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Cultural heritage applications of LIF I

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Cultural heritage applications of LIF I

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Laser Induced Fluorescence and the cultural heritage

- LIF ➡ Laboratory investigation
- *in situ* LIF
  ➡ Portable instrumentation
- Remote LIF
  ➡ Fluorescence lidar

➡ !! Outdoor cultural heritage !! ⬅

Cultural heritage:

UNESCO World Heritage Sites

Zone	Natural	Cultural	Mixed	Total	%	State Party with inscribed properties
Africa	33	40	3	76	9%	27
Arab States	4	60	1	65	7%	16
Asia-Pacific	48	125	9	182	21%	27
Europe & North America (including Israel & Russia)	54	372	9	435	50%	49
Latin America & Caribbean	35	82	3	120	14%	25
Total	174	679	25	878	100%	145

Three basic questions …

♣What is a lidar?

♣What is it for?

♣Why use it?

1. **What is a fluorescence lidar?**

2. **What is it for?**

3. **Why use it?**

1st question …

♣What is a lidar?

♣What is it for?

♣Why use it?

♣Examples

What is a lidar?

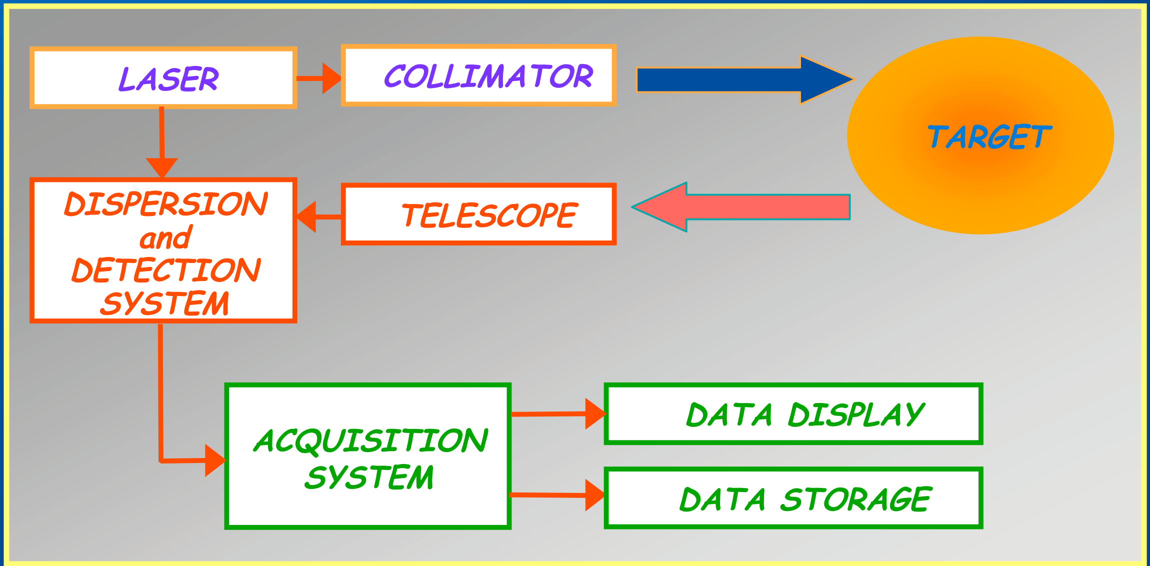
LIDAR operating principles

- LIght Detection And Ranging
- Fluorescence lidar is an active remote sensing technique extending the application of Laser Induced Fluorescence (LIF) to the outdoor environment
- Applications: marine environment and vegetation; recently applied to the investigation of the cultural heritage

♣What is a lidar?

♣What is it for?

♣Why use it?



Historical background

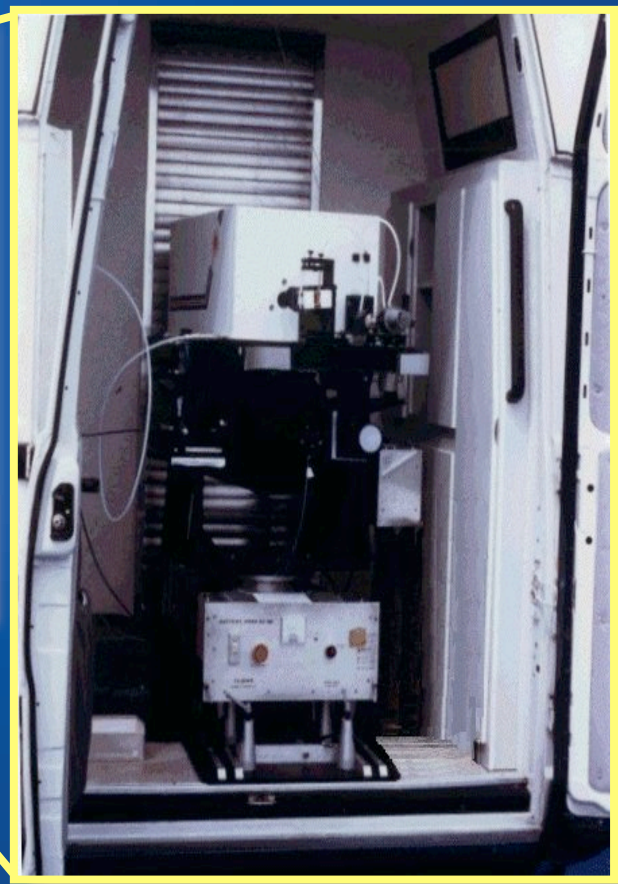
- 1840first photographic images from baloons
- Photography from aircraft – WWI and WWII
- 1957: Sputnik program – first artificial satellites, on board cameras
- '60s: first meteorological satellites for b/w images; **first atmospheric lidars**
- '70s: Landsat, first satellite dedicated to ocean and earth monitoring ; **first fluorescence lidar for sea monitoring**
- '80s: dedicated sensors aboard satellites, such as: CZCS, AVHRR, SIR-A ; **fluorescence lidar for vegetation remote sensing**
- '90s: improved spatial resolution sensors, SPOT ; **fluorescence lidar for cultural heritage applications**
- 2000: improved spectral resolution sensors, ENVISAT ; **fluorescence lidar imaging, lidars for space applications**

The FLIDAR mobile laboratory

♣What is a lidar?

♣What is it for?

♣Why use it?



Parma, the Cathedral - September 2000

2nd question …

♣What is a lidar?

♣What is it for?

♣Why use it?

What is a lidar for?

Applications to the cultural heritage

♣What is a lidar?

♣What is it for?

♣Why use it

ISSUE A - Characterisation of different lithotypes and other masonry materials (bricks, mortars, etc.)

ISSUE B - Detection and characterisation of protective treatments and their distribution on the surface

ISSUE C - Detection and spectroscopic characterisation of photoautotrophic biodeteriogens

DIAGNOSTICS
and
DOCUMENTATION

3rd question …

♣What is a lidar?

♣What is it for?

♣Why use it?

Why use a lidar?

FLIDAR technique for the cultural heritage

♣What is a lidar?

♣What is it for?

♣Why use it?

Pros

- Non invasive method
- No scaffolds or lift required
- No sampling
- Quick to use, even on extended areas
- *In situ*, outdoor operation
- Global assessment

Cons

- Scientific instrumentation
- Specialised personnel
- Qualitative / quantitative data

Advantages analysis

- Non Invasive Method essential for applications to the cultural heritage
- Sampling or scaffold not required Samples are not manipulated, costs are limited, monument fruibility is not affected
- Quick to use on extended areas Periodical monitoring of the stone cultural heritage with limited cost
- In situ, outdoor operation Key role for monuments
- Global assessment Easy to read, useful for specific measurements, support for decision-makers

Moving forward …

♣What is a lidar?

♣What is it for?

♣Why use it?

