Seville, March 26-30, 2019

IV International Congress Science and Technology for the Conservation of Cultural Heritage

Laser remote and in situ spectroscopic diagnostics to CH surfaces - results of case studies in recent regional projects: COBRA and ADAMO in Latium

R. Fantoni

Fusion and Technology for Nuclear Safety and Security Department, ENEA, Via E. Fermi 45 Frascati, Italy

Roberta Fantoni

The needs for *in situ* and remote surface diagnostics on CH

The preservation of CH surfaces requires suitable **material diagnostics**. CH surfaces have been produced on very different substrates, some of them very fragile, and often at a monumental scale (large size) with limitation of access (remote view). CH surfaces can be located in hostile environments (underwater) or must be examined in dangerous situations (after earthquakes, wars) which ask for complex interventions.

<u>The laser break-through</u>: Laser scanners for non invasive or micro-destructive interrogation of the surface

- **Optical measurements**: collection of sets of monochromatic images by multiple visible laser scanners to reconstruct 3D model with native color information. Laser reflectance (backscattered and diffused signals). Data relevant to surface appearance and morphology.
- **Spectroscopic measurements**: space resolved collection of spectra containing information on surface layers. Laser spectroscopies (LIF, Raman, LIBS, with possibilities of time resolved detection). Data relevant to surface elemental and aggregate composition. Possibilities of subsurface analysis and stratigraphy.
- **Joint application** of different remote and in-situ diagnostics (thermography, XRF, PIXE), with point detection or imaging capabilities.

Laser surface interactions:
Remote surface characterization

The monochromatic laser beam interaction with a surface may cause different phenomena, with a probability depending on the incoming power for surface unit (irradiance), which determines the final energy balance.

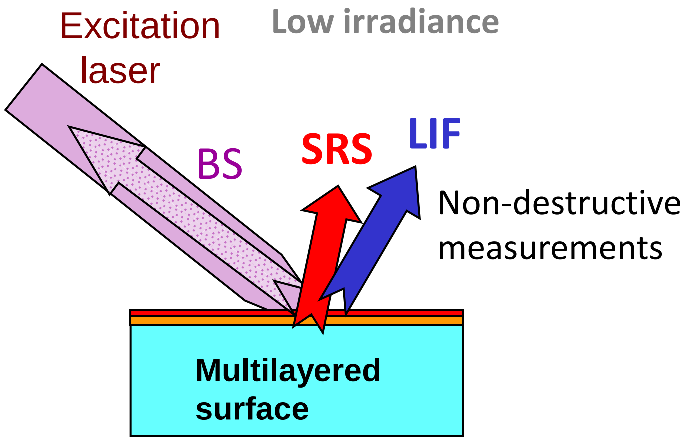
Laser irradiance

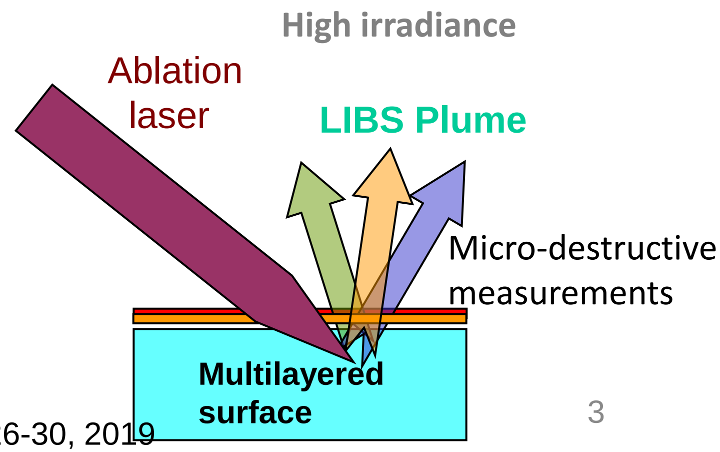
Together with partial radiation absorption, at growing irradiance, we may have:

- Back Scattering (**BS**) at the same wavelength as the exciting beam;
- Laser induced Fluorescence (**LIF**) at wavelengths larger than the incoming one, with shifts related to energy differences between electronic states, eventually coupled through internal relaxations processes in species at the surface;
- Stokes Raman Scattering (**SRS**) at wavelengths larger than the incoming one, with shift related to vibrational modes in species at the surface;

Ablation threshold

- Laser Induced Breakdown (**LIBS**) with atomic emission from the plasma generated at the surface, during an ablation/ionization process occurring above the threshold (~1 GW/cm^2).





