The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2018-15

Winter College on Optics in Environmental Science

2 - 18 February 2009

Multi-spectral Imaging

Svanberg S.
Lund Institute of Technology
Sweden

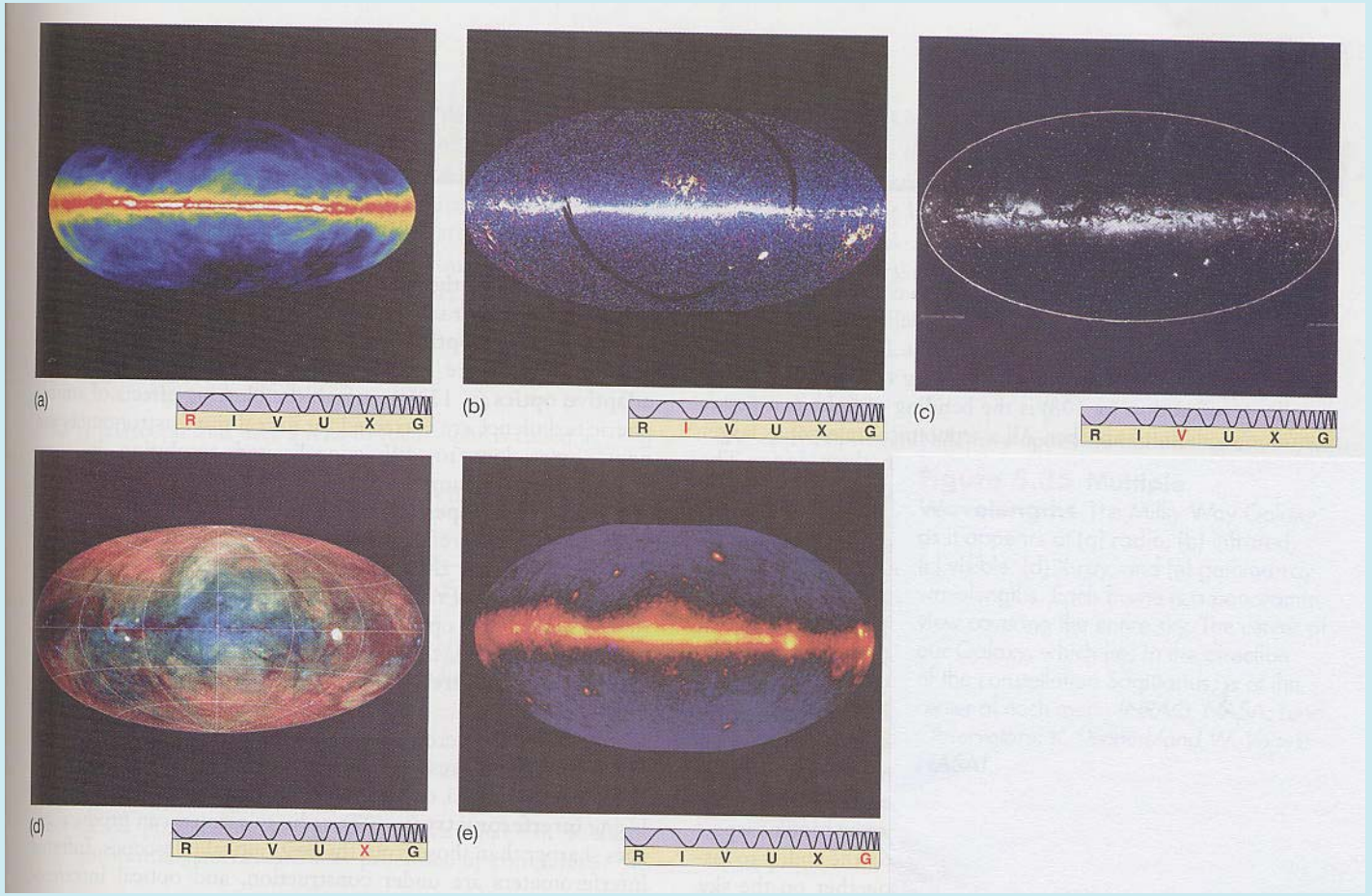
Multi-spectral Imaging

Sune Svanberg
Lund Laser Centre
Sweden

Lund Laser Centre

LUND INSTITUTE OF TECHNOLOGY
Lund University

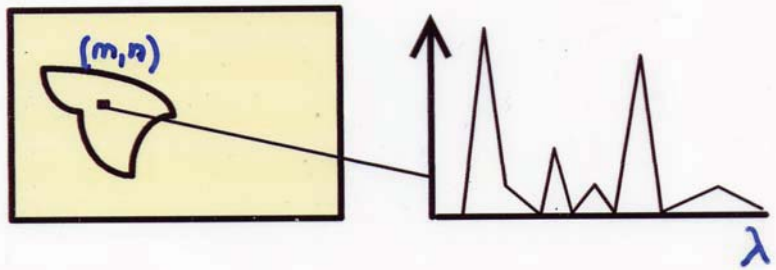
The Milky Way



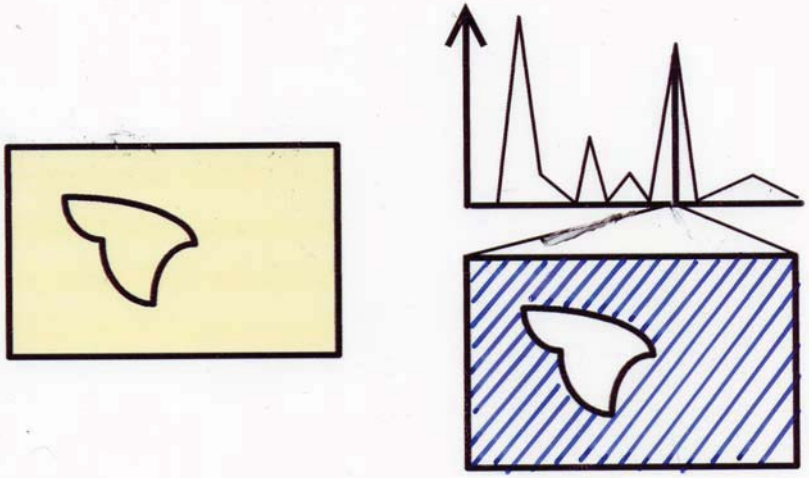
E. Chaisson, S. McMillan: *Astronomy Today*

A CHOICE TO BE MADE:

