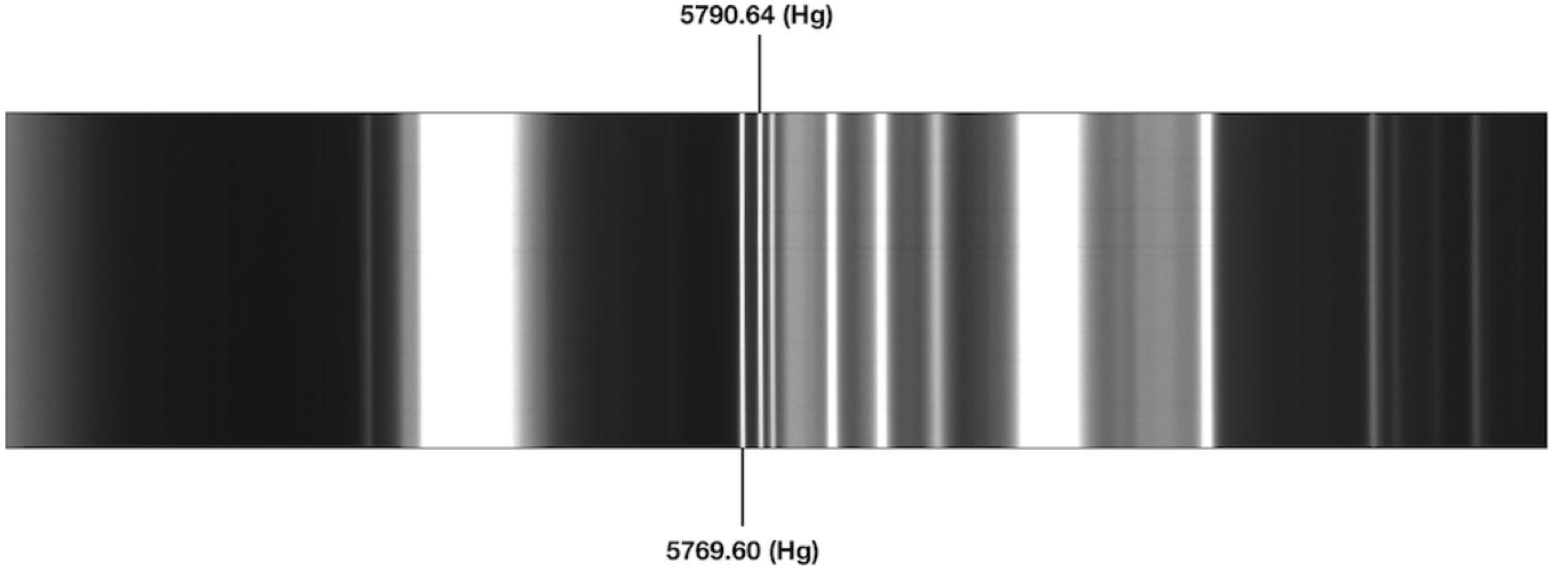




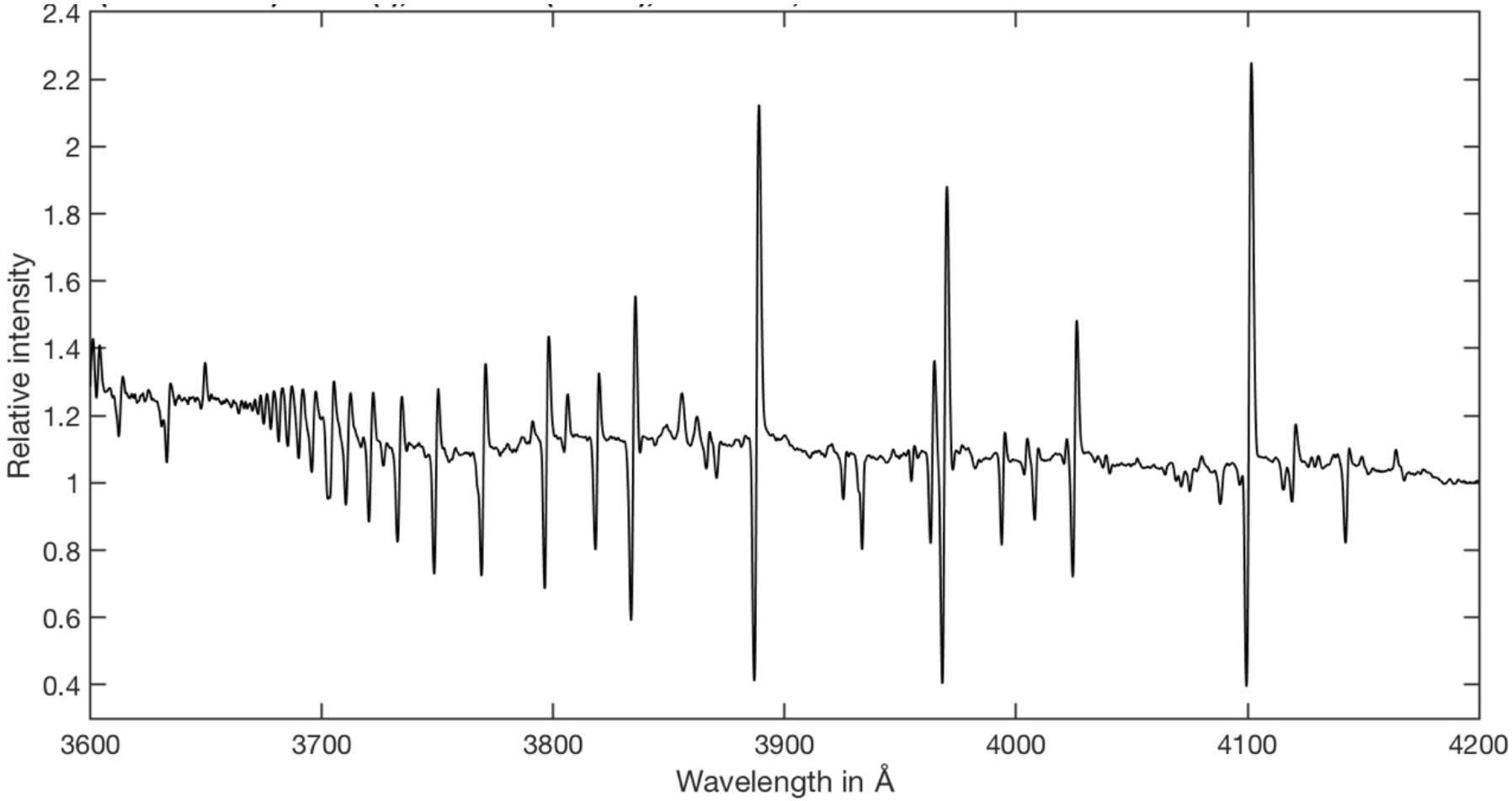
Calibration of spectrograph: using neon lamp

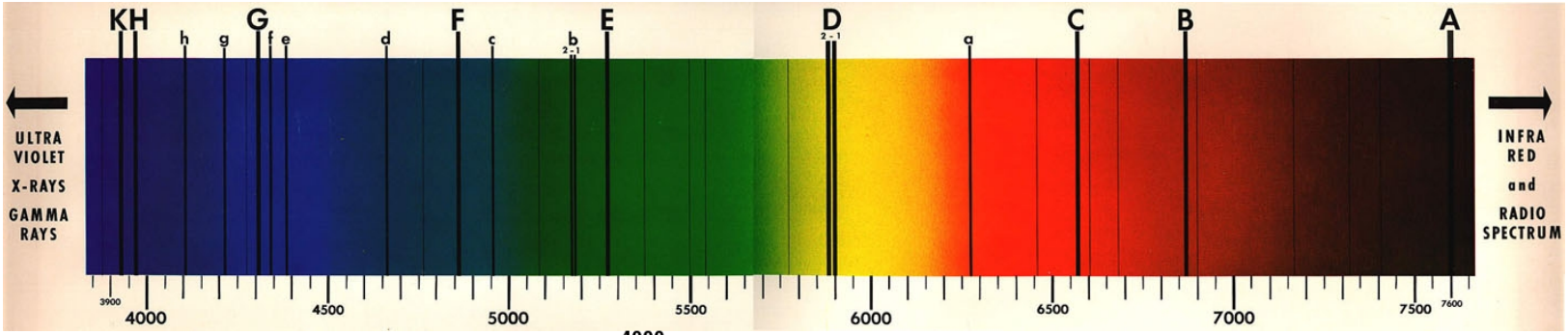



3650.15 (Hg)
4358.33 (Hg)
5790.64 (Hg)
7383.98 (Ar)
4046.56 (Hg)
5769.60 (Hg)
6965.43 (Ar)

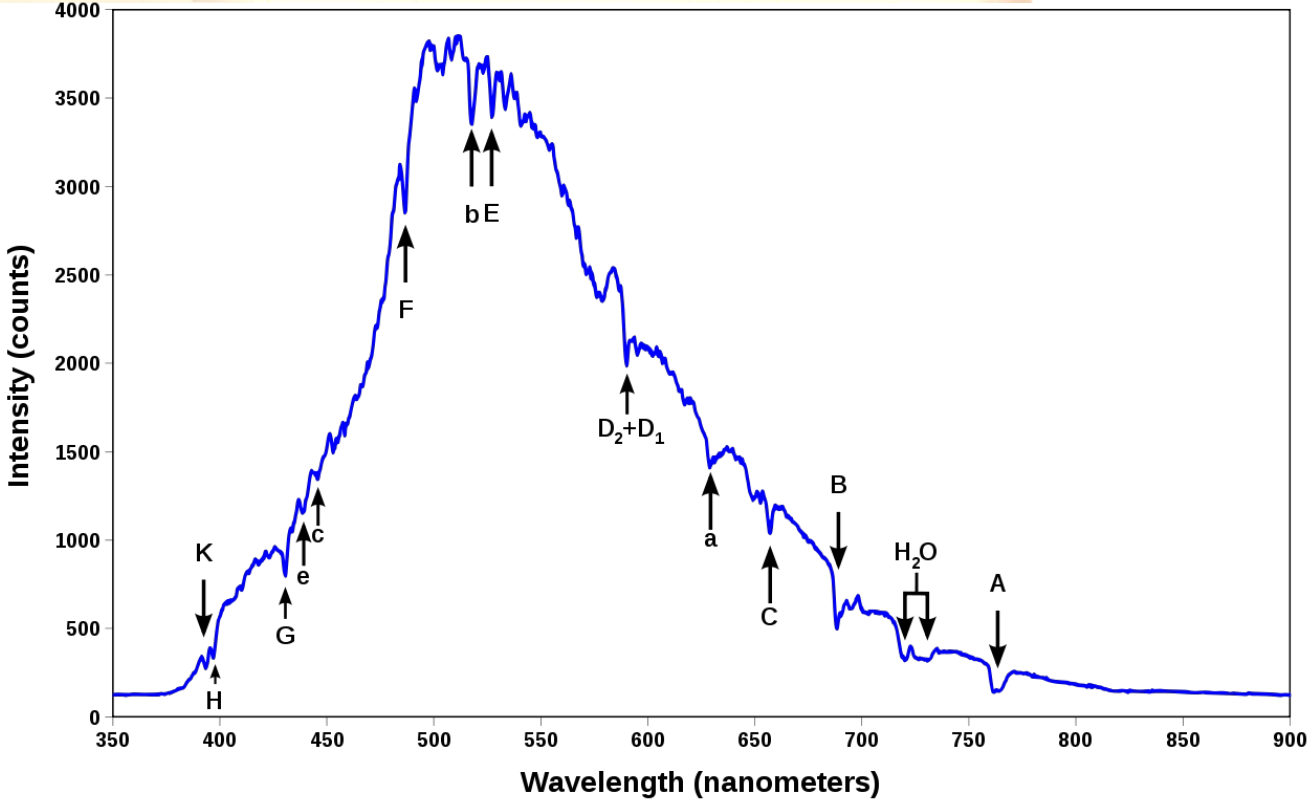

5790.64 (Hg)
5769.60 (Hg)