From ‘under controlled conditions’ …

Lithotypes characterization:

fluorescence of natural rocks

- Impurities
  - e.g. transition metals, rare earths
  - Activators, sensitizers, quenchers.
- Lattice defects
  - vacancies in the lattice classified on the basis of the changes in the simmetry

Fluorescence in the visible region

Spectral signatures

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

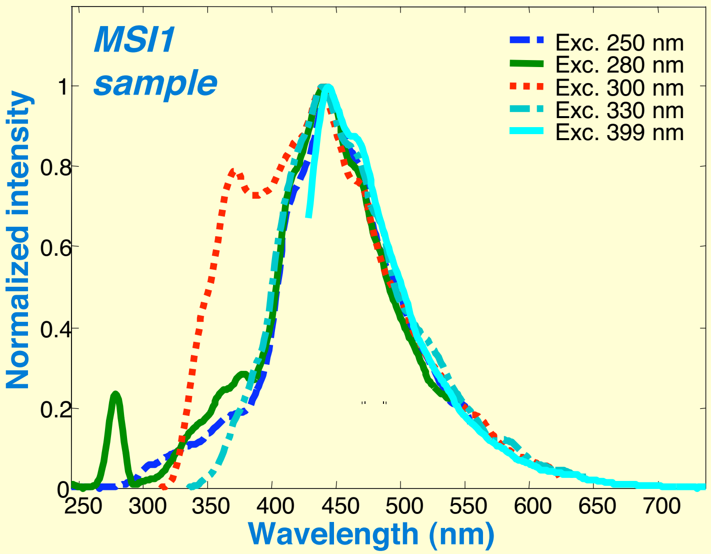
Example A1: lithotypes characterization

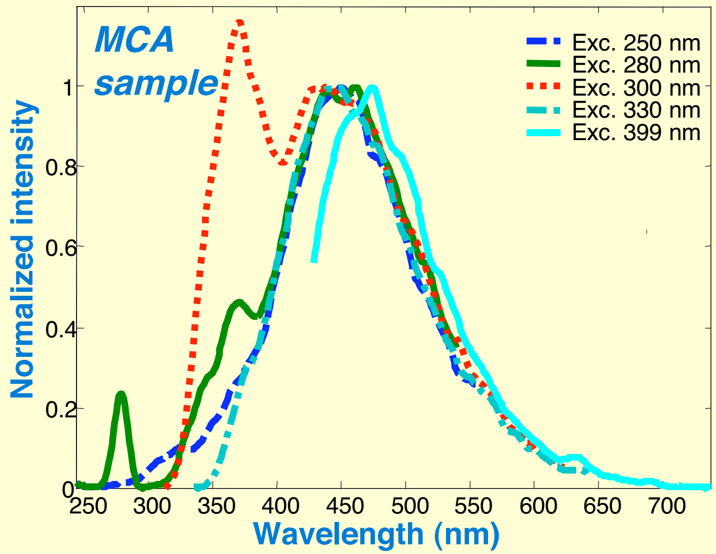
A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Fluorescence spectra of Carrara *marble (MCA) and* Montagnola senese *marble (MSI1)*





Pantani et al., SPIE Proc. 4886: 151 (2003)

In collaboration with: *UNI-Parma* *UNI-Siena*

Example A2: lithotypes characterization

Pantani et al., SPIE Proc. 4886: 151 (2003)

1	BOV1	*Rosso Veronese, Nembro*	Limestone
2	SIE1	*Arenaria Pliocenica Siena*	Sandstone
3	ROS	*Rosso Veronese, Rosa Corallo*	Limestone
4	BOV2	*Rosso Veronese, Nembro*	Limestone
5	BOV4	*Rosso Veronese, Corso Mezzo Brocato*	Limestone
6	ASIA	*Rosso Veronese, Asiago*	Limestone
7	FIR	*Arenacea Marnosa Firenze*	Sandstone
8	M2	Pozzolanic mortar	Mortar
9	BON1	*Rosso Veronese, Brocato*	Limestone
10	BOV5	*Rosso Veronese, Corso Grosso*	Limestone
11	ASIC	*Rosso Veronese, Rosso Magnaboschi*	Limestone
12	SIE3	*Arenaria Pliocenica Siena*	Sandstone
13	BOV3	*Rosso Veronese, Nembro*	Limestone
14	ASIB	*Rosso Veronese, Corso Bianco*	Limestone
15	SCA1	*Scaglia, Scisto*	Limestone
16	110EMAT	*Ematite*	Iron-formation
17	M1	Lime mortar	Mortar
18	MSI1	*Montagnola Senese* marble	Marble
19	MOC3	*Rosso Veronese, Roan*	Limestone
20	SIE2	*Arenaria Pliocenica Siena*	Sandstone
21	MOC1	*Rosso Veronese, Mandorlato*	Limestone
22	MSI2	*Montagnola Senese* marble	Marble
23	MOC2	*Rosso Veronese, Corso Rigato*	Limestone
24	MCA	*Carrara* marble	Marble
25	M3	Portland cement	Cement

Example A2: lithotypes characterization

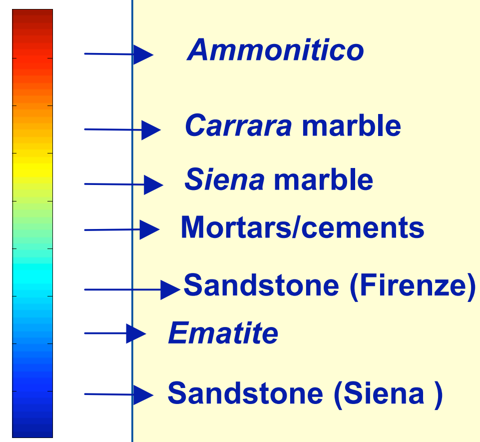
A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Artificial target with different lithotypes

Fluorescence data processed with PCA



Pantani et al., SPIE Proc. 4886: 151 (2003)

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Fluorescence of photoautotrophic biodeteriogens

A. Lithotypes
B. Protective coatings
C. Bio-deteriogens

- *Chl a* shows a fluorescence peak at about 680 nm
- High fluorescence quantum yield

→ Application 1 : detection of photoautotrophic biodeteriogens and their distribution on extended areas at an early stage of growth

- Accessory pigments with typical fluorescence peaks
- *Chl a* fluorescence peak shift