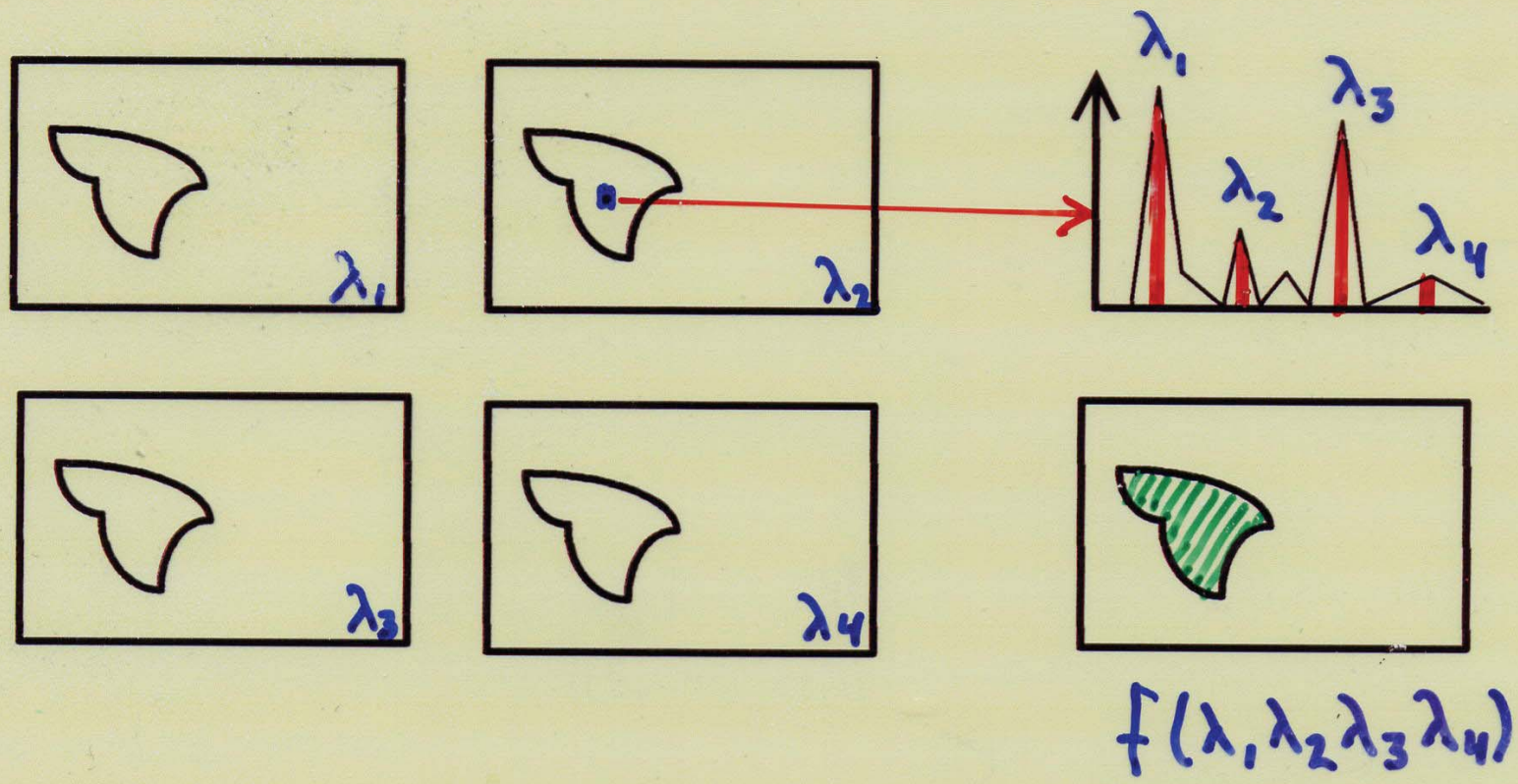
One point, all colours



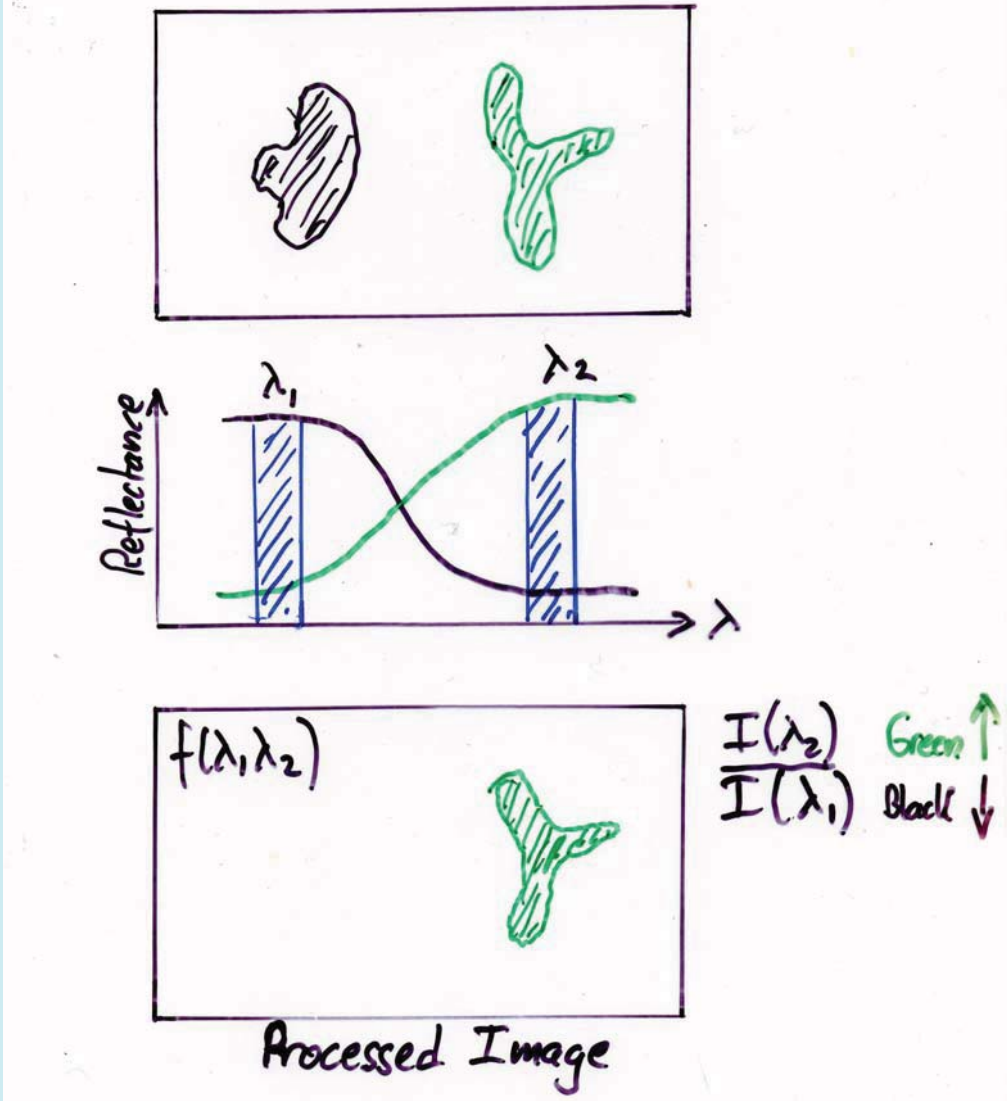
All points, one colour



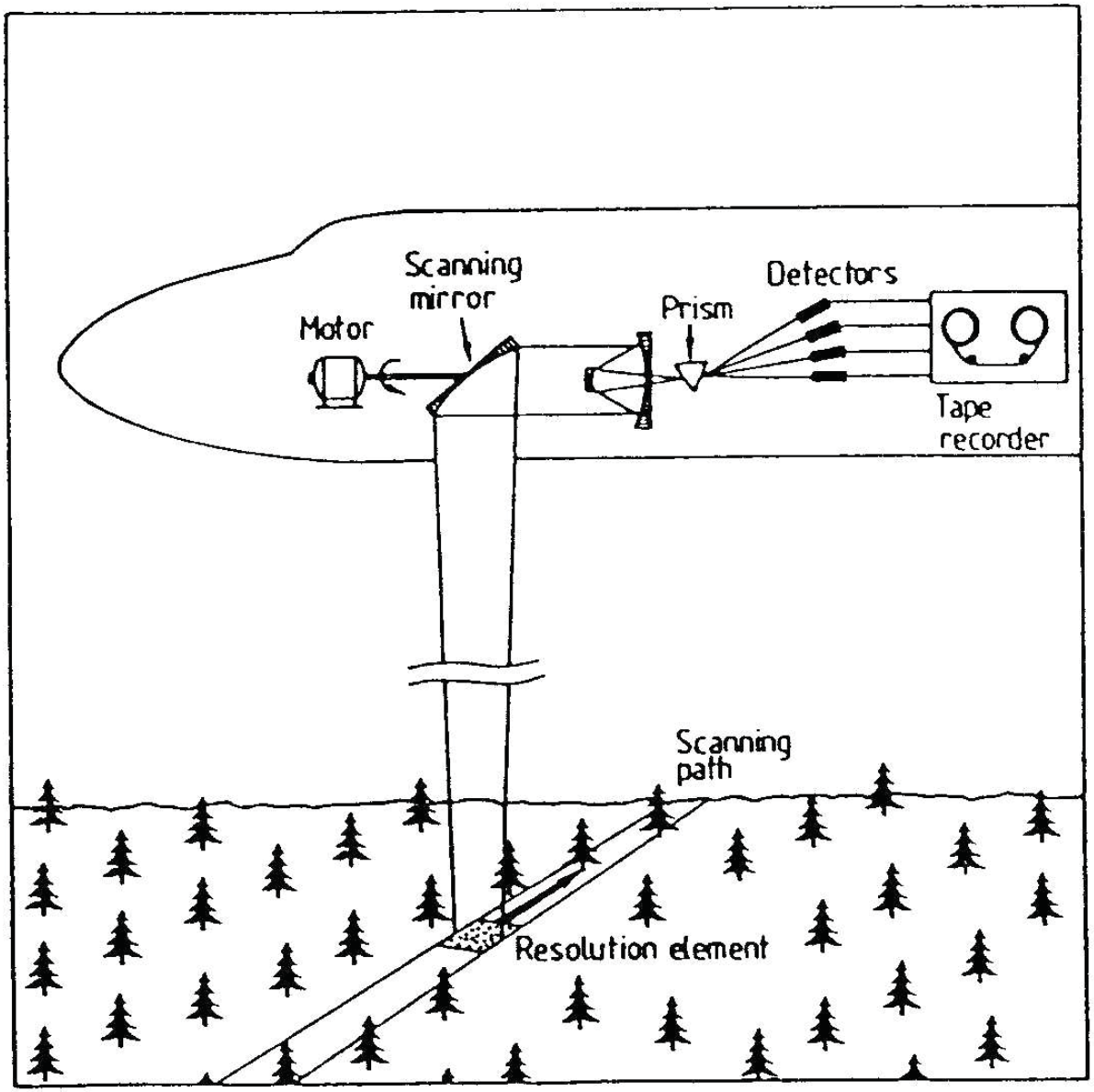
MULTISPECTRAL IMAGING

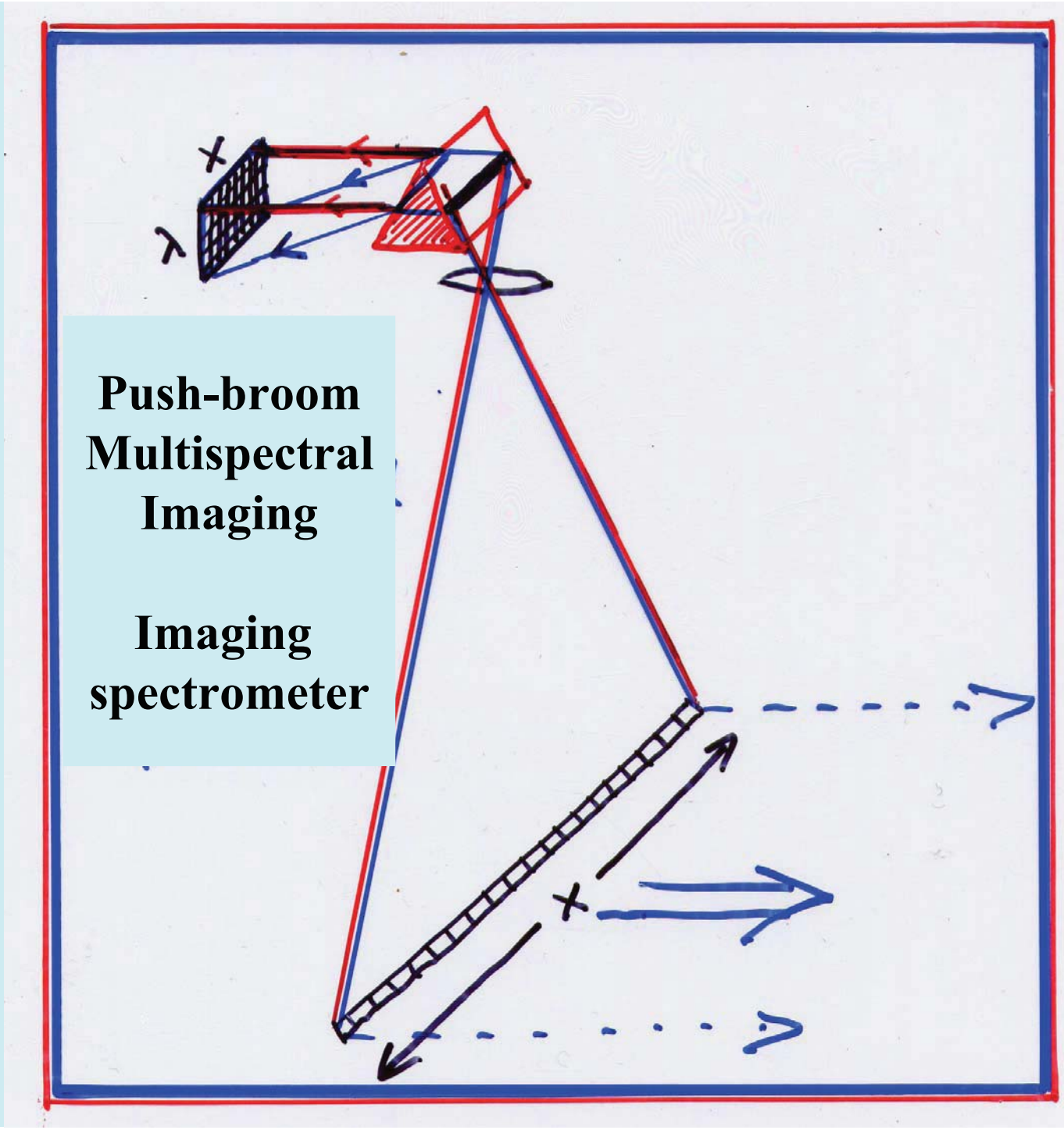


Multispectral imaging

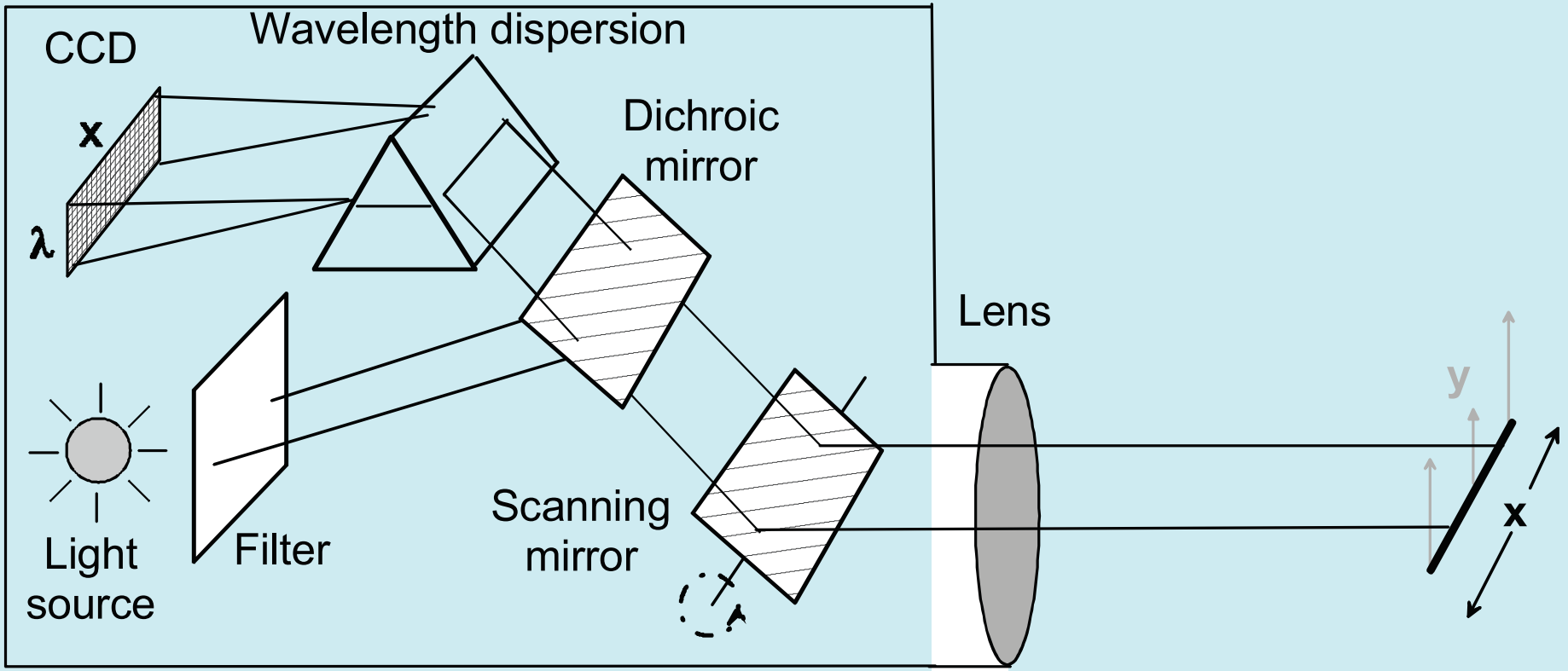


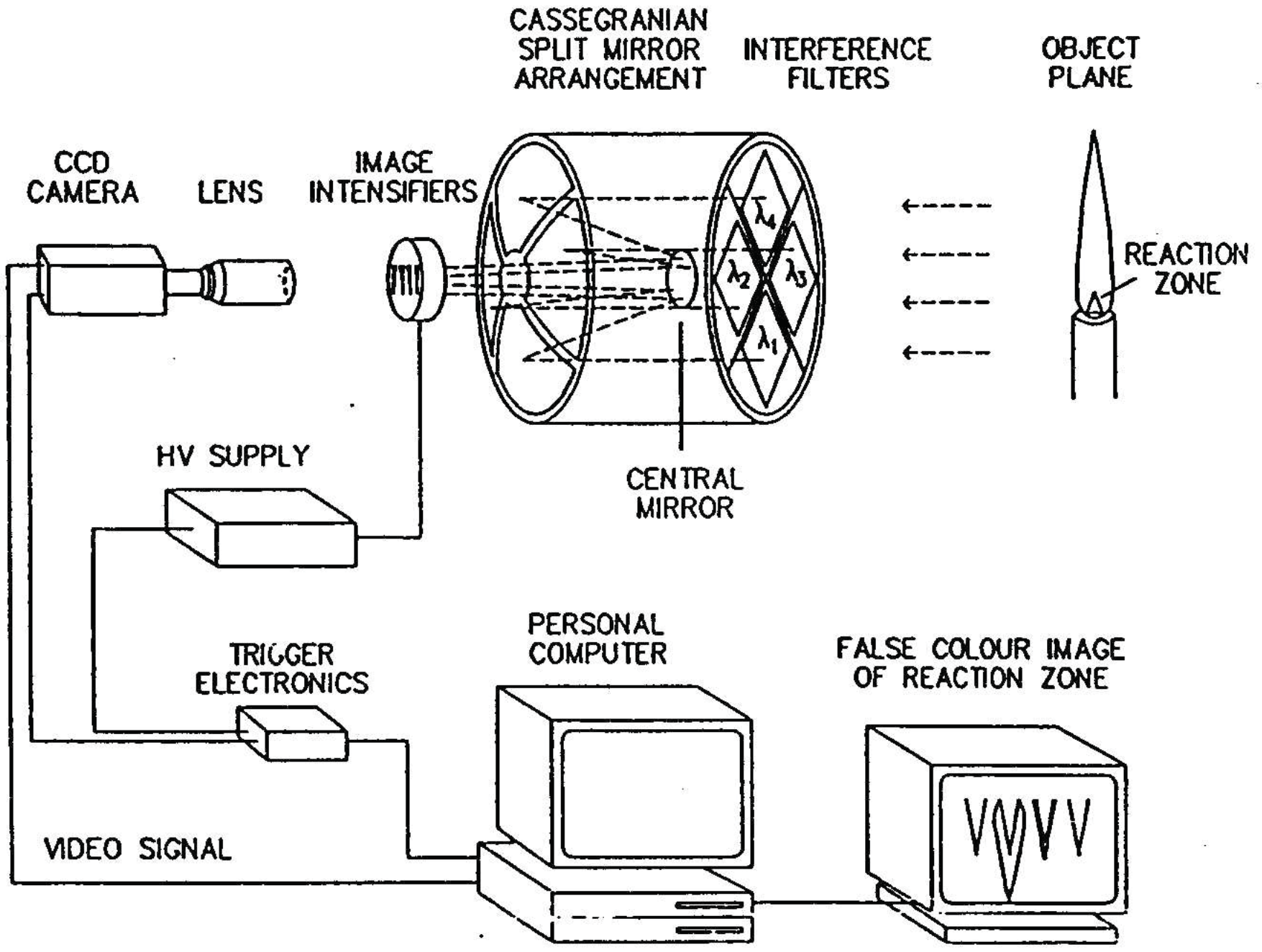
Whisk-broom multispectral scanner



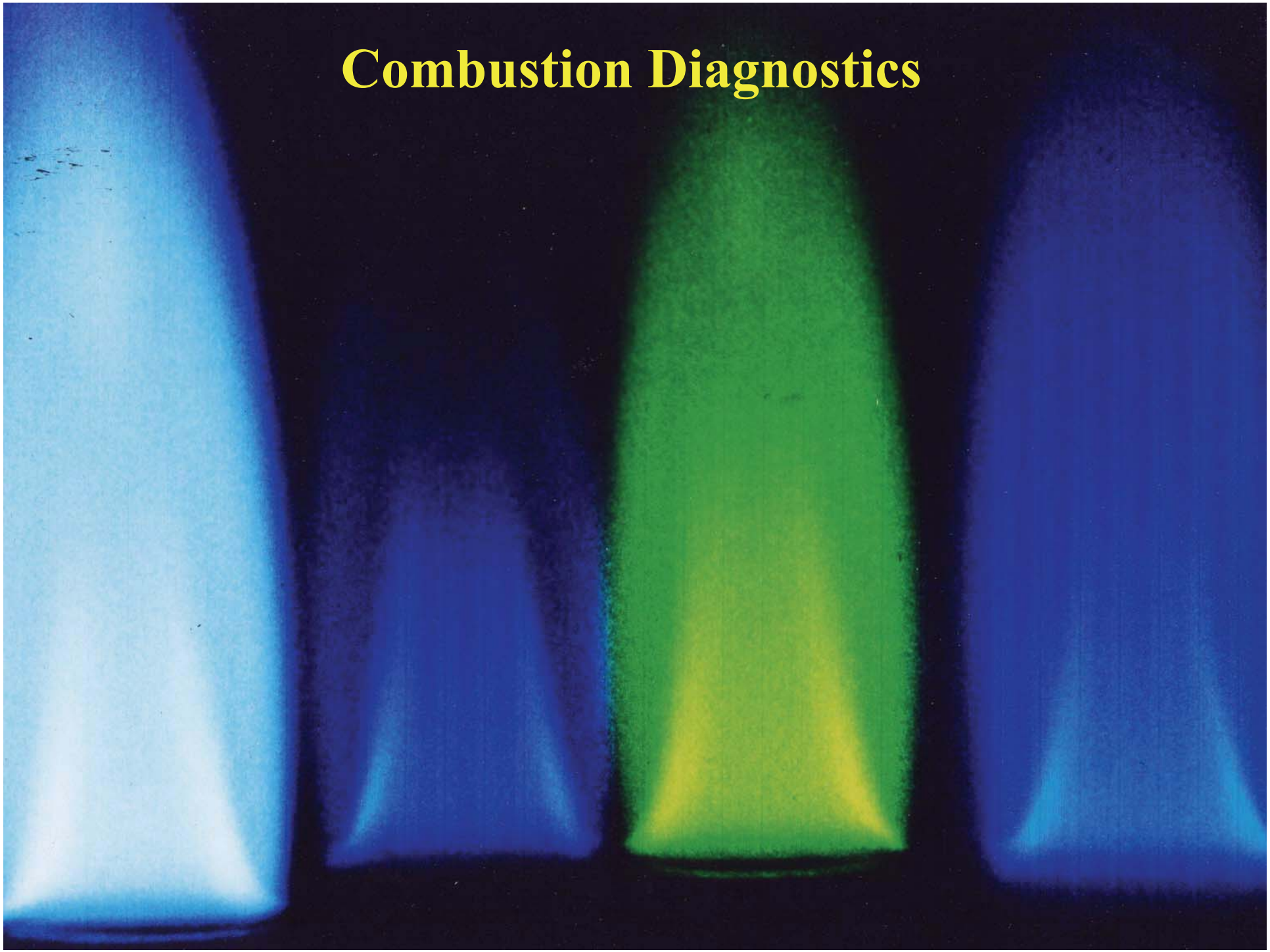

x
λ
Push-broom
Multispectral
Imaging
Imaging
spectrometer
λ
x
λ

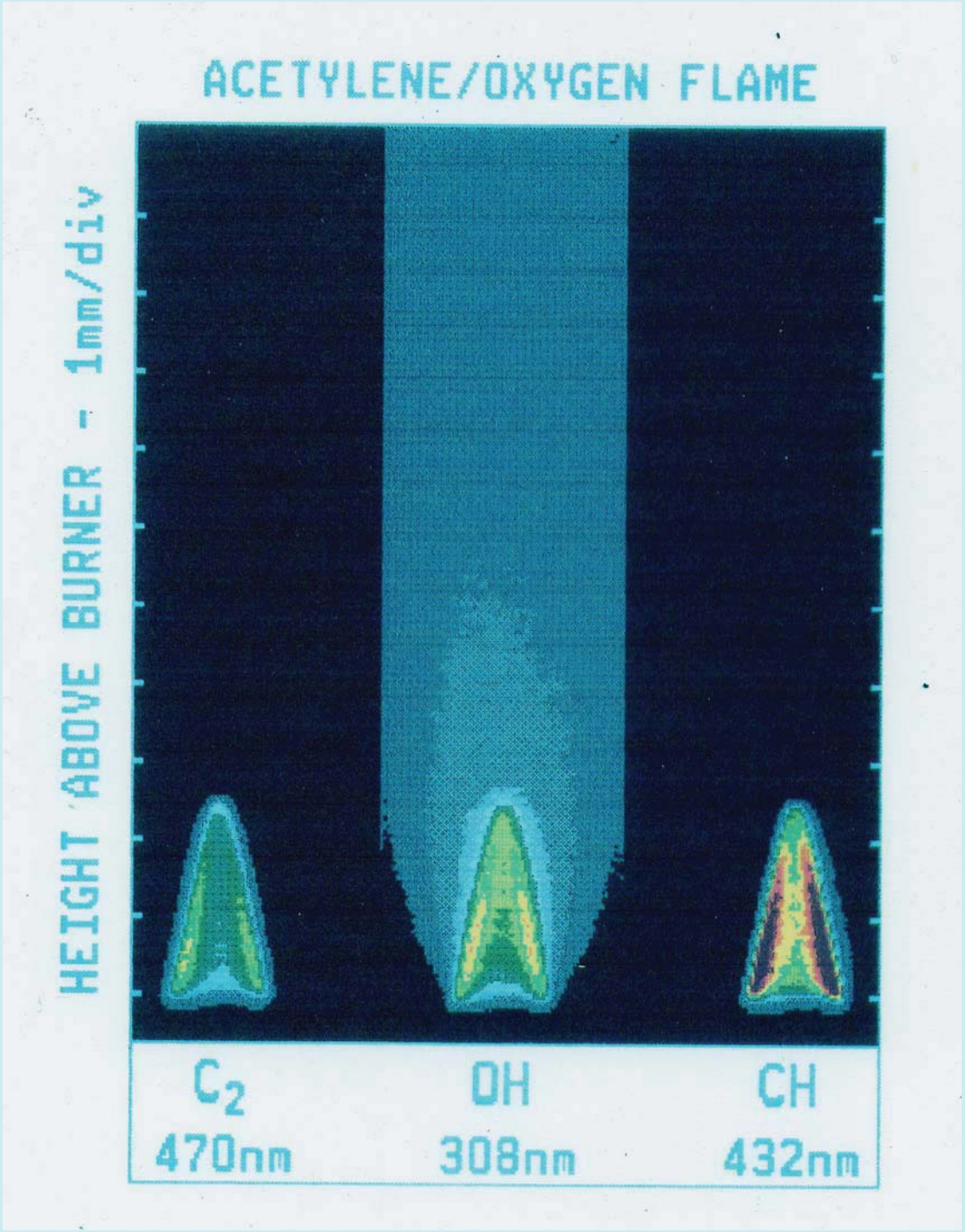
Push-broom imaging

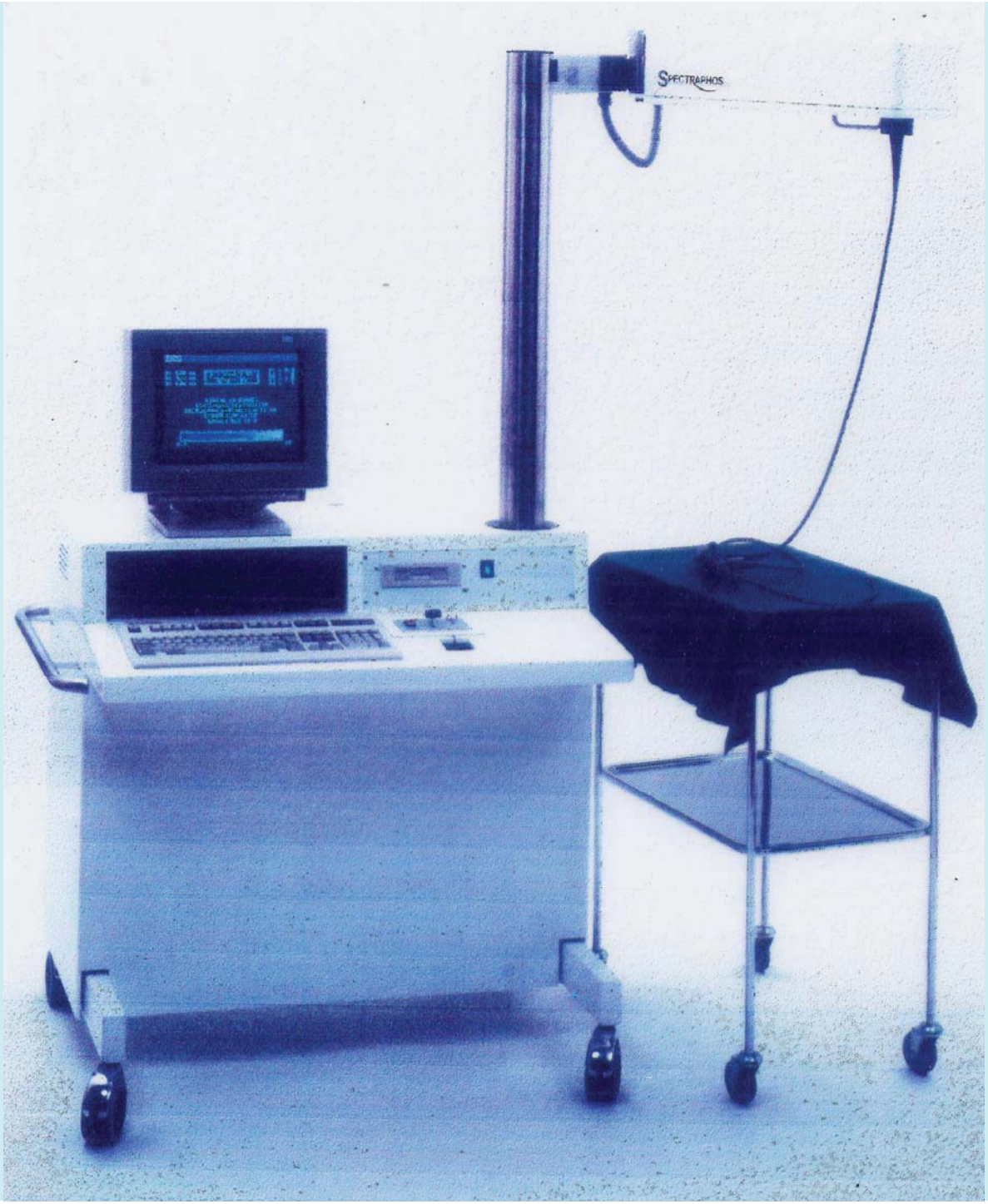



CASSEGRANIAN SPLIT MIRROR ARRANGEMENT
INTERFERENCE FILTERS
OBJECT PLANE
CCD CAMERA
LENS
IMAGE INTENSIFIERS
λ_4
λ_2
λ_3
λ_1
REACTION ZONE
HV SUPPLY
CENTRAL MIRROR
PERSONAL COMPUTER
TRIGGER ELECTRONICS
FALSE COLOUR IMAGE OF REACTION ZONE
VIDEO SIGNAL