High resolution laser scanners for remote imaging and analysis

Advantages

- Nondestructive and non invasive / micro-destructive (LIBS)
- Self illuminating
- Not affected by external light sources (at low or moderate irradiance)
- Additional geometrical requirements are taken into account
- Automatic software handling/processing of very large data sets
- Reference data for digital archiving (after calibration)

Novelty

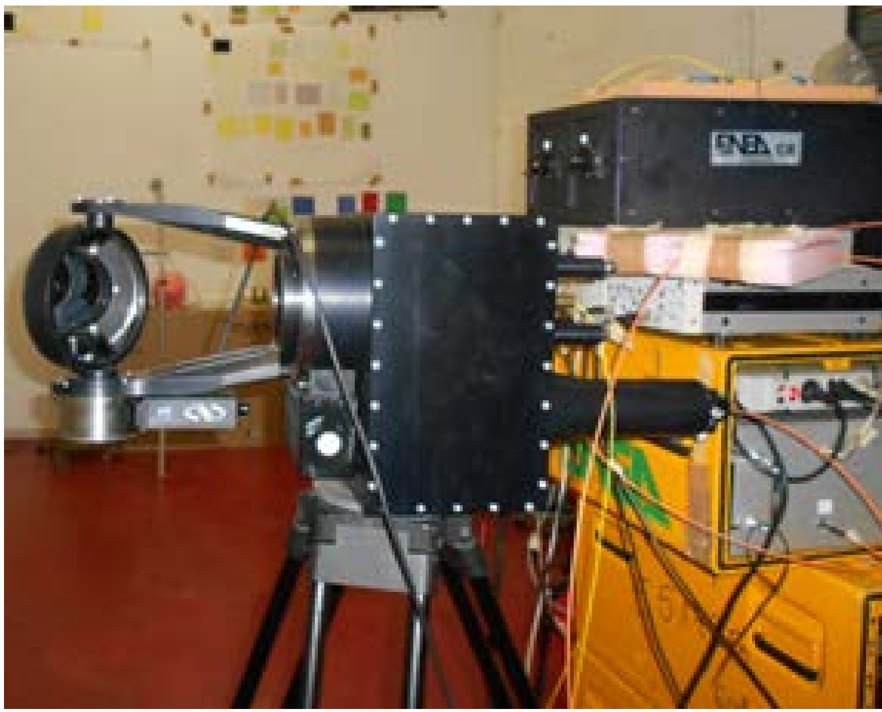
- Integrated use of more than one single prototype, in hardware or software
- Integration with different kinds of in situ sensors
- Surface diagnostics coupled to possibility of virtual fruition
- Suitable to development of augmented reality algorithms for restorers

High resolution laser scanner for 3D modeling with color images

The RGB-ITR set-up functioning principle

Optical head

Electronics for data acquisition and control



Fiber optics coupling

Operation from 3 to 35 m distance at submillimetric resolution

RGB-ITR is the acronym for Red Green Blue **Imaging Topological Radar**

It's based on double **Amplitude Modulation Technique** (190MHz/5MHz)

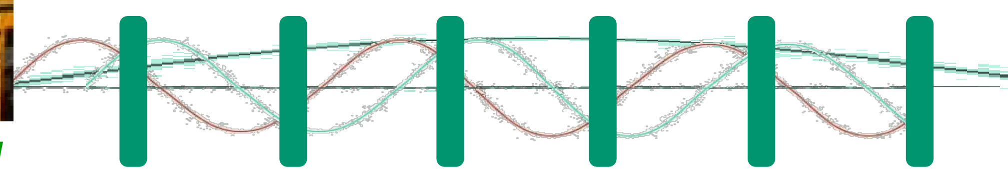
Collects **five information per pixel** – three colors and two distances