Spectrum of P Cygni





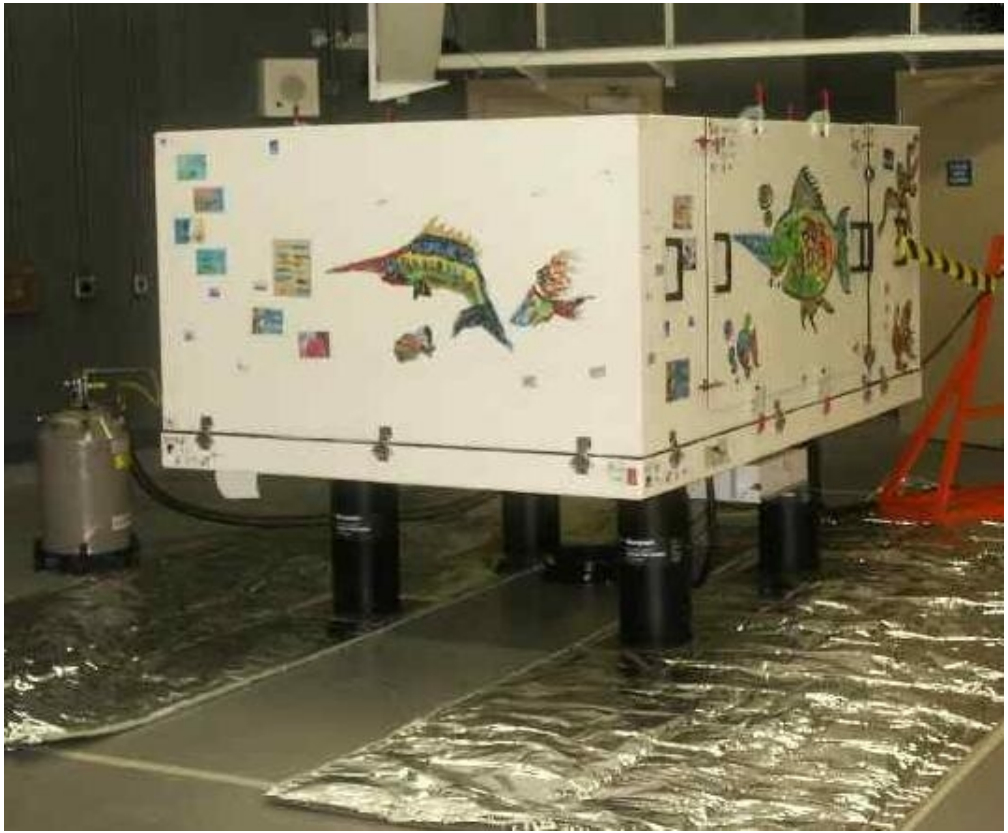
Low resolution solar optical spectrum – Fraunhofer lines are clearly visible



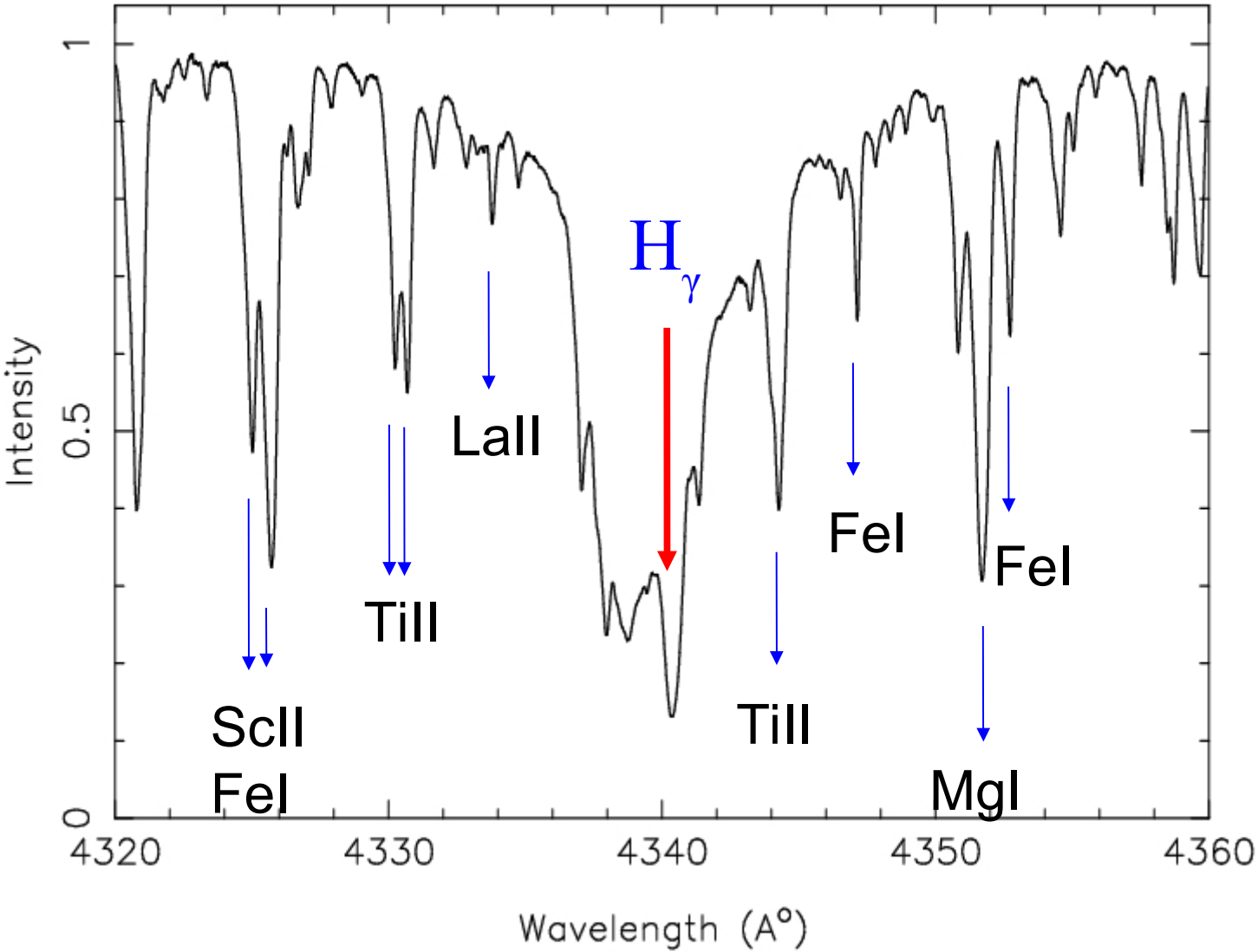
Stellar spectroscopy

CFH Telescope

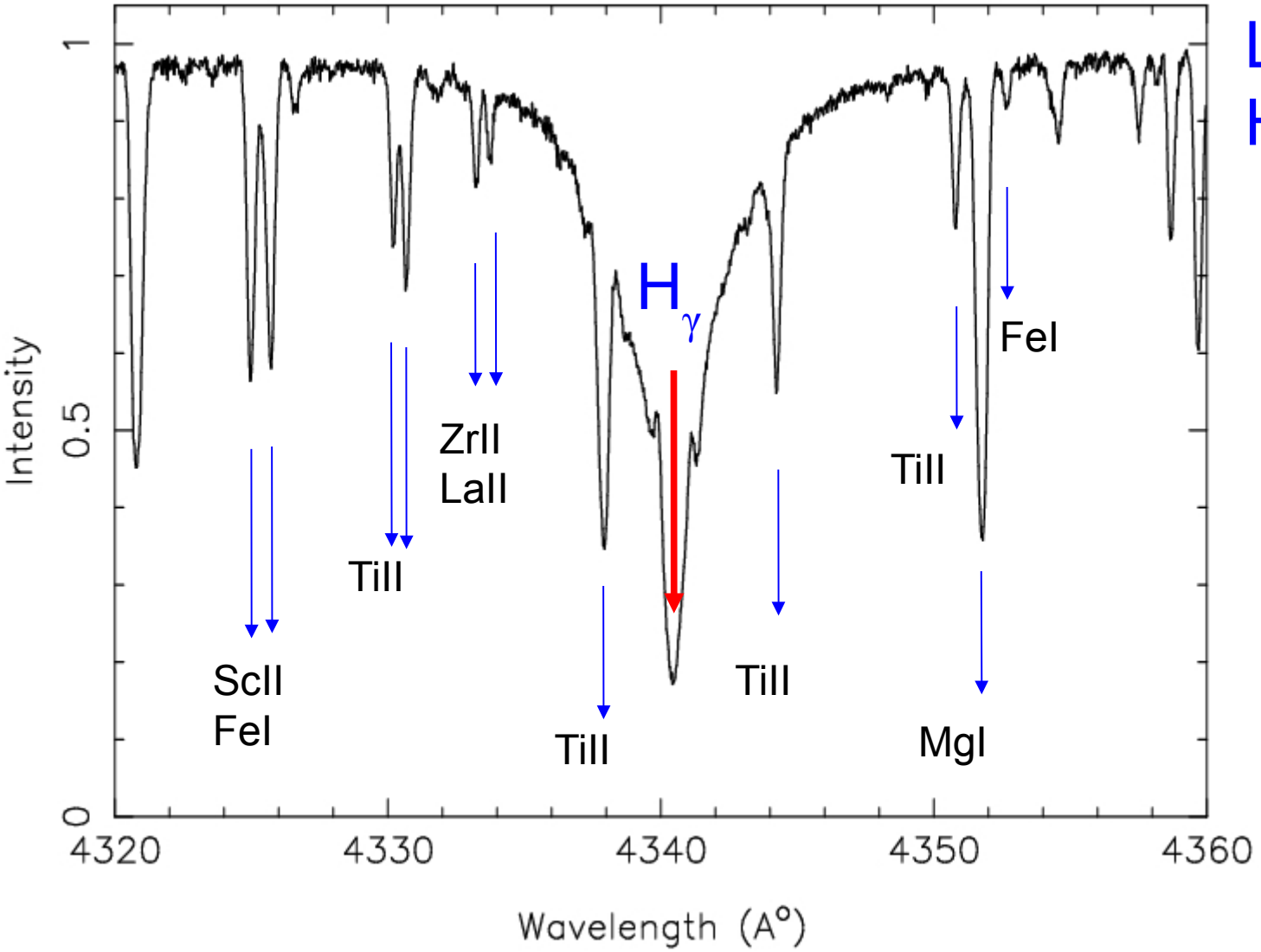
Spectropolarimeter Espadons



Very high spectral resolution
R~ 65000



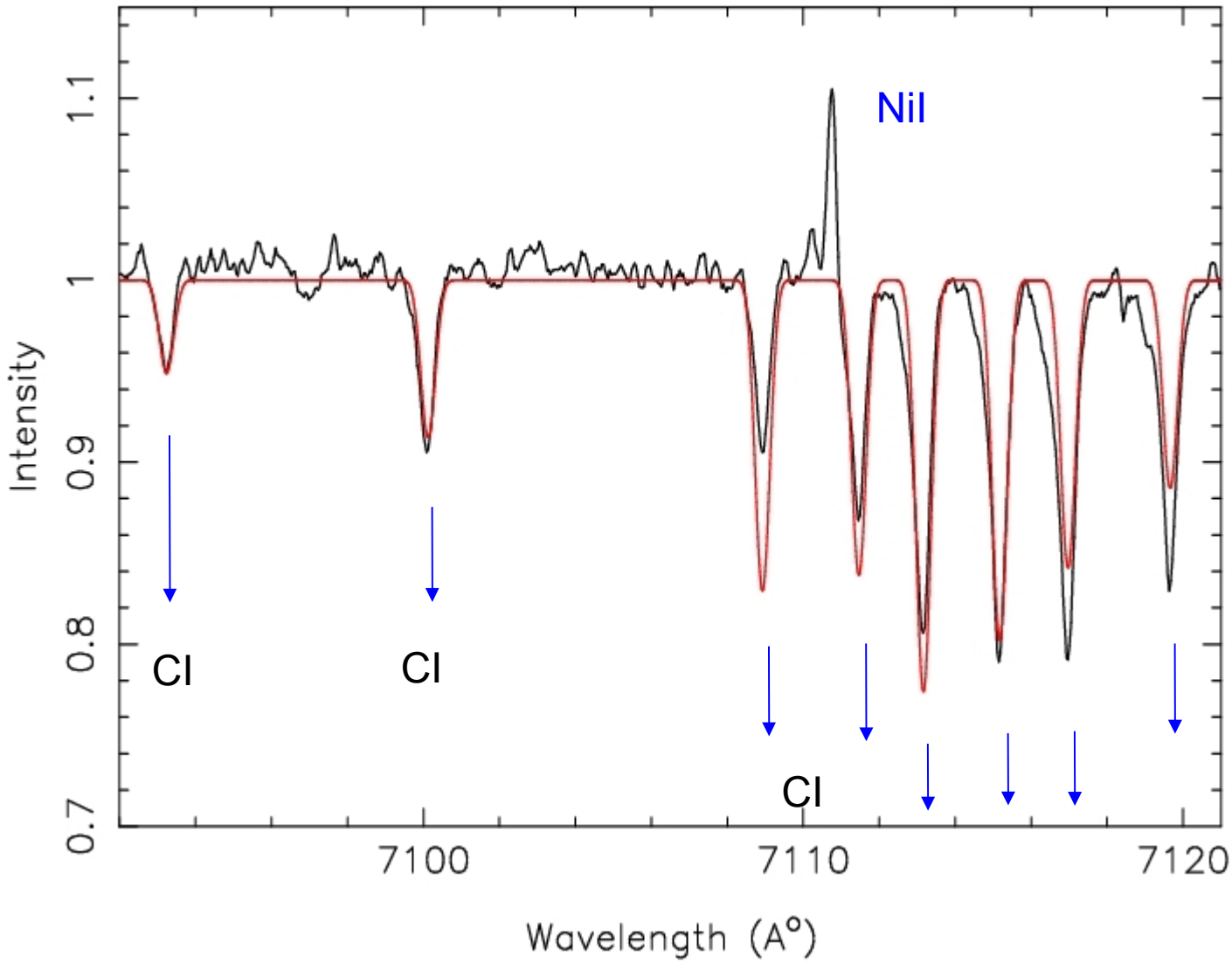
Atomic lines around Hγ region of 89 Herculis



