



**ENEA**

Tomsk, July 1<sup>st</sup> – 8<sup>th</sup>, 2006

FP 6 INCO PROGRAMME CA  
**enviromis**

# Local and remote laser sensing of bio-optical parameters in natural waters

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Italian Agency for New Technologies, Energy and the Environment

# PLAN

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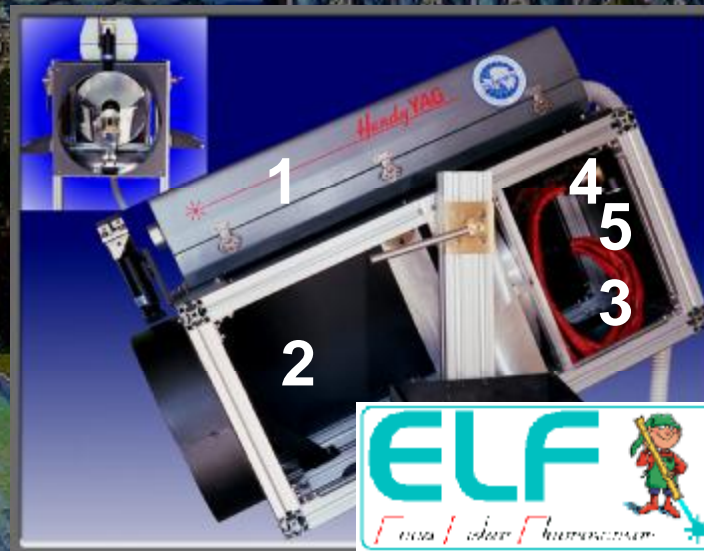
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- **ELF (remote)**
  - Principle: laser induced fluorescence (LIF)
  - Application: oceans
- **CLASS (local)**
  - Principle: laser scanning flow cytometry
  - Application: natural waters (from wells to oceans)
- **CASPER (local)**
  - Principle: LIF with double filtration and double excitation (patent pending)
  - Application: natural waters (from wells to oceans)

# ELF



- **ELF: Enea Lidar Fluorosensor**
  - **Transmitter:** frequency-tripled Nd:YAG laser (1)
  - **Receiver:** Cassegrain telescope (2)
  - **Detection:** optical fibers (3), bandpass filters (4), photomultiplier tubes (5)



# ELF: oceanographic campaigns



- 5 in Antarctica, 2 in the Italy-New Zealand transect
  - ELF is on board the Research Vessel *Italica*



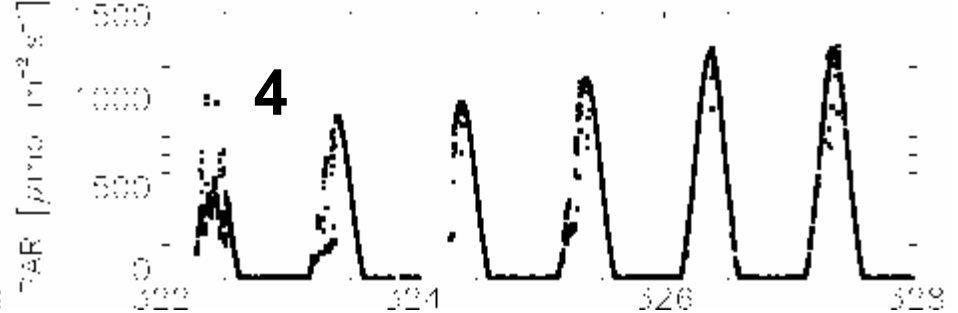
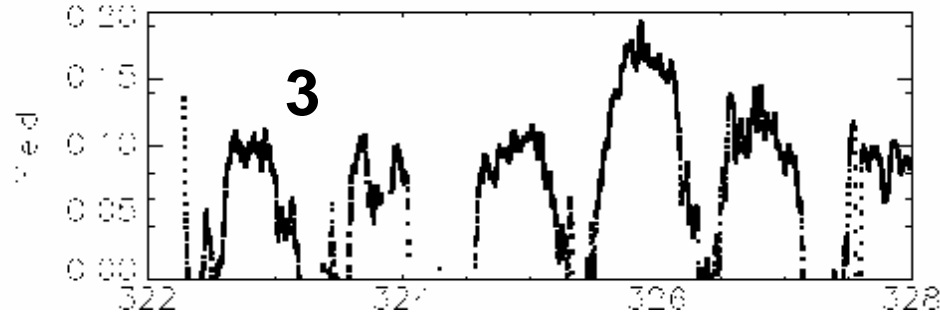
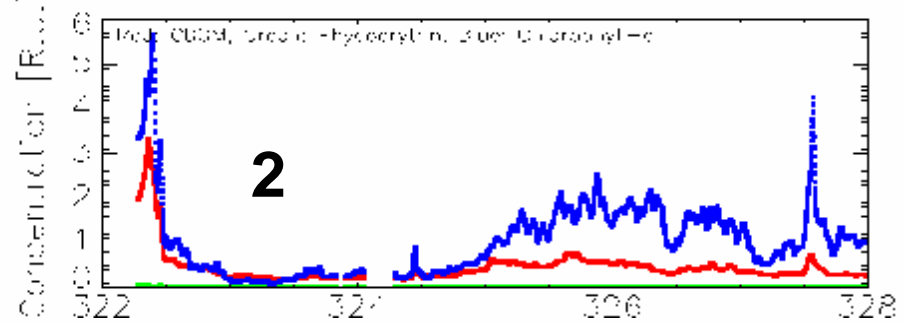
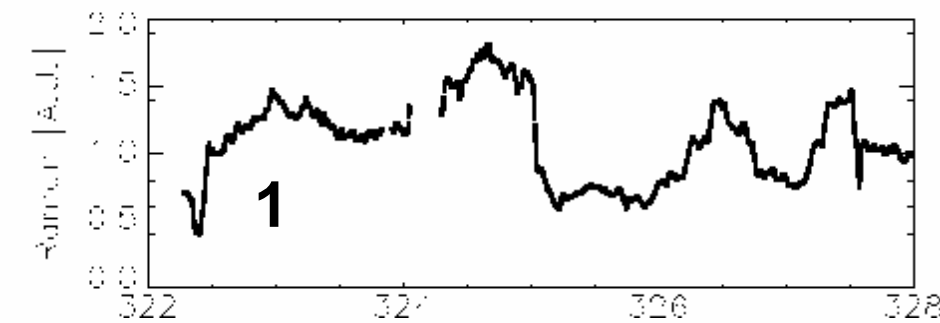
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# ELF: data

ENEA

- **Raman scattering** by water (1) → transparency
- **Fluorescence** of **CDOM**, **phycoerythrin**, **chl-a** (2) → concentration of phytoplankton-related substances
- **Fluorescence** of chl-a before & after a **pump** (3) → in vivo phytoplankton fluorescence yield
- **PAR** (4) → electron transport rate

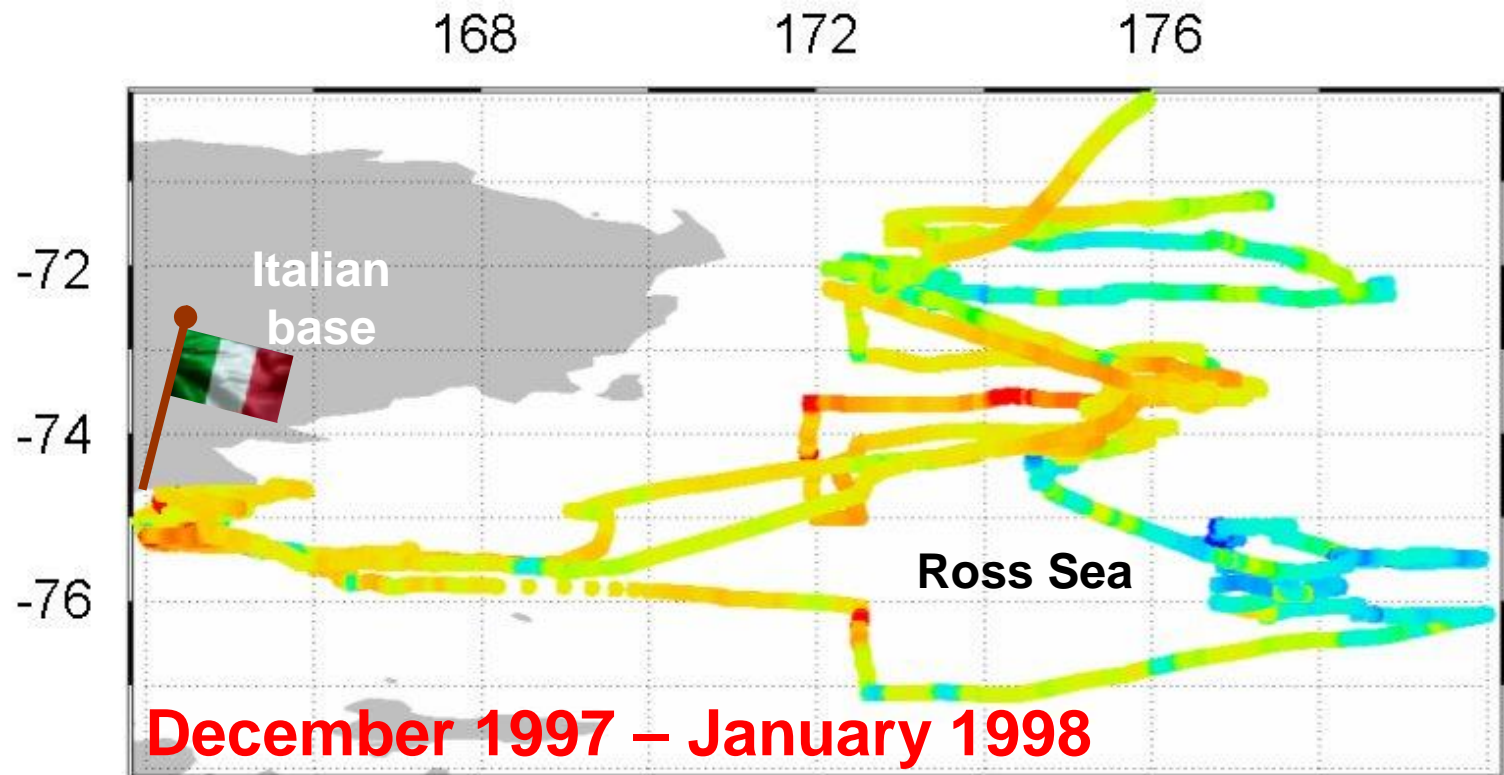
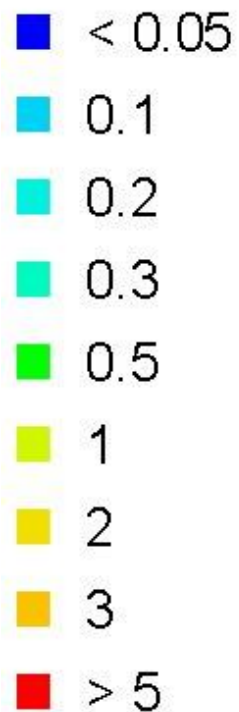


# ELF: thematic maps



- Many calibrated and georeferenced measurements

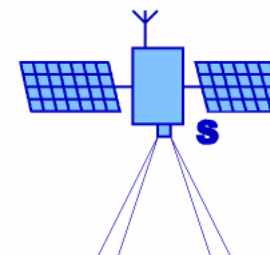
Chl-a [ $\text{mg m}^{-3}$ ]



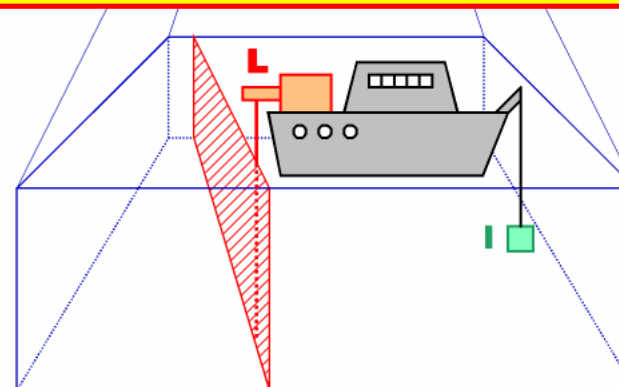
# ELF: advantages



- **Vs satellite radiometer**
  - Insensitive to **cloud covers** or **ice debris**
  - Accurate in **turbid waters**
  - Free from **atmospheric corrections**
  - **Operational H24**
- **Vs in situ sampler**
  - Closer to the **satellite coverage** and **resolution**