Combustion Diagnostics

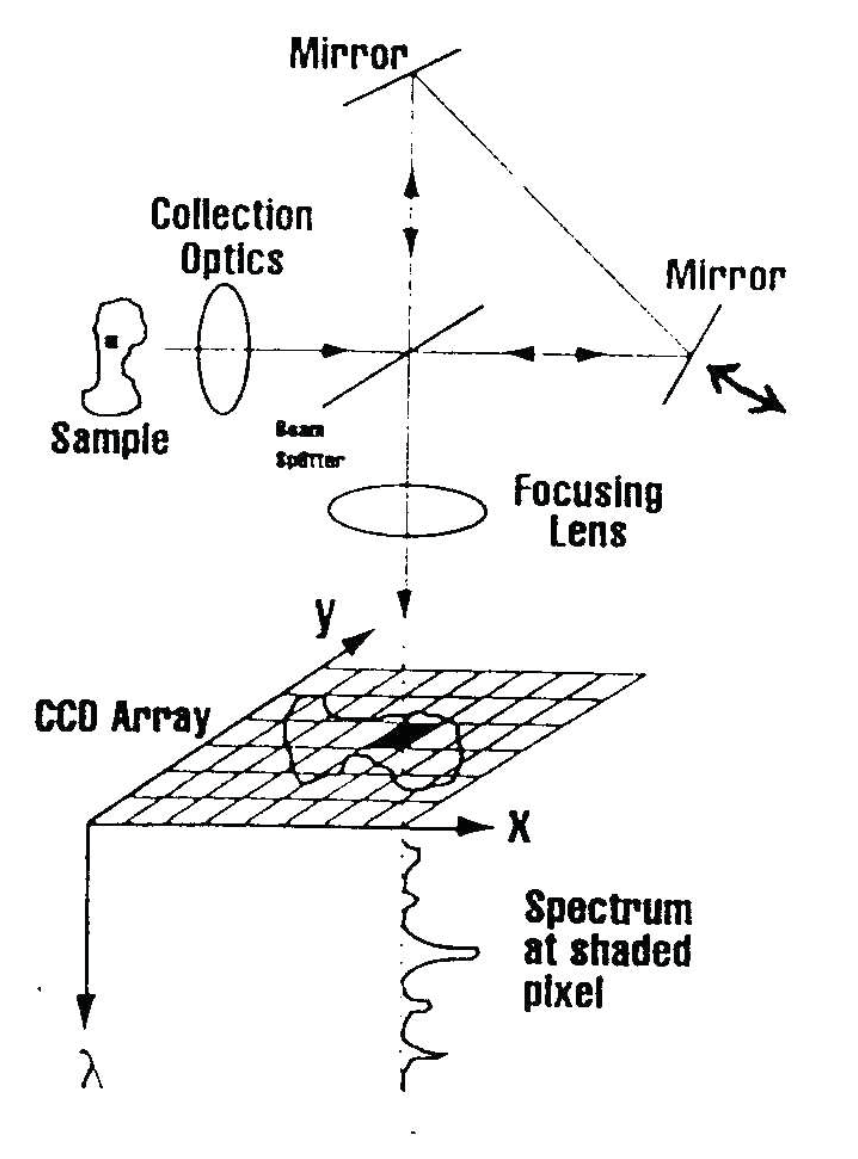



ACETYLENE/OXYGEN FLAME
HEIGHT ABOVE BURNER - 1mm/div
C2
470nm
OH
308nm
CH
432nm

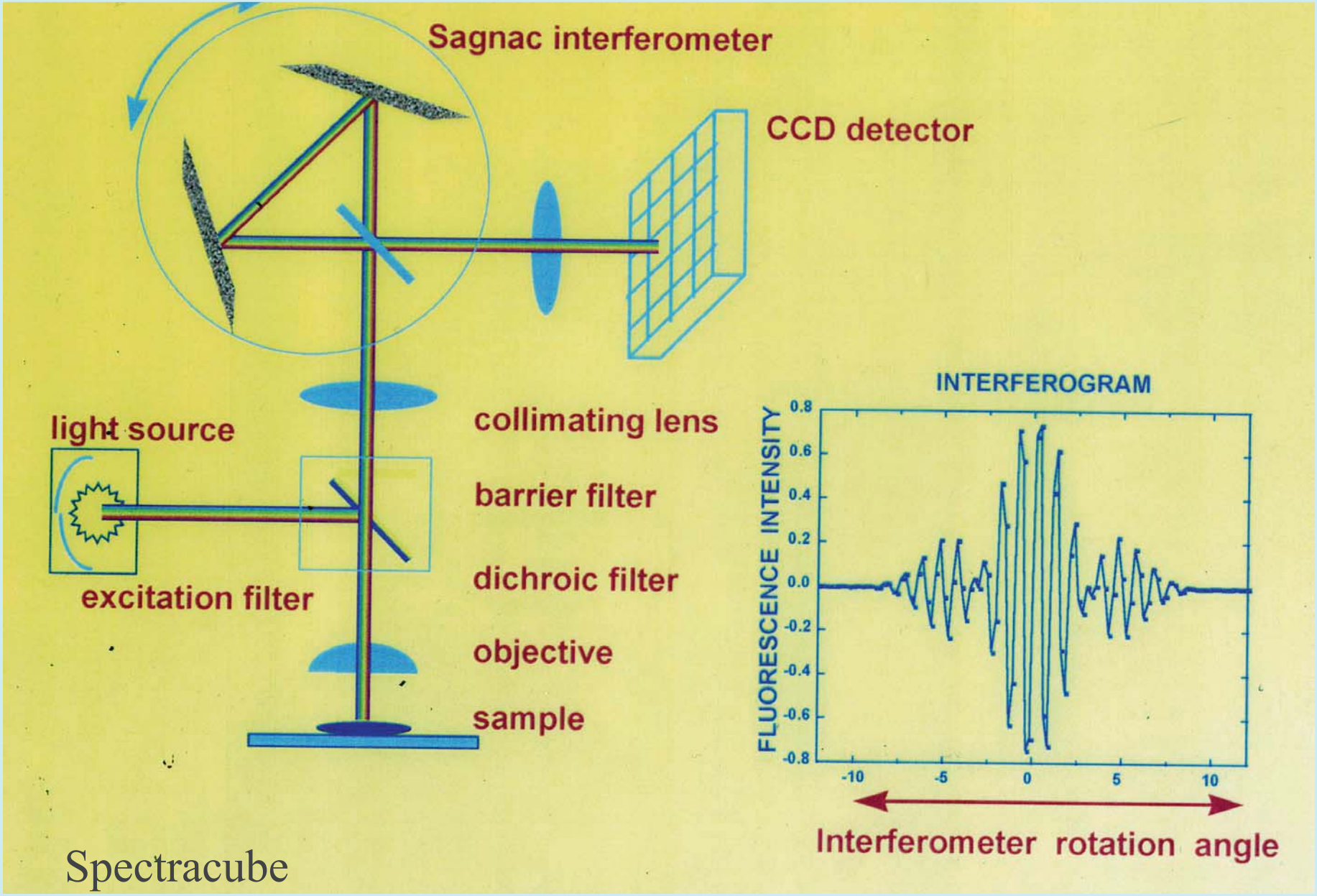

SPECTRAPHOS

White light image

Digitally processed image


Mirror
Collection Optics
Mirror
Sample
Beam Splitter
Focusing Lens
y
CCD Array
X
Spectrum at shaded pixel
λ

CCD multi-spectral Fourier transform imaging

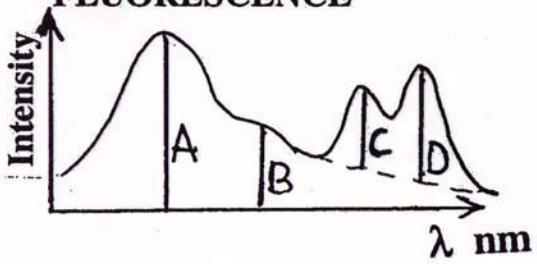


Spectracube

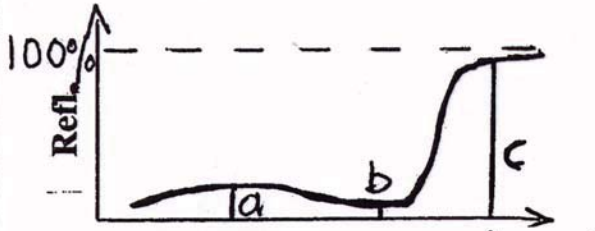
OBJECT IDENTIFICATION

FOREST DECLINE MONITORING

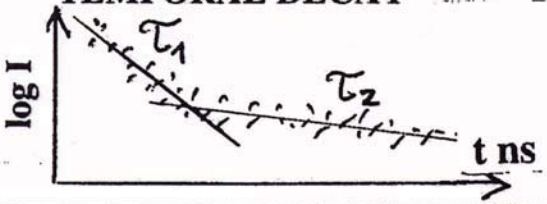
FLUORESCENCE



REFLECTANCE



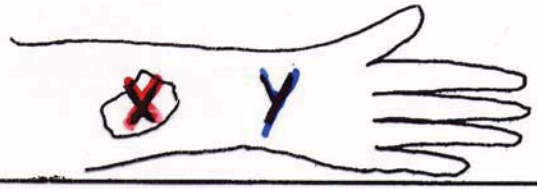
TEMPORAL DECAY

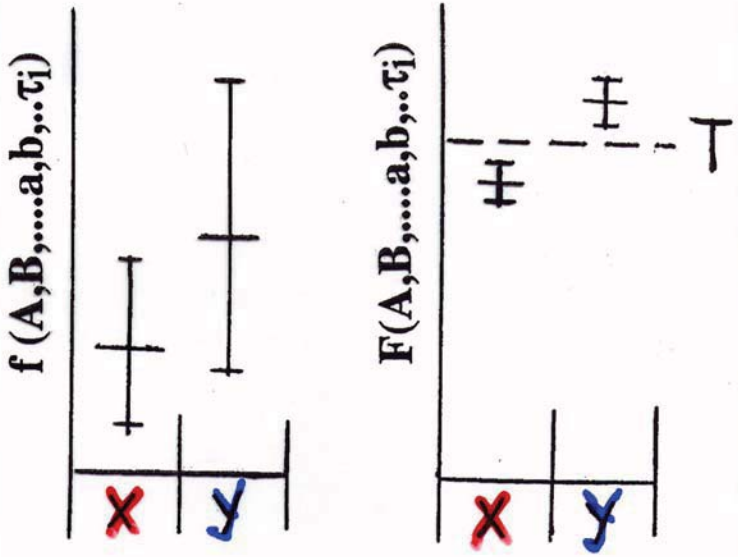


Who decides what is X and what is Y?

Plant physiologist

CANCER TUMOUR IDENTIFICATION



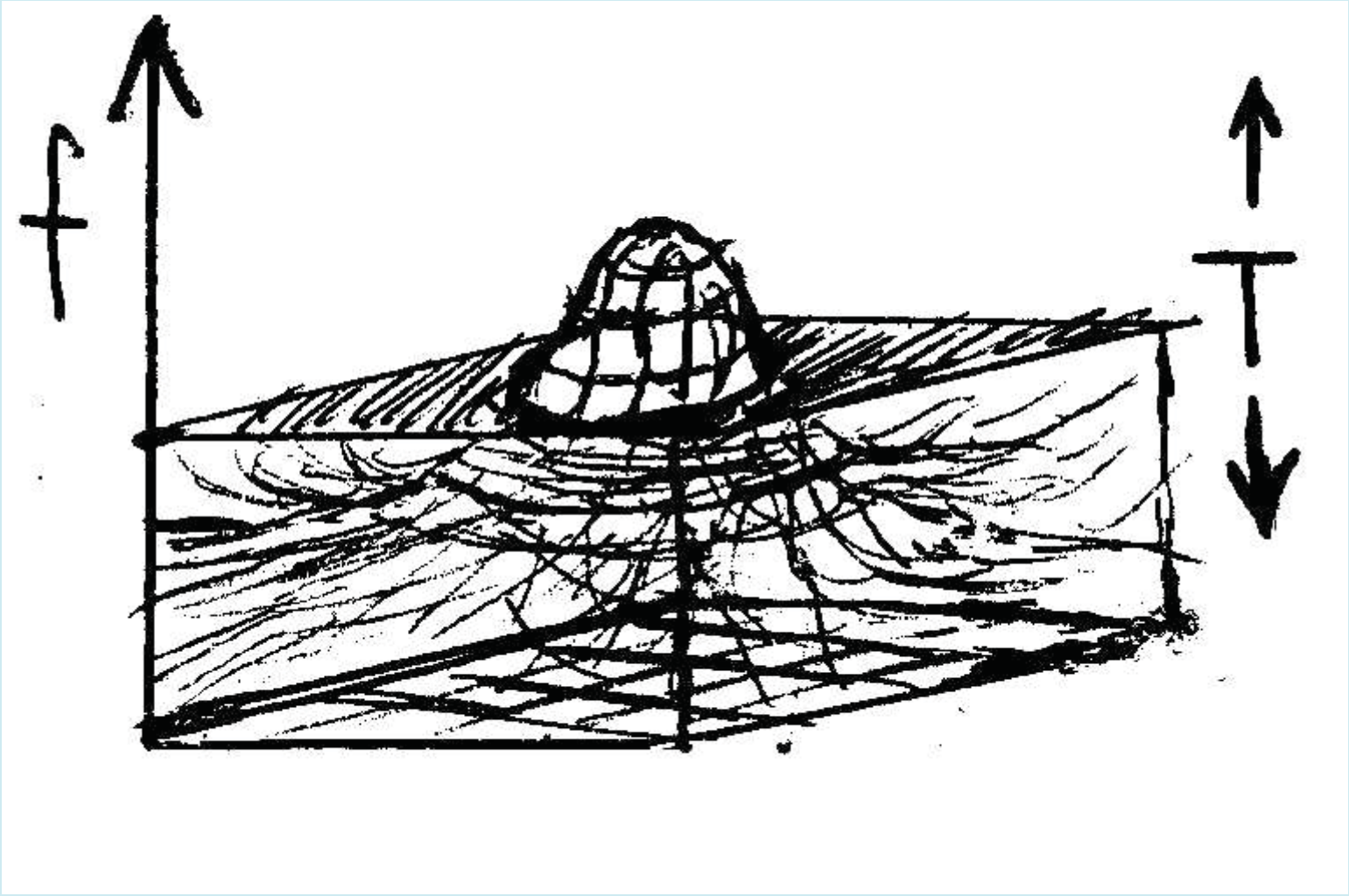


Discrimination index Q

$$Q = \frac{|M_y - M_x|}{\sqrt{\sigma_x^2 + \sigma_y^2}}$$

Pathologist

Thresholding

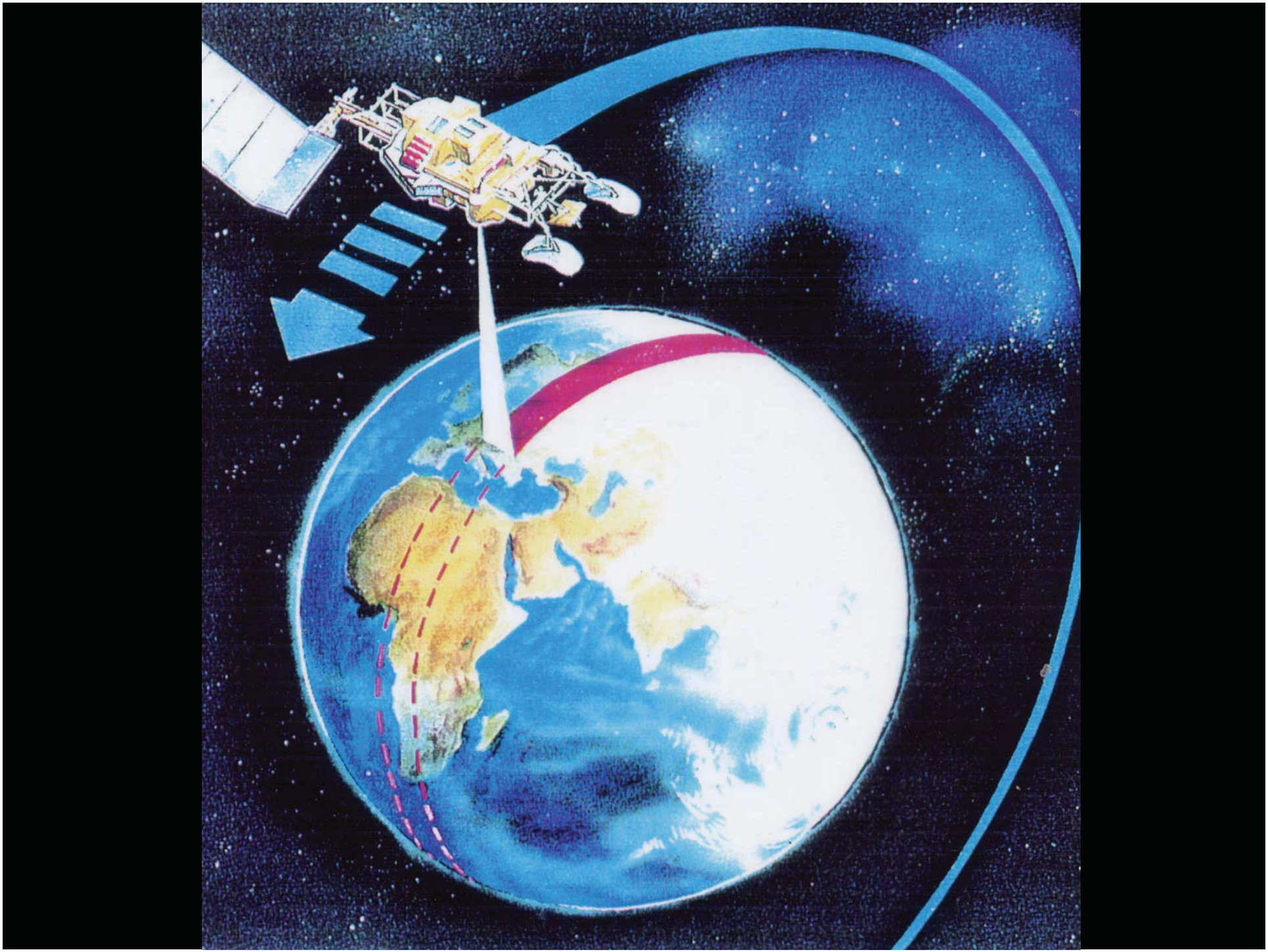


Generalization: Multi-variate analysis

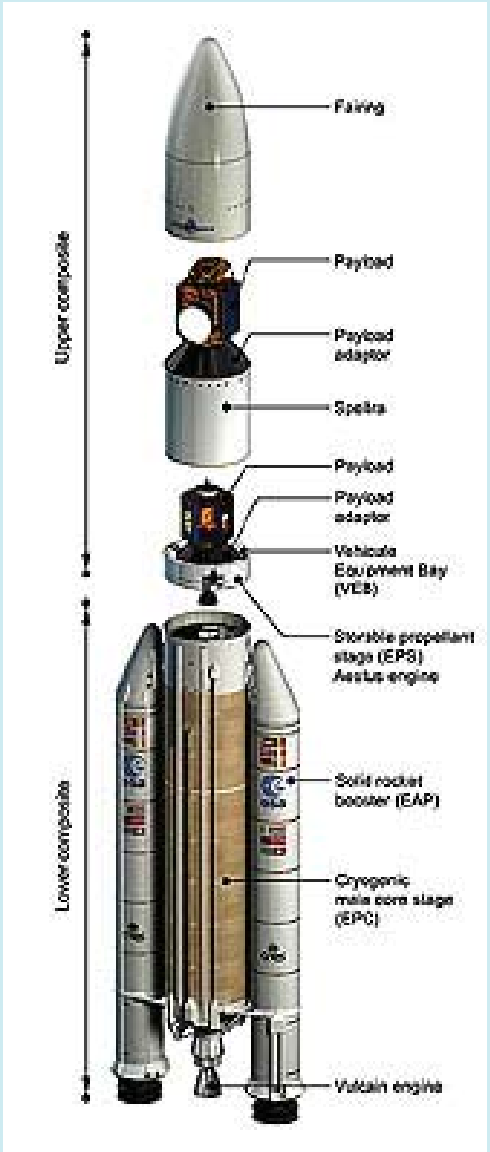
Advantages of dimensionless quantity recording

Immunity to:

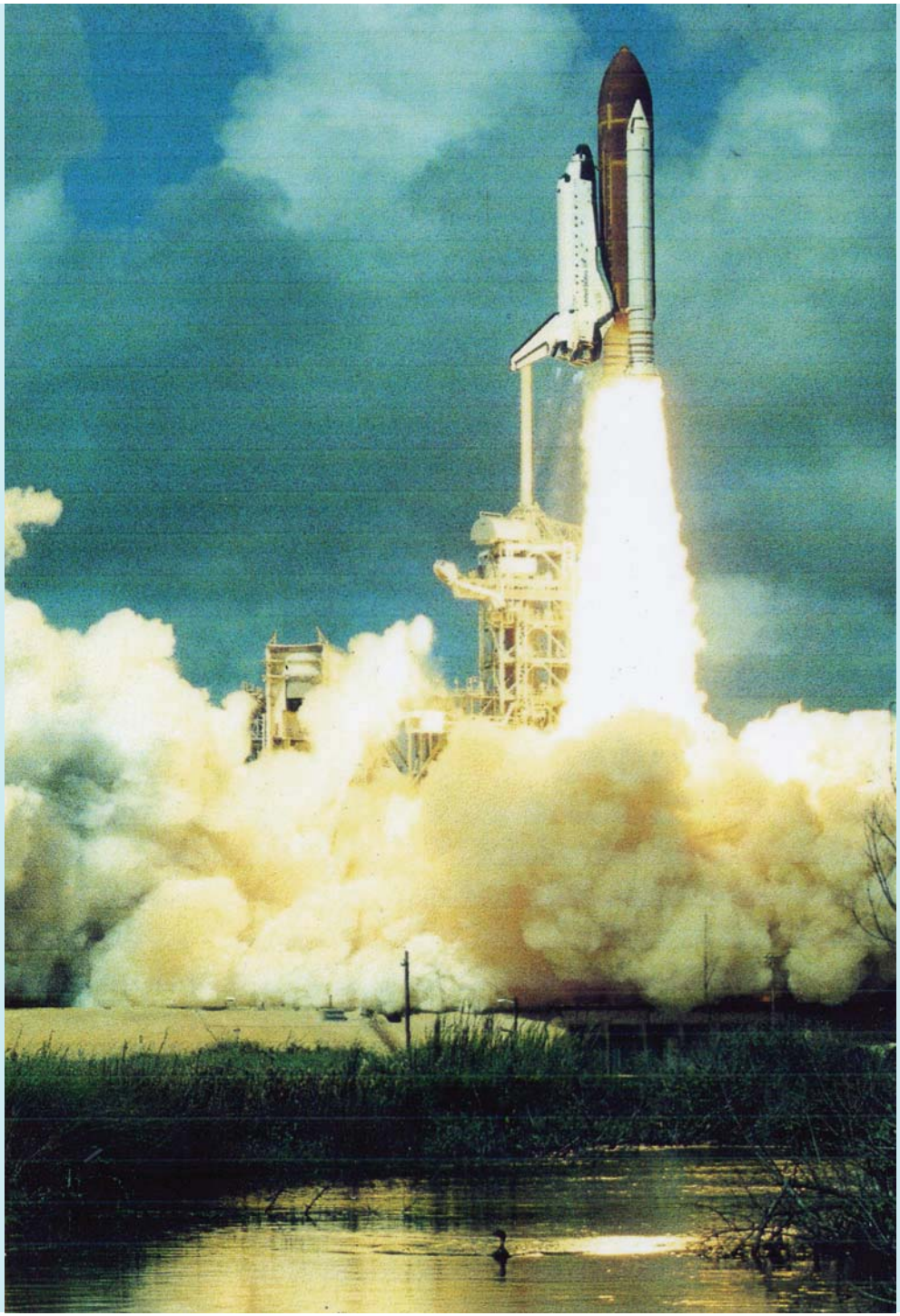
- Variations in the angle of incidence of the radiat. (topography)
- Variations in the distance from the object to the detector
- Variations in intensity of illumination over the image
- Intensity fluctuations in the illumination source
- Variations in wavelength-independent absorption factors




Ariane 44LP
Ariane 40
Ariane 42P
Ariane 44P
Ariane 42L

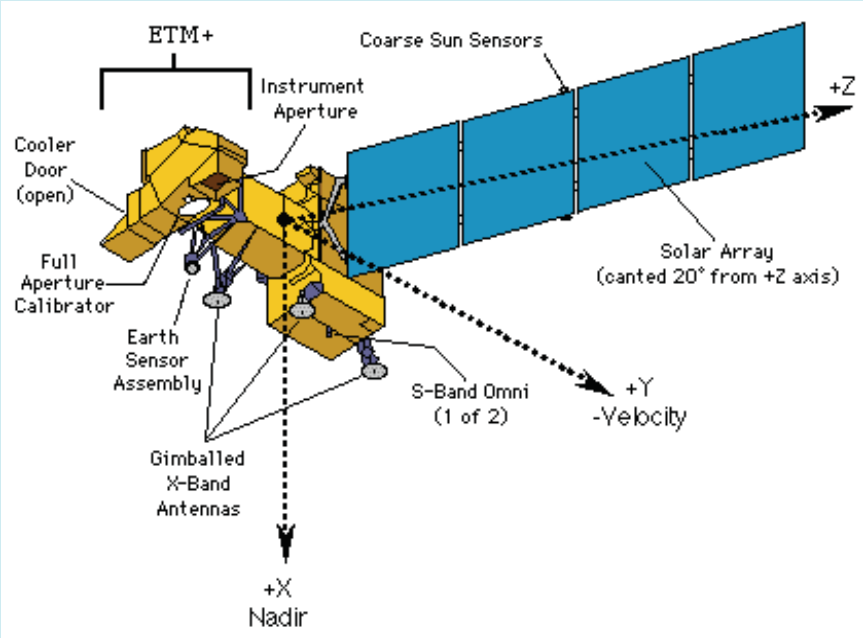

Fairing
Payload
Payload adaptor
Spelta
Payload
Payload adaptor
Vehicle Equipment Bay (VEB)
Storable propellant stage (EPS) Aestus engine
Solid rocket booster (EAP)
Cryogenic main core stage (EPC)
Vulcain engine
Upper composite
Lower composite