→ Application 2 : characterization of photoautotrophic biodeteriogens

- *Chl a* fluorescence is linked to photosintetic process

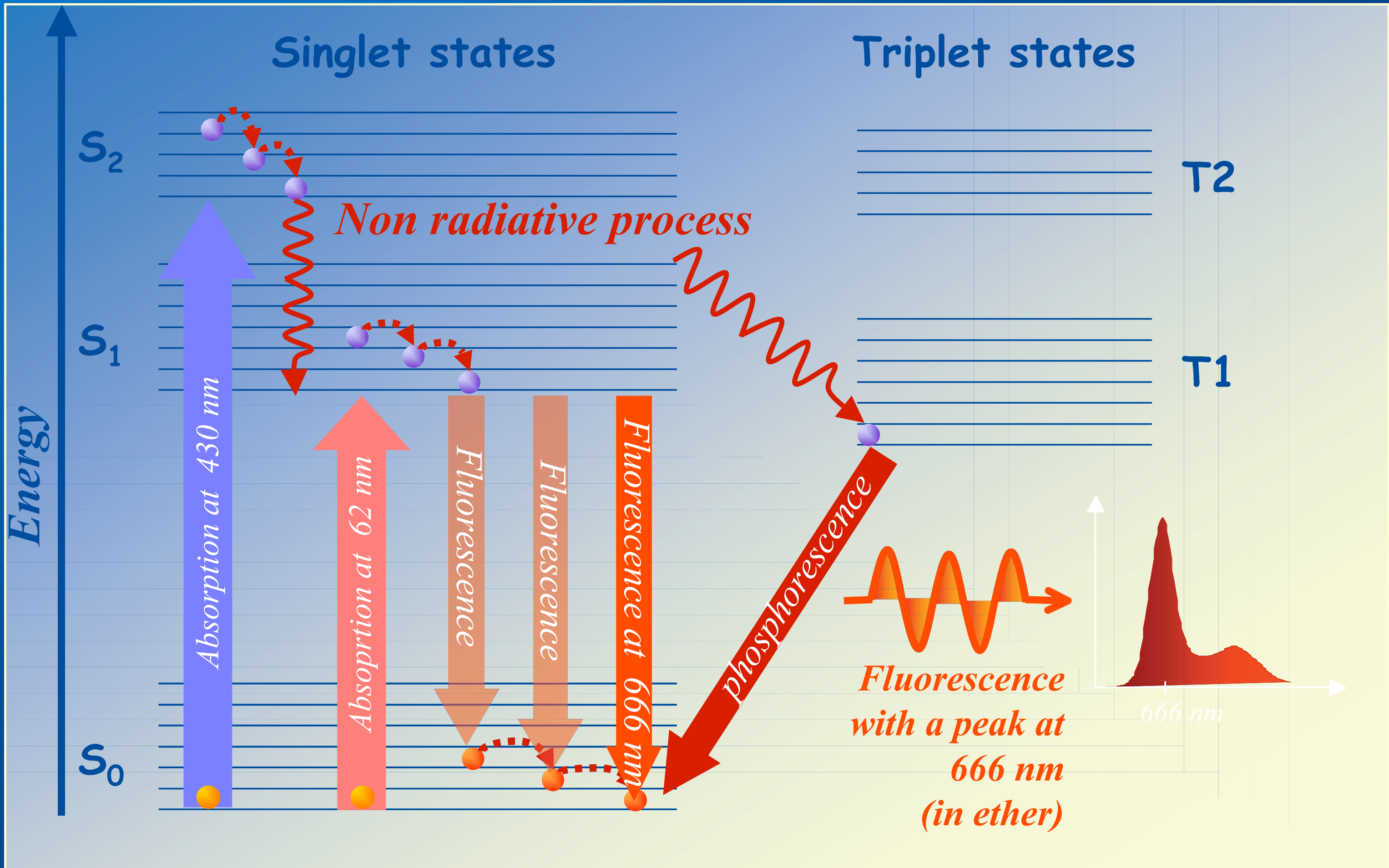
→ Application 3 : monitoring of biocides action

Fluorescence process in Chlorophyll a

A. Lithotypes

B. Protective coatings

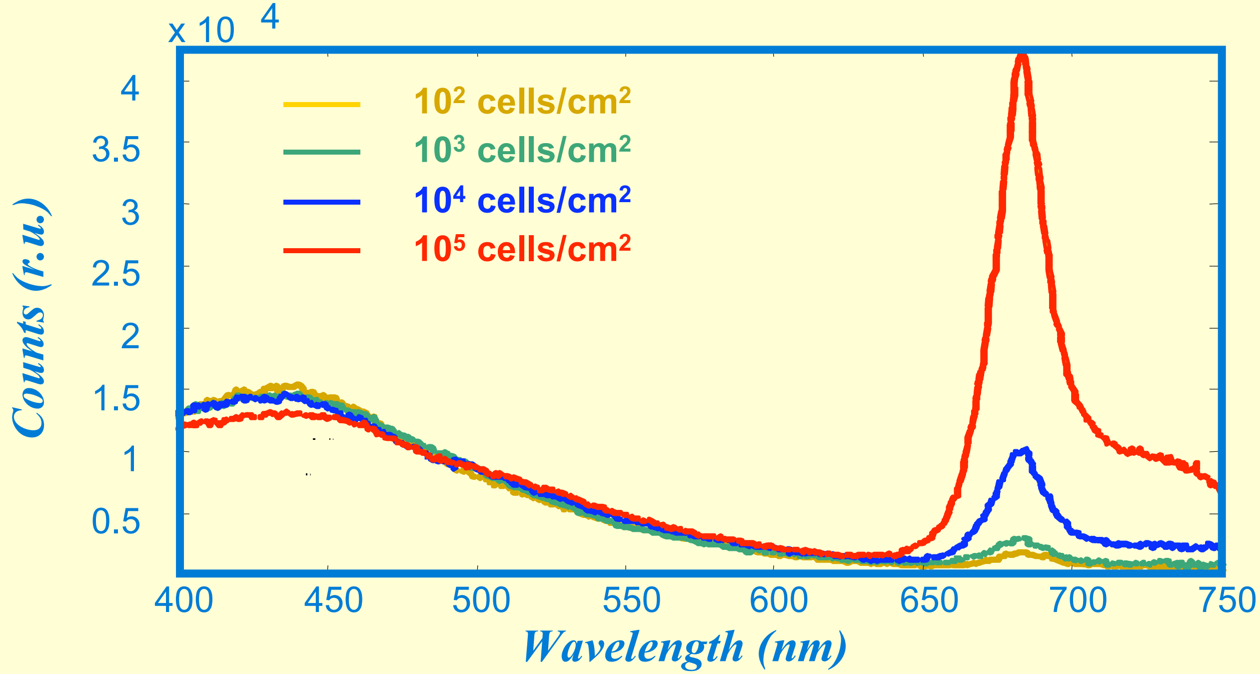
C. Bio-deteriogens



Example C1: biodeteriogens detection

- *A. Lithotypes*
- *B. Protective coatings*
- *C. Bio-deteriogens*

Green algae (*Coccomyxa sp.*) on dolomitic marble



Lognoli et al., Appl. Optics 41: 1780 (2002)

In collaboration with: ICVBC-CNR, ISE-CNR

Example C1: biodeteriogens detection

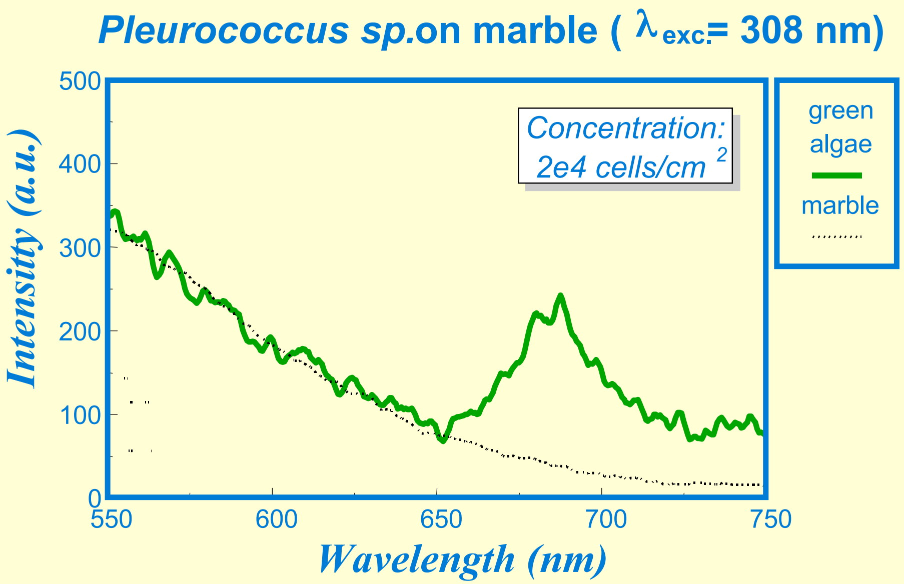
A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Green algae (*Pleurococcus sp.*) on Carrara marble