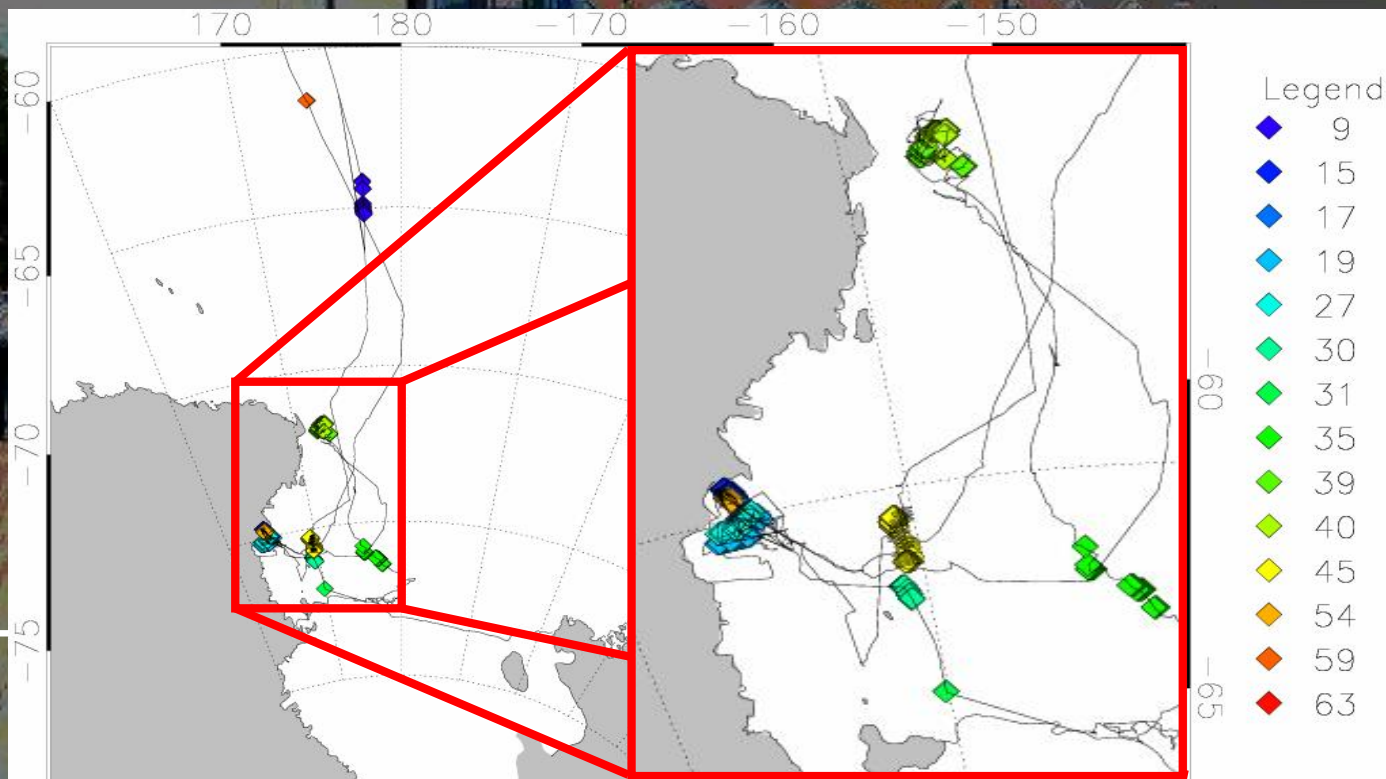
ELF is a “connecting ring” merging the accuracy of in situ samplers and the coverage of ocean color satellite radiometers



# ELF: comparing with radiometers



- **MODIS-Terra and ELF**
  - 18<sup>th</sup> Italian Campaign (01/05 – 03/04, 2003)
  - Daily L3 products (~ 4 km × 4 km)
  - Averaging of ELF data in a pixel (~ 4 km × 0.1 m)



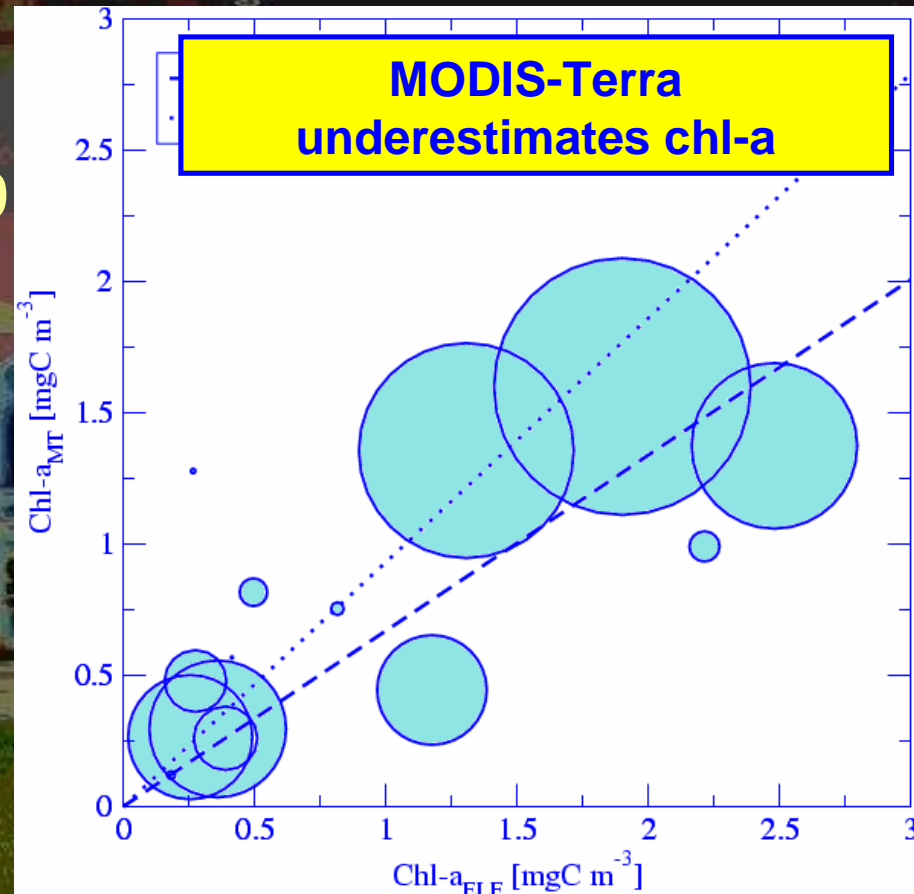
Tomsk,



# ELF: comparing with radiometers



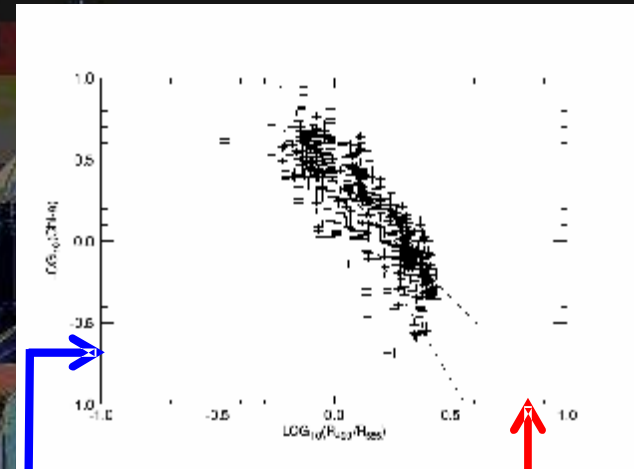
- **MODIS-Terra and ELF**
  - 258 pixels are crossed by ELF 1270 times in 14 days
  - 14 “simultaneous” measurements
  - **Weight** = SQRT (# of pixels × # of crossings)
  - **Slope without and with weights:** 0.67 and 0.93



# ELF: calibrating chl-a algorithm



- **SeaWiFS and ELF**
  - **16<sup>th</sup> Italian Campaign**  
(01/05 – 02/26, 2001)
  - **8-day L3 products**  
(~ 9 km × 9 km, 8 days)
  - **Averaging of ELF data in a pixel**  
(~ 9 km × 0.1 m)



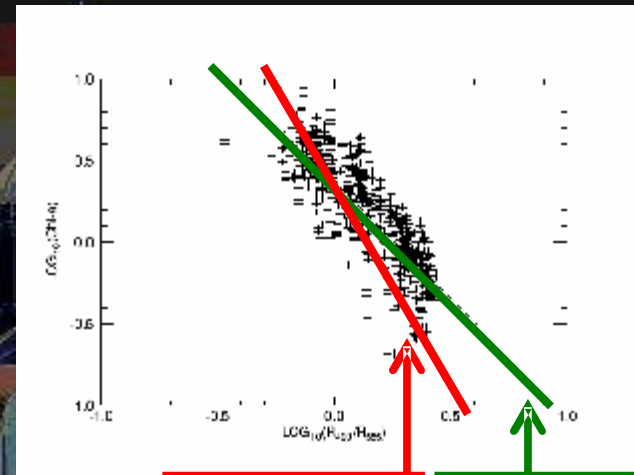
$\text{LOG}_{10}(\text{chl-a})$

$\text{LOG}_{10}(R_{490}/R_{555})$

# ELF: calibrating chl-a algorithm



- SeaWiFS and ELF
  - Concurrent measurements: 1523
  - Standard algorithm weakly overestimates high chl-a, strongly underestimates low chl-a



standard

ELF-calibrated

# ELF: calibrating PP algorithm

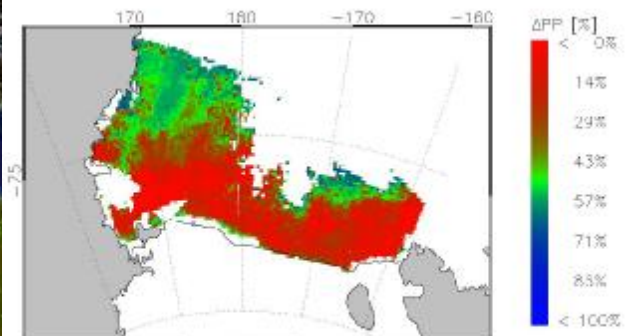
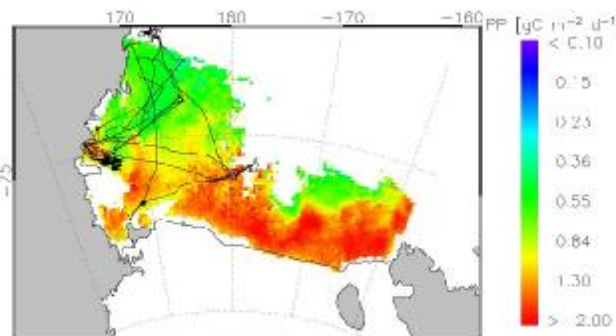
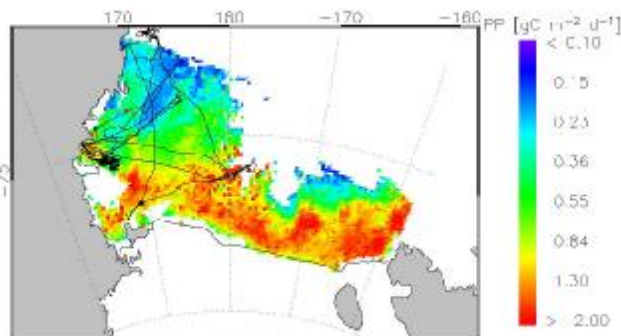


- **Ross Sea calibration**
  - **BF** (Behrenfeld and Falkowski 1997), **S** (Smith *et al* 2000)
  - **New PP estimates** are **similar** in algal blooms, **higher** in oligotrophic waters

standard chl-a & BF

ELF-calibrated chl-a & S

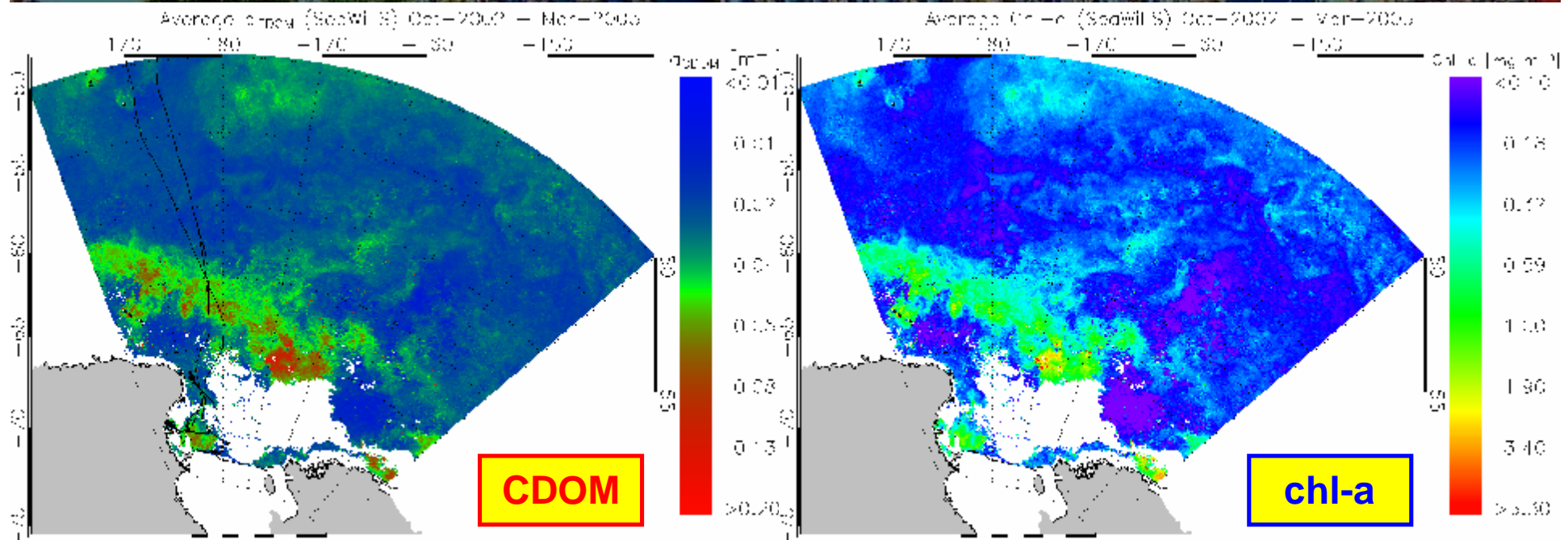
difference



# ELF: calibrating CDOM algorithm



- **SeaWiFS and ELF**
  - 18<sup>th</sup> Italian Campaign, 8-day L3 products, averaging of ELF data in a pixel
  - Concurrent measurements: 854
  - Correlation between chl-a and  $a_{\text{CDOM}}(440)$  (season)