ESA

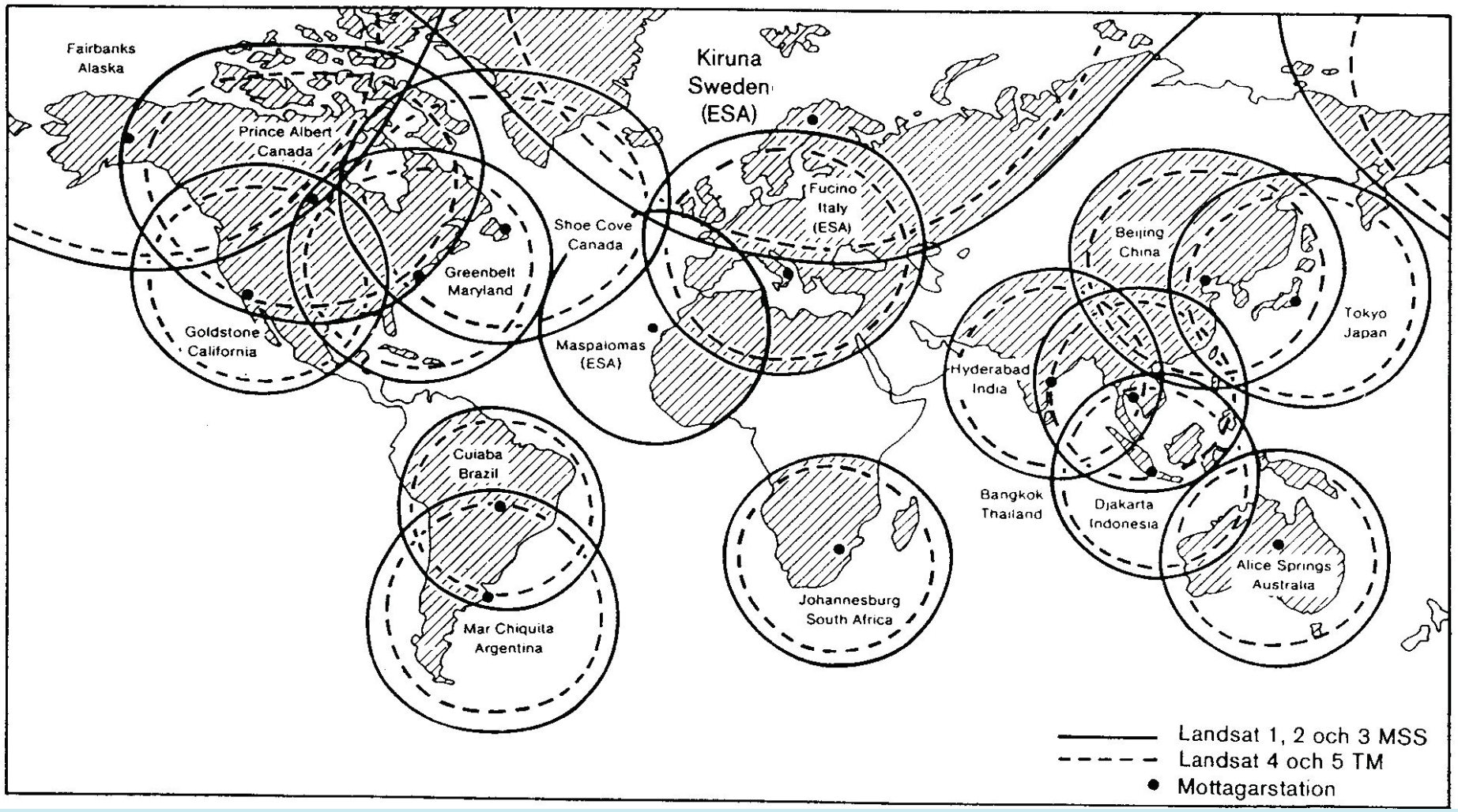


NASA

LANDSAT-7 and SPOT-5

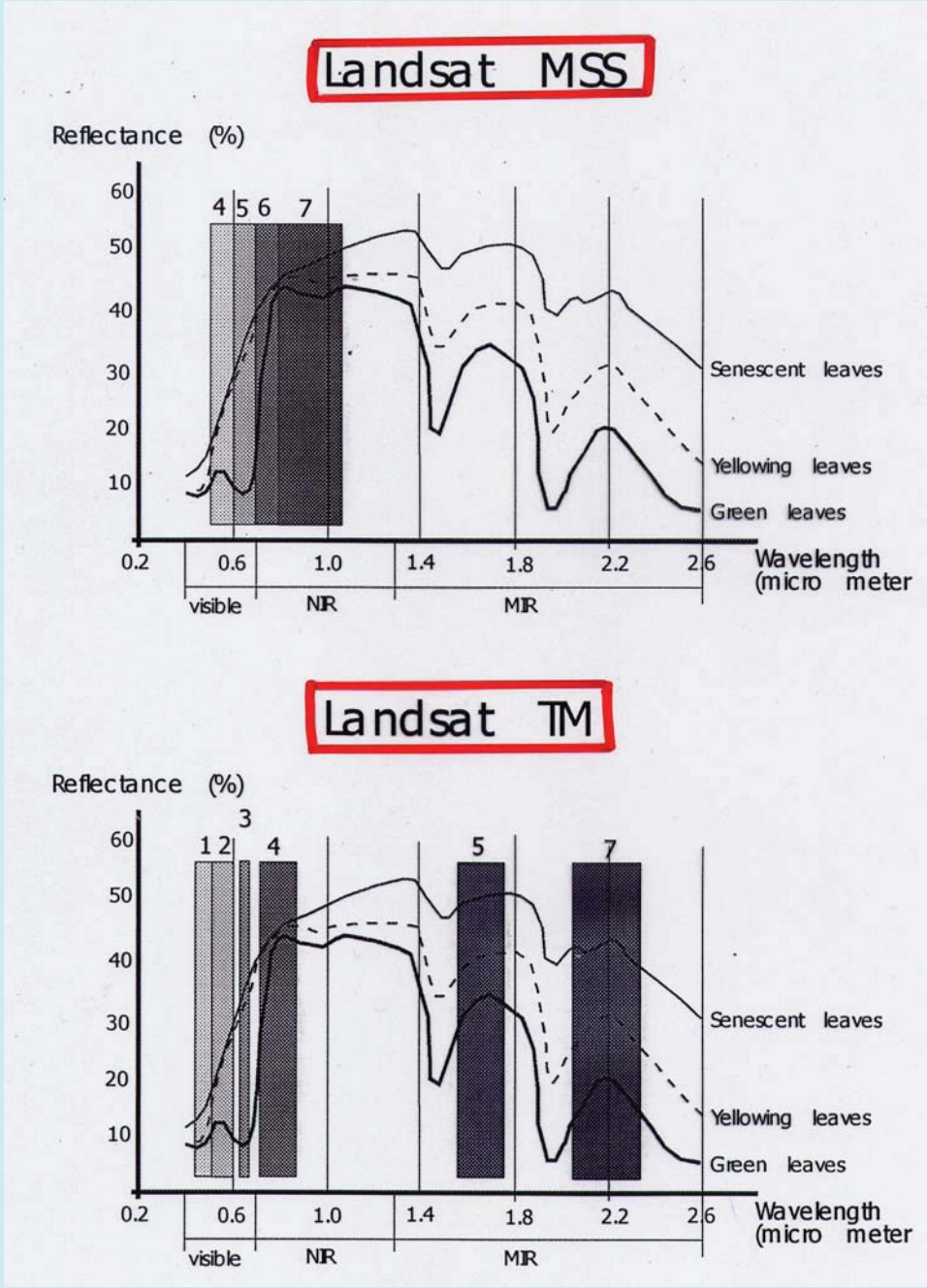


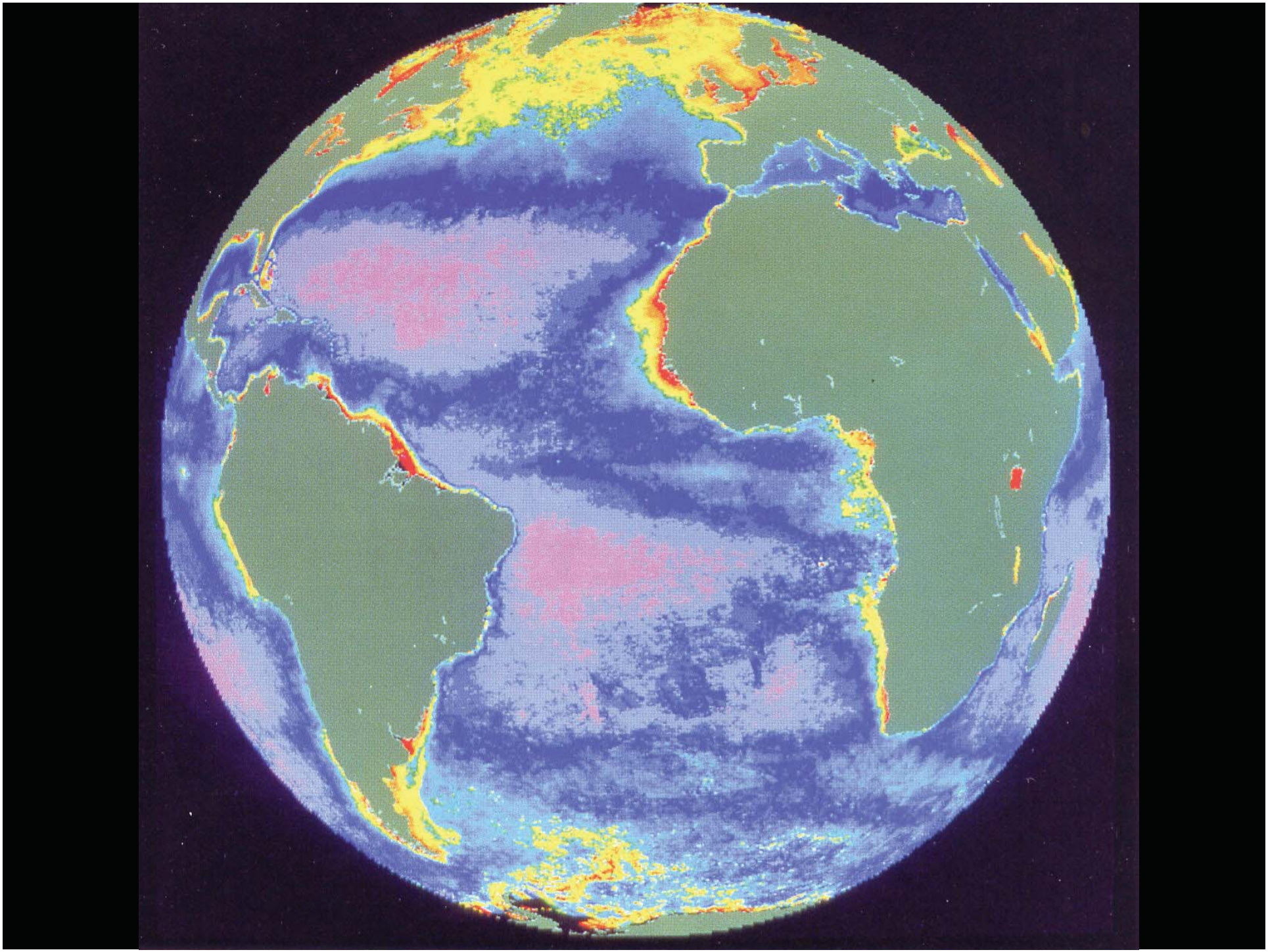
Receiving stations



Wastensson

Vegetation reflective spectroscopic imprint



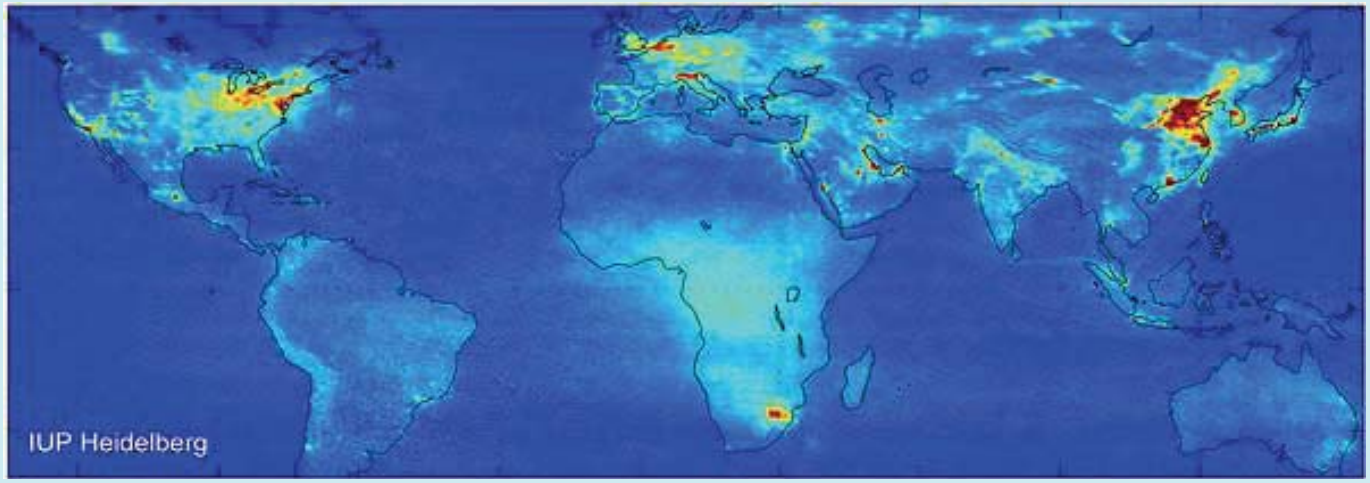


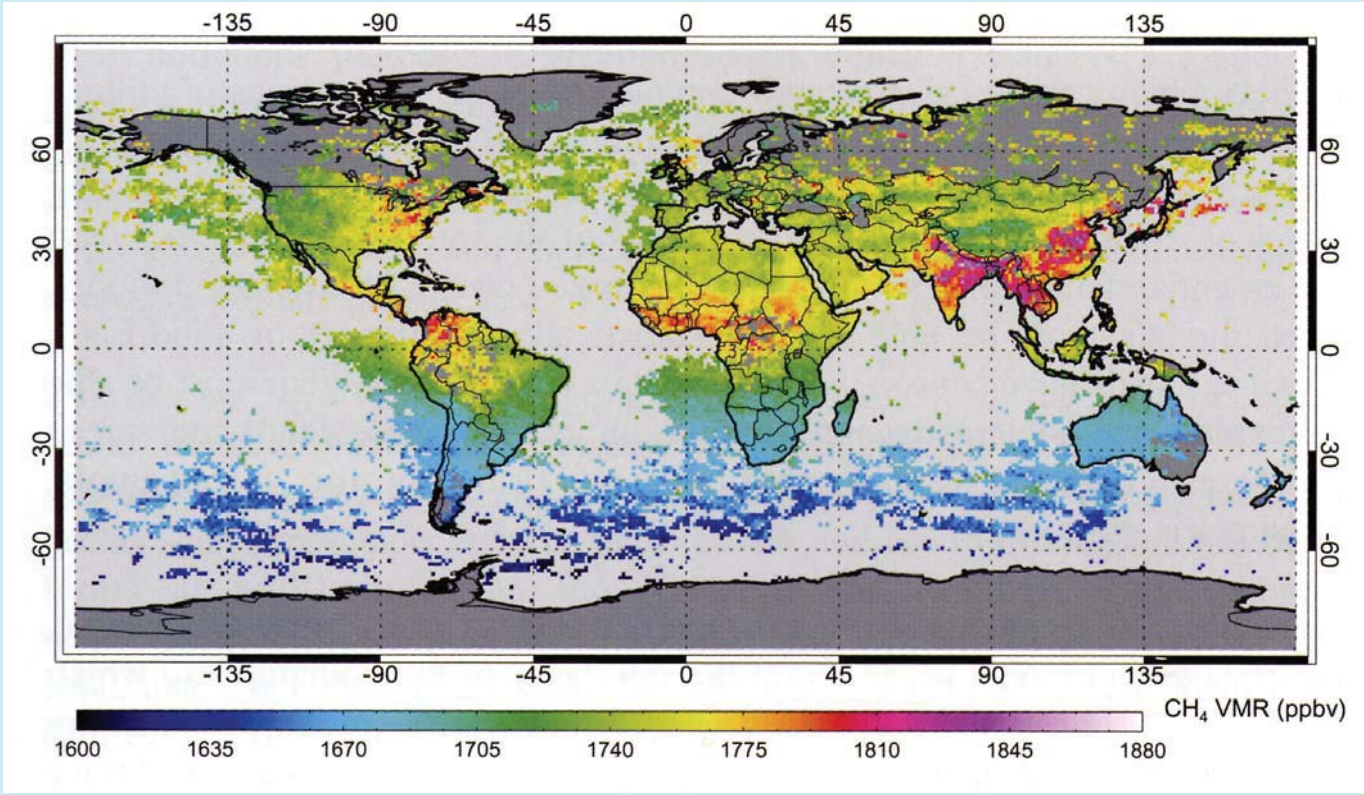
Bandar Aceh Tsunami Disaster

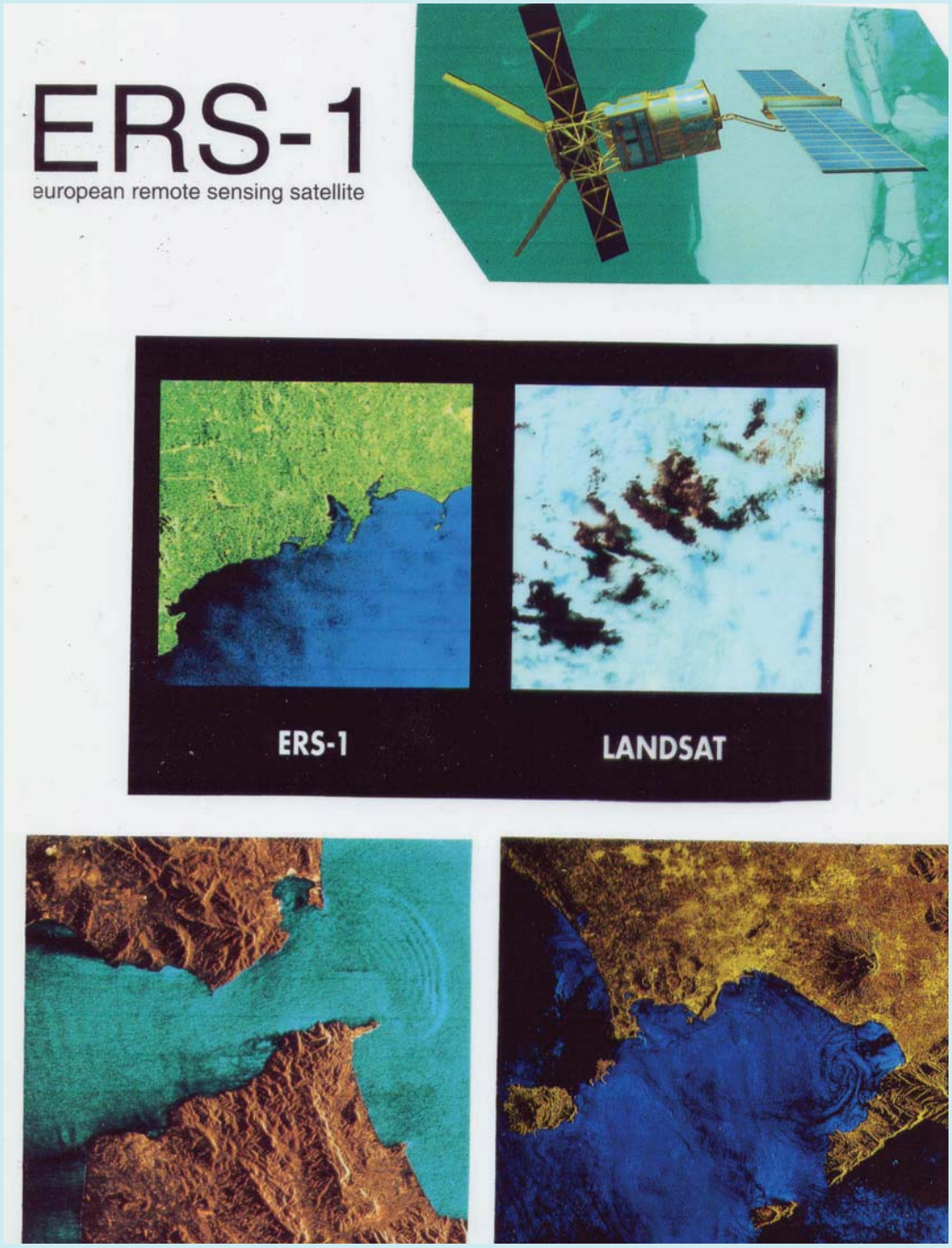
Before

After

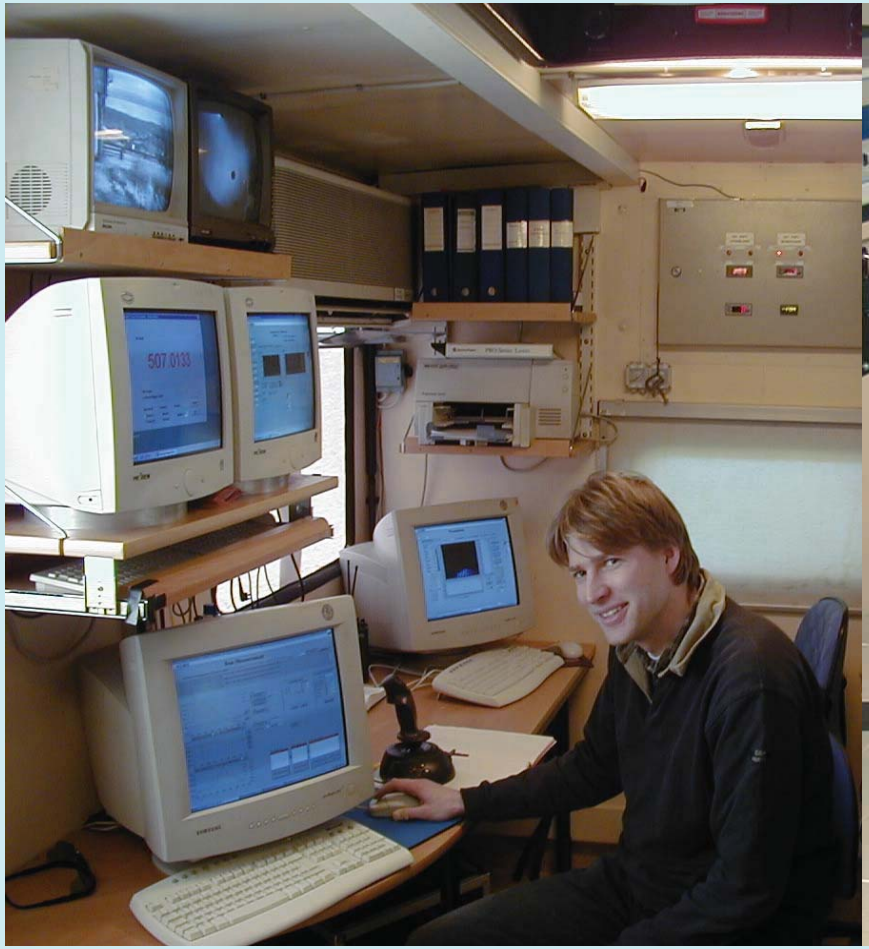
Nitrogen dioxide and methane maps







Optical
vs
Microwave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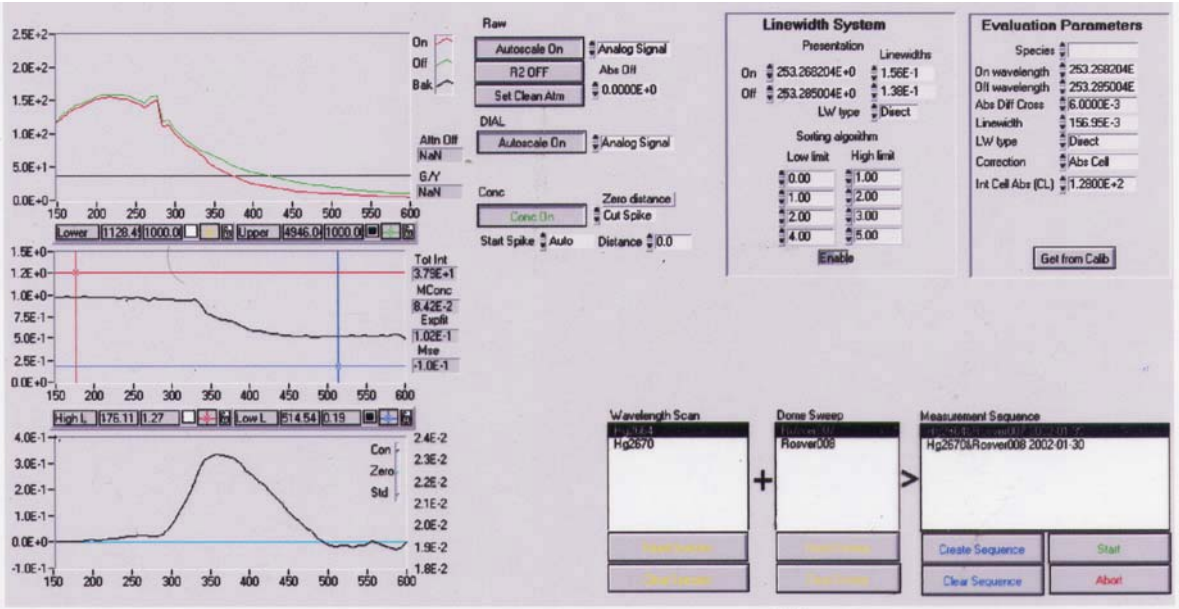
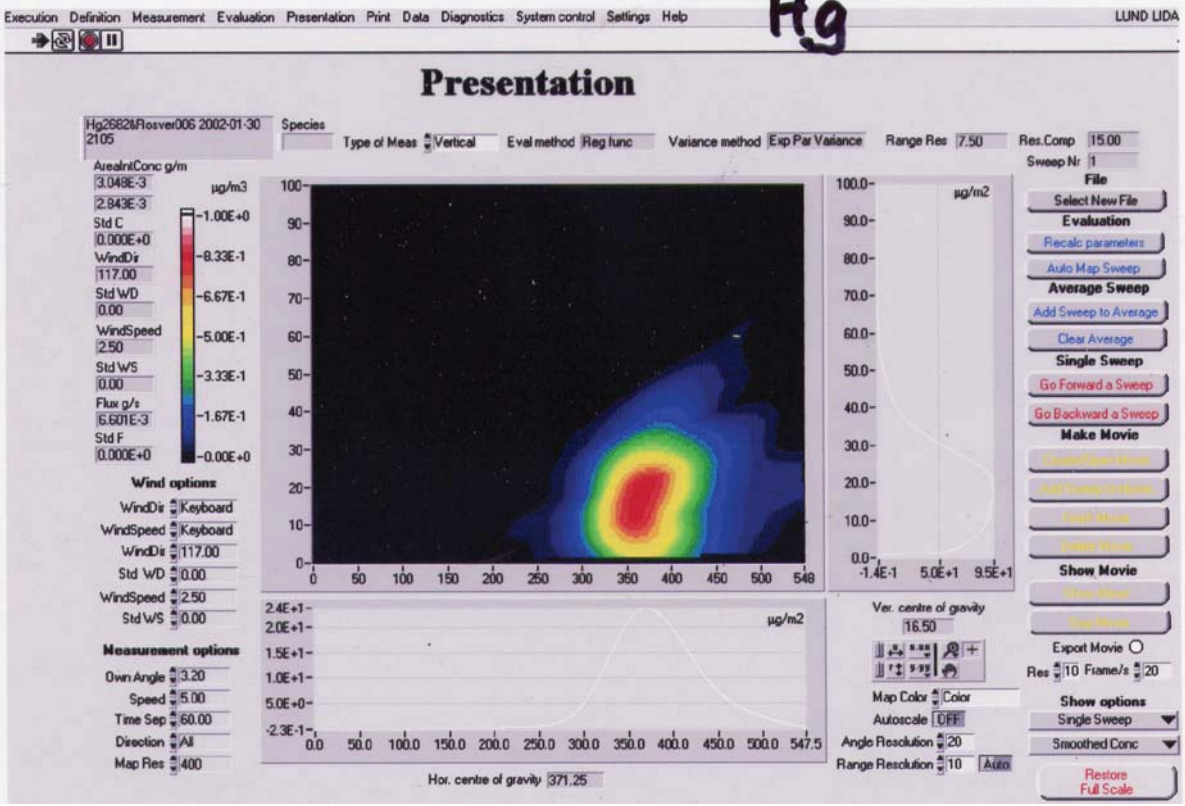
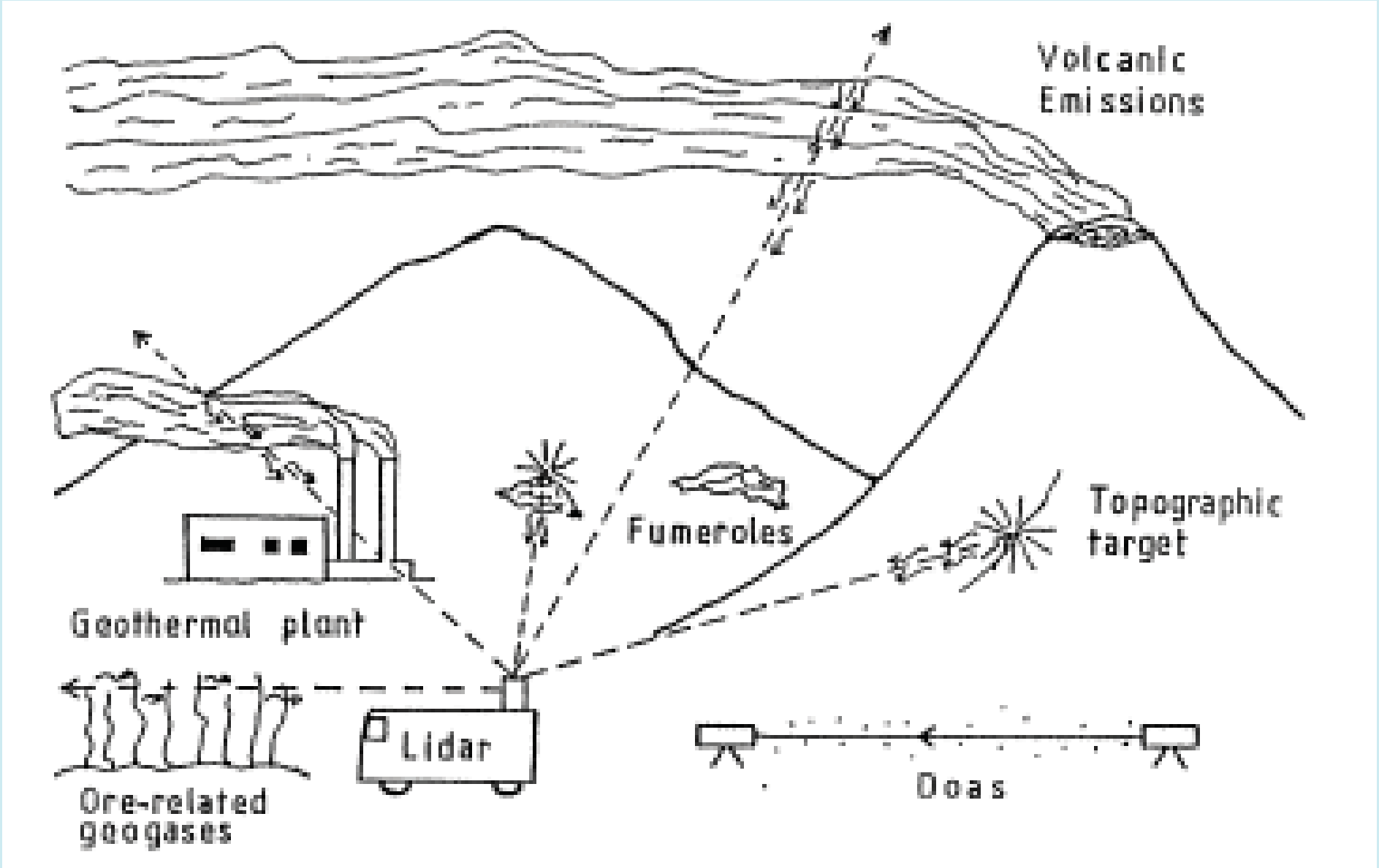
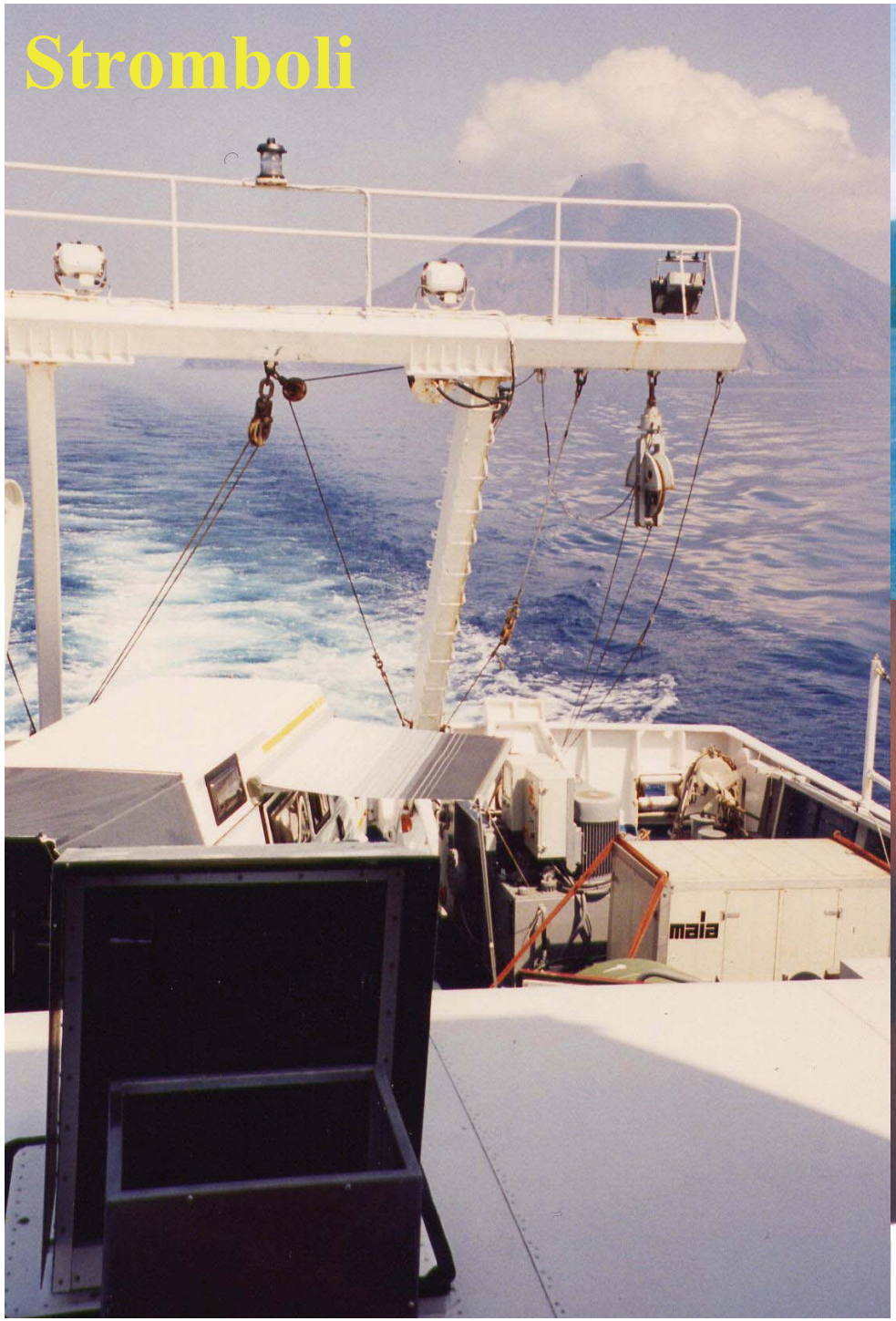