Late type star
HD 187885

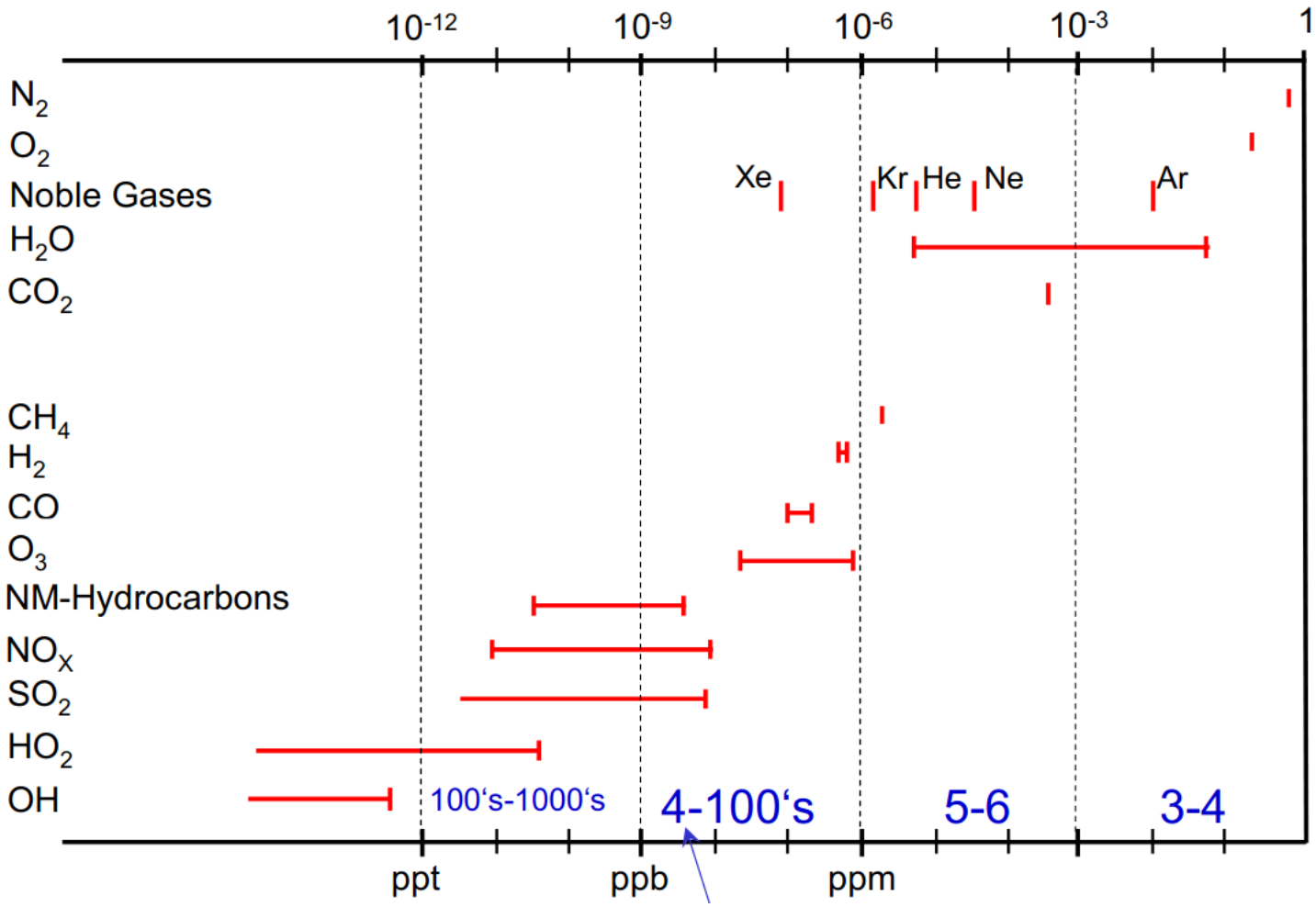
89 Herculis	HD 187885
Teff = 7000 K	Teff = 8000 K
*log***g** = 1.0	*log***g** = 1.0
[Fe/H] = -0.5	[Fe/H] = -0.5
V_t = 4 km/s	V_t = 5 km/s

$$[Fe/H] = \log\{N(Fe)/N(H)\}_{star} - \log\{N(Fe)/N(H)\}_{sun}$$

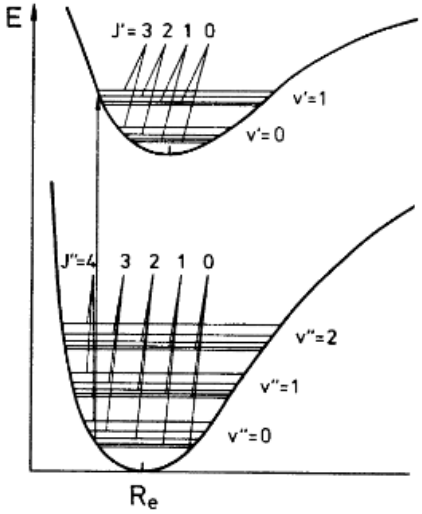


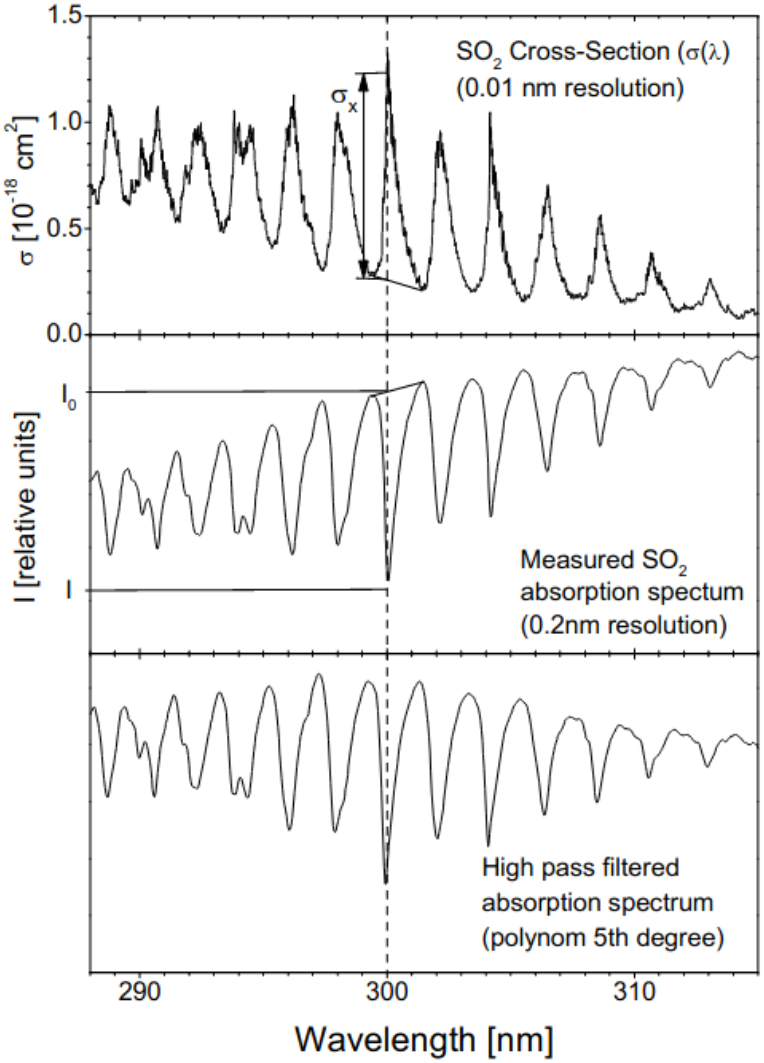
Synthesis of CI multiplet around 7100 A° in 89 Her

Typical mixing ratio of gases in Earth's atmosphere

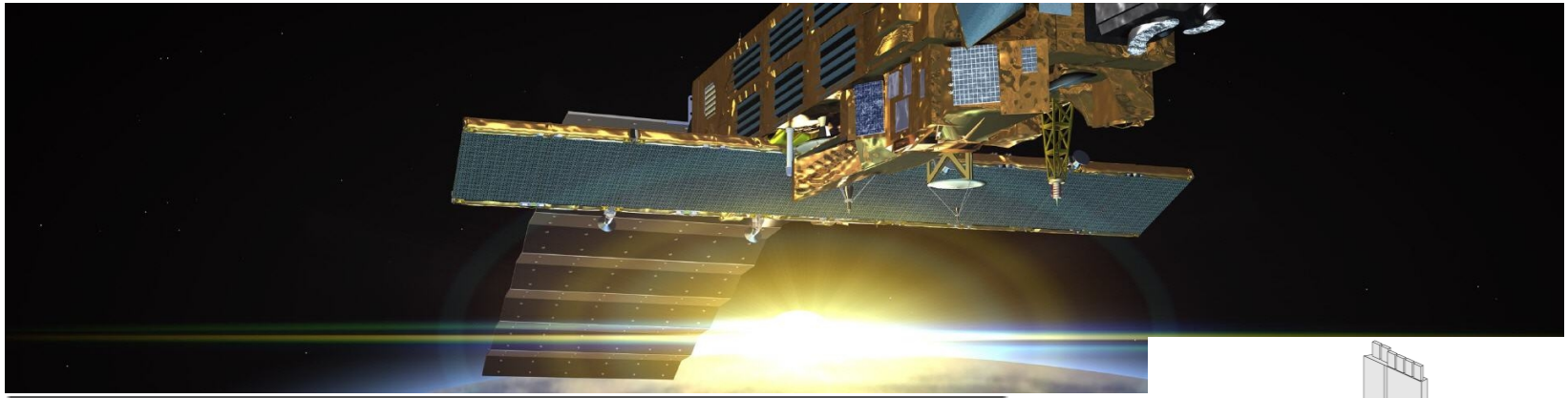


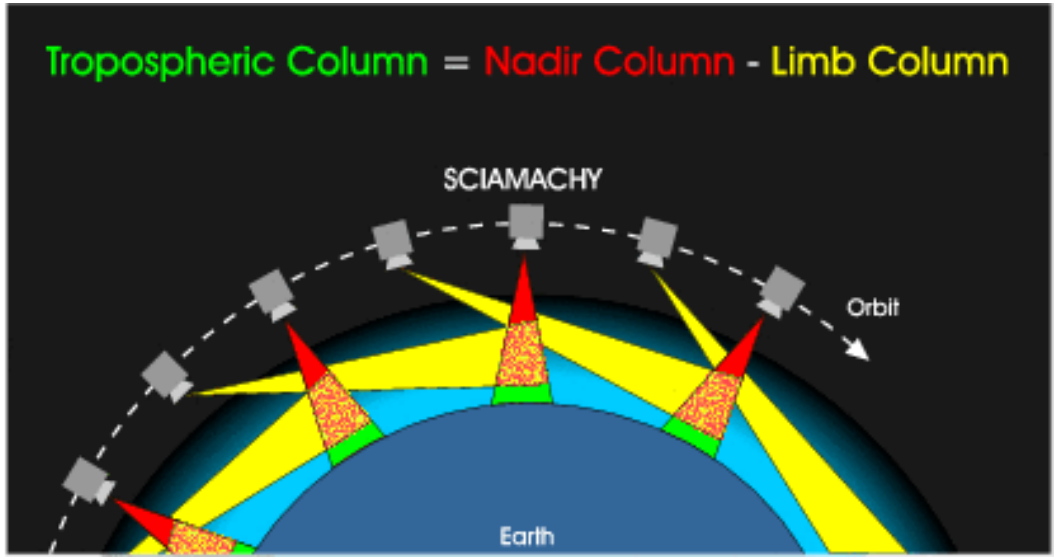
Example: Absorption Cross Section and DOAS – Spectrum of SO_2