Working range of 3-35 m

Modular configuration – suitable for hostile environments

Works with **three independent** laser sources – 660 nm, 517 nm, 440 nm

Double modulation distance measurement



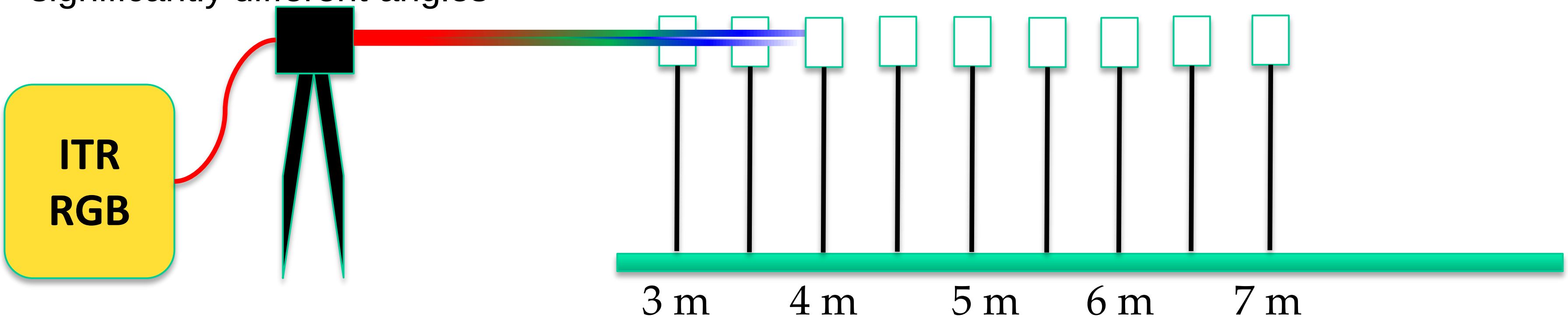
Accurate (θ, ϕ) scanning (0.002º) on large angles

Color calibration of remote imaging prototypes

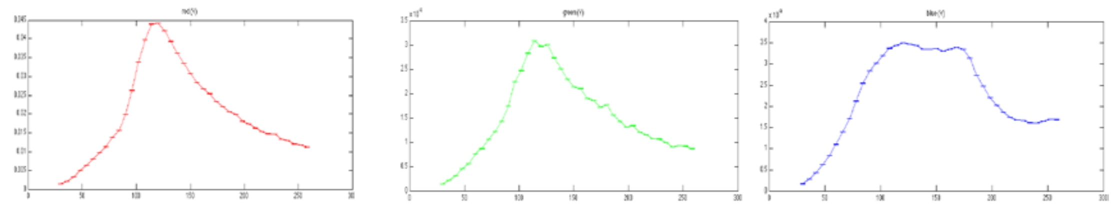
Color calibration is needed for:

1. BS measurements performed by using different monochromatic laser sources;
2. BS measurements collected at significantly different angles

Calibration curves for trichromatic ITR images are obtained by detecting the BS radiation at each wavelength from a white target at different distances.