Lidar measurements from a distance of 17 m

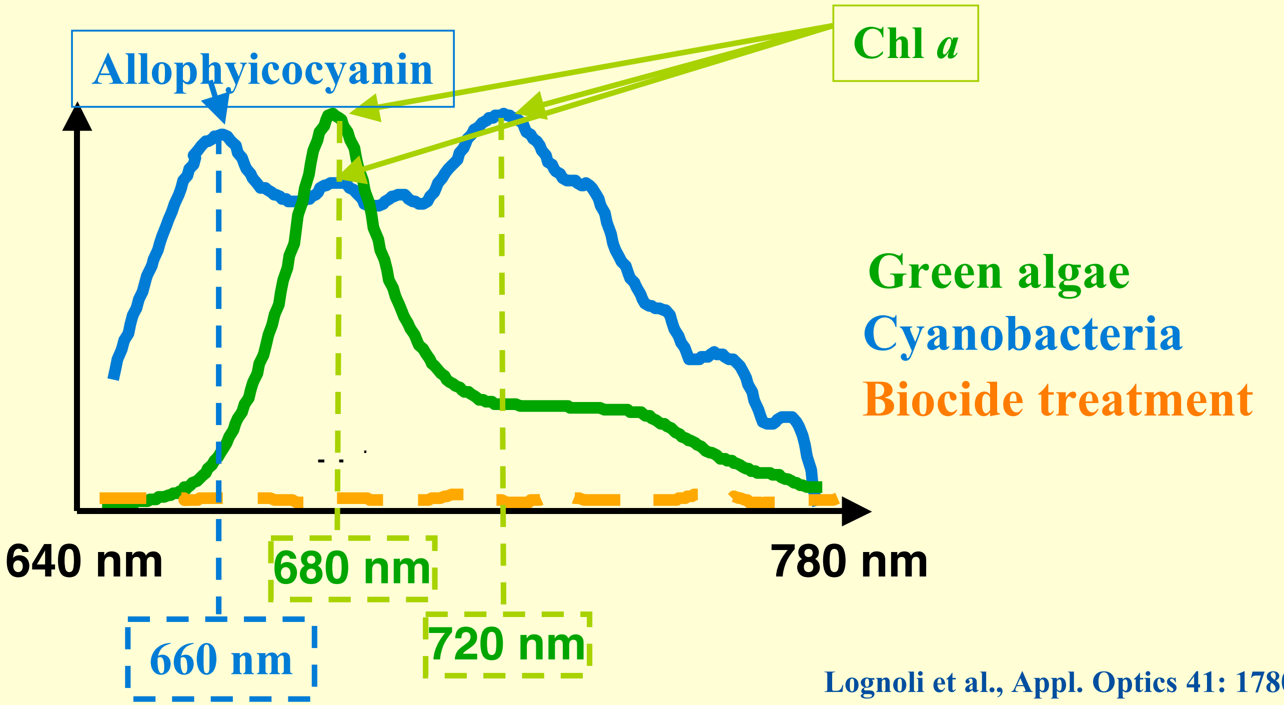


Cecchi et al., SPIE Proc. 2960: 137 (1996)

In collaboration with: *ICVBC-CNR*
ISE-CNR

Example C2:
biodeteriogens characterization

Method A : fluorescence signatures of different pigments and chlorophylls



Lognoli et al., Appl. Optics 41: 1780 (2002)

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

In collaboration with: *ICVBC-CNR*
ISE-CNR

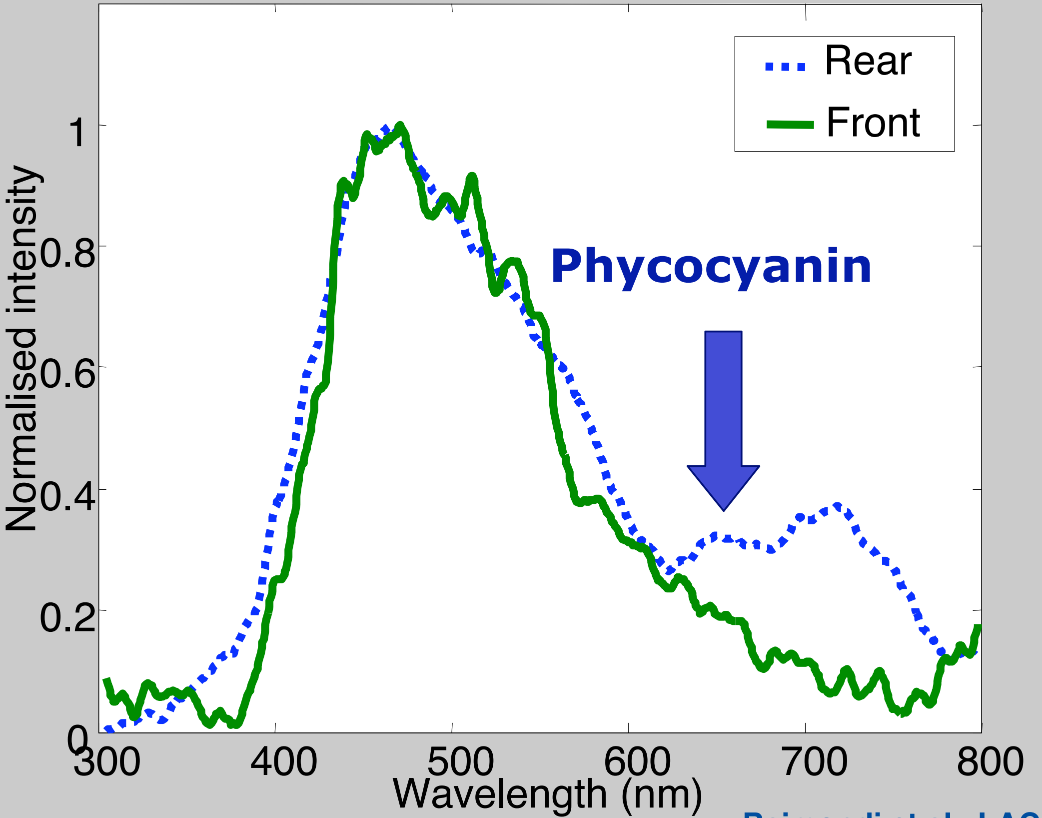
Example C2: biodeteriogens characterization

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Sample A (*Parmelia sp.*) –LIDAR spectra



Sample A – front surface

Sample A – rear surface

Raimondi et al., LACONA VII Proc. , pp.157-162 (2008)

Example C2: biodeteriogens characterization

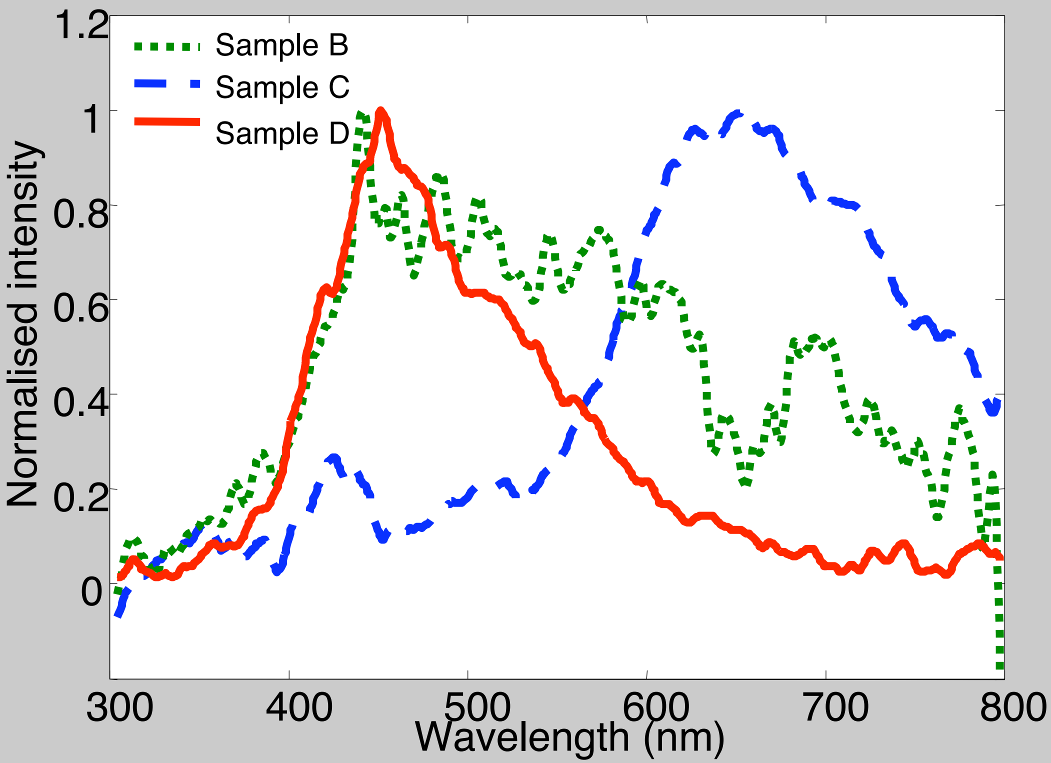
A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Sample B (Parmelia sp., Caloplaca sp.) – LIDAR spectra