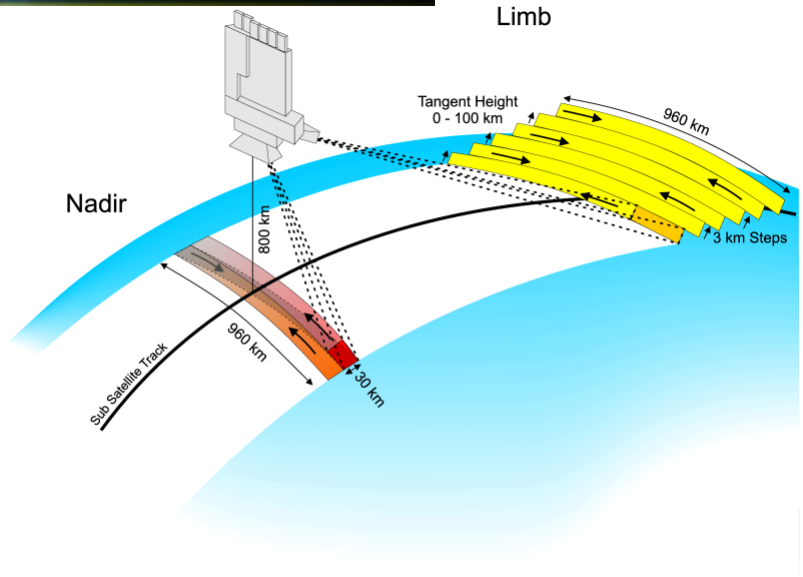


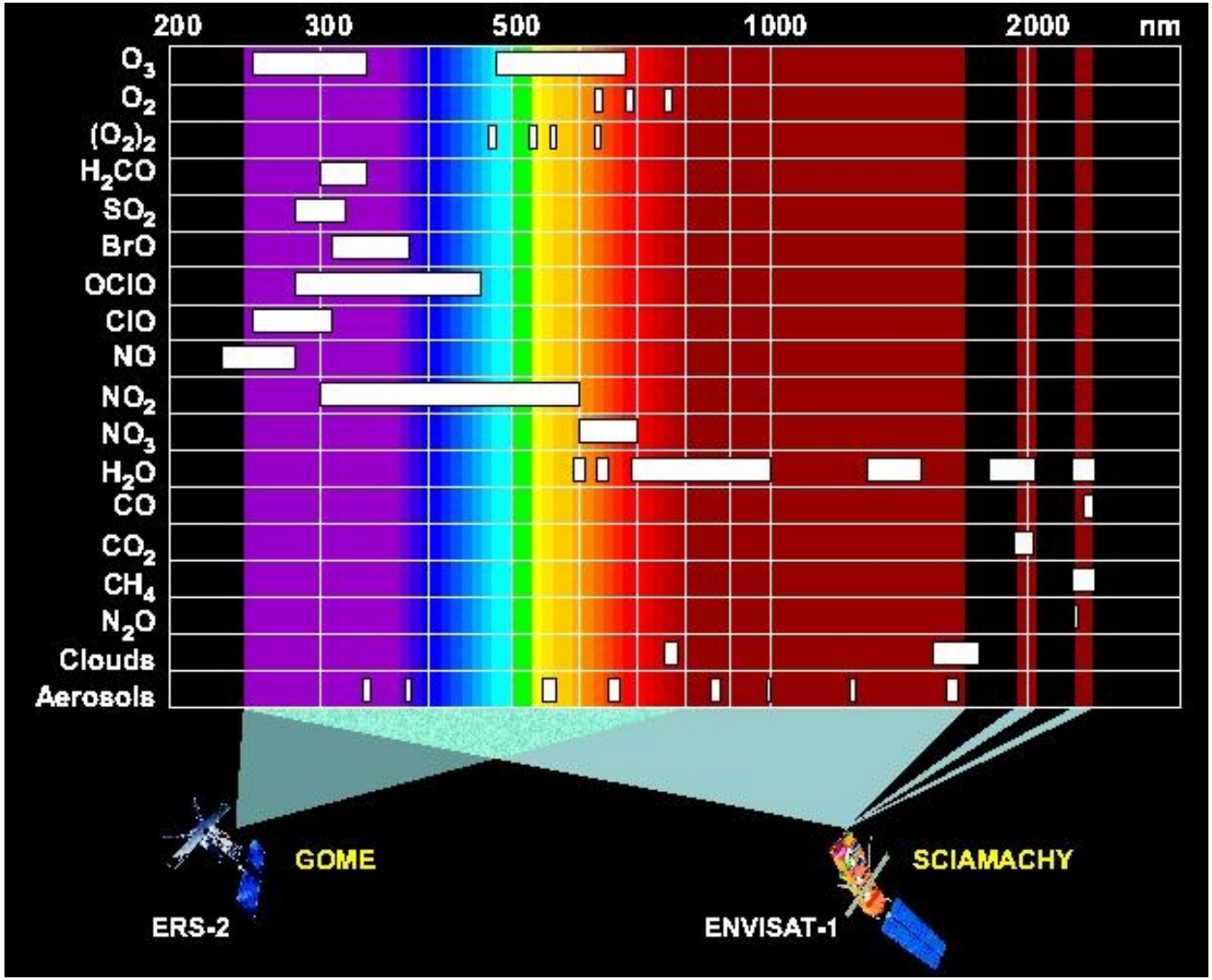


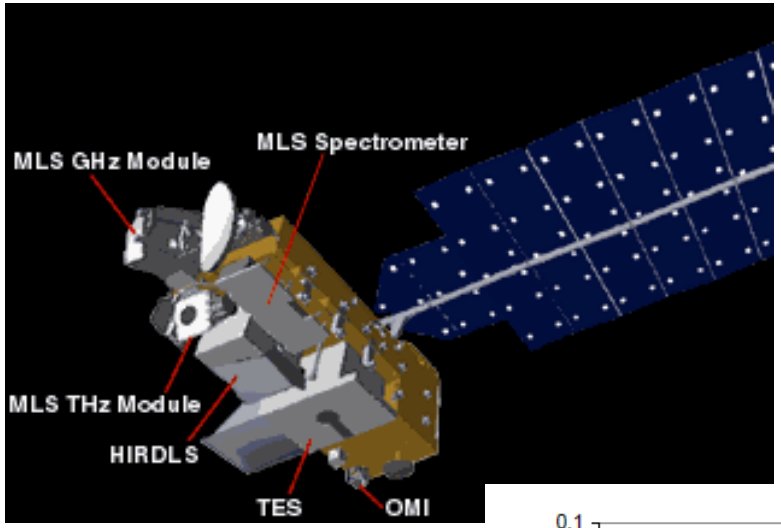
Envisat Satellite with Sciamachy instrument on board



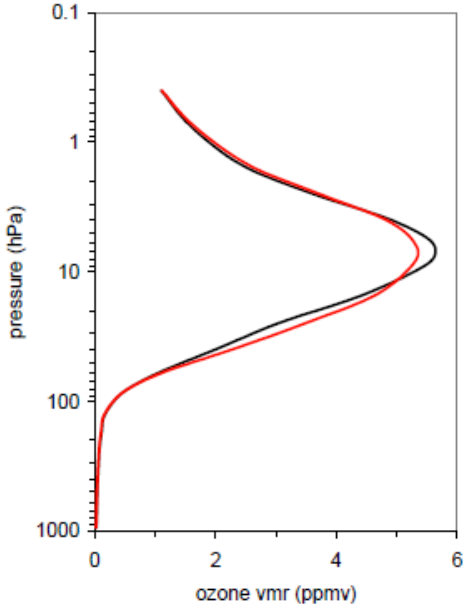


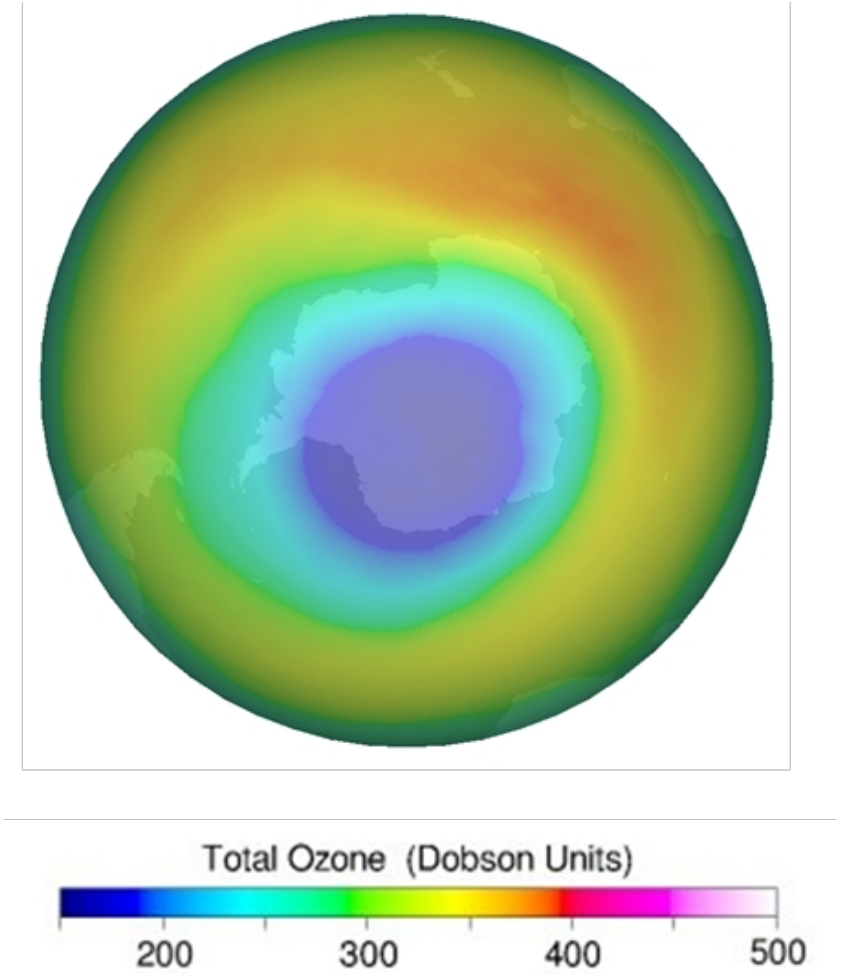


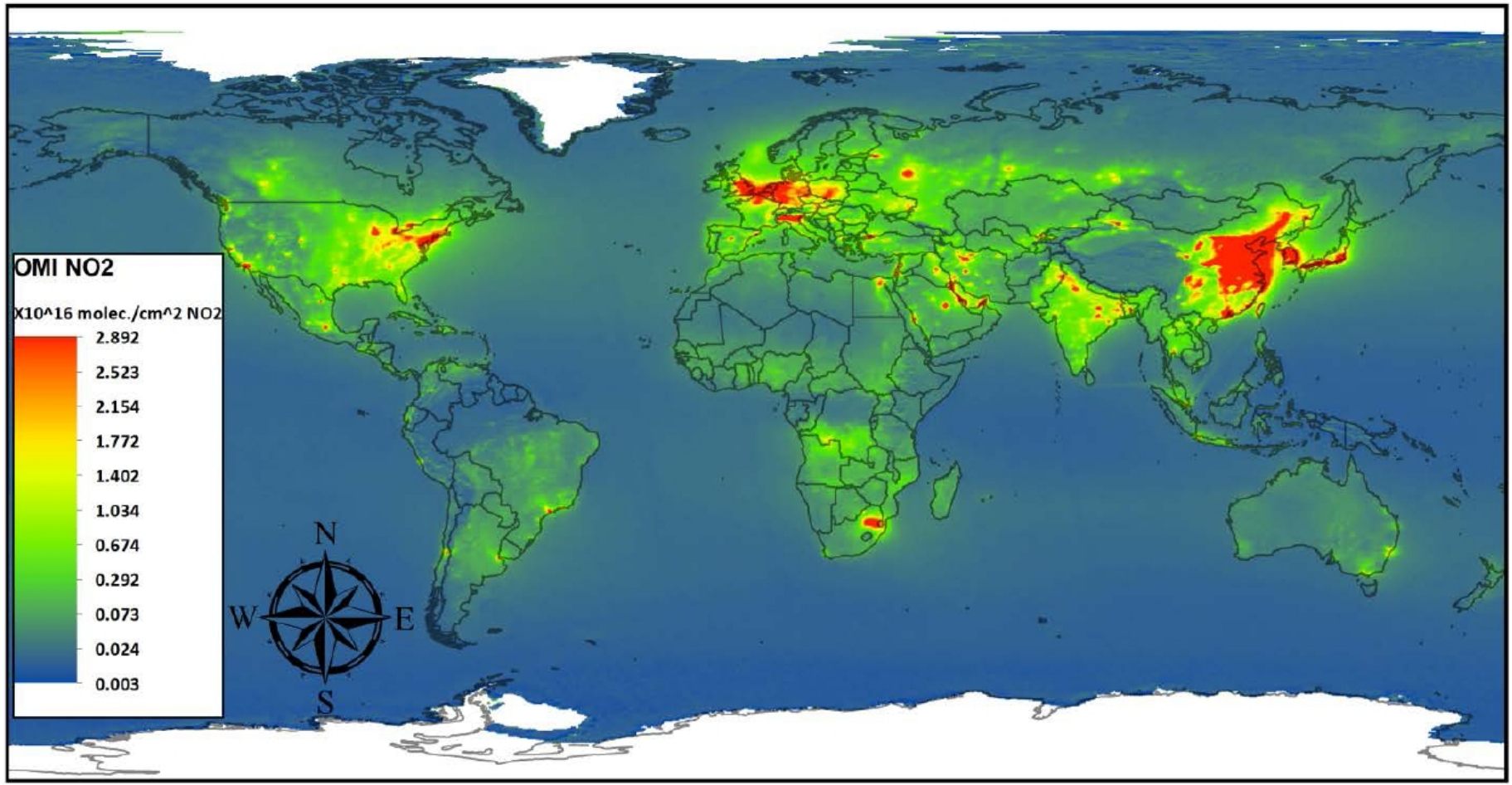

200
300
500
1000
2000
nm
O_3
O_2
$(O_2)_2$
H_2CO
SO_2
BrO
OClO
ClO
NO
NO_2
NO_3
H_2O
CO
CO_2
CH_4
N_2O
Clouds
Aerosols
GOME
ERS-2
SCIAMACHY
ENVISAT-1