# ELF: conclusions

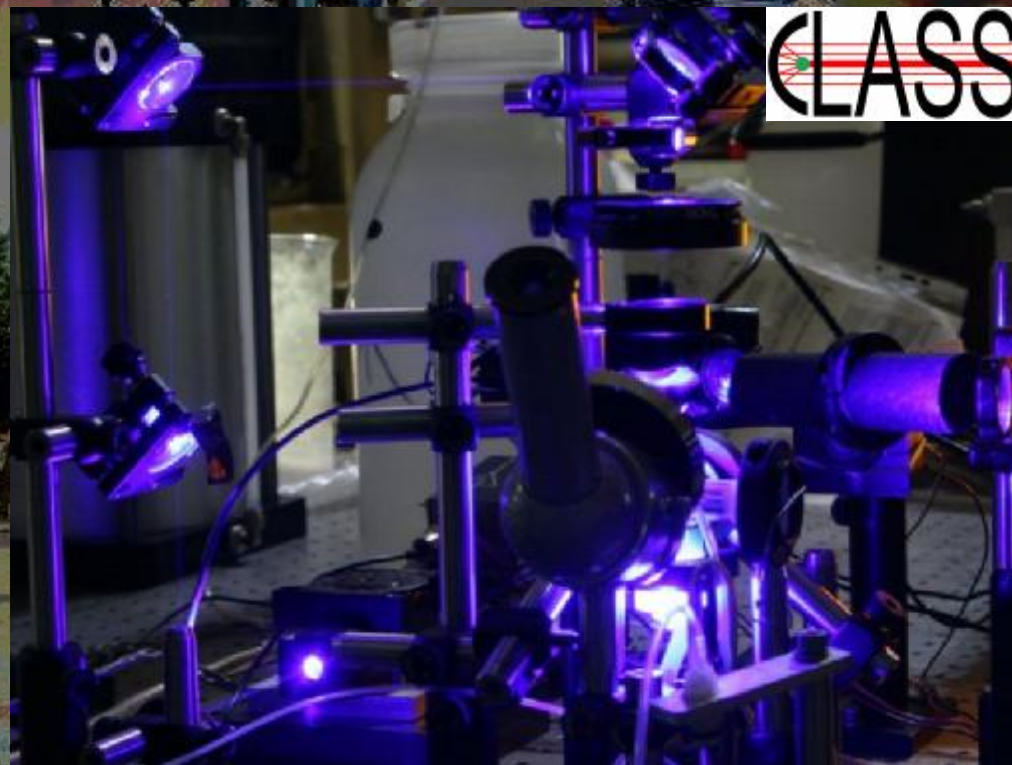


- Accuracy of in situ samplers and coverage of satellite radiometers have been merged by shipborne lidar.
- Present estimates of chl-a and PP should be reviewed in the Antarctic coastal environment.
- SeaWiFS-based CDOM retrieval is feasible.

# CLASS

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- **CLASS: Citometro LASer in flusso a Scansione**  
(laser scanning flow cytometer)



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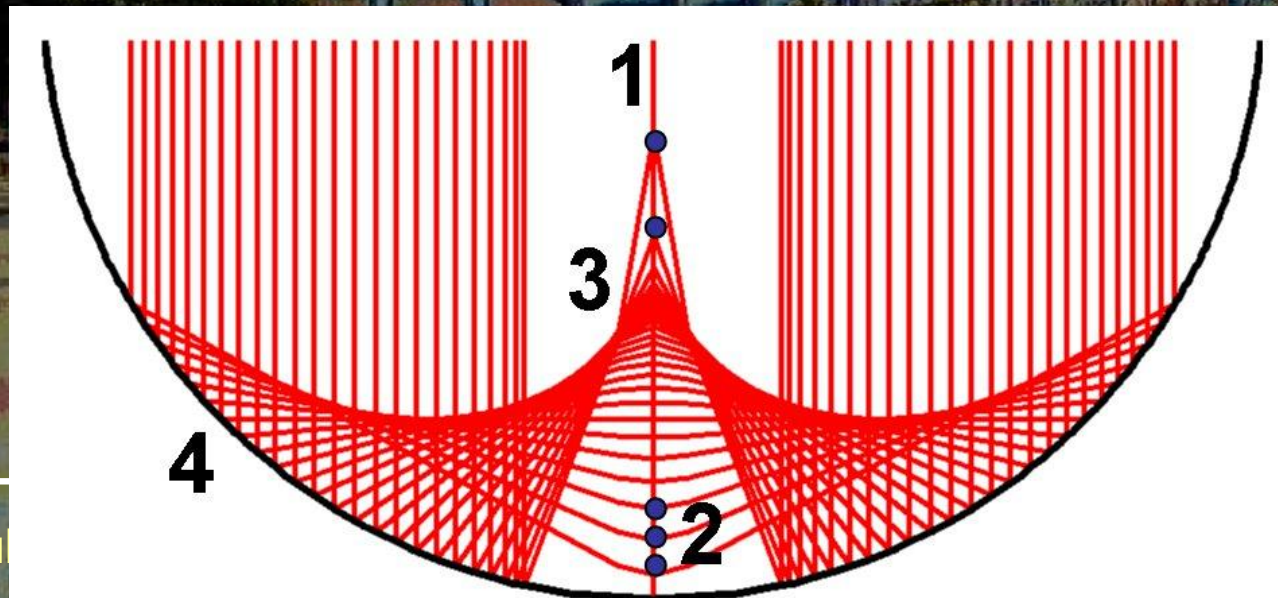
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# CLASS: a Siberian story!



- **Laser scanning flow cytometry (LSFC)**
  - Introduced in Novosibirsk by Maltsev *et al*
  - Laser (1), from the top, and sample (2), from the bottom, are collinear
  - **Detection time** of the scattered light (3), collected by the mirror (4), and **scattering angle** are related

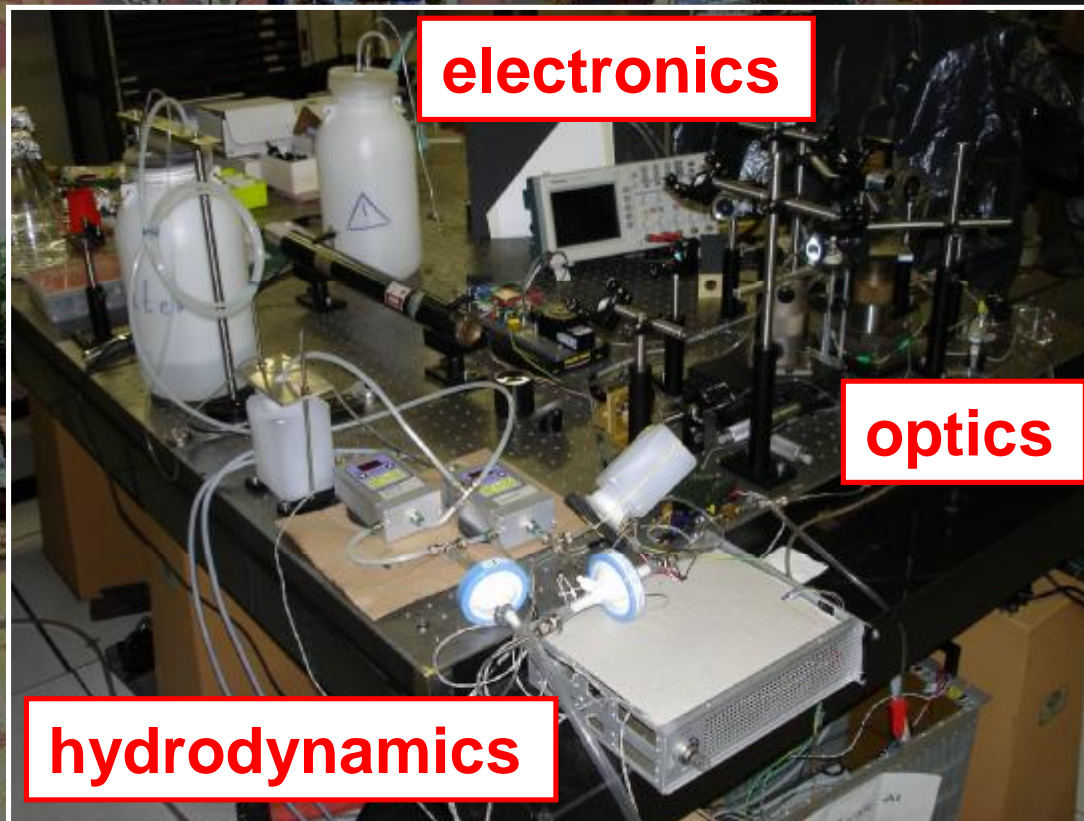




# CLASS: system

ENEA

- CLASS
  - System



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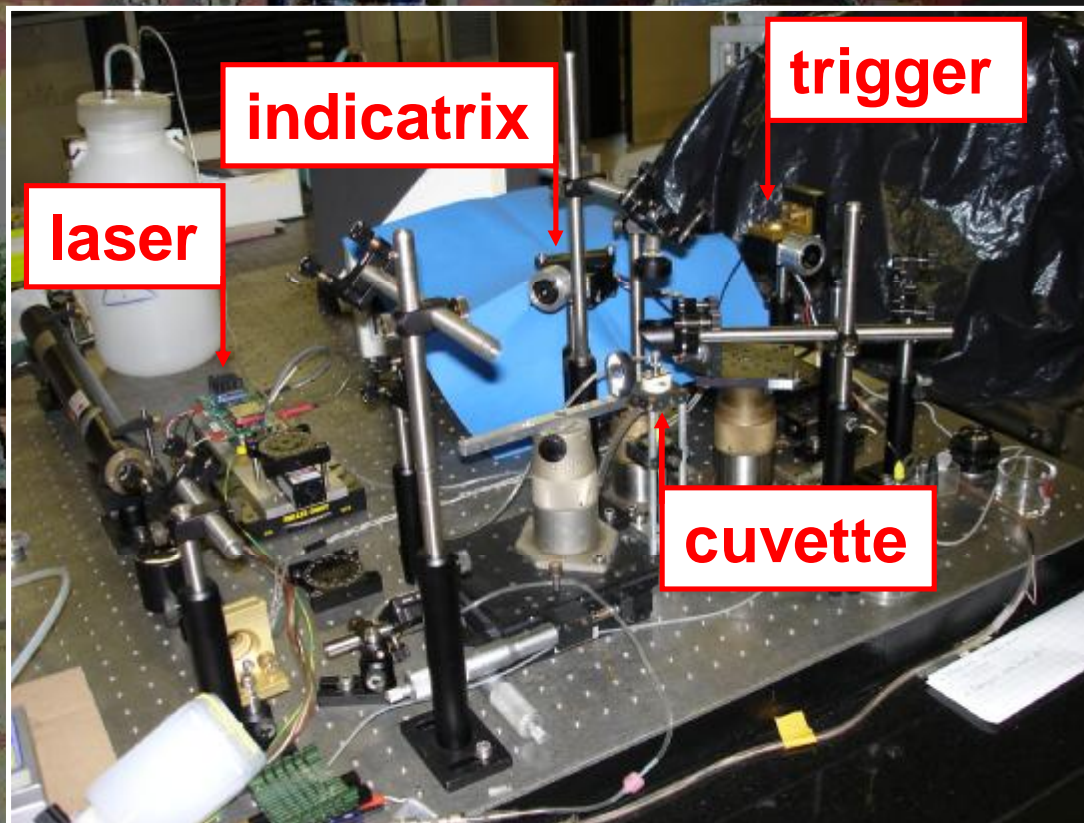
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# CLASS: system