Raw
Autoscale On
Analog Signal
R2 OFF
Abs Diff
Set Clean Atm
0.0000E+0
DIAL
Autoscale On
Analog Signal
Conc
Zero distance
Conc On
Cut Spike
Start Spike Auto
Distance 0.0
Linewidth System
Presentation
Linewidths
On 253.268204E+0
1.56E-1
Off 253.285004E+0
1.38E-1
LW type Direct
Sorting algorithm
Low limit High limit
Enable
Evaluation Parameters
Species
On wavelength 253.268204E
Off wavelength 253.285004E
Abs Diff Cross 6.0000E-3
Linewidth 156.95E-3
LW type Direct
Correction Abs Cell
Int Cell Abs (CL) 1.2800E+2
Get from Calib
Wavelength Scan
Hg2670
Dome Sweep
Rosver008
Measurement Sequence
Hg2670&Rosver008 2002-01-30
Create Sequence
Start
Clear Sequence
Abort

Hg


Execution Definition Measurement Evaluation Presentation Print Data Diagnostics System control Settings Help
LUND LIDA
Presentation
Hg2682&Rosver006 2002-01-30 2105
Species
Type of Meas Vertical
Eval method Reg func
Variance method Exp Par Variance
Range Res 7.50
Res.Comp 15.00
Sweep Nr 1
AreaIntConc g/m
3.048E-3
2.843E-3
Std C 0.000E+0
WindDir 117.00
Std WD 0.00
WindSpeed 2.50
Std WS 0.00
Flux g/s 6.601E-3
Std F 0.000E+0
µg/m3
Wind options
WindDir Keyboard
WindSpeed Keyboard
WindDir 117.00
Std WD 0.00
WindSpeed 2.50
Std WS 0.00
Measurement options
Own Angle 3.20
Speed 5.00
Time Sep 60.00
Direction All
Map Res 400
µg/m2
Hor. centre of gravity 371.25
Ver. centre of gravity 16.50
Map Color Color
Autoscale OFF
Angle Resolution 20
Range Resolution 10 Auto
File
Select New File
Evaluation
Recalc parameters
Auto Map Sweep
Average Sweep
Add Sweep to Average
Clear Average
Single Sweep
Go Forward a Sweep
Go Backward a Sweep
Make Movie
Show Movie
Export Movie
Res 10 Frame/s 20
Show options
Single Sweep
Smoothed Conc
Restore Full Scale