Sample C (Caloplaca sp., Physcia sp.) – LIDAR spectra



Sample B

Sample C

Sample D white crust

Raimondi et al., LACONA VII Proc. , pp.157-162 (2008)

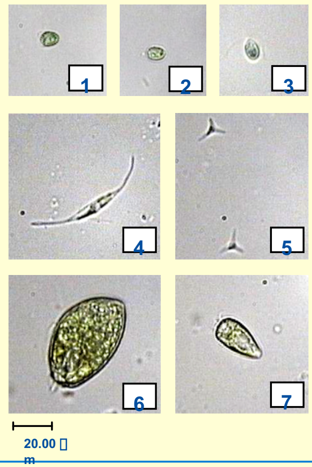
Example C3: biodeteriogens characterization

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Method 2 : Chl fluorescence peak shift

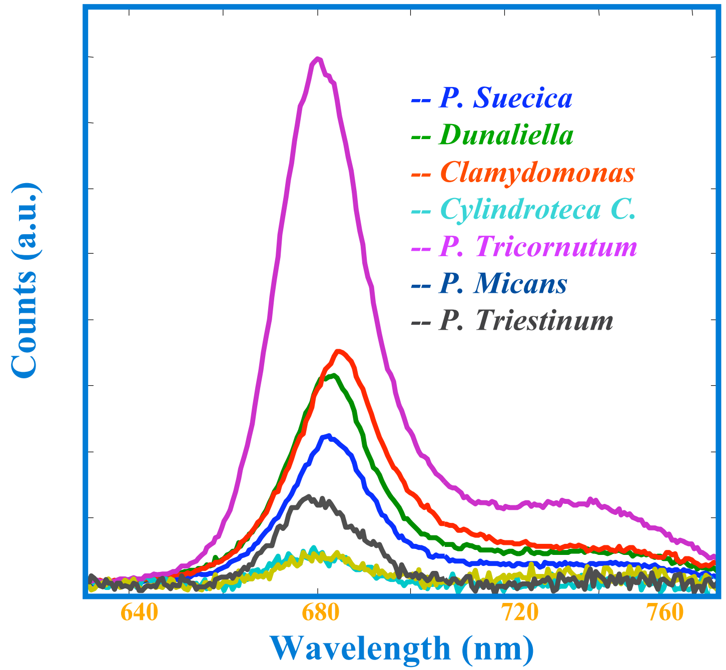


Phytoplankton samples

N	Name	Class
1	Platimonas suecica	Chlorophyceae
2	Dunaliella sp.	Chlorohhyceae
3	Clamydomonas sp.	Chlorophyceae
4	Cylindrotheca closterium	Bacillariophyceae
5	Phaeodactylum tricornutum	Bacillariophyceae
6	Prorocentrum micans	Dinophyceae
7	Prorocentrum triestinum	Dinophyceae

Mochi et al., SPIE Proc. 4880: 117 (2003)

Main pigment: chlorophyll



In collaboration with: *CRAM-ENEA*

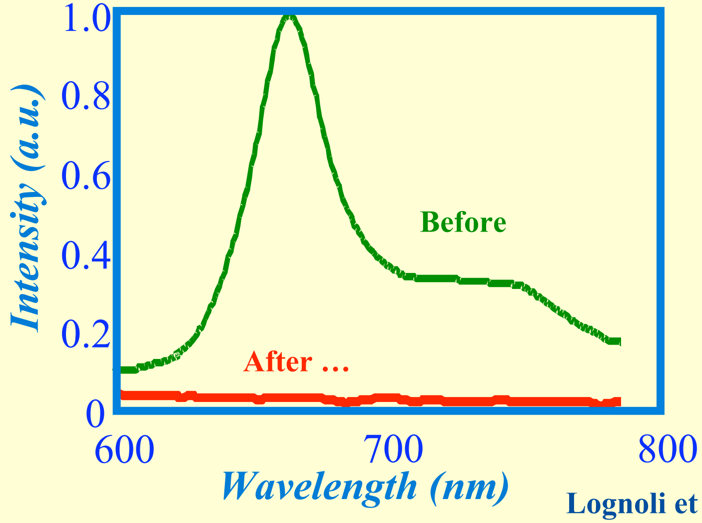
Example C4: biocide action investigation

- Monitoring of the acrtion of biocide treatments
  - Choice of the most suitable treatment
  - Feedback on decisions

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens



Lognoli et al., Appl. Optics 41: 1780 (2002)

Example C4: monitoring of biocides action

A. Lithotypes

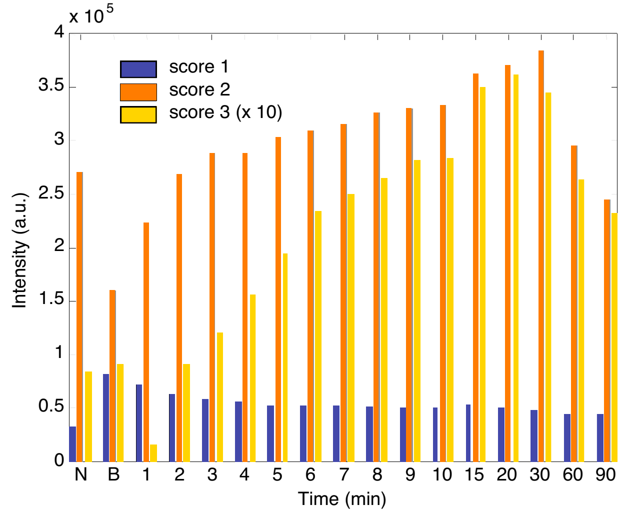
B. Protective coatings

C. Bio-deteriogens

LIF measurements on green algae (*Coccomyxa sp.*) treated with a biocide (*Metatin*)

Temporal behaviour

Analysis with Principal Components



Lognoli et al., Appl. Optics 41: 1780 (2002)