ENEA

- CLASS
  - Optics



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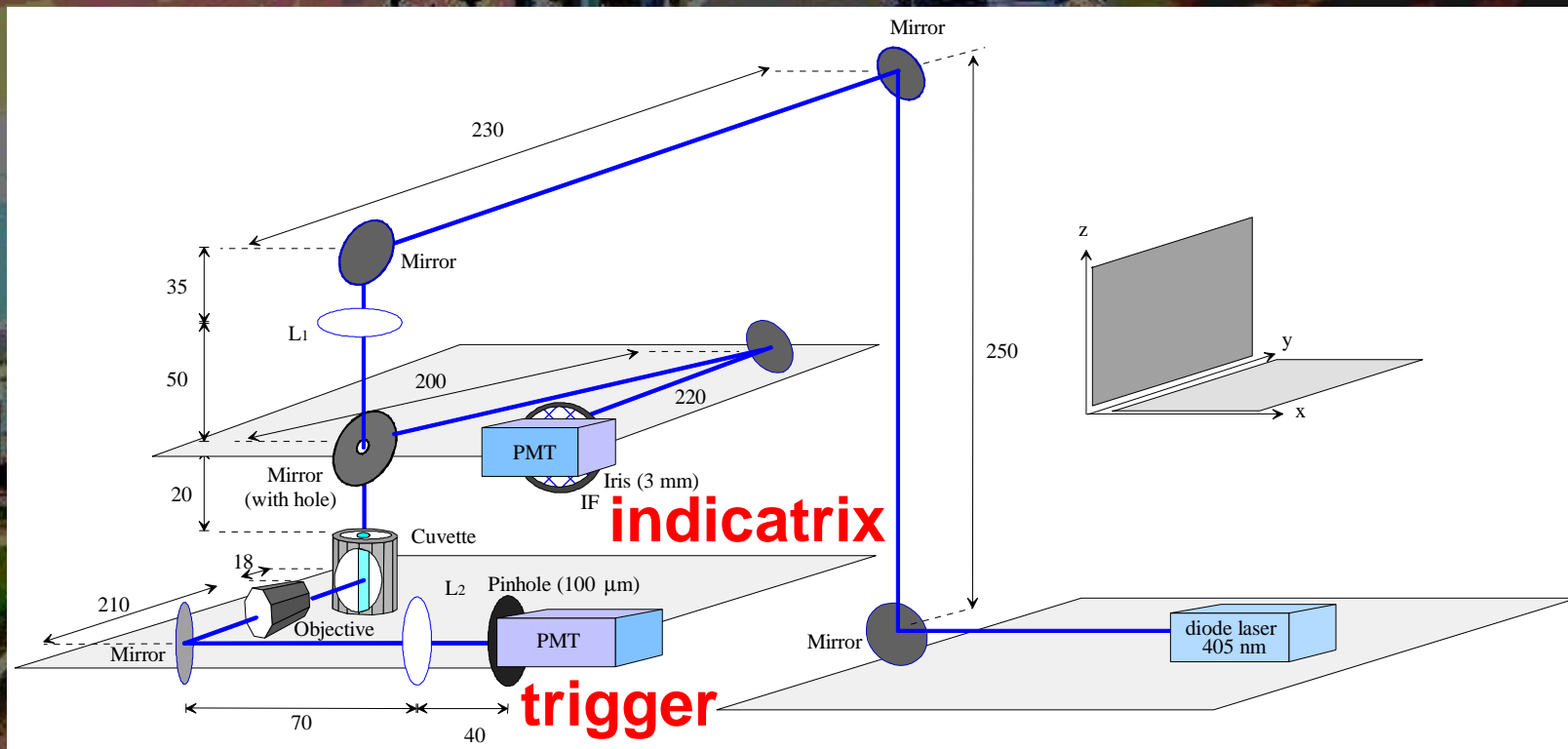
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# CLASS: system

ENEA

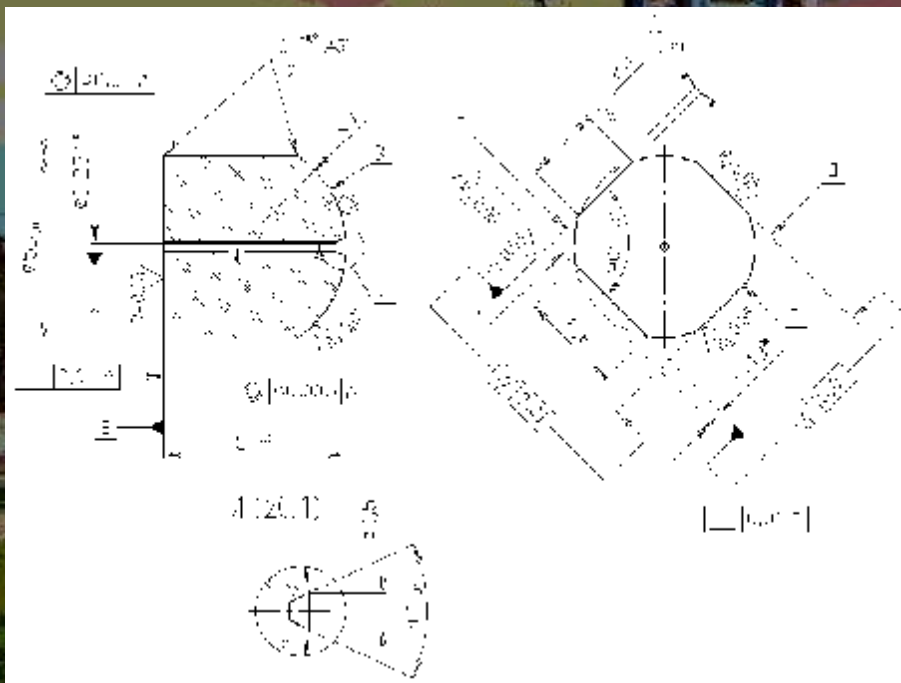
- CLASS  
– Optical scheme



# CLASS: system

ENEA

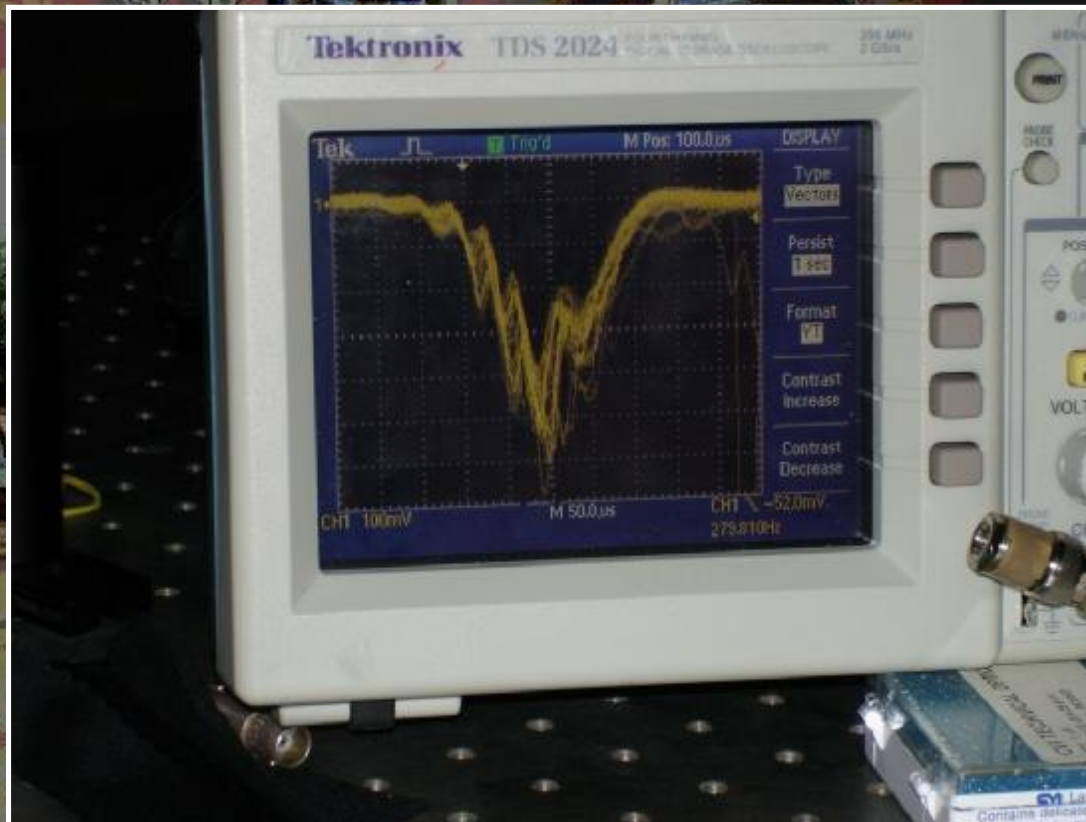
- CLASS  
– Cuvette



# CLASS: results



- **First indicatrix**
  - July 14<sup>th</sup>, 2005: 2  $\mu\text{m}$  spherical latex particles



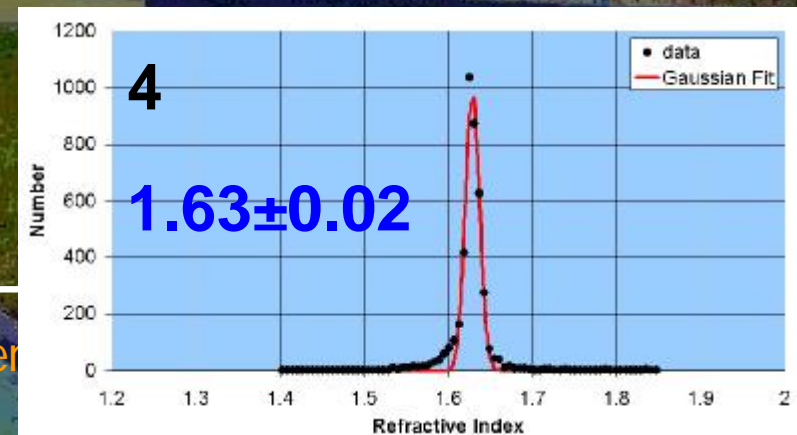
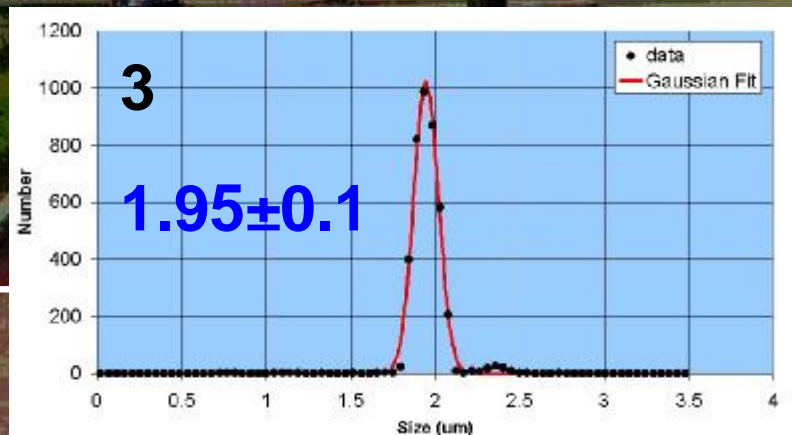
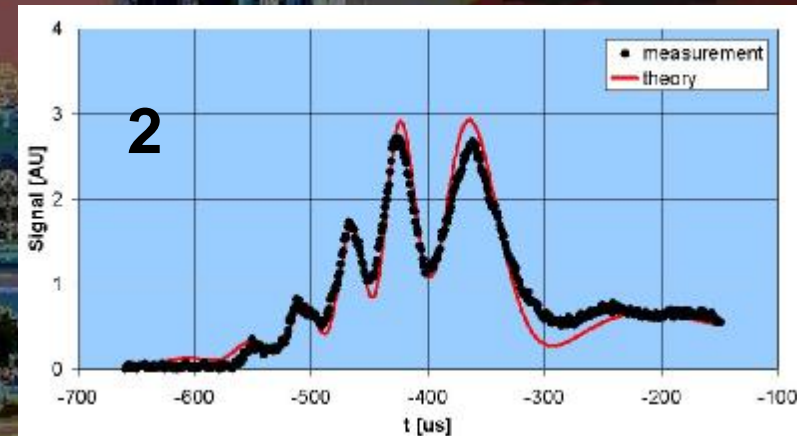
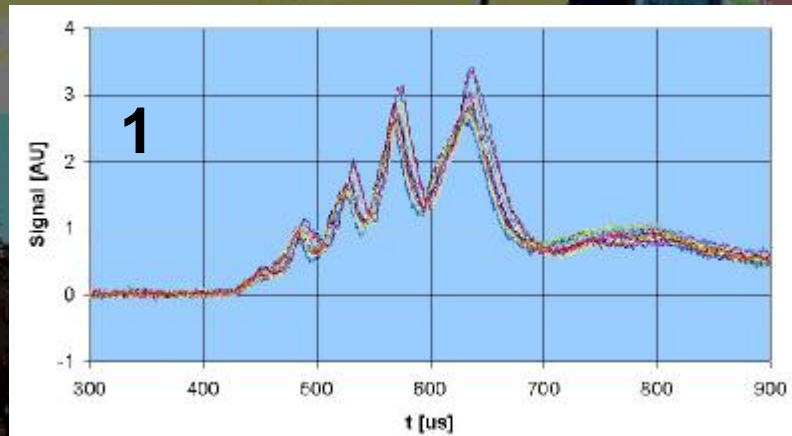
Tomsk, July 1<sup>st</sup> 2006