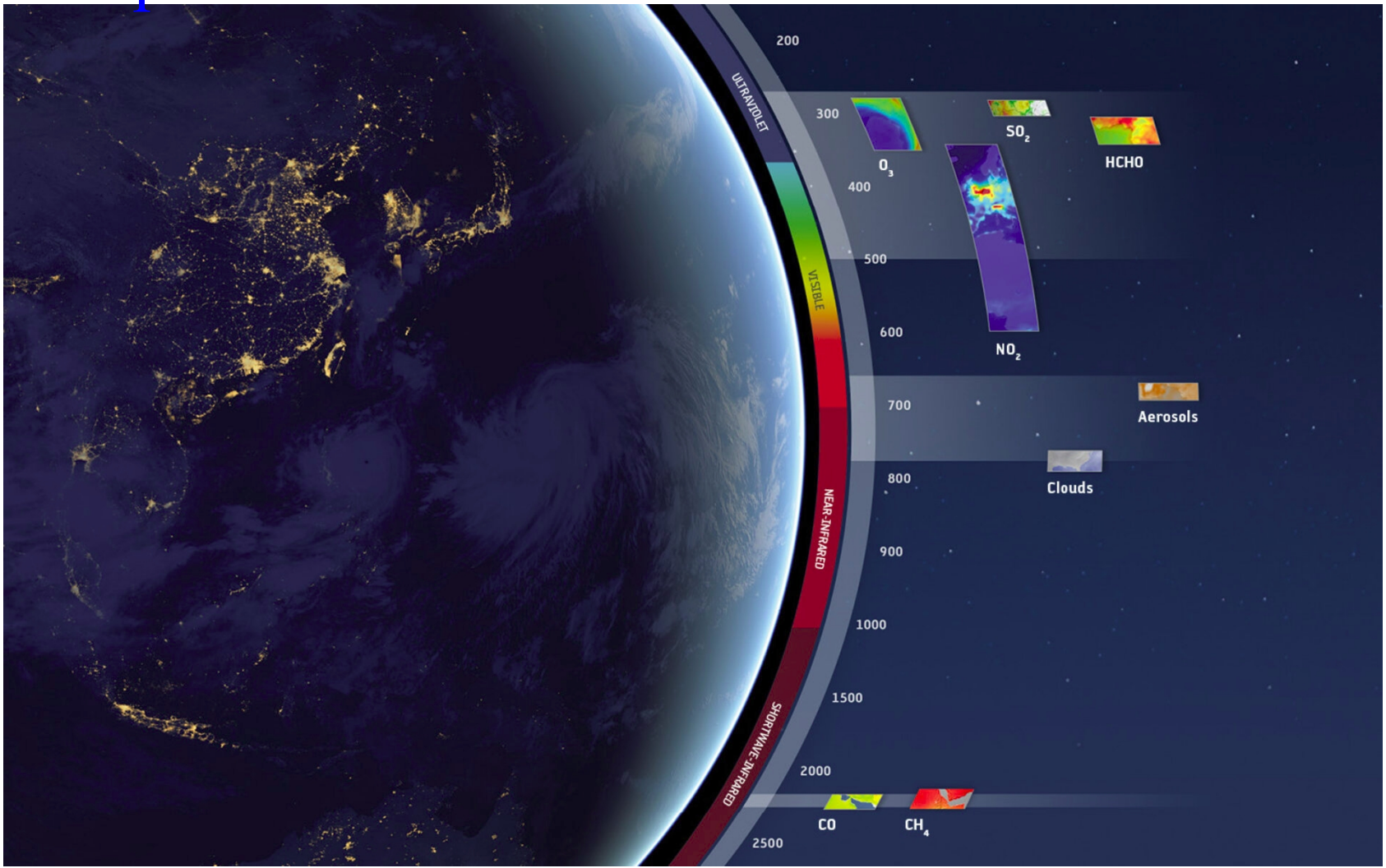
Ozone Monitoring Instrument OMI onboard Aura satellite

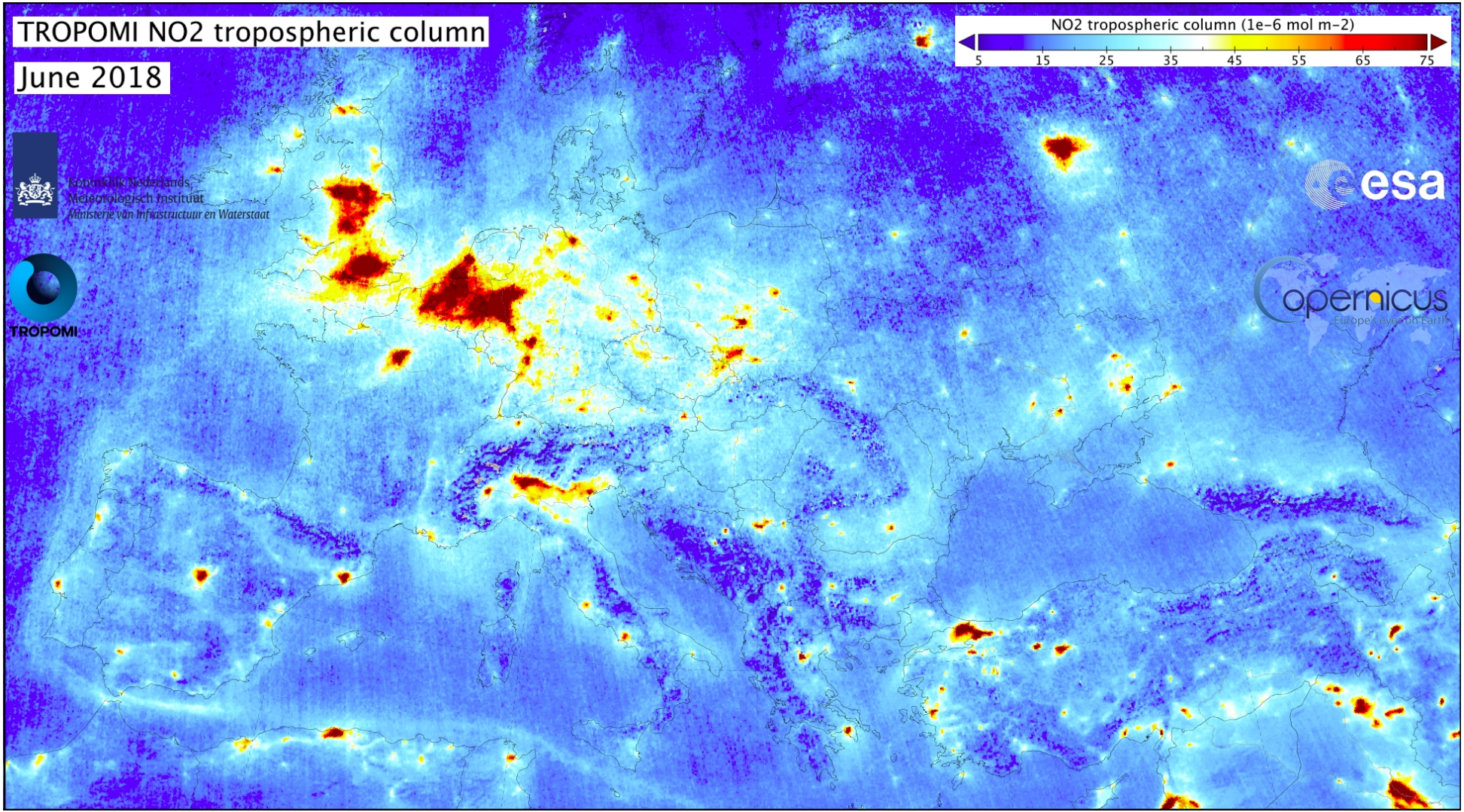




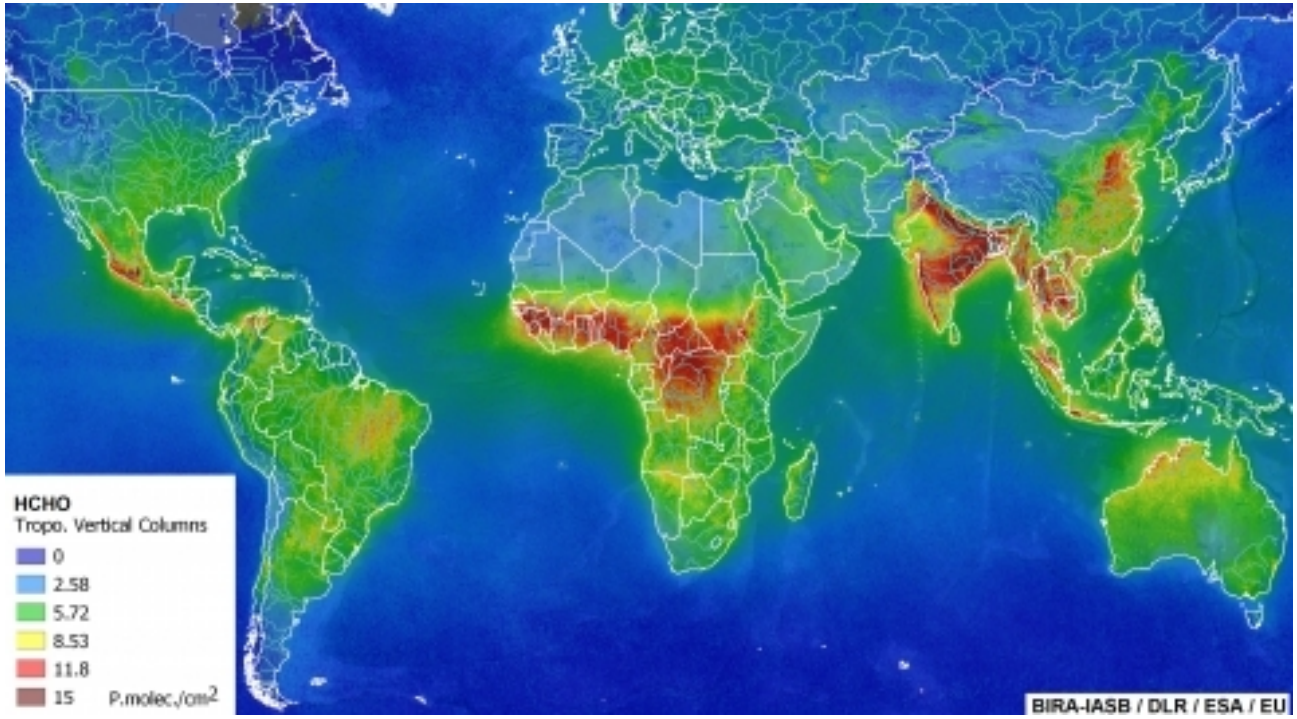

OMI NO2
X10^16 molec./cm^2 NO2
2.892
2.523
2.154
1.772
1.402
1.034
0.674
0.292
0.073
0.024
0.003
N
W
E
S

Tropomi instrument onboard Sentinel-5P




TROPOMI NO2 tropospheric column
June 2018
NO2 tropospheric column (1e-6 mol m-2)
5
15
25
35
45
55
65
75
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat
TROPOMI
esa
copernicus
Europe's eyes on Earth