Optical monitoring of geophysical gases

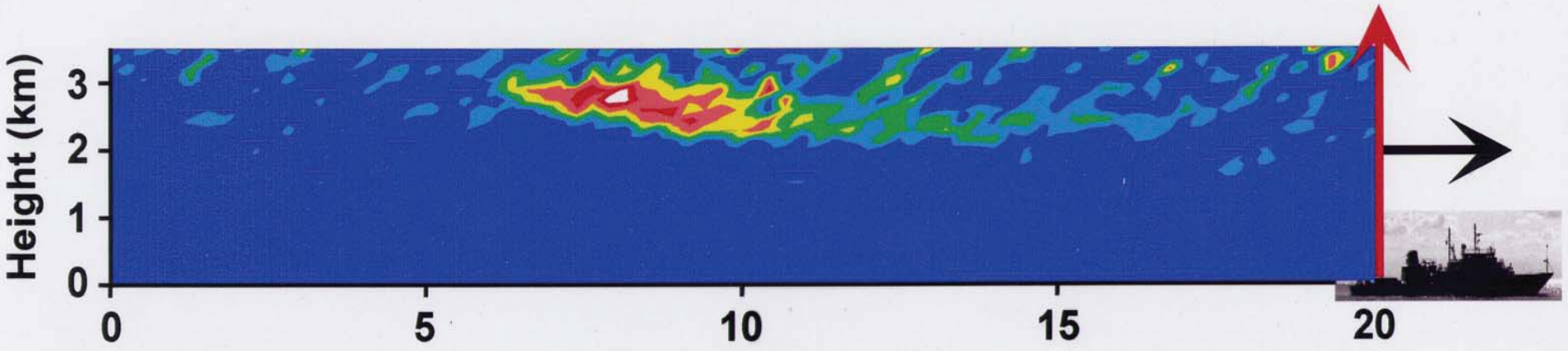


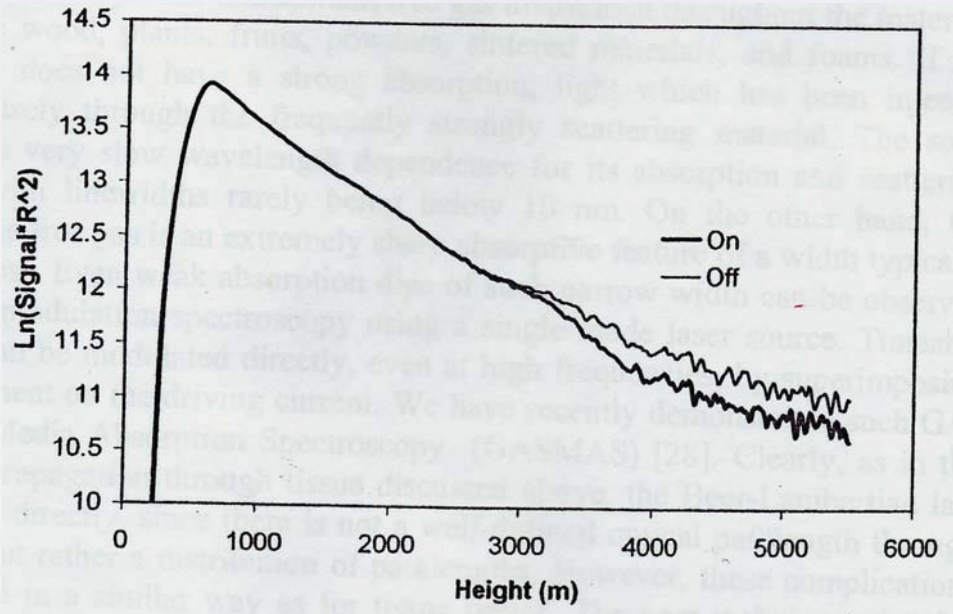

Stromboli
maia


Vulcano

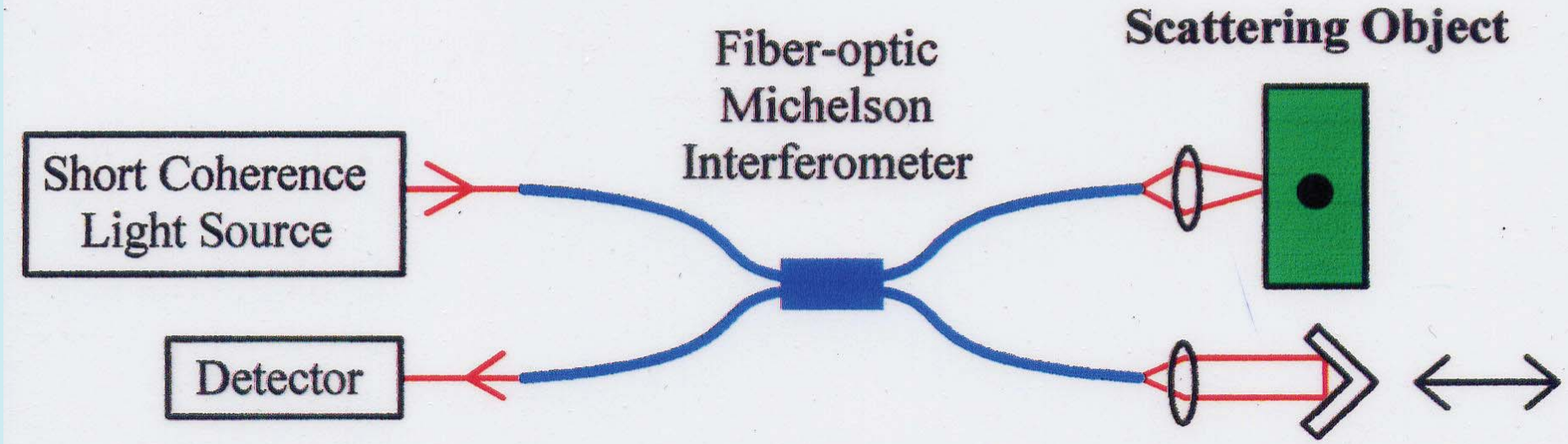

Etna

Sulphur dioxide plume from Etna - Flux: 50 tonnes/h



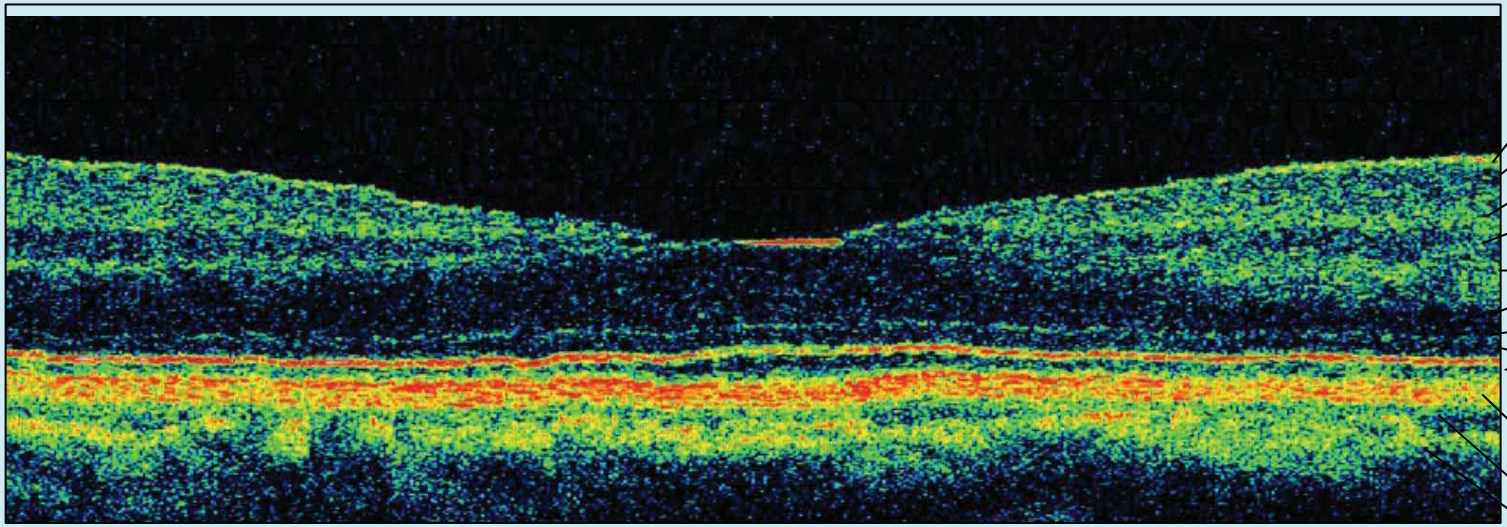


Optical Coherence Tomography

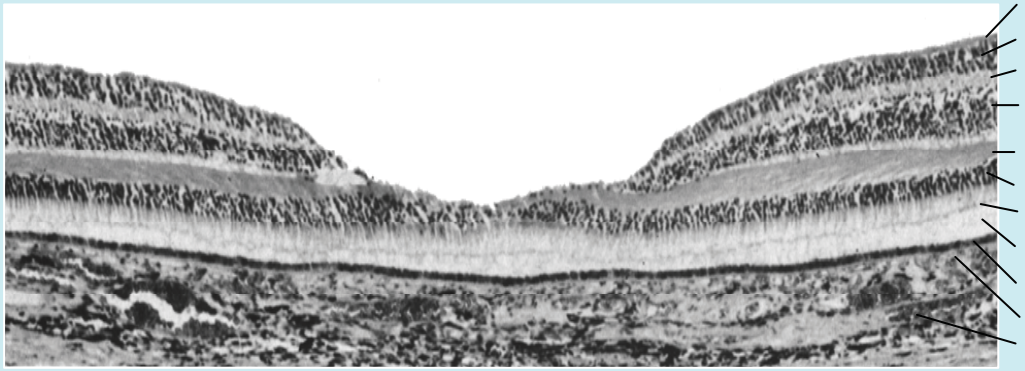


J. Fujimoto et al.

In Vivo Ultrahigh Resolution OCT versus Histology



250 m

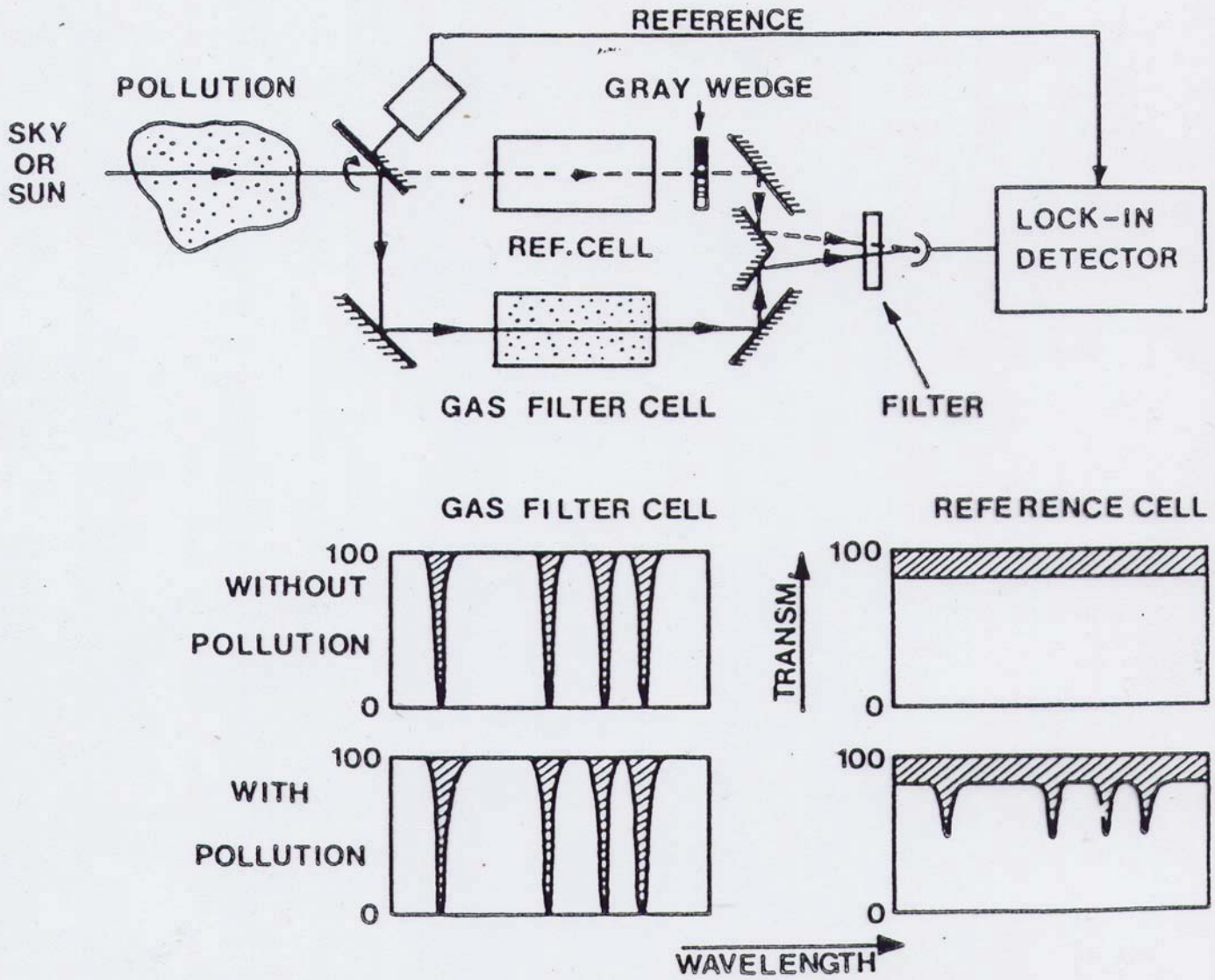


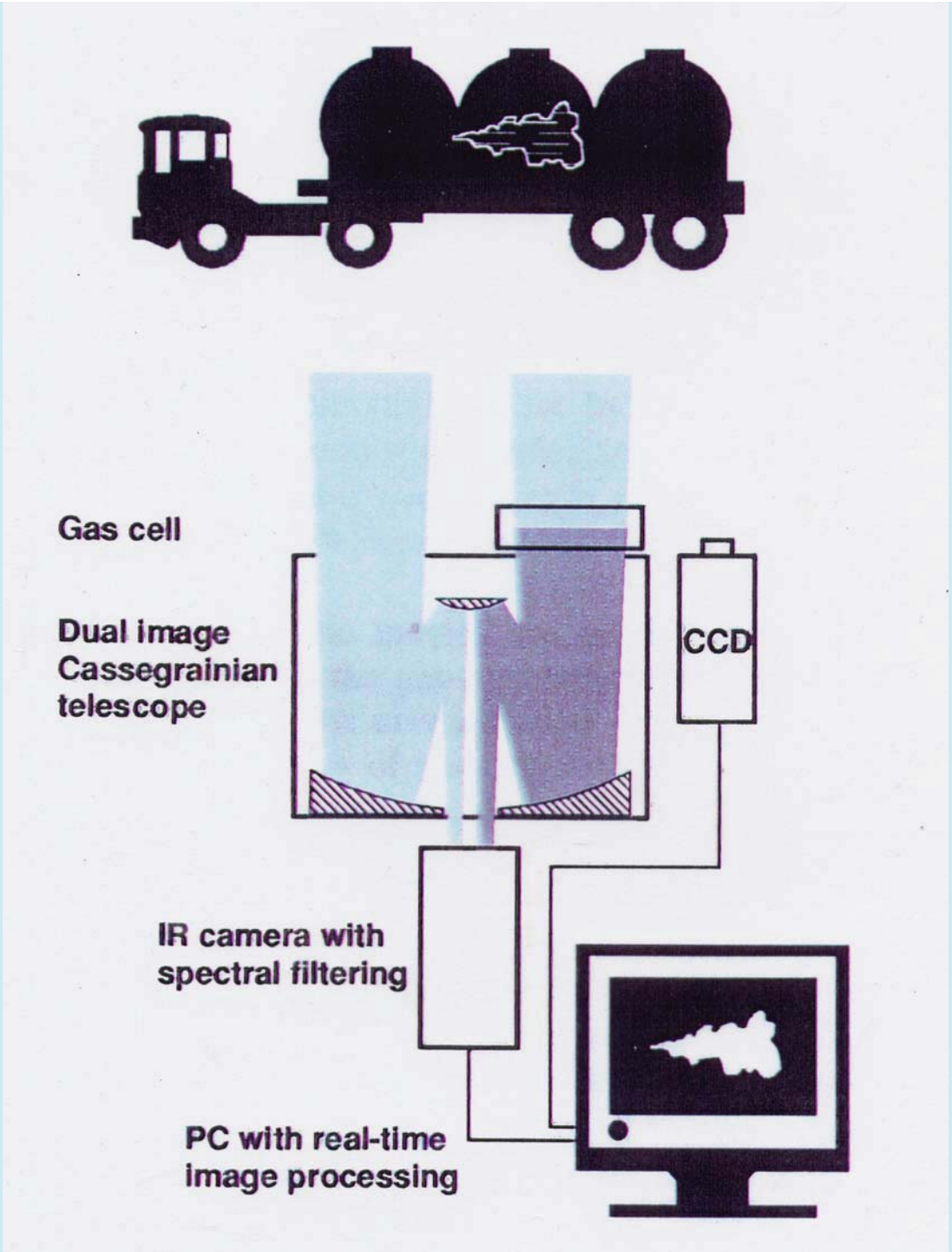
Gass J.D.M., 1997

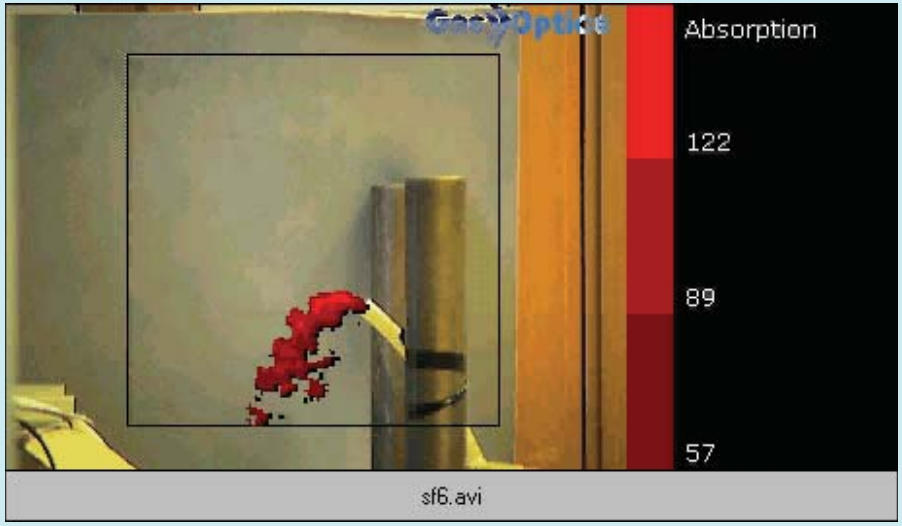
W. Drexler et al.; Vienna

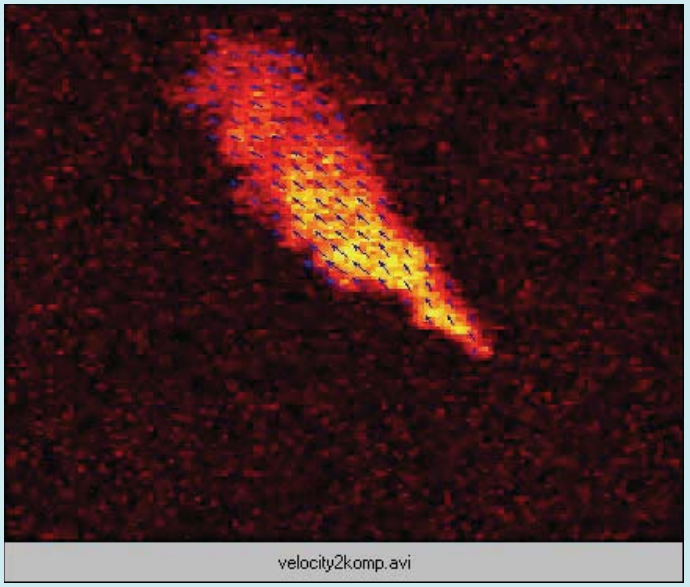
W. Drexler et al. *Nature Medicine*, Vol 7, No. 4, 502-507, 2001

Gas correlation spectroscopy

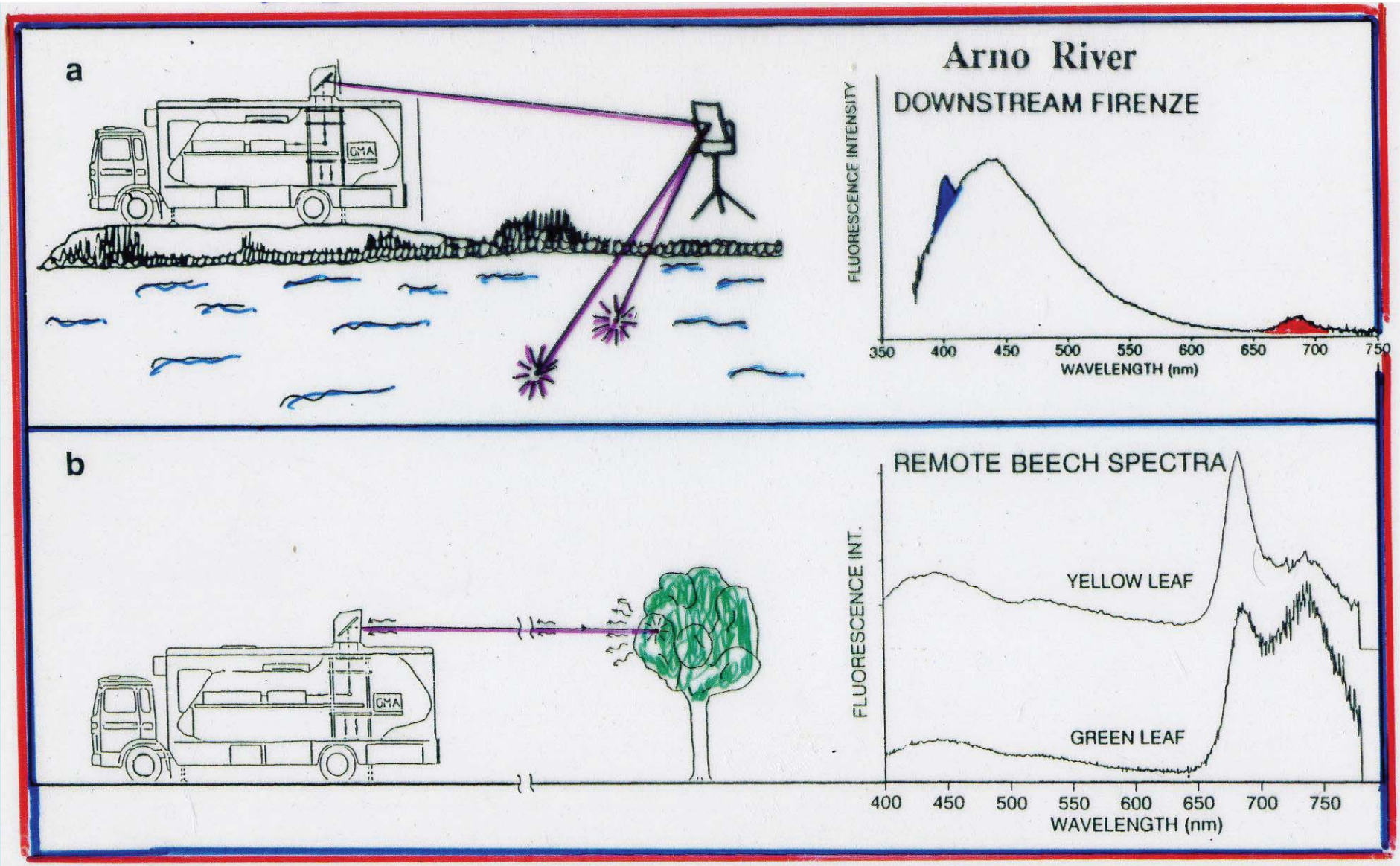


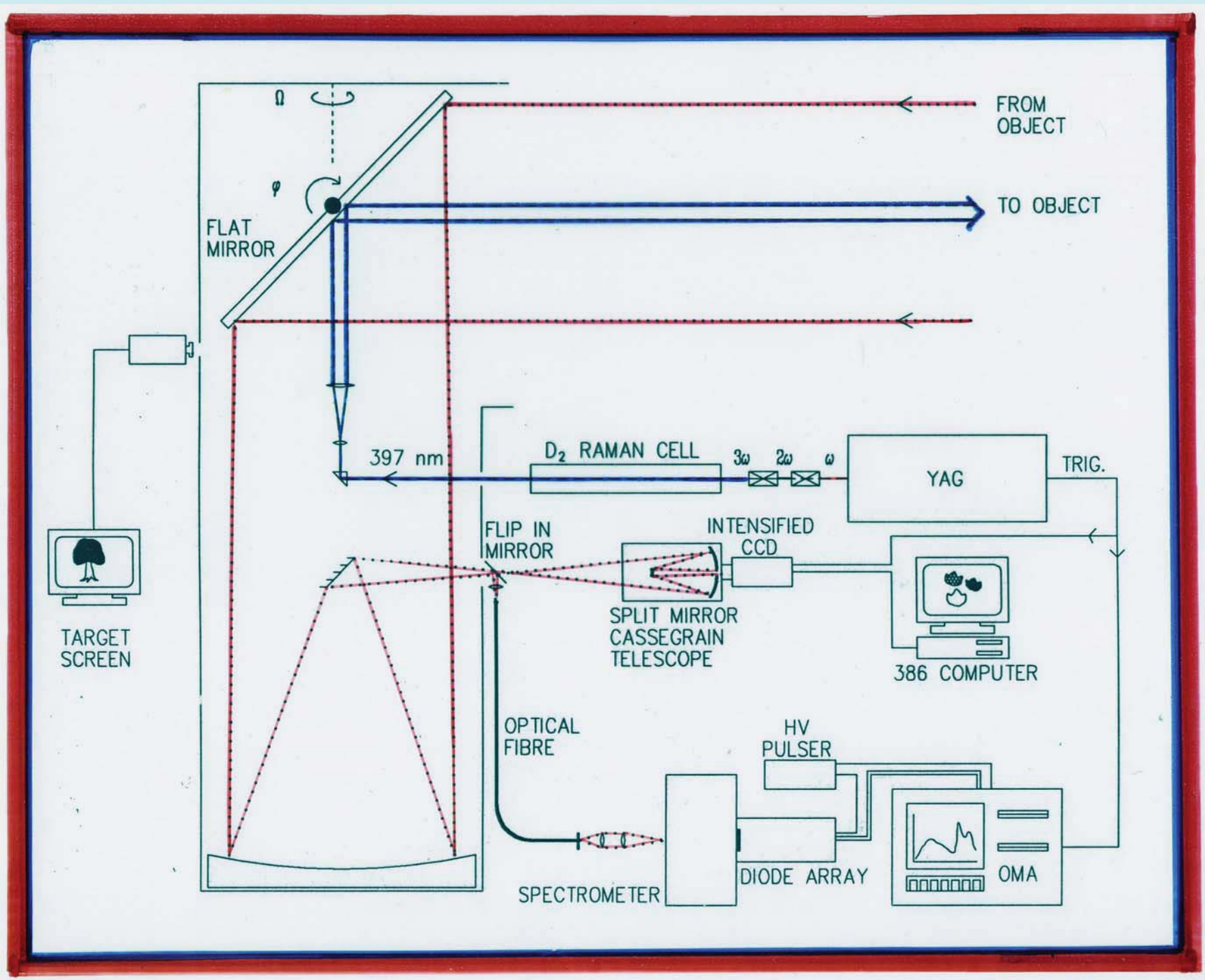

Gas cell
Dual image
Cassegrainian
telescope
CCD
IR camera with
spectral filtering
PC with real-time
image processing


Absorption
122
89
57
sf6.avi

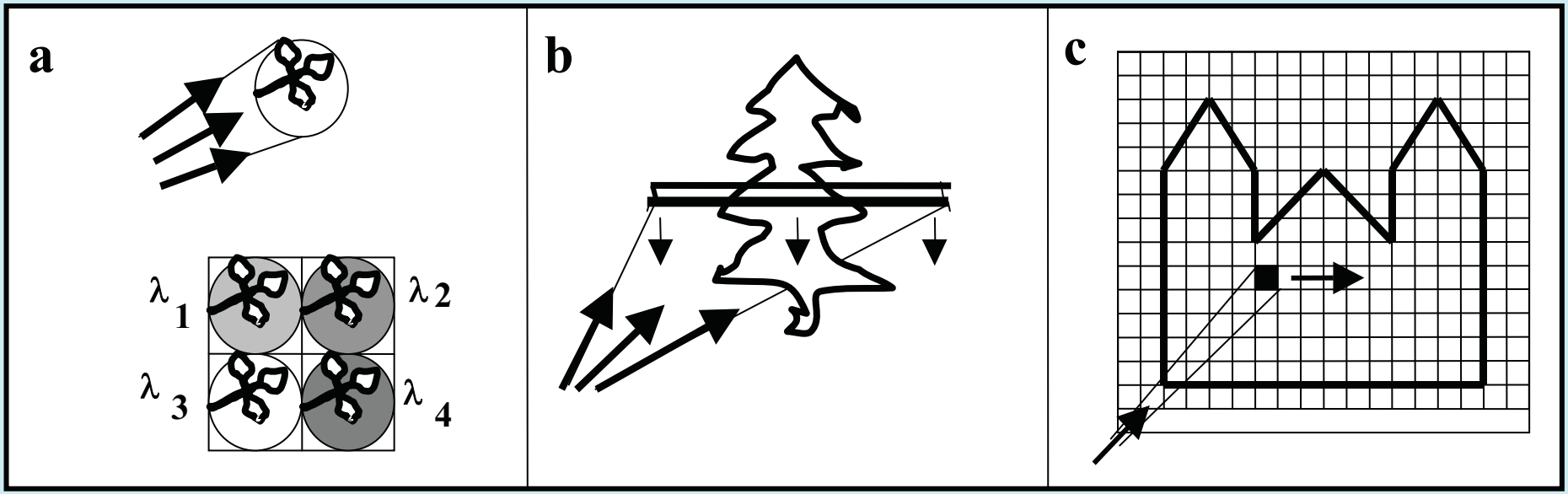

velocity2komp.avi

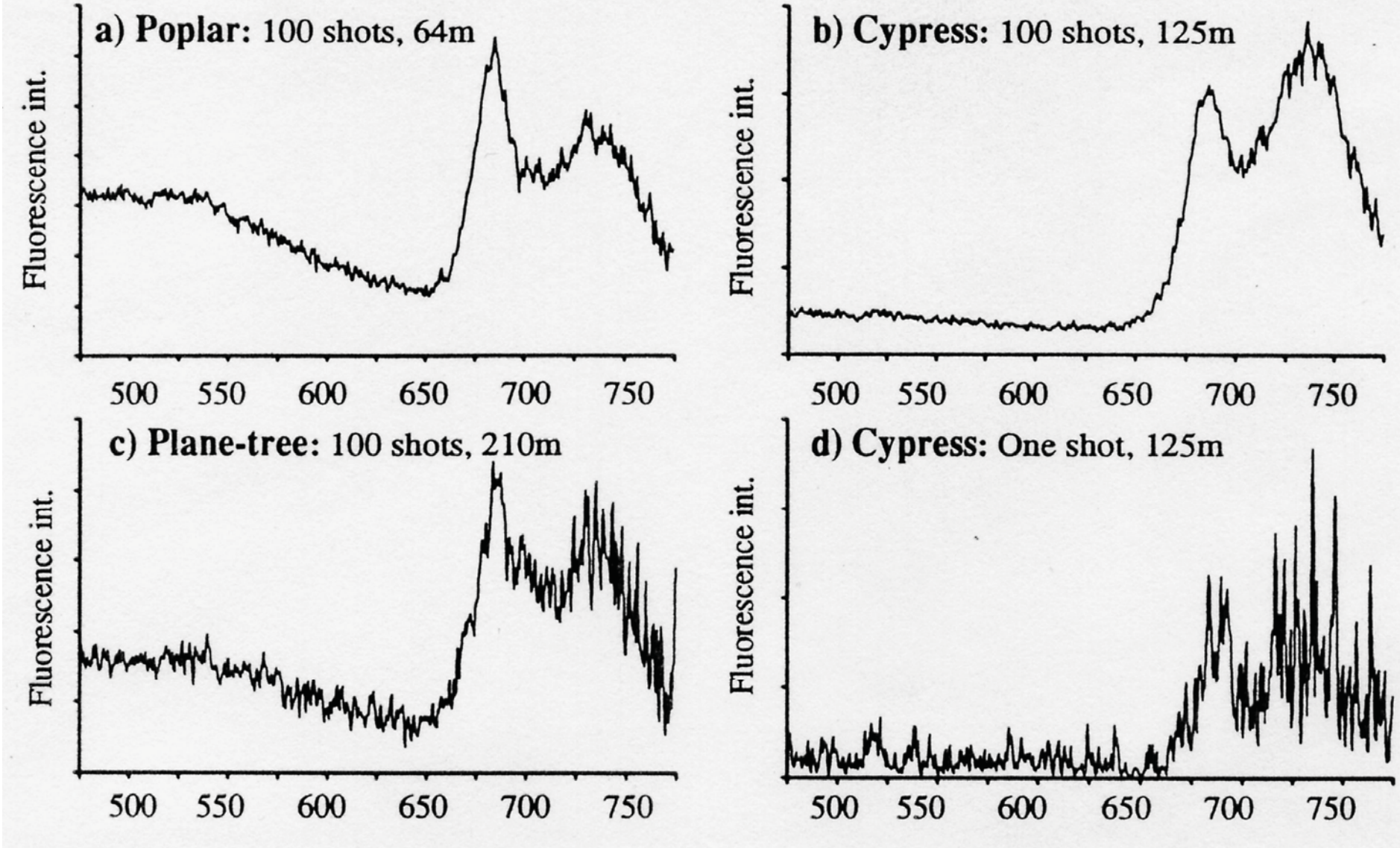
LIDAR REMOTE FLUORESCENCE MONITORING




Ω
φ
FLAT
MIRROR
FROM
OBJECT
TO OBJECT
397 nm
D2 RAMAN CELL
3ω
2ω
ω
YAG
TRIG.
FLIP IN
MIRROR
INTENSIFIED
CCD
SPLIT MIRROR
CASSEGRAIN
TELESCOPE
386 COMPUTER
TARGET
SCREEN
OPTICAL
FIBRE
HV
PULSER
SPECTROMETER
DIODE ARRAY
OMA

Imaging scenarios
for different background light conditions



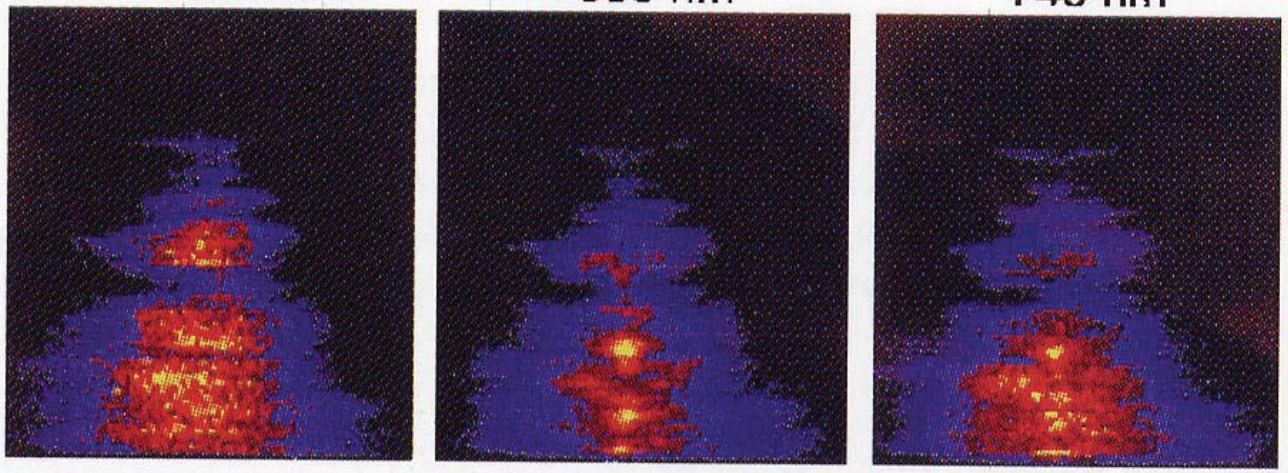

a) Poplar: 100 shots, 64m
b) Cypress: 100 shots, 125m
c) Plane-tree: 100 shots, 210m
d) Cypress: One shot, 125m
Fluorescence int.
500
550
600
650
700
750