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# CLASS: results



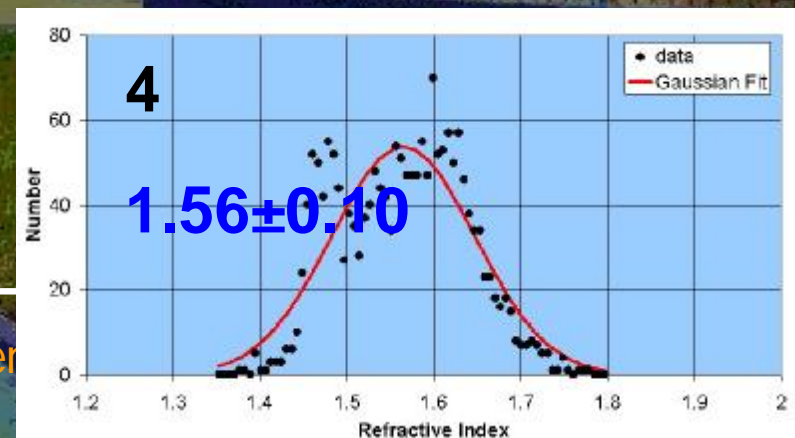
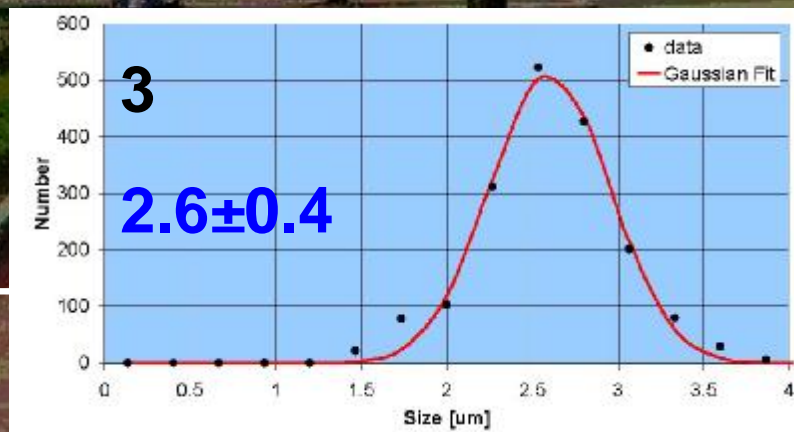
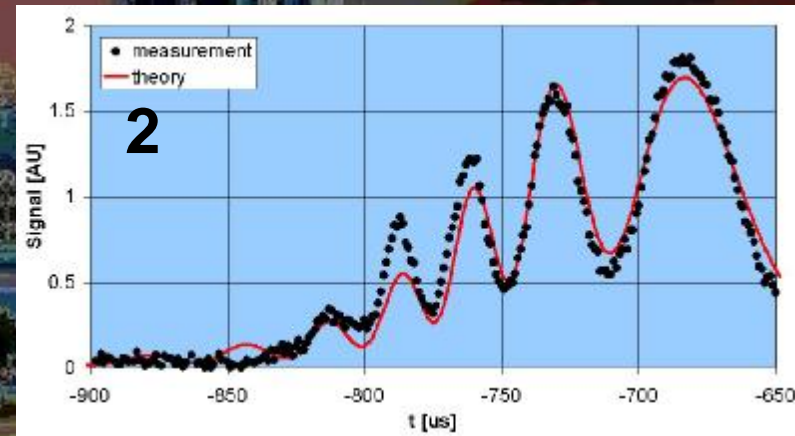
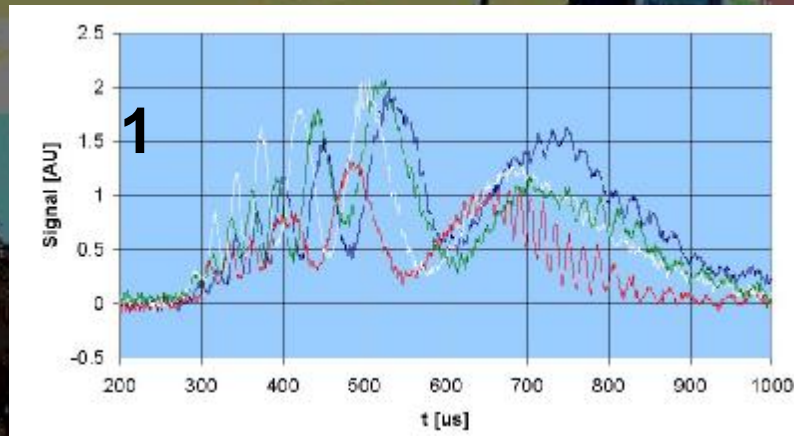
- **2  $\mu\text{m}$  spherical latex particles**
  - **Size (3) and refractive index (4) are computed by theoretical fits (2) on the measured indicatrices (1)**



# CLASS: results



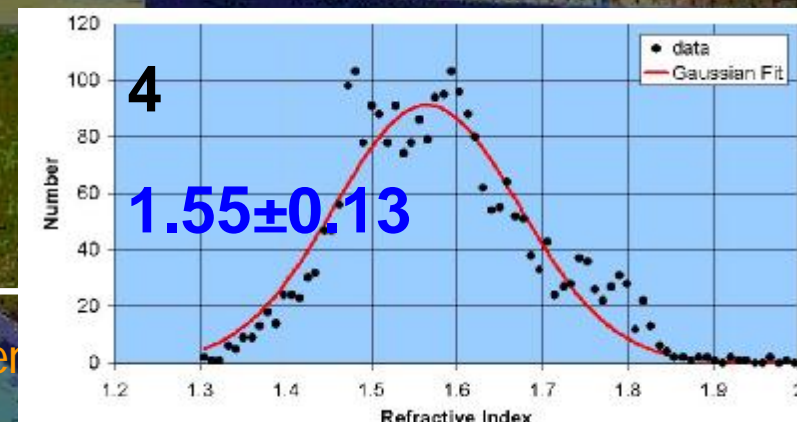
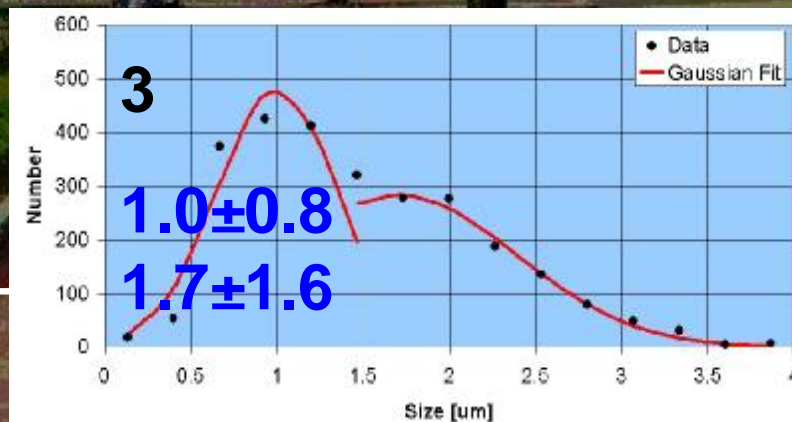
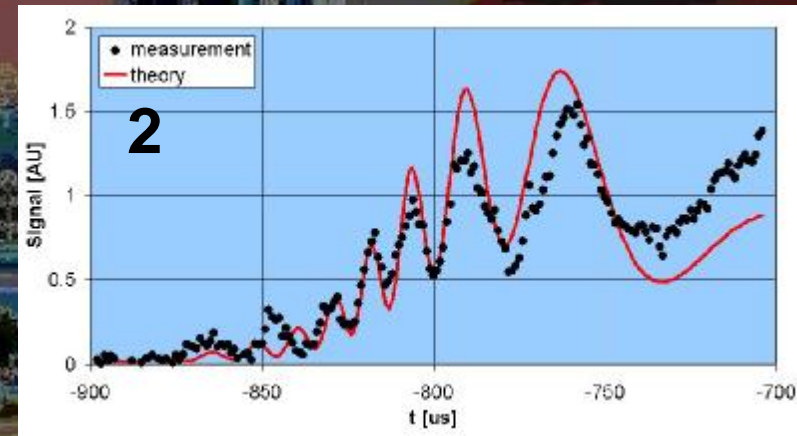
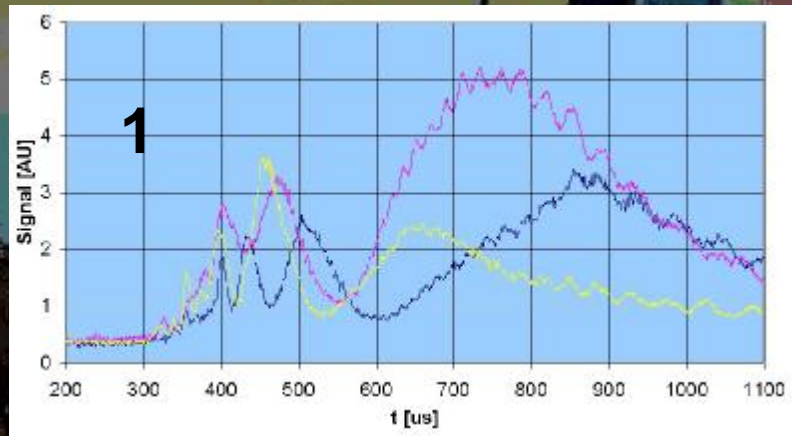
- **Penicillium Italicum**
  - **Size (3)** and **refractive index (4)** are computed by **theoretical fits (2)** on the measured **indicatrices (1)**



# CLASS: results



- **Marine Synechocystis**
  - **Size (3)** and **refractive index (4)** are computed by **theoretical fits (2)** on the measured **indicatrices (1)**