Formaldehyde HCHO from Tropomi 2018 data



Differential Optical Absorption Spectroscopy

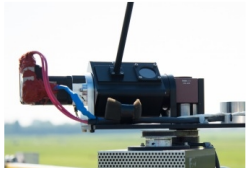
IUP-B

BIRA

Pandora

Phaeton

CU-Boulder

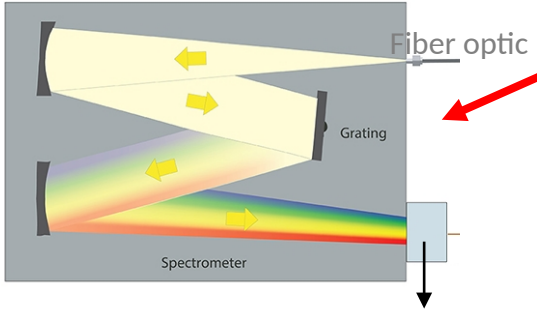


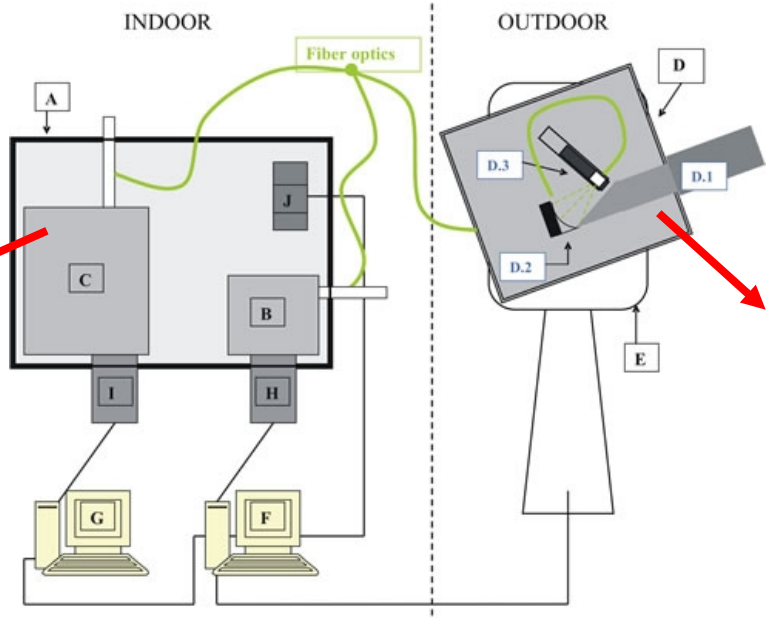
AIOFM

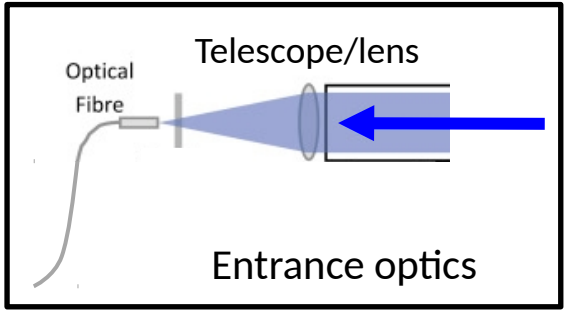
Airyx Skyspec

SAOZ

Grating spectrometer

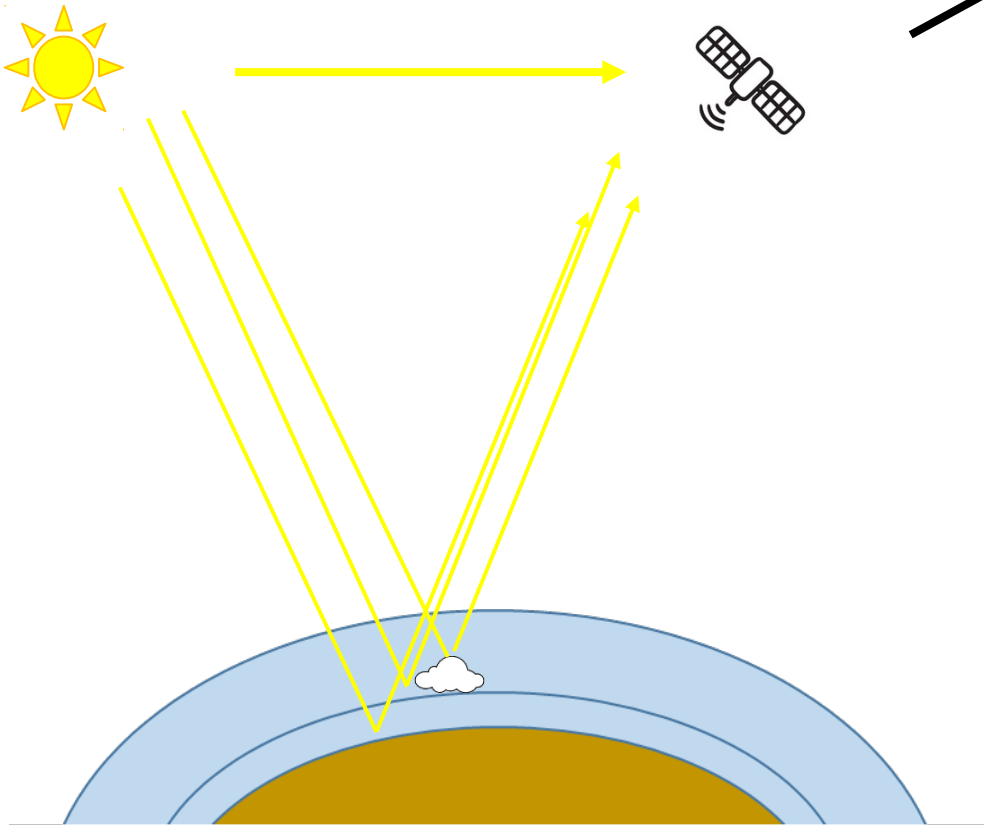


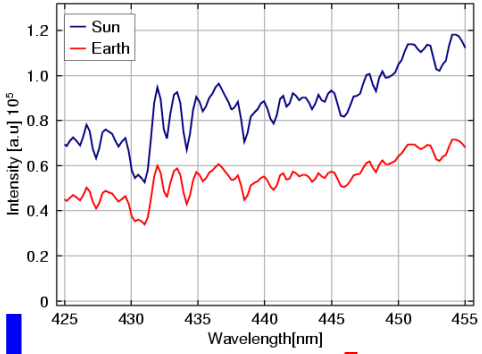




Remote sensing of gaseous pollutants

Space nadir geometry (e.g. Sentinel-5p)





DOAS spectral fitting

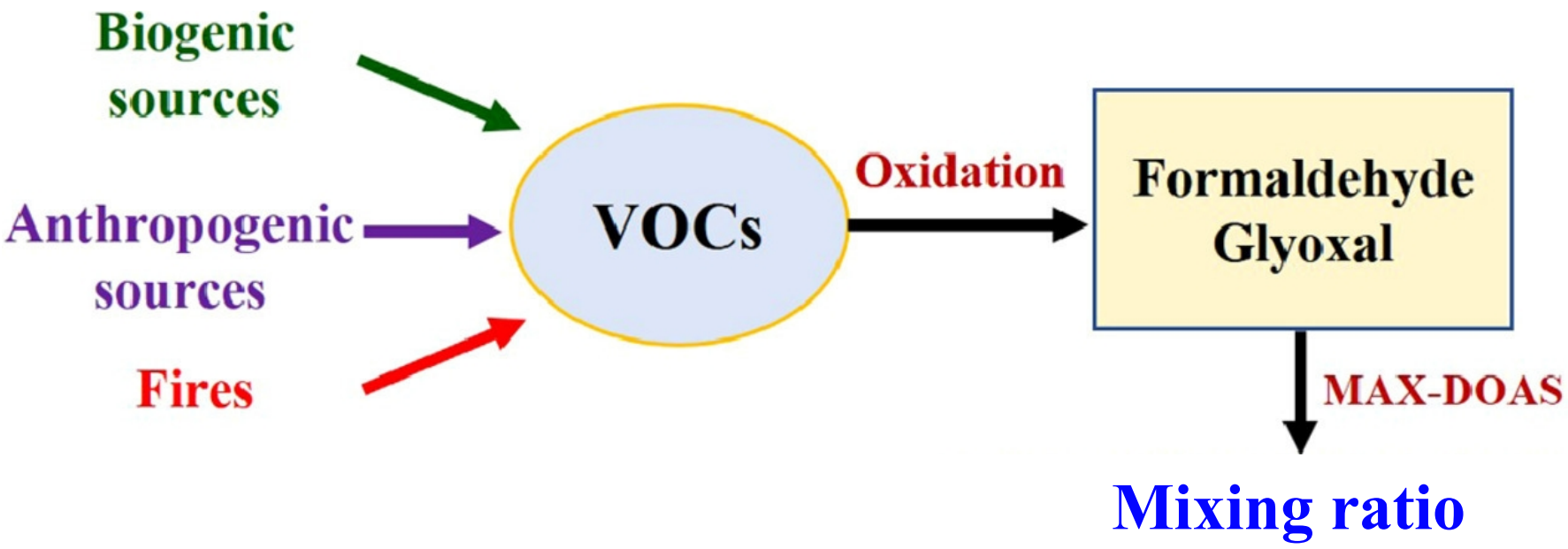
Molecular absorption cross-sections

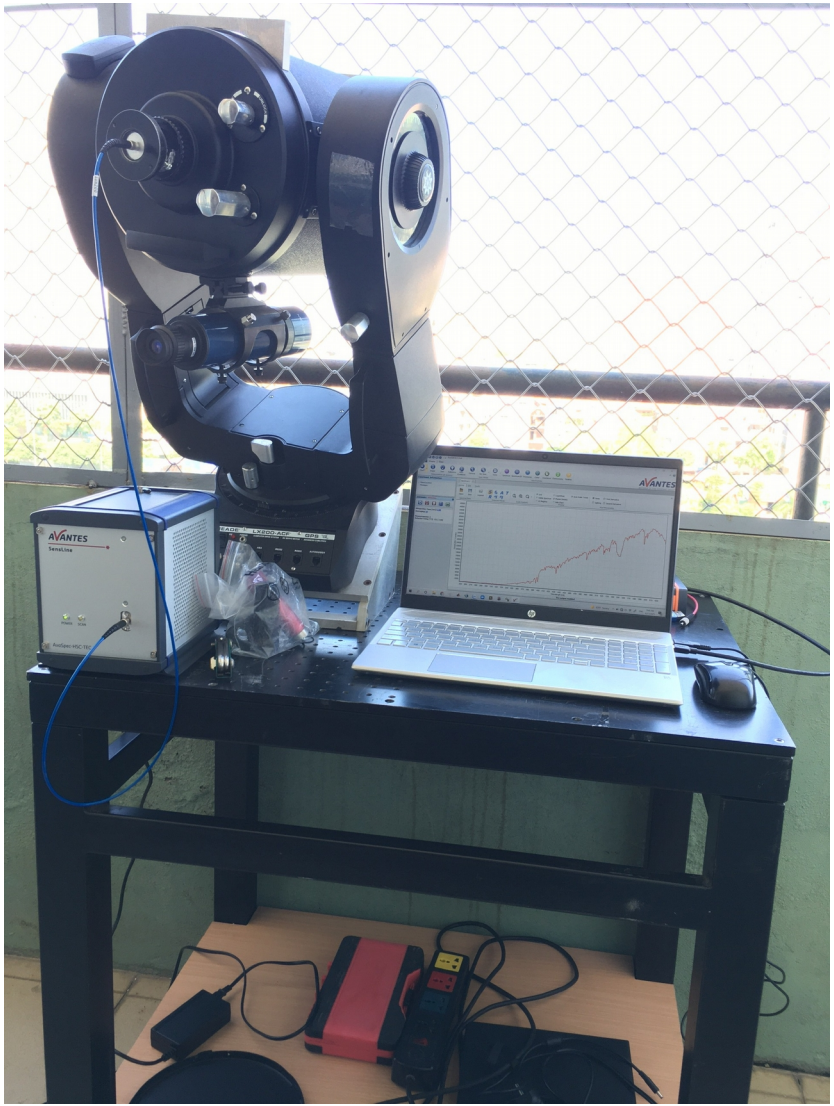
Slant column

- Radiative transfer model
- Ancillary informations on atmospheric and surface parameters