In collaboration with: *ICVBC-CNR* *ISE-CNR*

Example C4: monitoring of biocides action

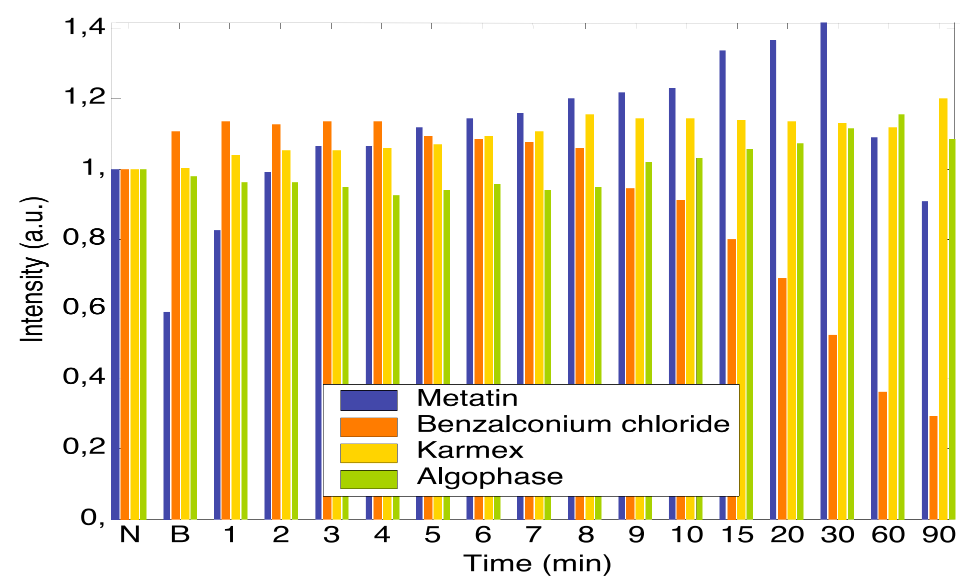
LIF measurements on green algae (*Coccomyxa sp.*) treated with different biocides

A. Lithotypes

B. Protective coatings

C. Bio-deteriogens

Analysis with Principal Components



Lognoli et al., Appl. Optics 41: 1780 (2002)

In collaboration with: ***ICVBC-CNR***
ISE-CNR

Moving forward …

To
the 'real field' …

Archaeological site of *Adamclisi* (Constanta, Romania)

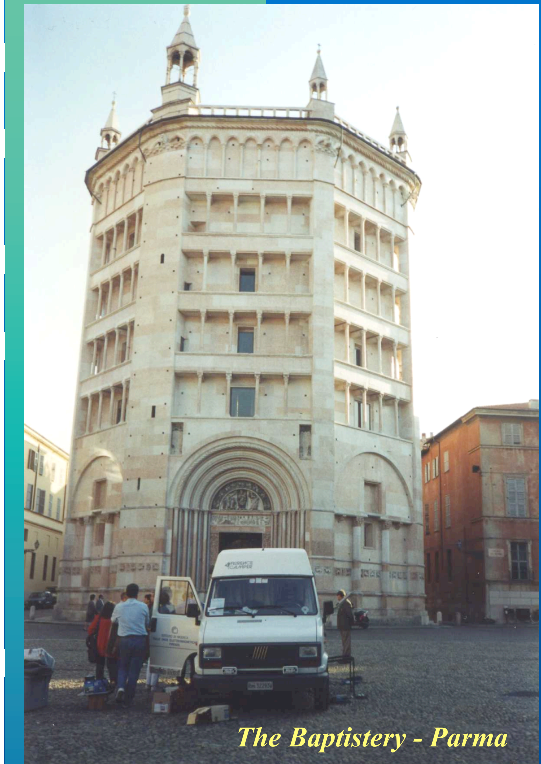
Archaeological site of *Adamclisi* (Constanta, Romania)

Archaeological site of *Adamclisi* (Constanta, Romania)

Fluorescence lidar experiments on monuments

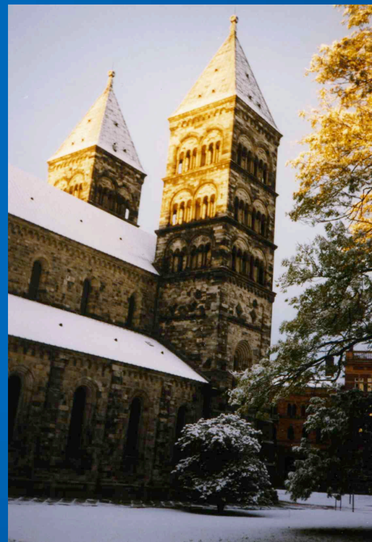
- Parma, Italy (Oct. 1994) - IFAC
- Lund, Sweden (Oct. 1997) – Lund and IFAC
- Pisa, Italy (Aug. 2000) - IFAC
- Parma, Italy (Sept. 2000) – IFAC and Lund
- Ravenna, Italy (Nov. 2001) - IFAC
- Constanta, Romania (Apr. 2004) - IFAC
- Övedskloster, Sweden, (May 2004) – Lund
- Colosseo, Italy (Jan. 2005) – IFAC and Lund
- Laterano, Italy (Feb. 2005) – IFAC and Lund

Fluorescence lidar experiments on monuments



The Baptistery - Parma

The Cathedral   Lund



The Cathedral - Parma

The Cathedral - Pisa

Fluorescence lidar experiments on monuments

Adamclisi archaeological site - Constanta

Muretto degli Ariani - Ravenna

Fluorescence lidar experiments on monuments


The Baptistery of S.Giovanni in Laterano - Rome


The Coliseum - Rome


Övedskloster castle - Sweden

1st case study …

The first fluorescence lidar experiment on monuments

Parma, October 1994

The Baptistery of Parma *(October 1994)*

- Point fluorescence lidar monitoring
- Excitation wavelength: 308 nm and 480 nm
- Output data: fluorescence spectra in the 300-800 nm range
- Distance from the target: 30 m

The Baptistery of Parma *(October 1994)*

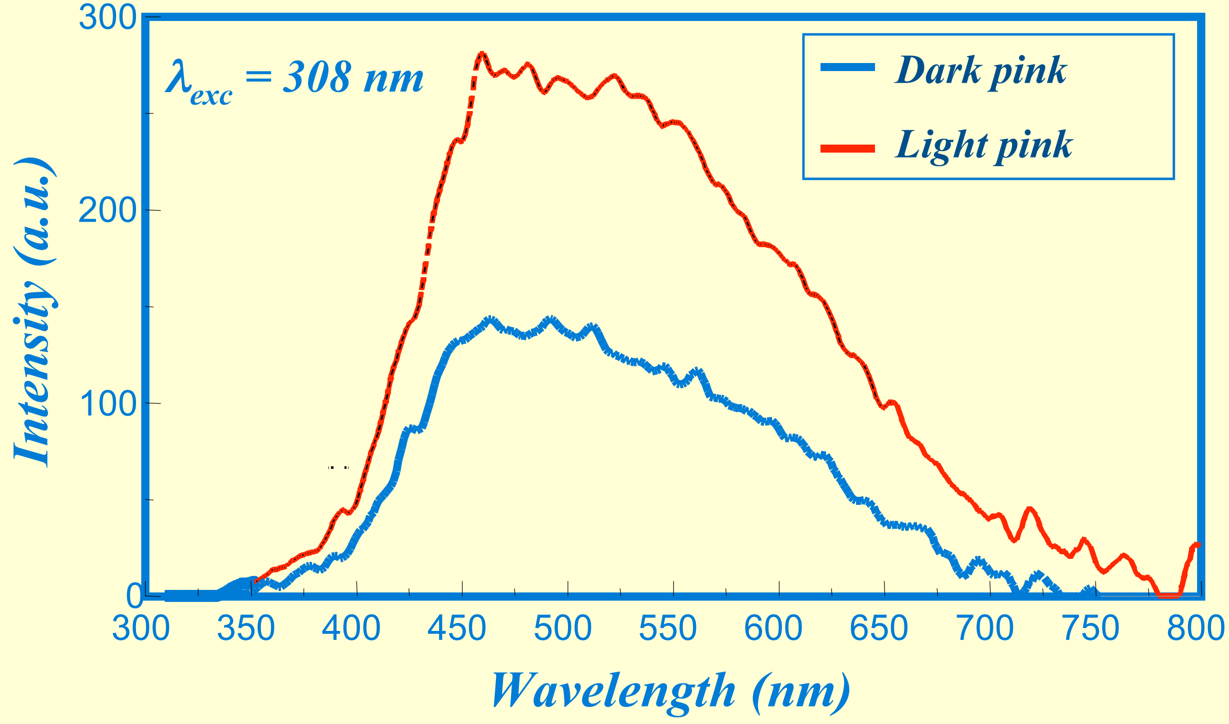
Measurements on the Baptistery

- Lidar measurements on the Baptistery ashlars
- Selection of several lithotypes of *Rosso Veronese* with petrographic features very similar to those of the ashlars
- Lidar measurements on the samples