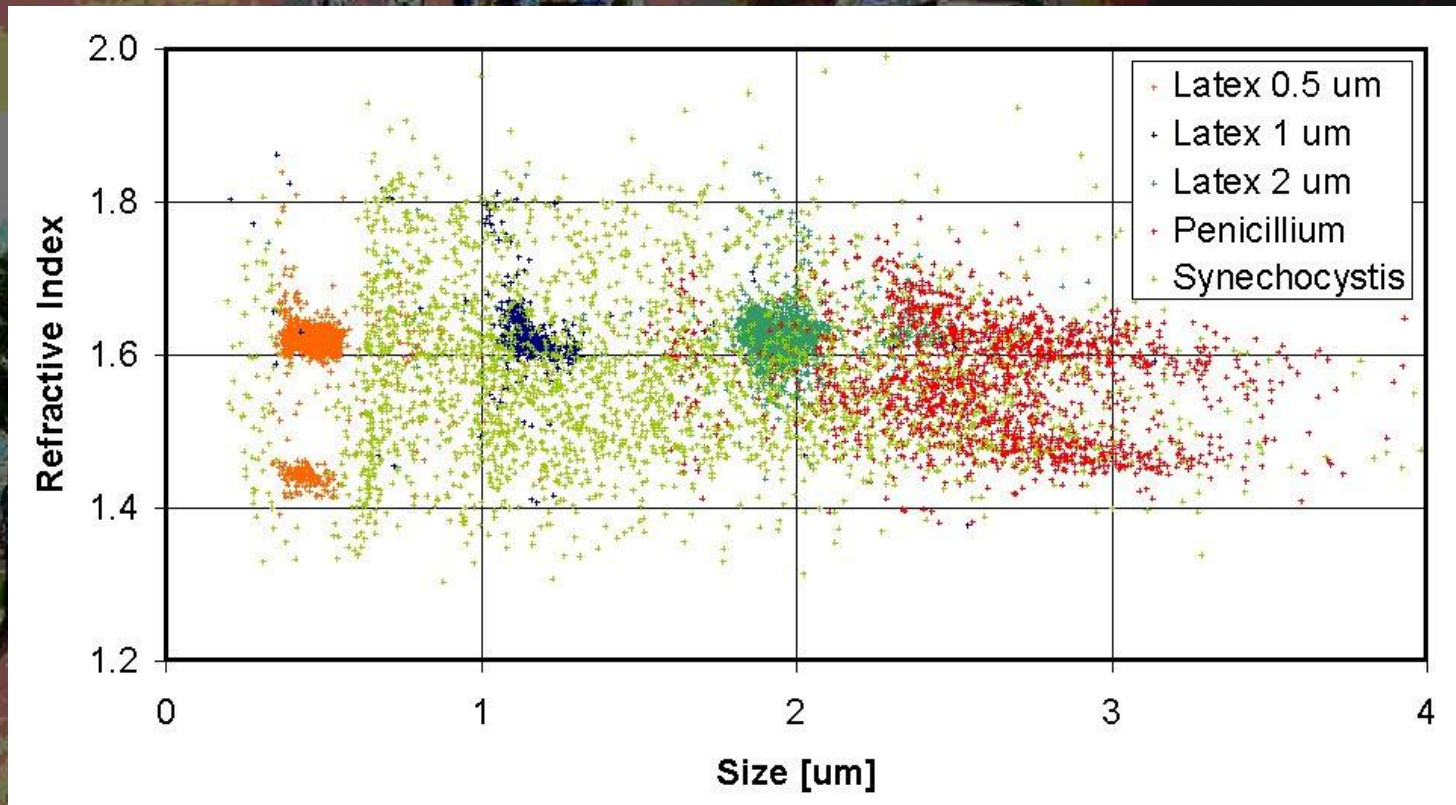




# CLASS: results



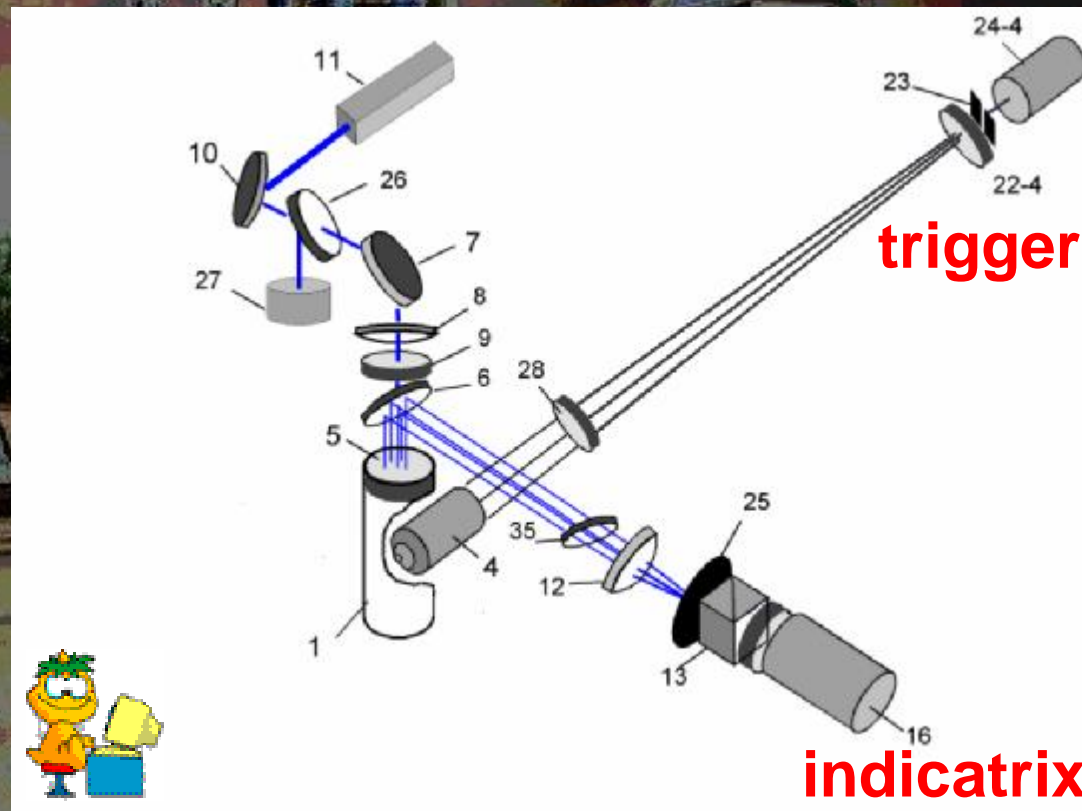
- All particles
  - The Synechocystis sample was old



# CLASS: perspectives



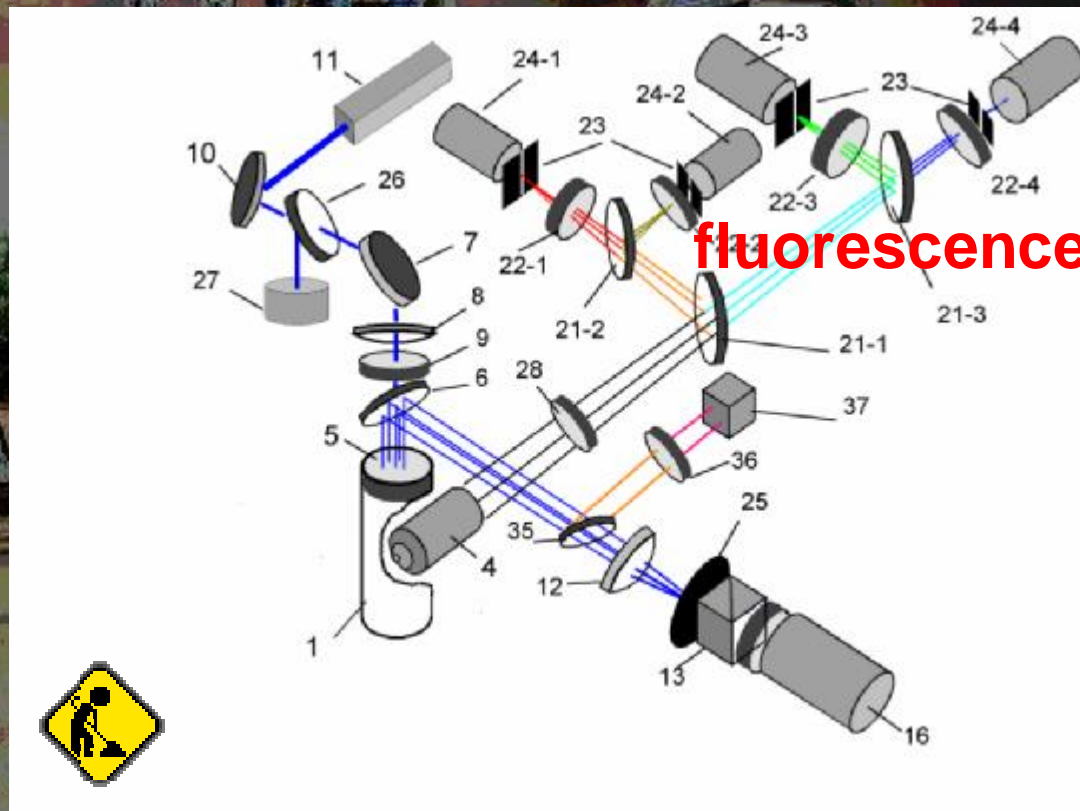
- Phase 1: scattering
  - Size and refractive index: done



# CLASS: perspectives



- Phase 2: fluorescence
  - Pigments: preliminary results



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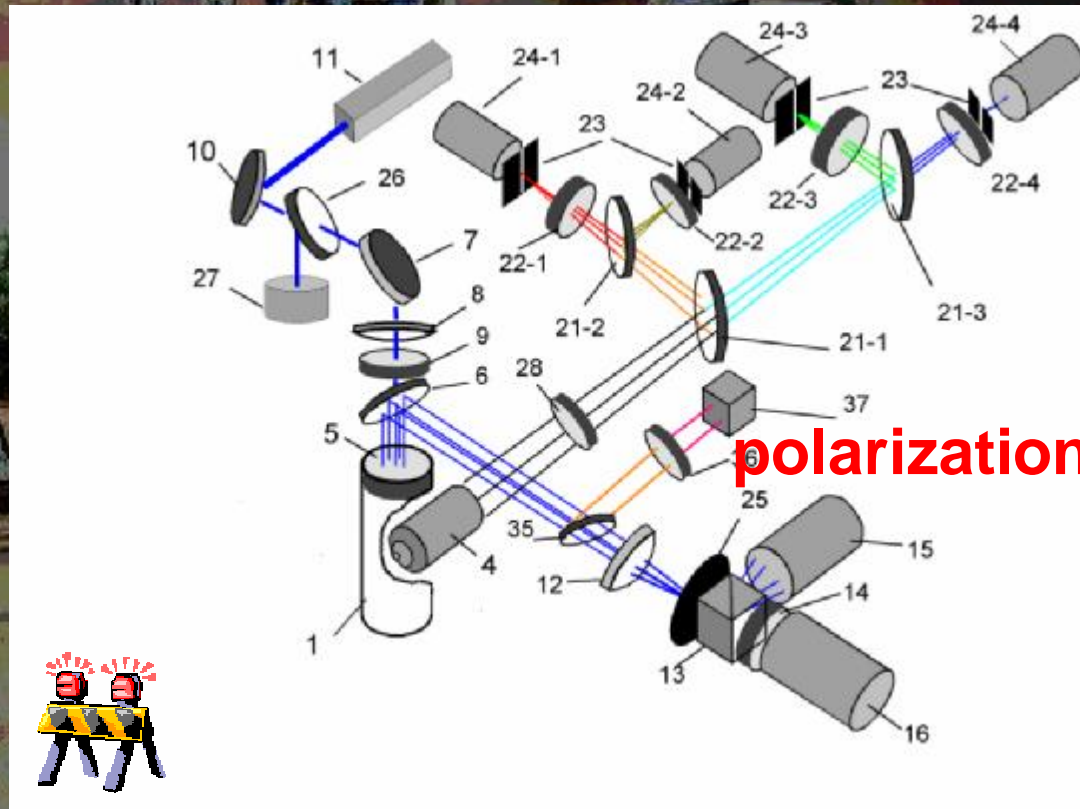
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# CLASS: perspectives



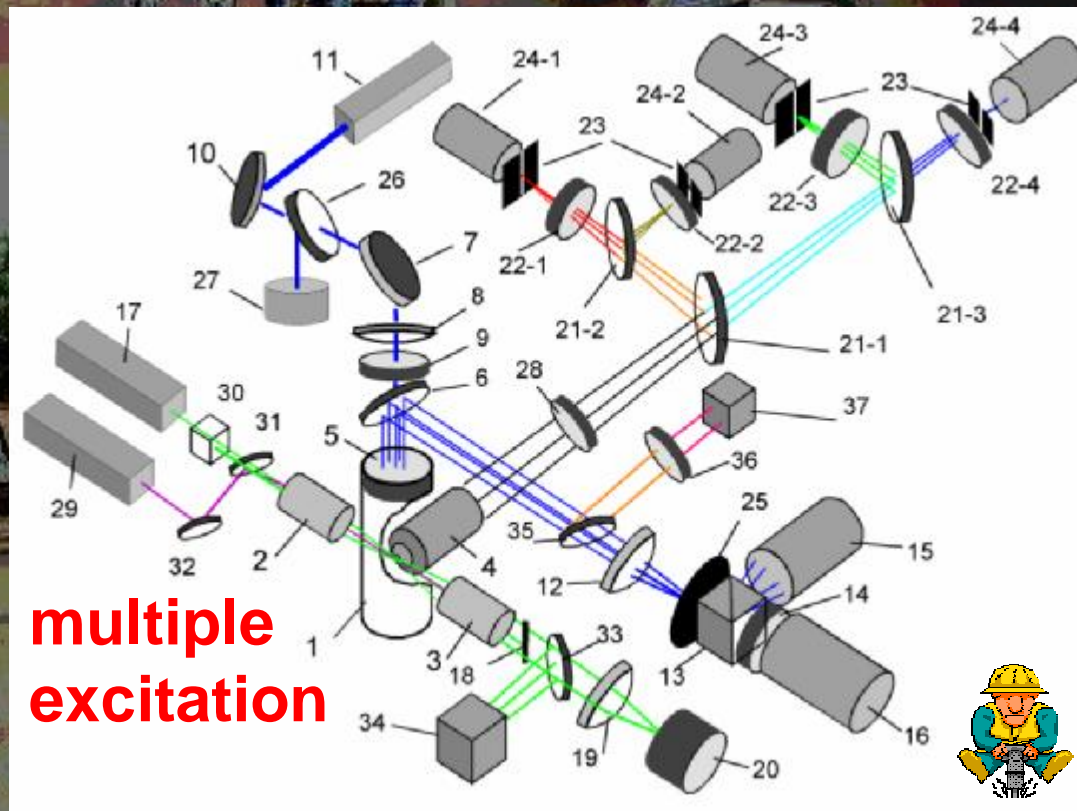
- Phase 3: polarization
  - Shape: preliminary results



# CLASS: perspectives



- Phase 4: multiple excitation (pump and probe)
  - Fluorescence yield: lasers under construction



# CLASS: conclusions



- **CLASS**, a new laser scanning flow cytometer, **operates** at the **ENEA** Research Center in Frascati
- **Laser scanning flow cytometry** has been applied for the **first time** to **marine particles** (**August 2<sup>nd</sup>, 2005**)
- **Fluorescence** and **polarization** channels have been **implemented**
- **In the near future multiple excitation** will be added, thus enlarging the **characterizing capabilities of marine particles** by CLASS