AMF calculation

Vertical column

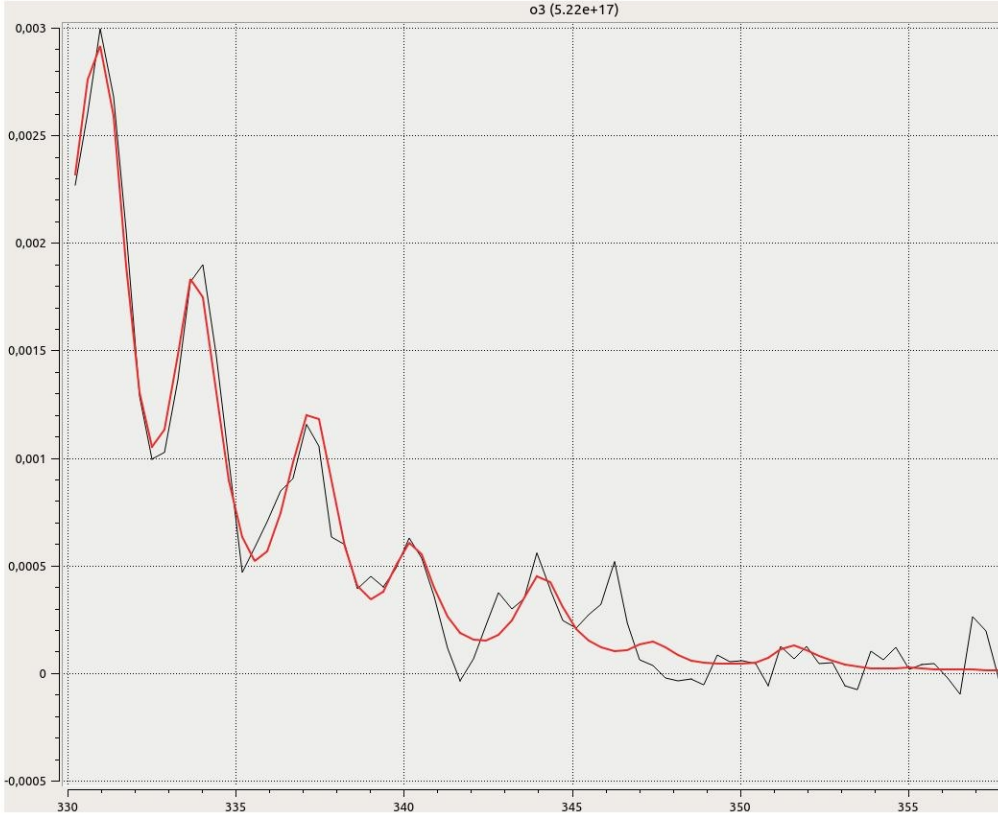

Biogenic sources
Anthropogenic sources
Fires
VOCs
Oxidation
Formaldehyde
Glyoxal
MAX-DOAS
Mixing ratio



Multiangle Differential Optical Absorption Spectroscopy

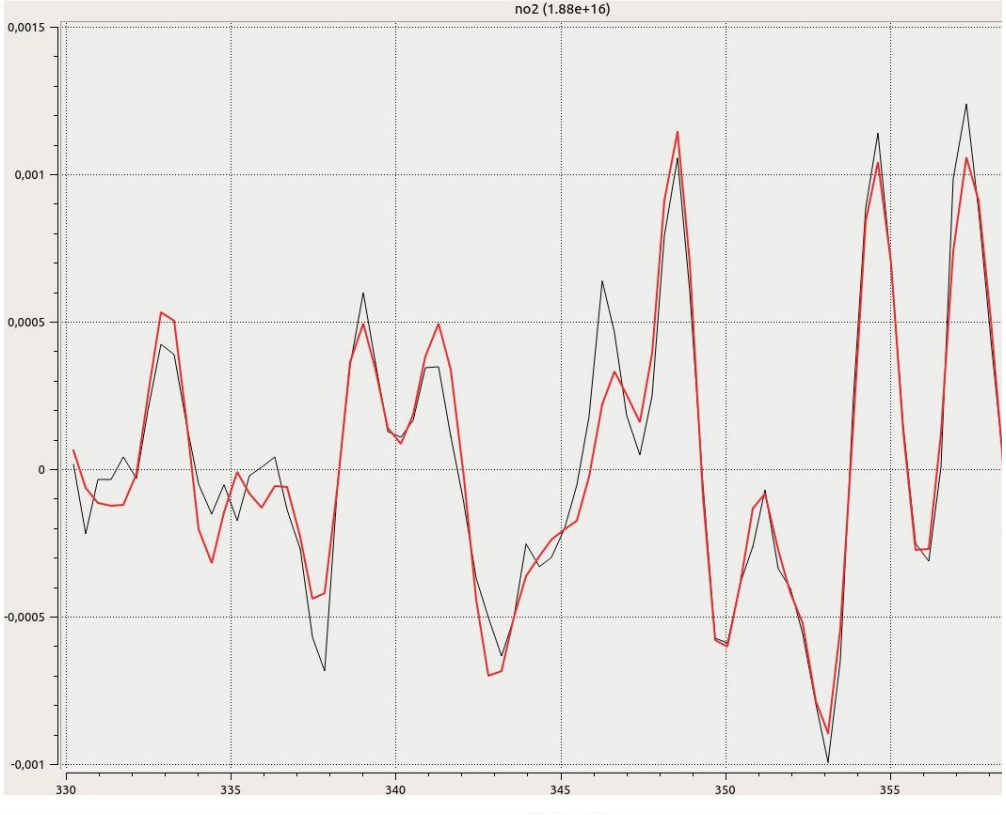
MAX-DOAS

Ozone



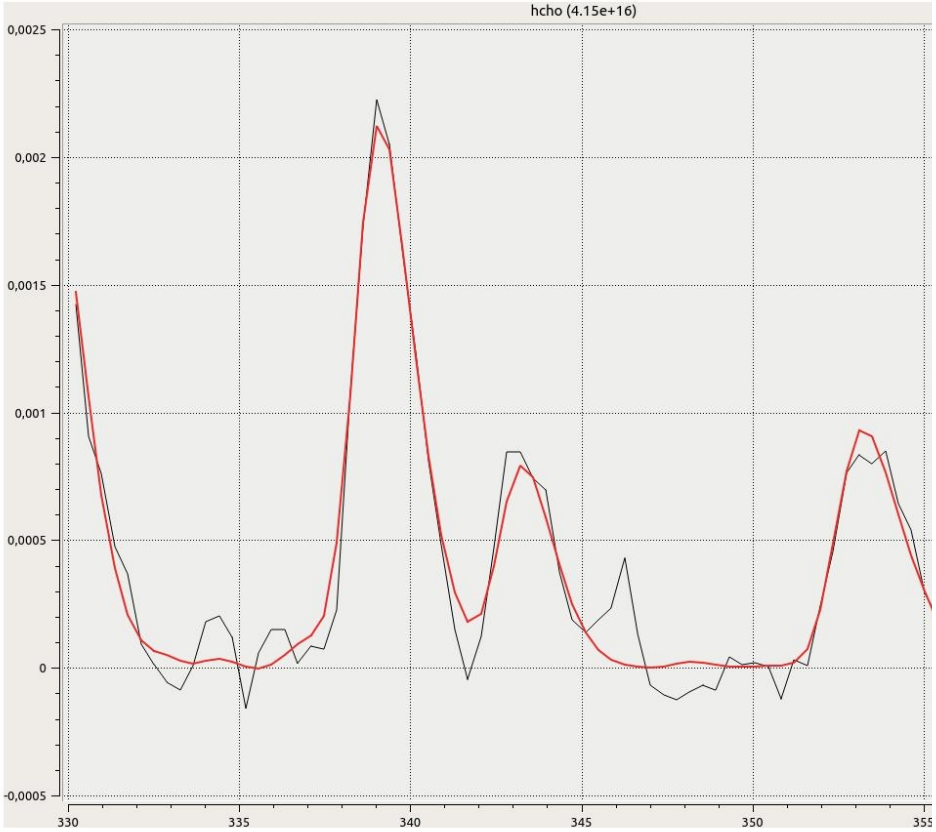
Wavelength (nm)

NO2



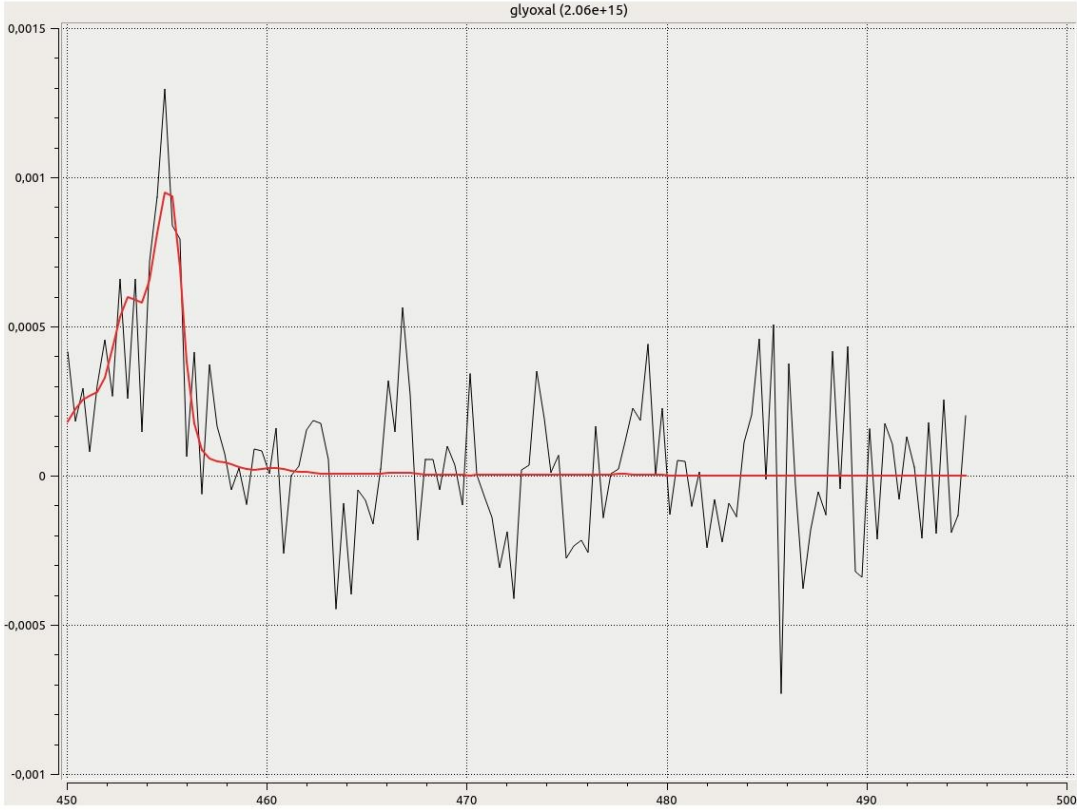
Wavelength (nm)

Formaldehyde HCHO



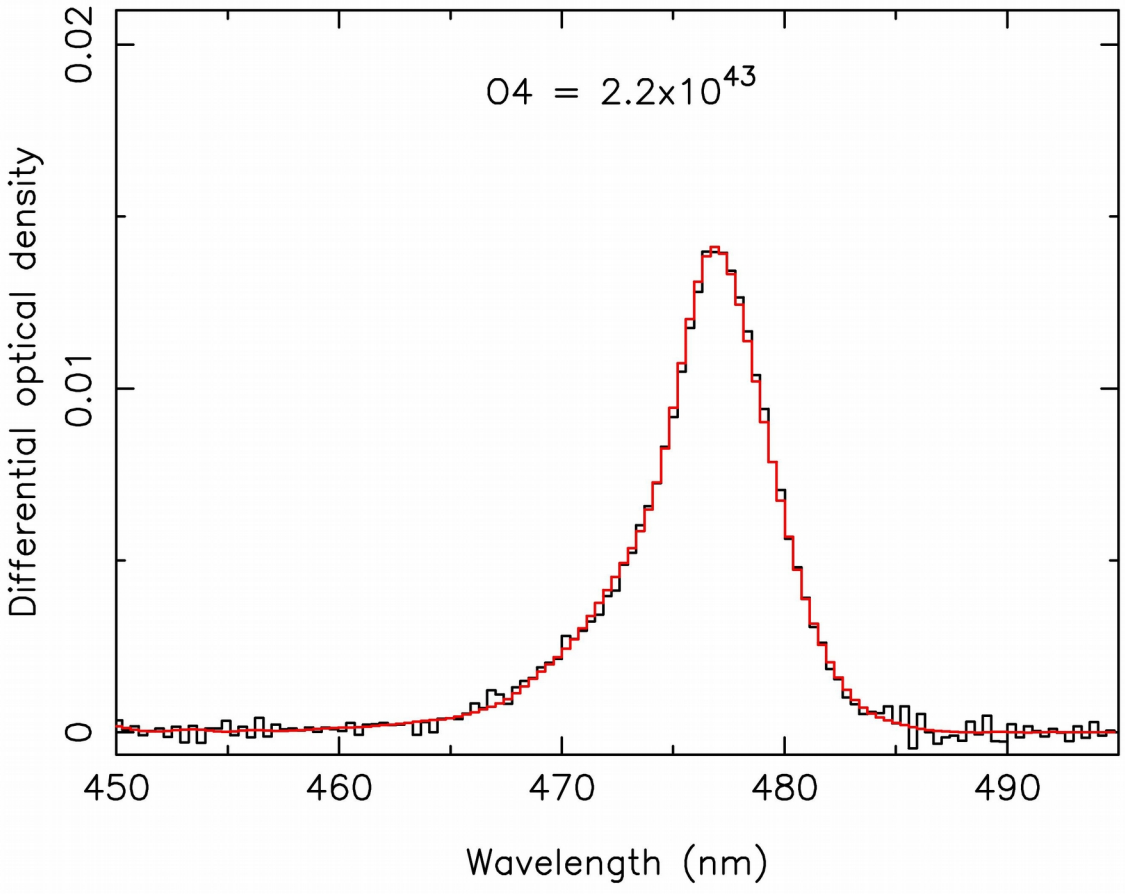
Wavelength (nm)