The Baptistery of Parma

(October 1994)

Point fluorescence measurements on the Baptistery ashlars

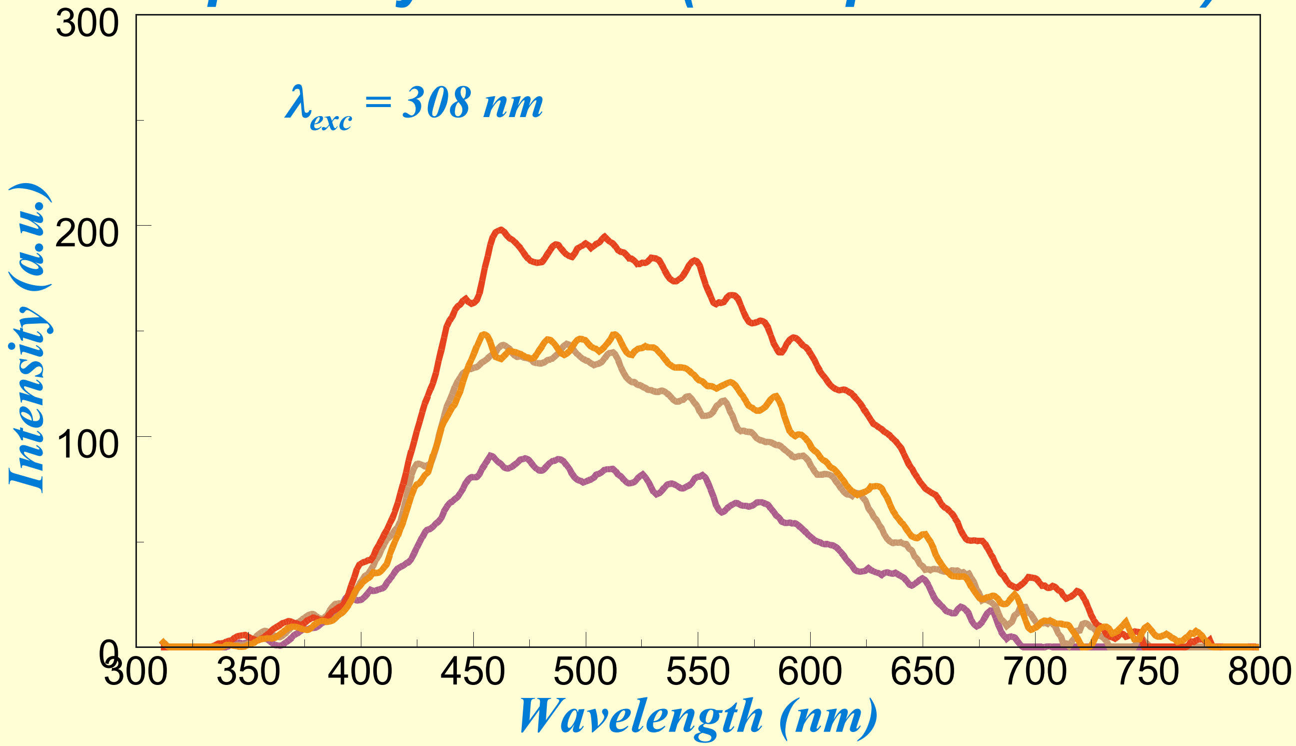


Raimondi et al., Appl. Optics 37: 1089 (1998)

The Baptistery of Parma

(October 1994)

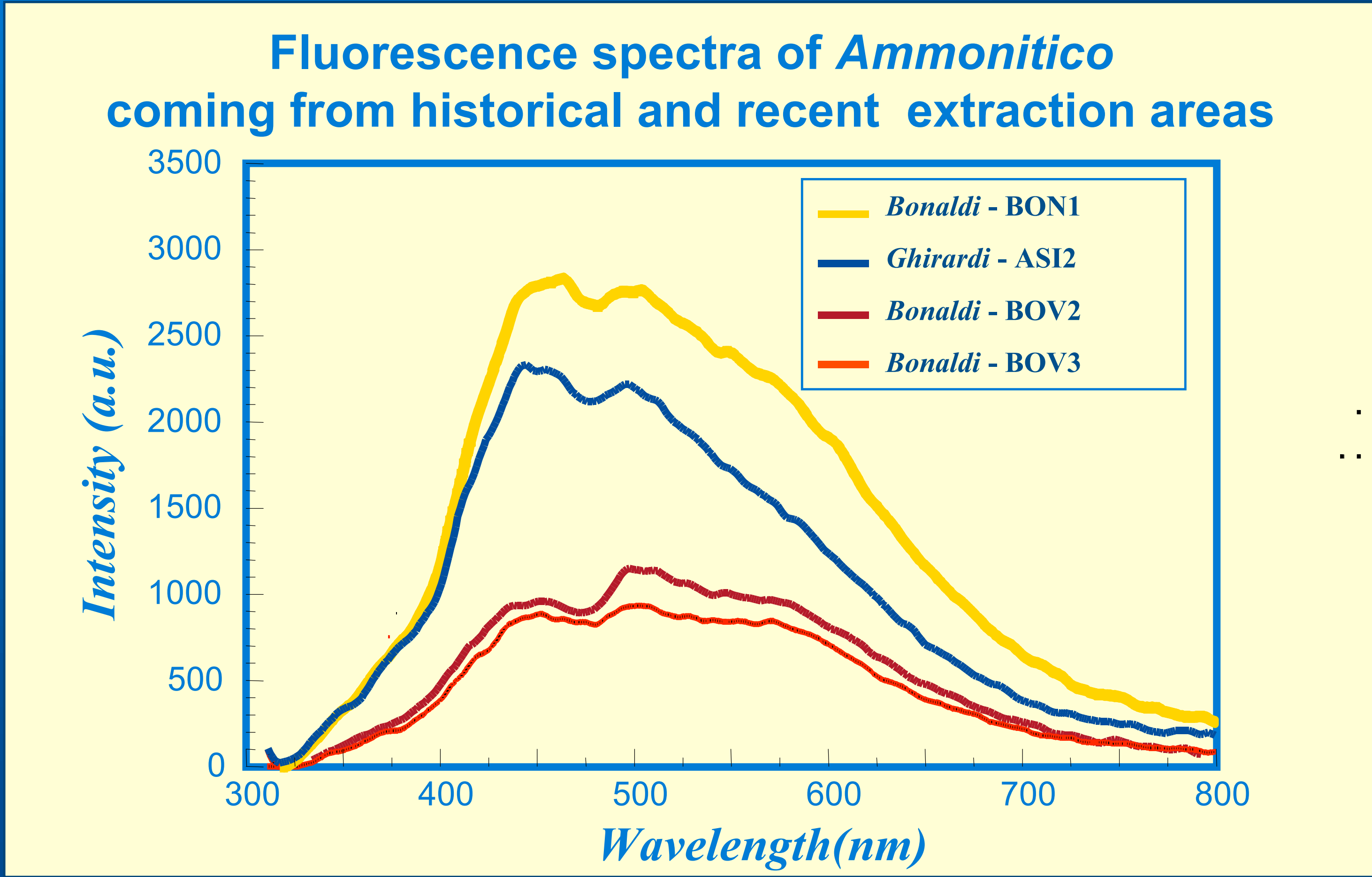
Point fluorescence measurements on the Baptistery ashlars (dark pink ashlars)



Raimondi et al., **Appl. Optics 37: 1089 (1998)**

The Baptistery of Parma

(October 1994)