Picea abies
60 m distance

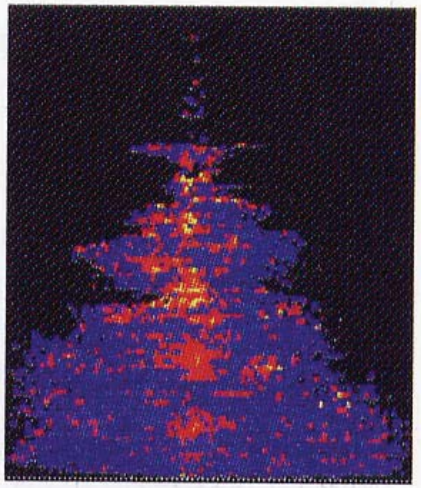
480 nm

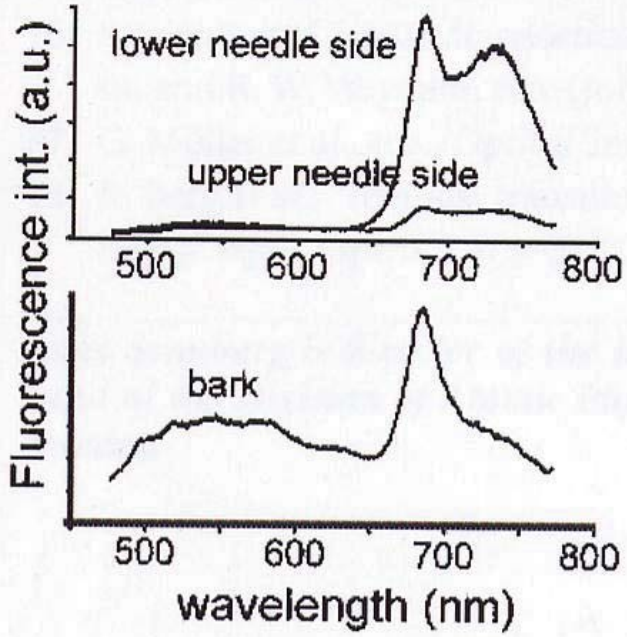
685 nm

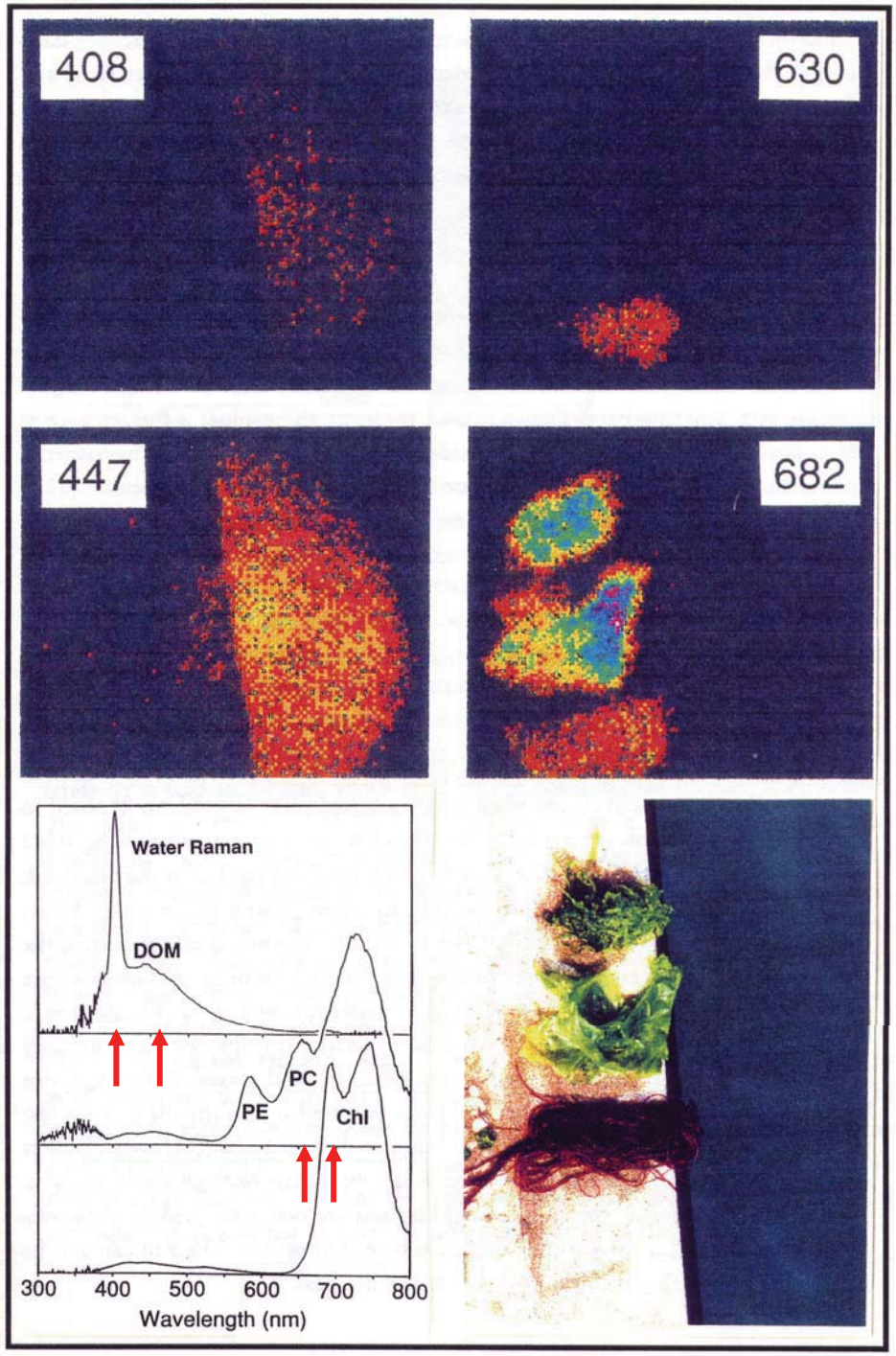
740 nm

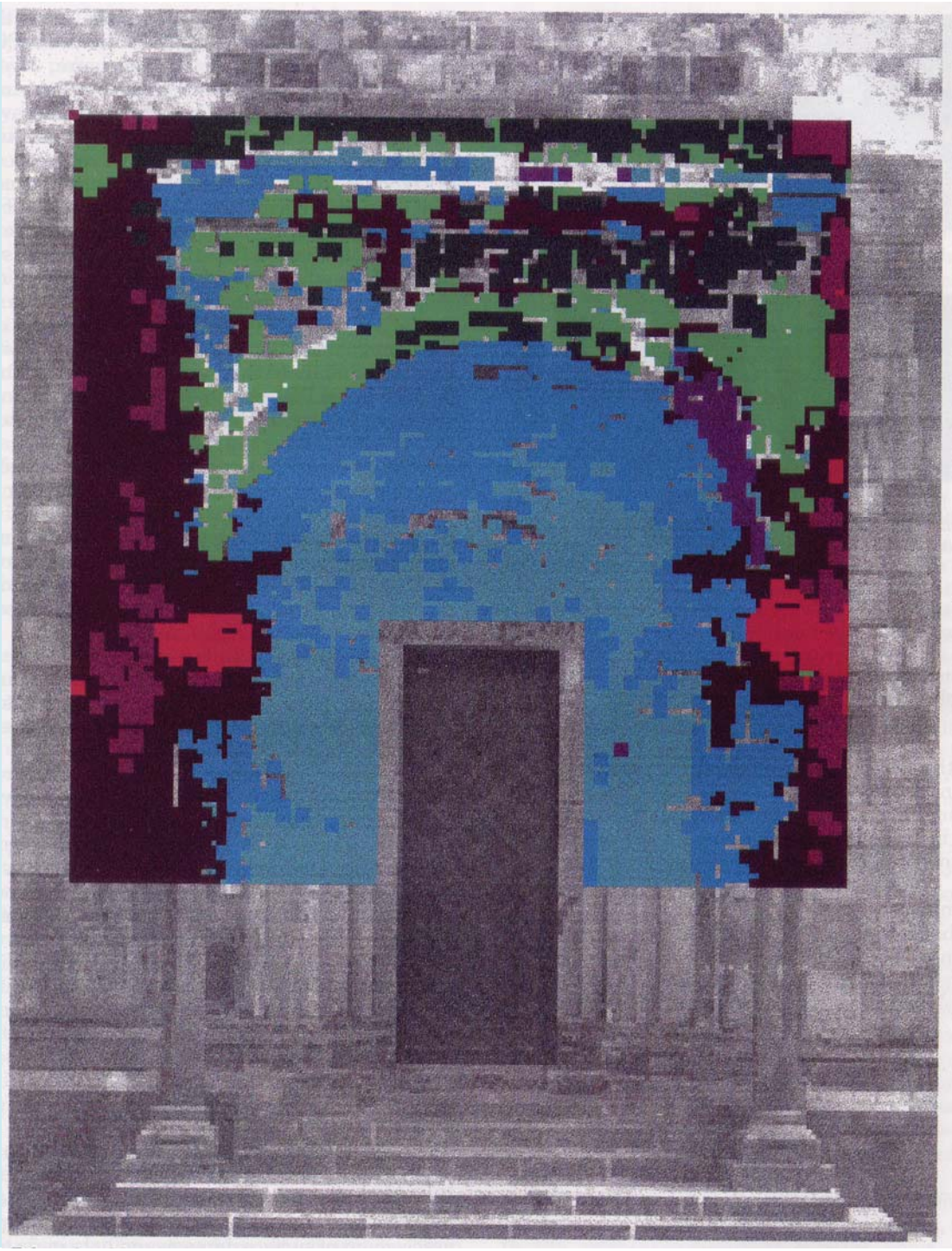


685nm / 740nm



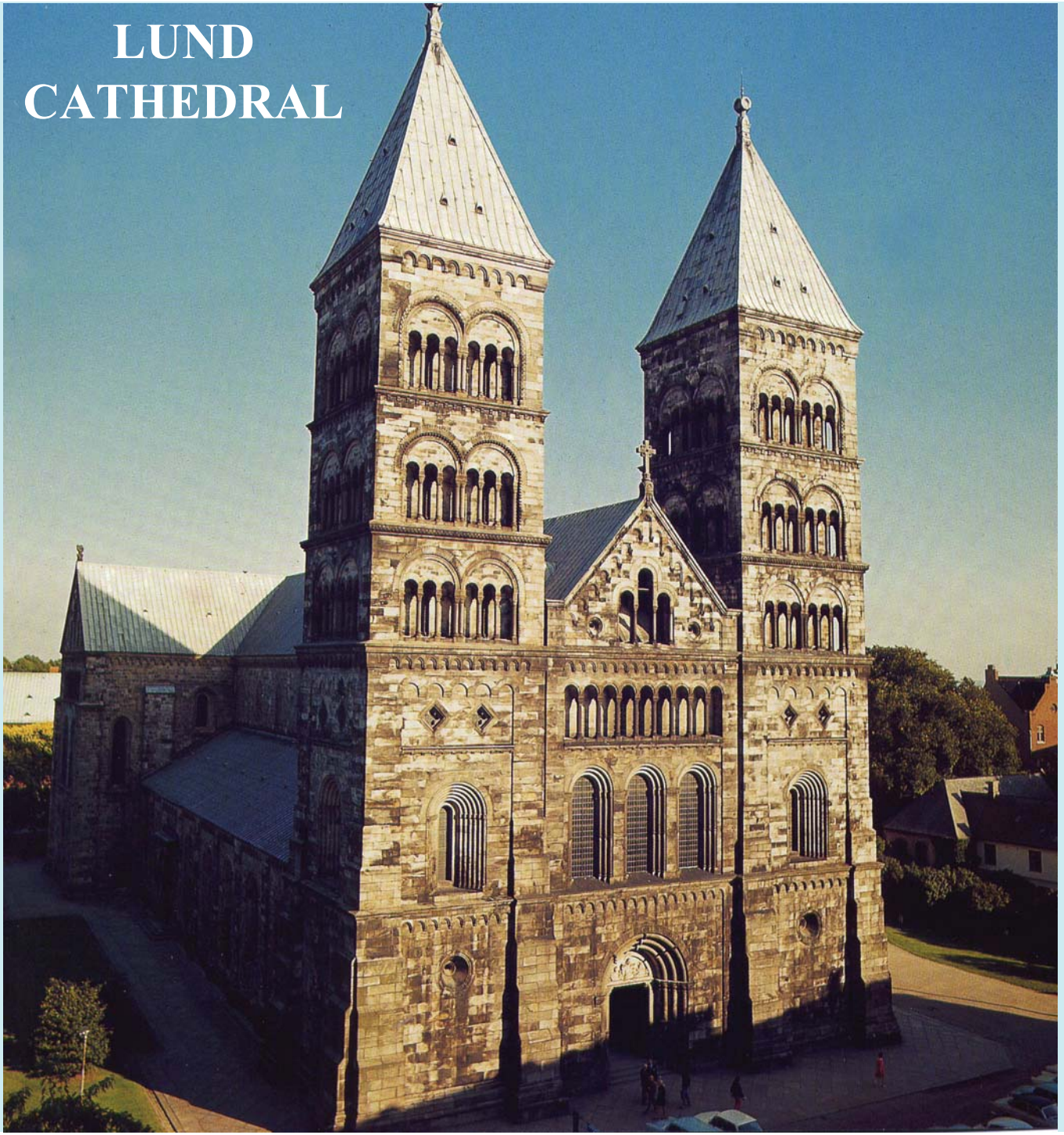



408
630
447
682
Water Raman
DOM
PC
PE
Chl
300
400
500
600
700
800
Wavelength (nm)

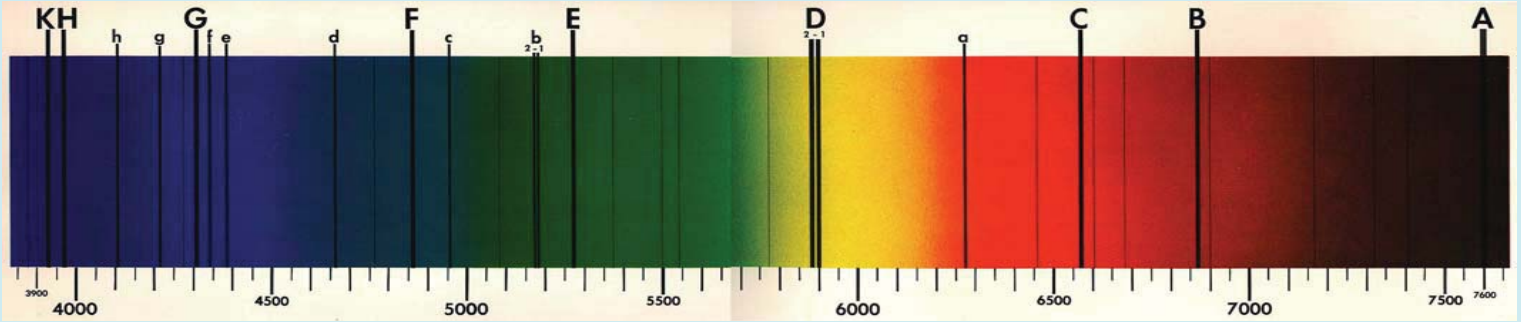


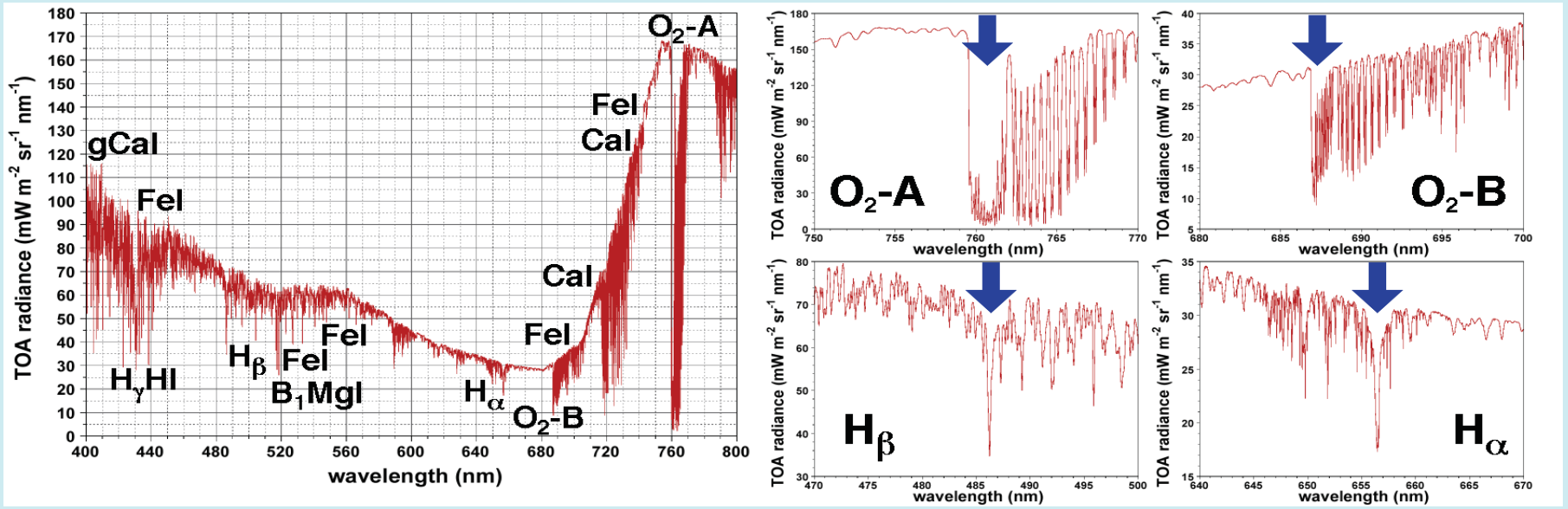
Multi-variate spectral analysis classifies areas

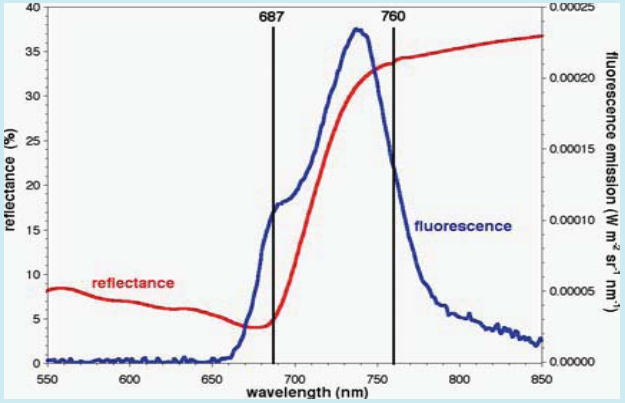
LUND CATHEDRAL

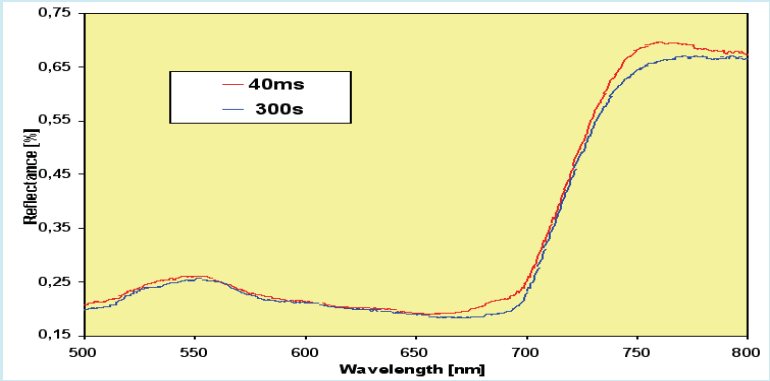


FLEX Fraunhofer Discrimination Vegetation Fluorescence Satellite









Multi-spectral Imaging

-from astronomy to microscopy-
-from radiowaves to gammarays

Springer, Heidelberg, 2009, to appear

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