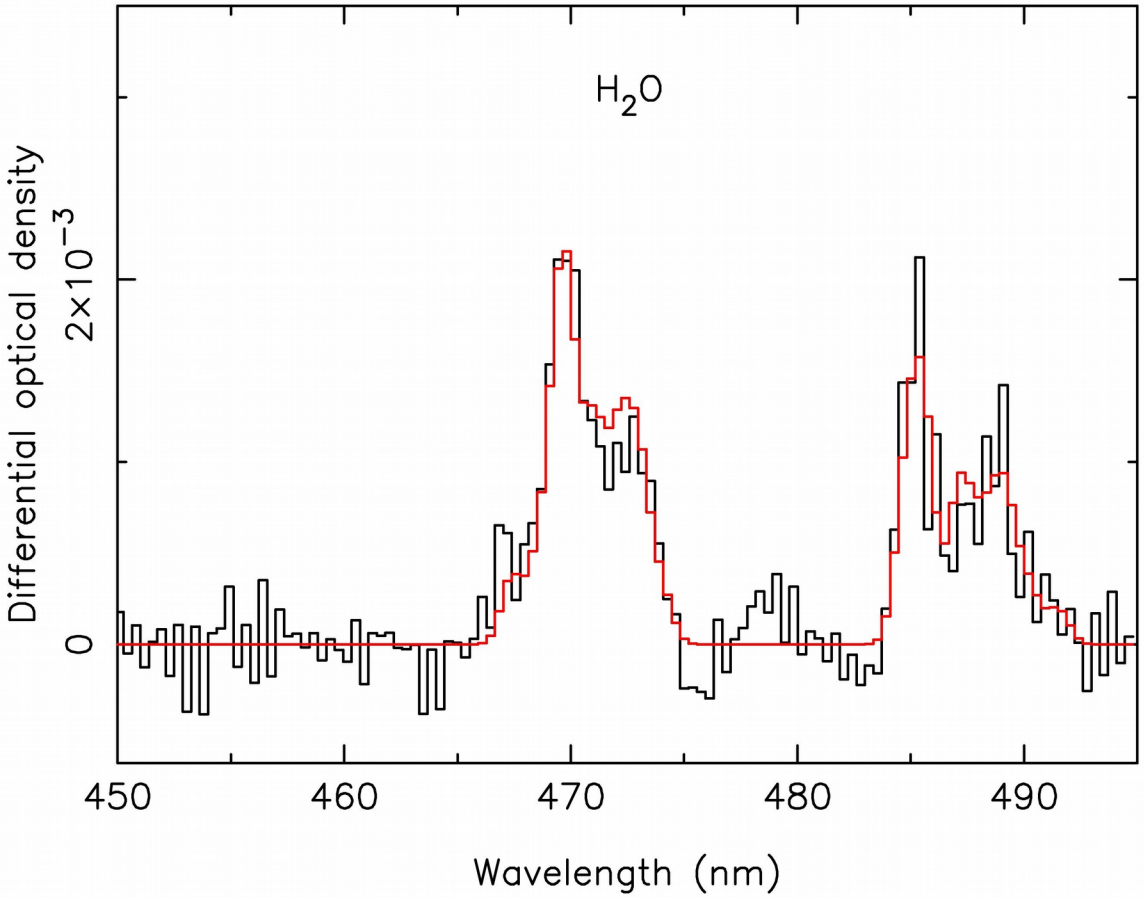
Glyoxal CHOCHO

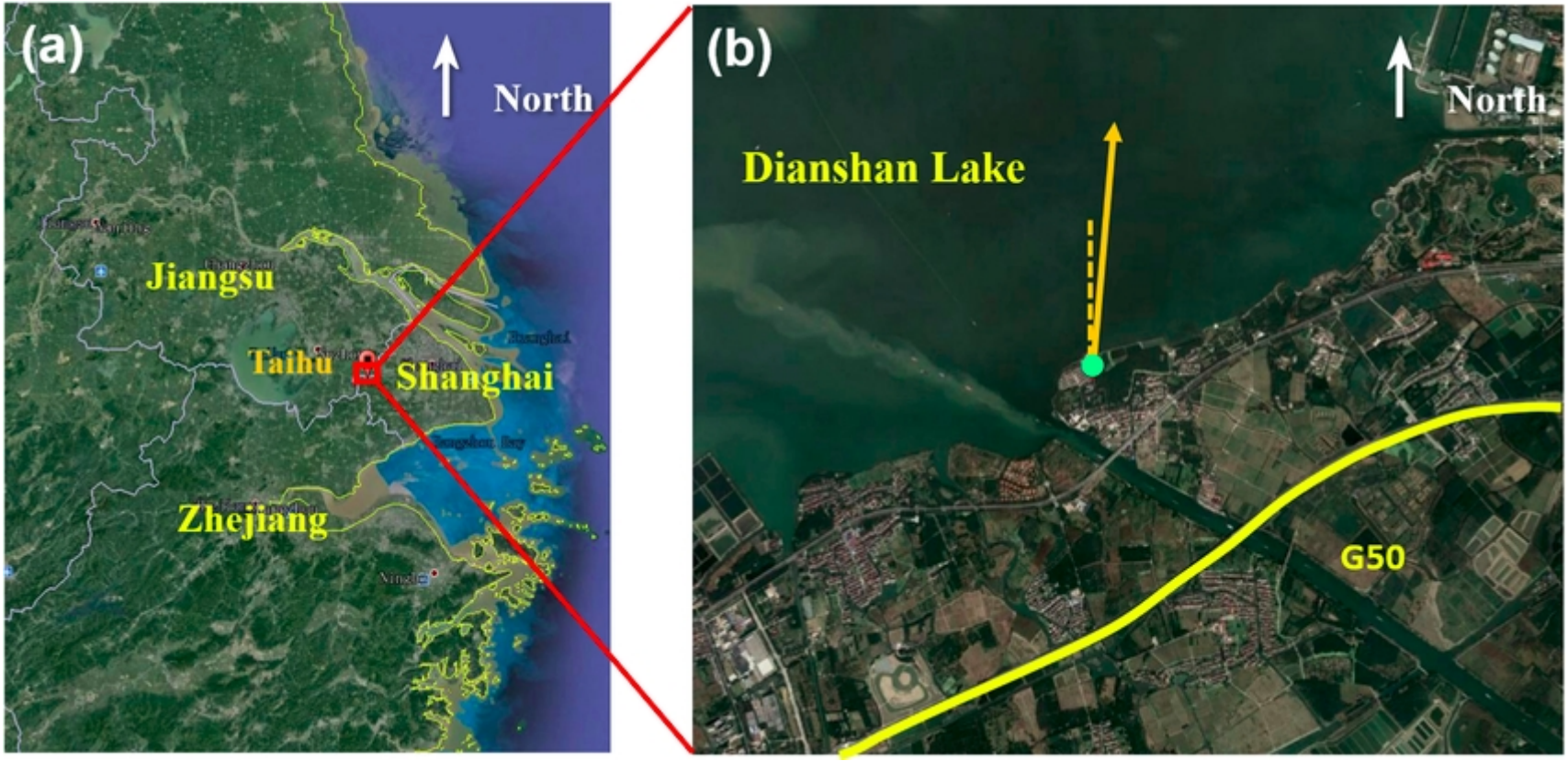


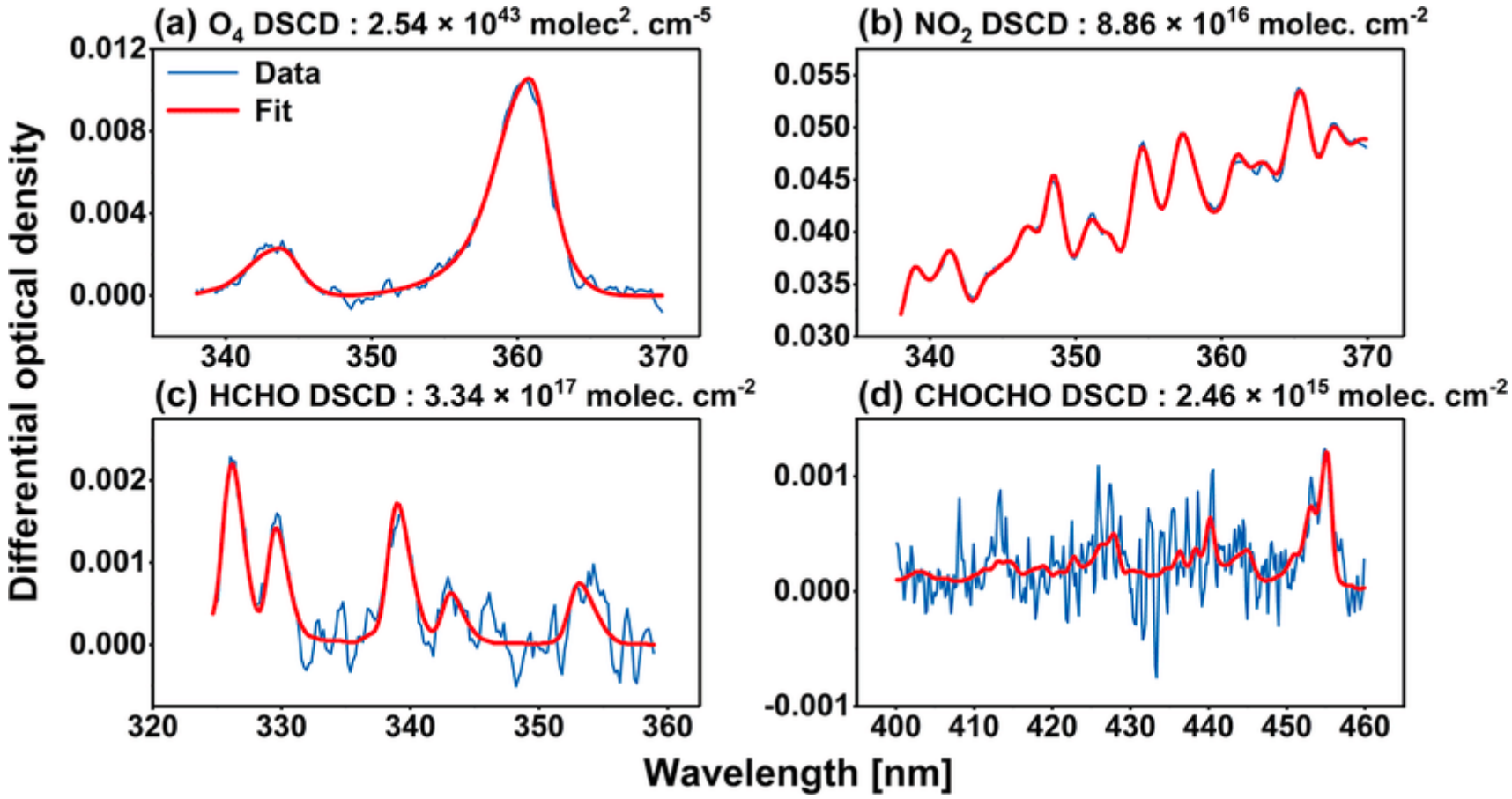
Wavelength (nm)

AVANTES
SensLine
POWER
SCAN
AvaSpec-HSC-TEC
DELL


O4 = 2.2x10^43
Differential optical density
0.02
0.01
0
450
460
470
480
490
Wavelength (nm)


H_2O
Differential optical density
2×10^{-3}
0
450
460
470
480
490
Wavelength (nm)


(a)
North
Jiangsu
Taihu
Shanghai
Zhejiang
(b)
North
Dianshan Lake
G50


(a) O_4 DSCD : 2.54 × 10^{43} molec^2. cm^{-5}
Data
Fit
(b) NO_2 DSCD : 8.86 × 10^{16} molec. cm^{-2}
(c) HCHO DSCD : 3.34 × 10^{17} molec. cm^{-2}
(d) CHOCHO DSCD : 2.46 × 10^{15} molec. cm^{-2}
Differential optical density
Wavelength [nm]