# CASPER



- **CASPER: Compact and Advanced laser SPEctrometer for Riade** (RIADE is an Italian project to combat desertification)

CASPER 



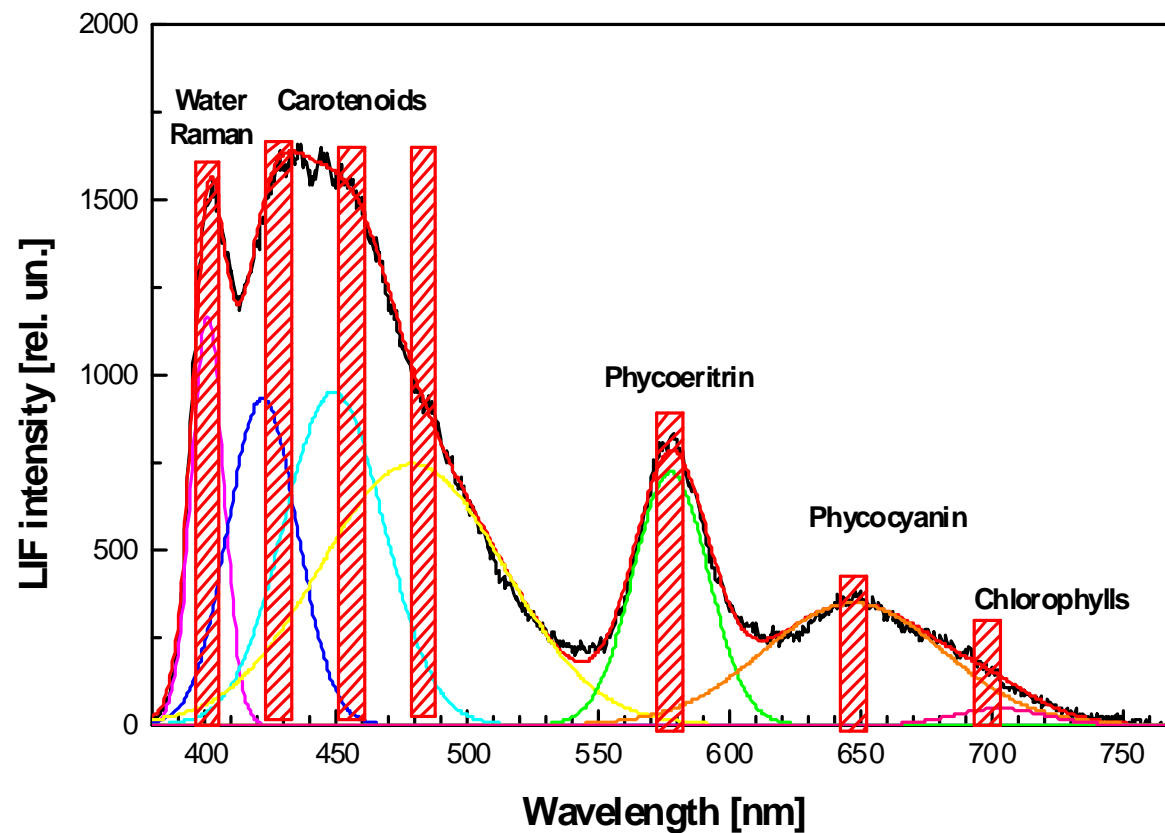
Tomsk, July 1<sup>st</sup> 2006

Local and remote laser sensing in natural waters

# CASPER: principle



- Laser induced fluorescence (LIF)
  - Emission spectrum of *Synechococcus leopoliensis* excited at 355 nm



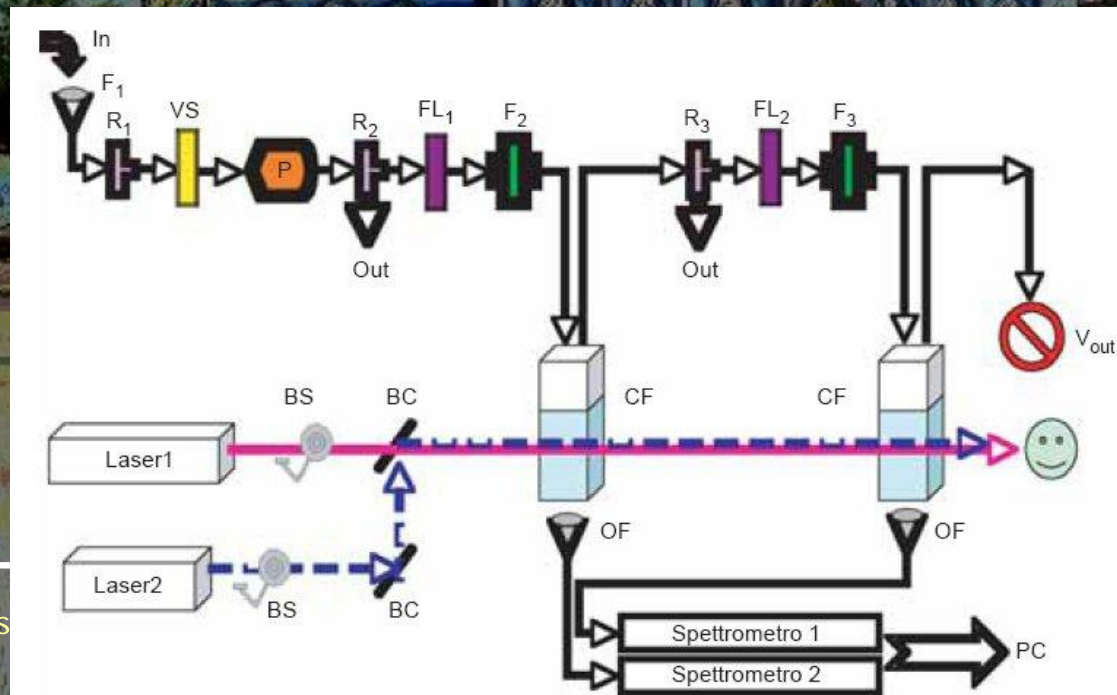
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# CASPER: principle

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- Double filtration (30 and 0.2  $\mu\text{m}$ )
  - Discrimination of particulate and dissolved matter
- Double excitation (266 and 405 nm)
  - Detection of oils, PAH and proteins (266) and CDOM, chl-a and other algal pigments (405)