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The Baptistery of Parma

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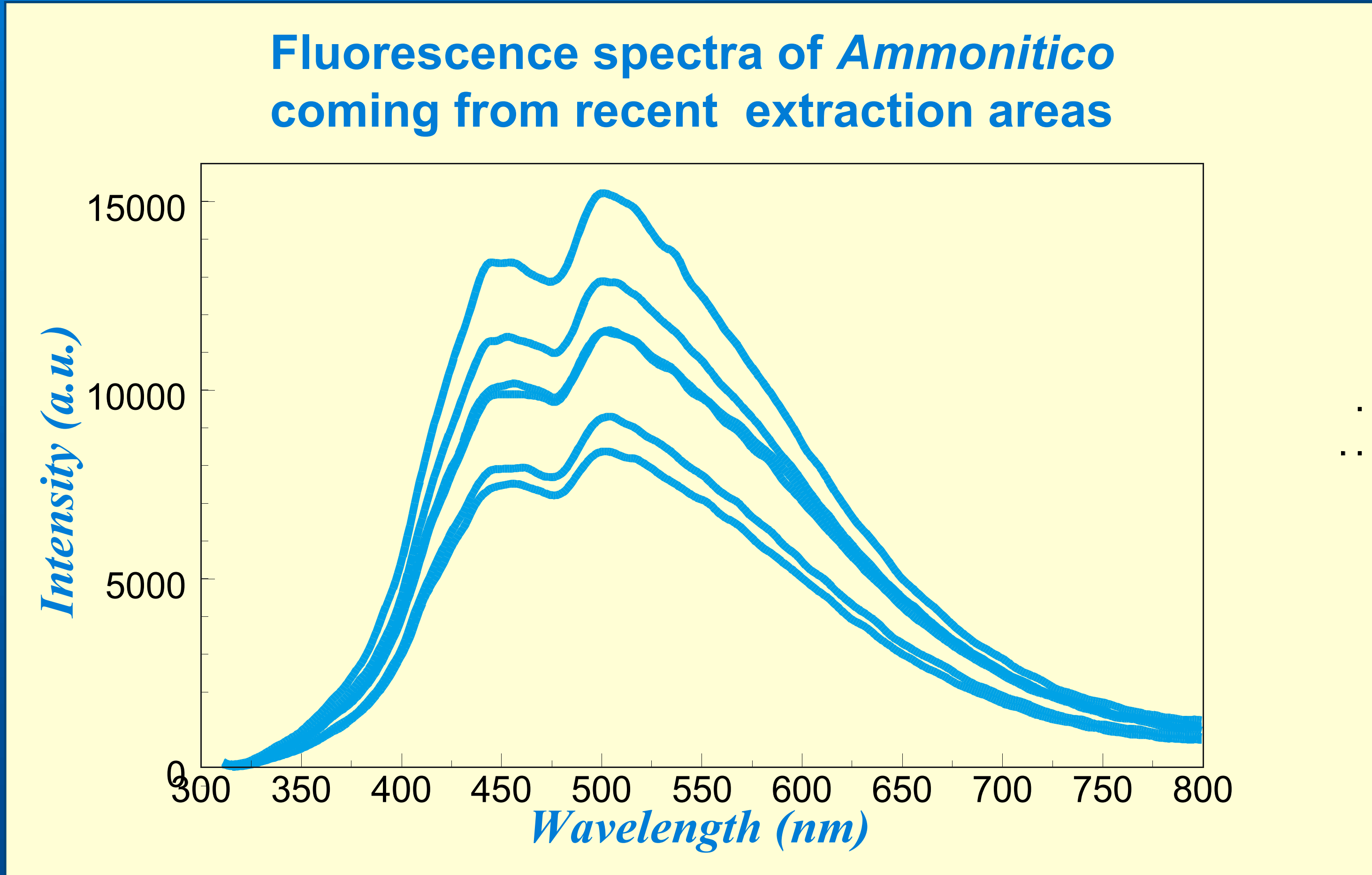

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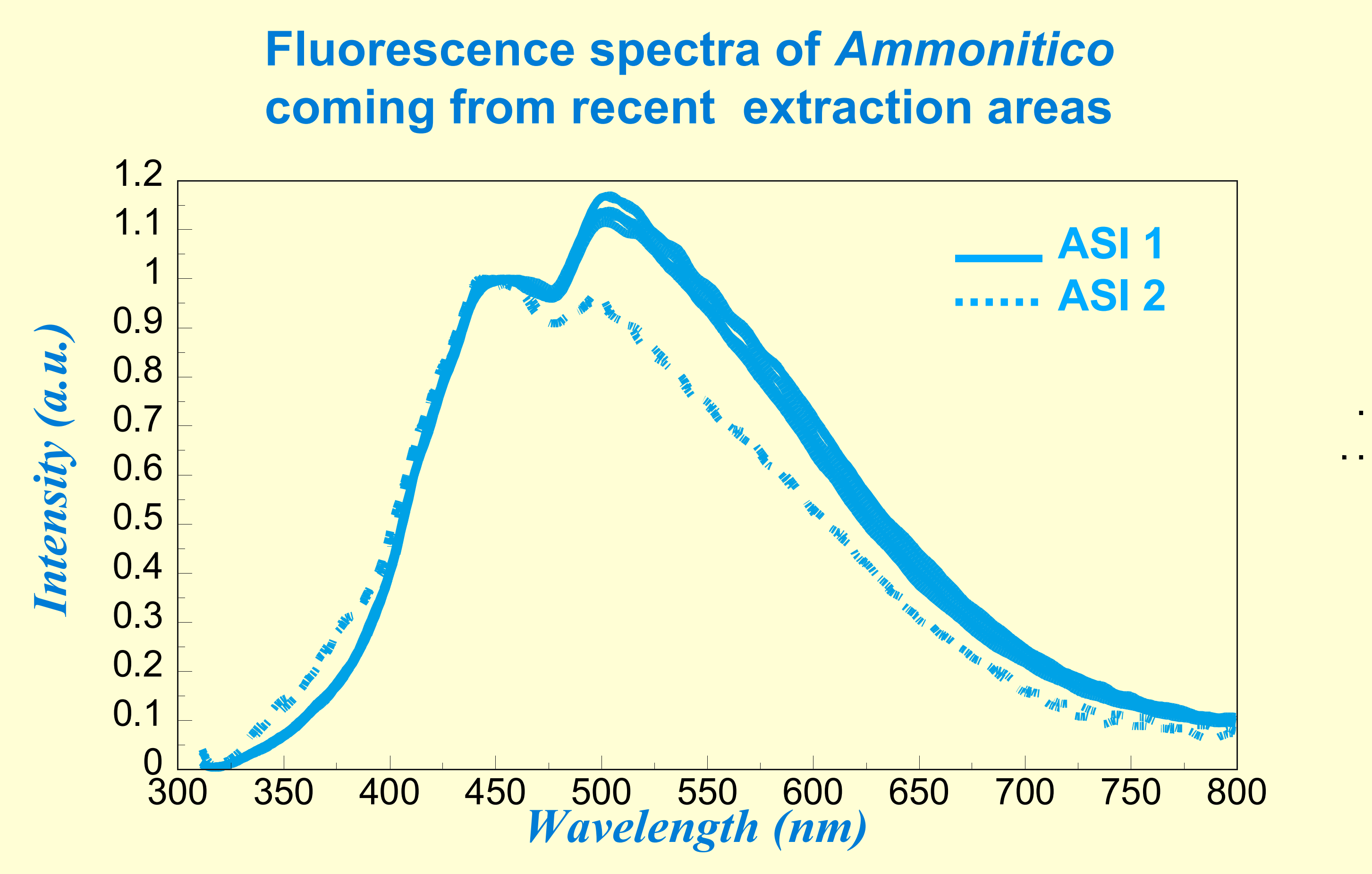
The Baptistery of Parma
(October 1994)



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