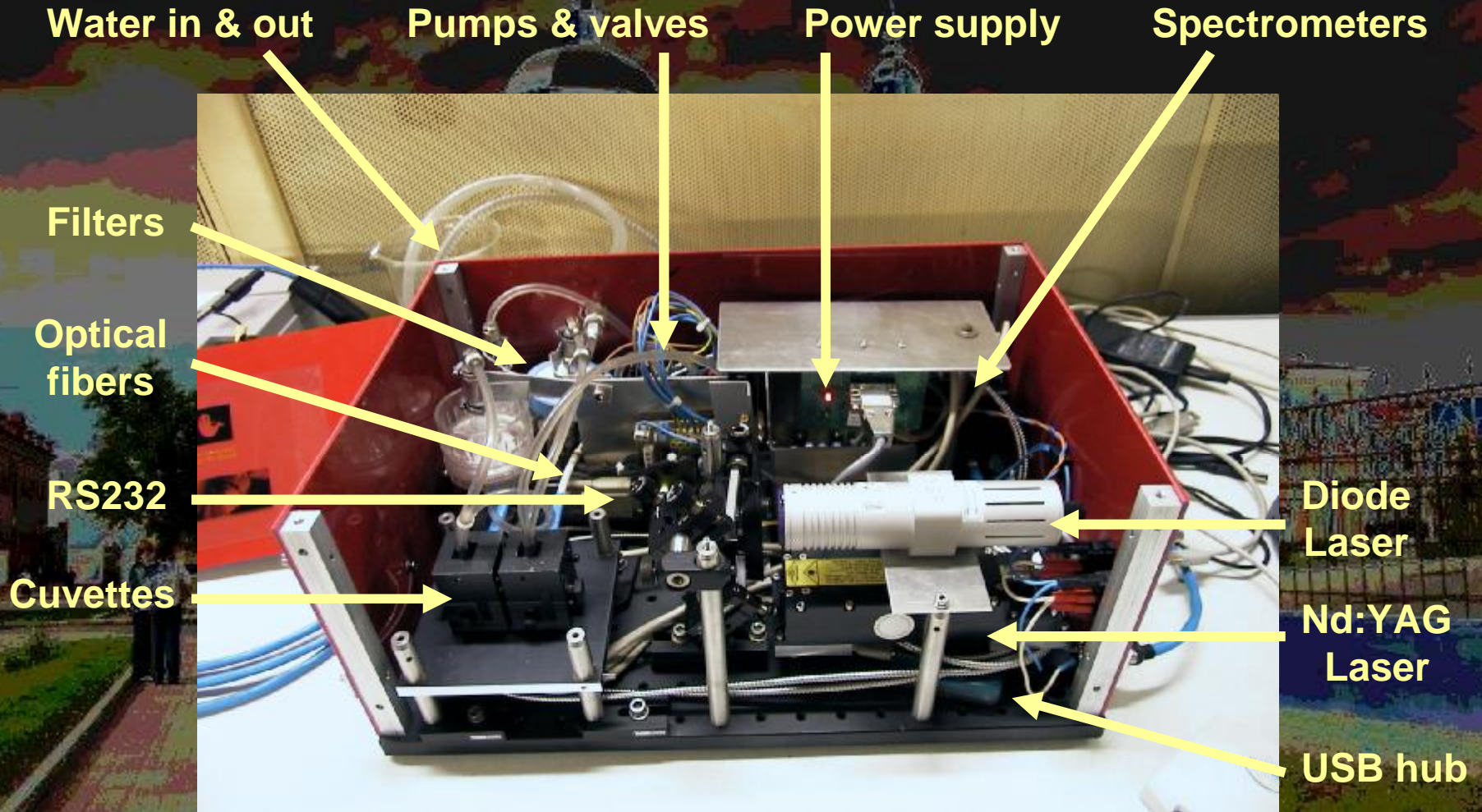


Tomsk, July 1st

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# CASPER: hardware



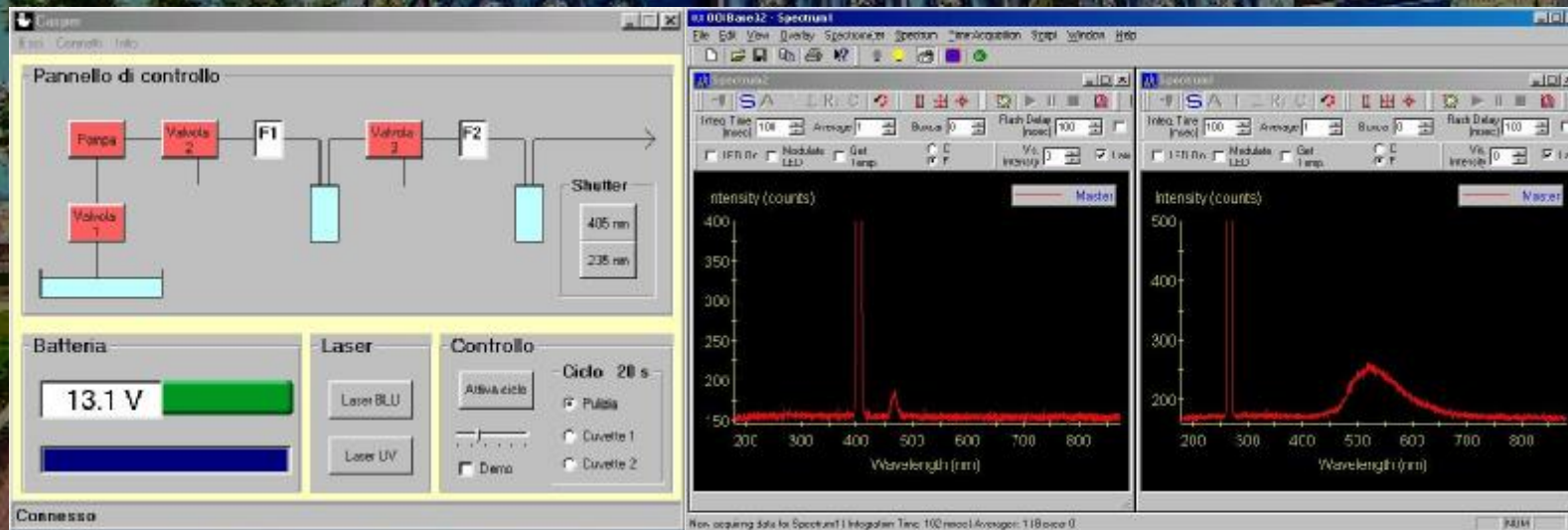
Tomsk, July 1<sup>st</sup> 2006

Local and remote laser sensing in natural waters

# CASPER: software



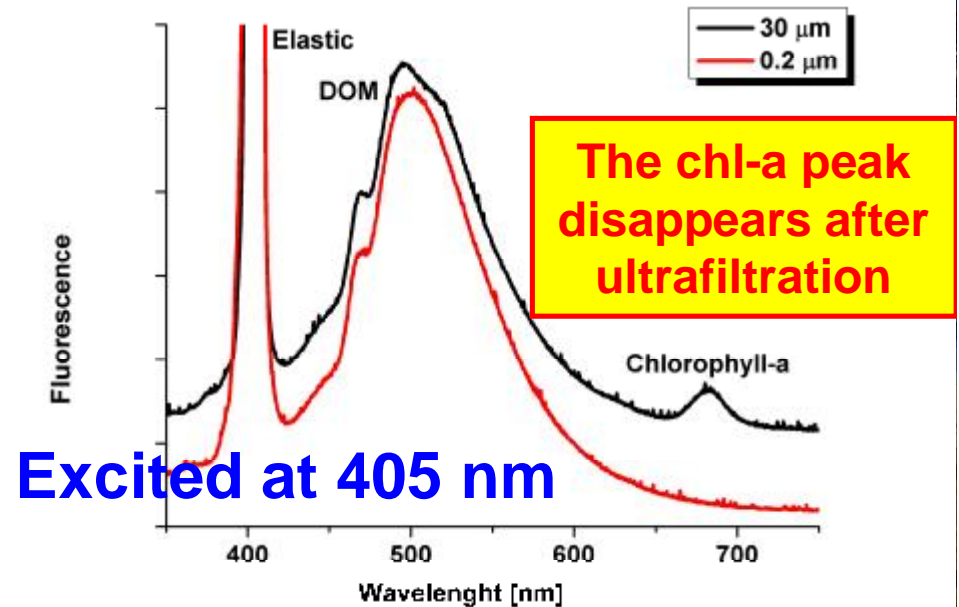
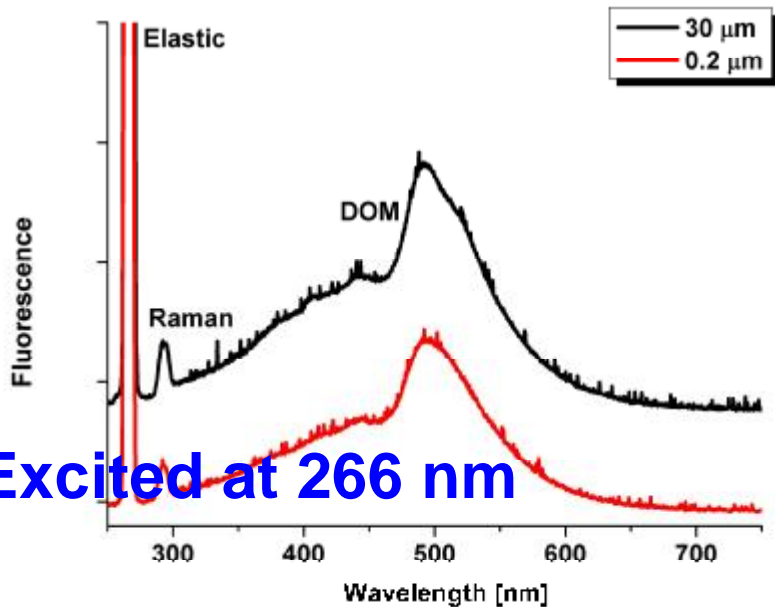
- Remote control
  - Battery, lasers, shutters, pumps and valves are controlled from the laptop (left)
- Data acquisition
  - Spectra are acquired from the laptop (right)



# CASPER: emission spectra

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- **CDOM**
  - Sensitivity: about 0.1 mg/l
- **Chlorophyll-a**
  - Sensitivity: about 0.1 ug/l



# CASPER: Sicily Campaign 2005



- **Licata and Siracusa, May 22 – 27, 2005**
  - **81 samplings: GPS, conductivity, temperature, pH, chlorophyll-a and CDOM (CASPER)**



Tomsk, July

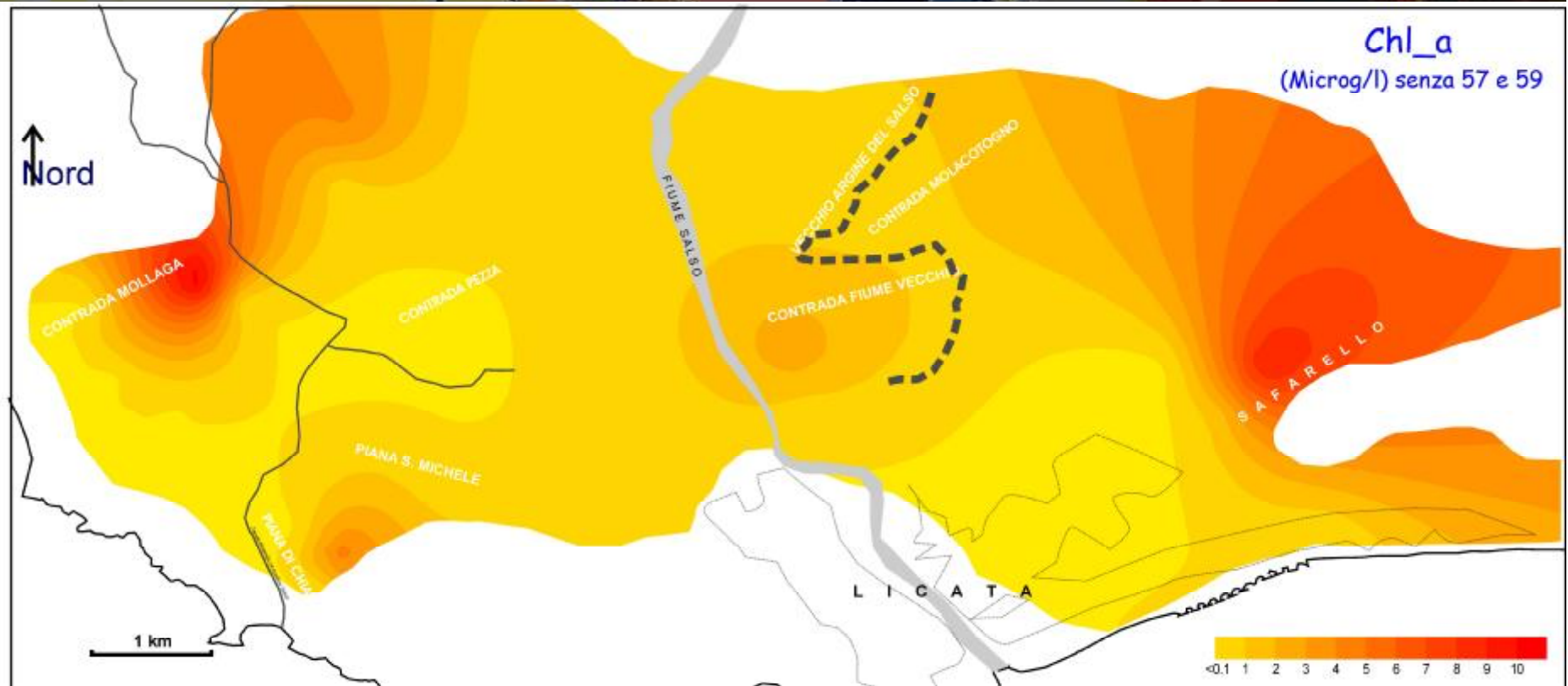
rs

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# CASPER: Sicily Campaign 2005

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- Chl-a
  - Licata, May 22 – 25, 2005



# CASPER: Sicily Campaign 2005

ENEA

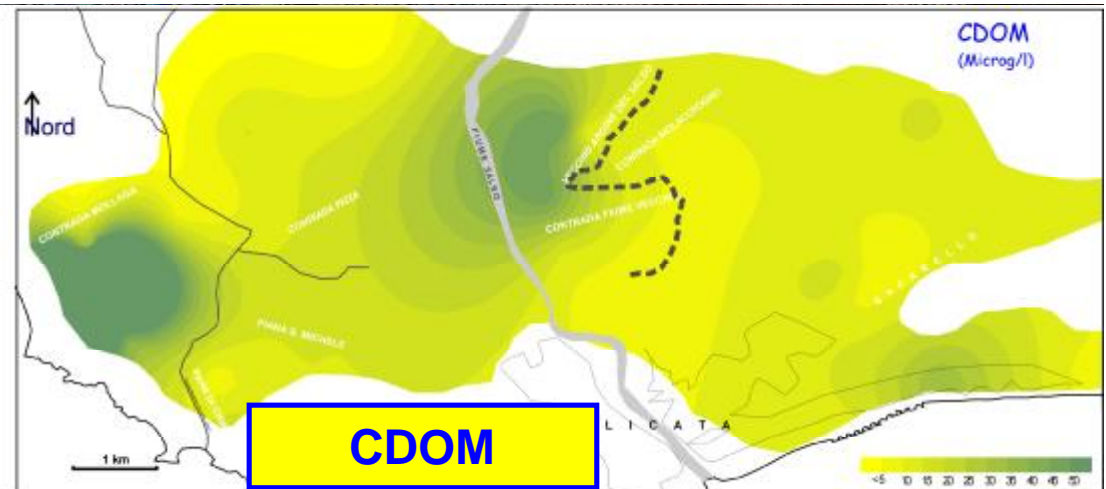
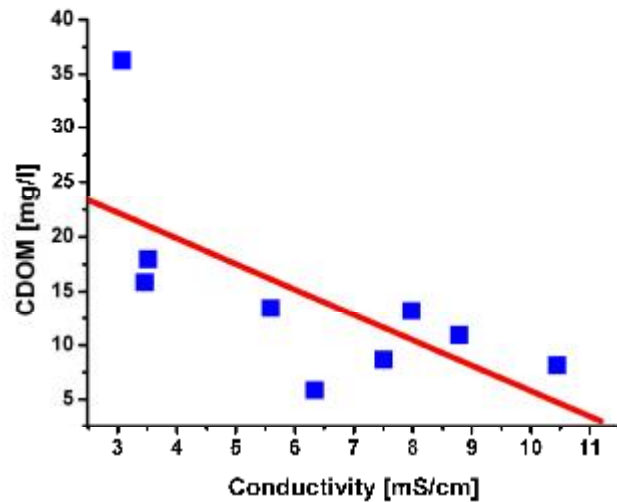
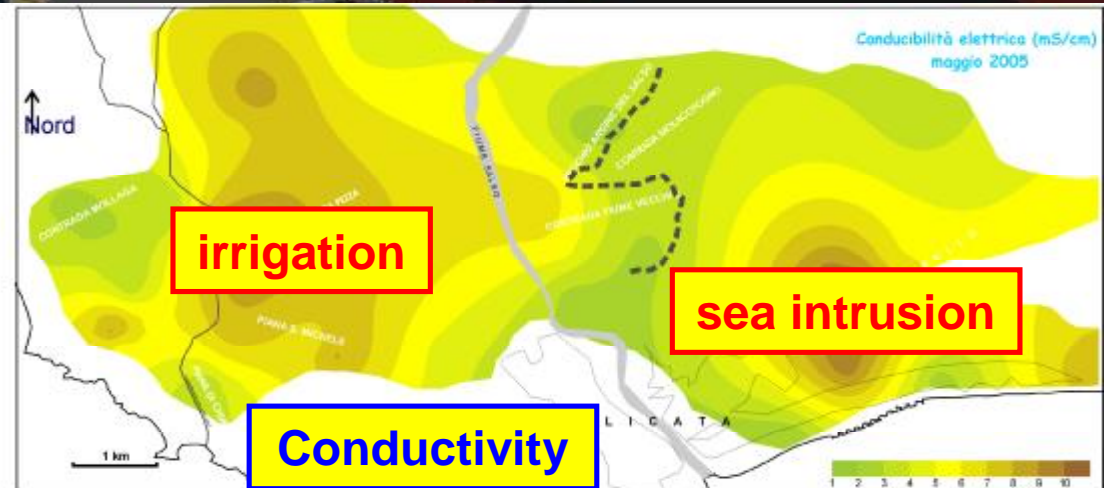
- **CDOM**
  - Licata, May 22 – 25, 2005



# CASPER: Sicily Campaign 2005



- CDOM and conductivity (salinity)



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Local



# CASPER: conclusions



- **CASPER**, an innovative laser spectrofluorometer, has been developed at the **ENEA** Research Center in Frascati (patent pending)
- **CASPER** operated during a **field campaign** in Sicily (May 22 – 27, 2005)
- **CASPER data** will improve our understanding of **salinization and desertification**

# Acknowledgements



- **The authors** are deeply grateful to **R. Barbini**, **F. Colao** and **R. Fantoni** for their involvement
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- **A special thank** is addressed to the best “**software developer**” we know: **I.G. Okladnikov**
- **This work** has been supported by **CNR**, **ENEA**, **NASA**, **NATO** and **PNRA**



Rome



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Thank you for your attention...

... it's time to answer your questions...

... and to thank the organizers!