BS intensity as a function of target distance at each laser wavelength

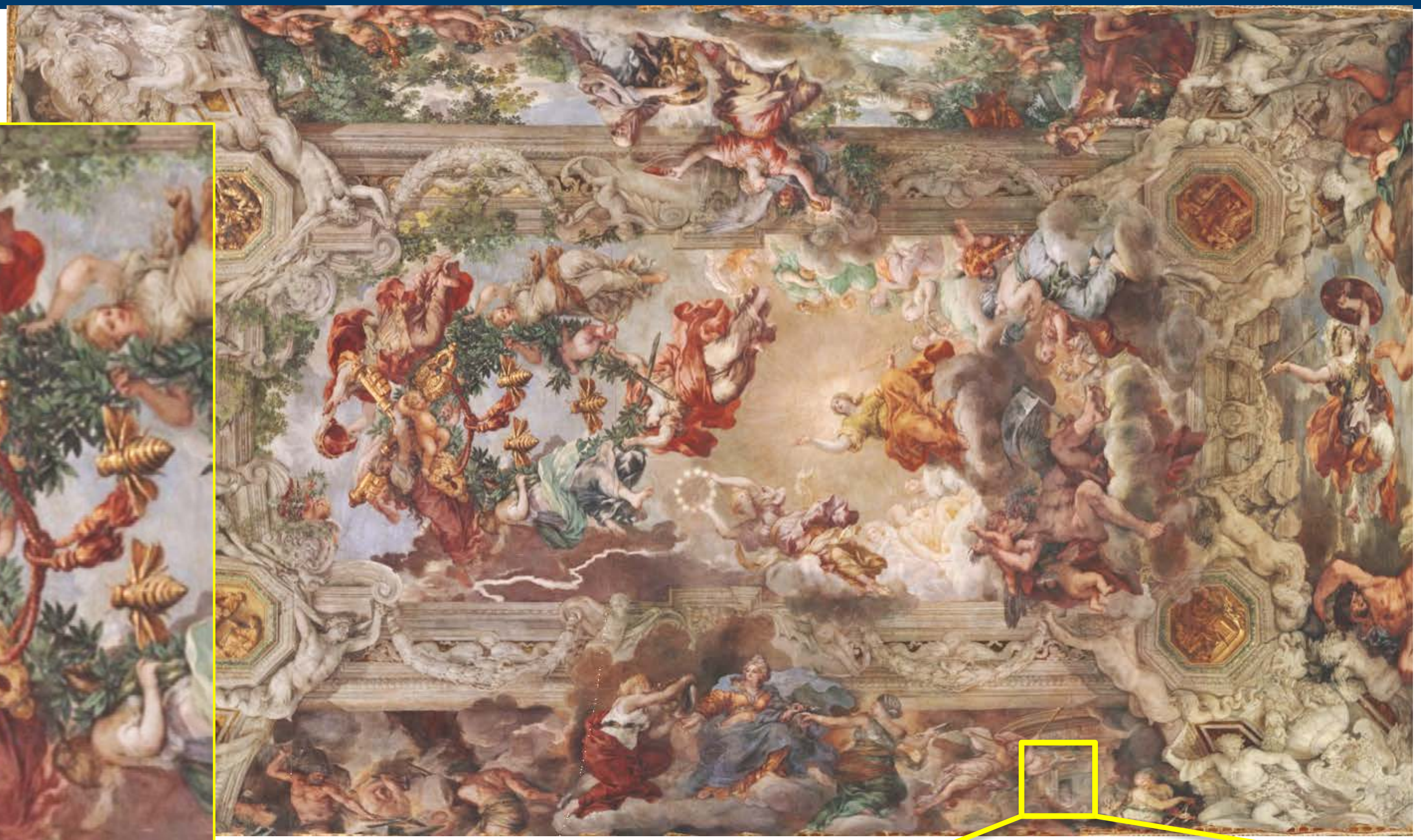


Angular corrections are included to take into account different efficiency of BS.

The possibility to inspect both colour and structure information permits to study pigments and structure modifications, to give an early warning for possible efflorescence outcrops or micro-cracking outcomes.

Pietro da Cortona's vault at Barberini Palace in Rome

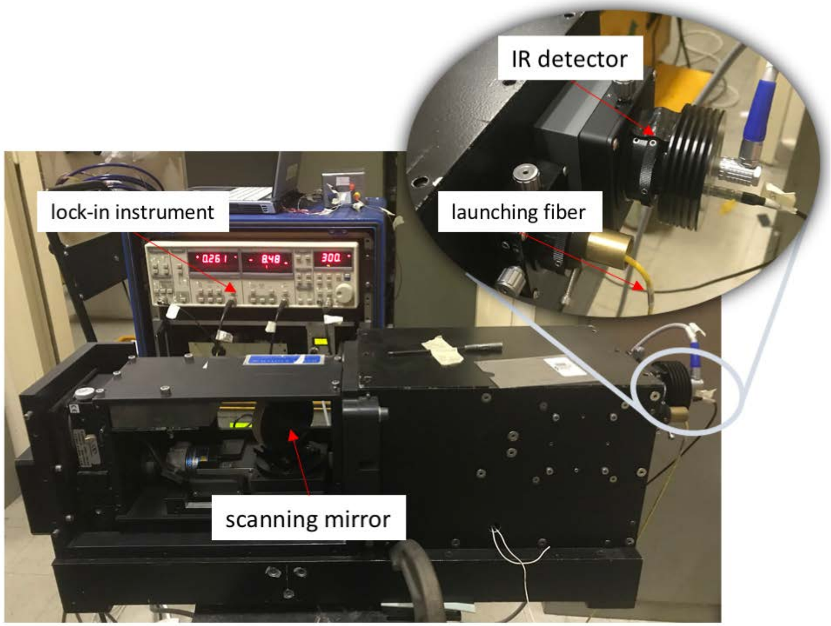
An application of RGB-ITR high resolution laser scanner



The average operating distance of 18 meters allowed to obtain a spatial point-to-point resolution of about 1mm, on the entire surface (14 x 24 m in total 530 m^2).

A small portion of the vault (60x45 cm) in which a post-processing was carried out to enhance the contours of the figure of the skeleton-soldier →

High resolution laser scanner for subsurface monochromatic imaging



A new prototype operating in the near infrared (IR-ITR) at 1.5 μm has been realized for subsurface-imaging and modeling

	5m Distance	10m Distance
Scanned size	418x452mm	489x558mm
Angular resolution	0.002x0.002 gradi	0.002x0.002 gradi
Pixel resolution	2400x2600	1400x1600
Space resolution	0.174x0.174mm	0.349x0.349mm
Acquisition time	1h45min	39min
Spot size at the surface	1.5-2mm	3-4mm

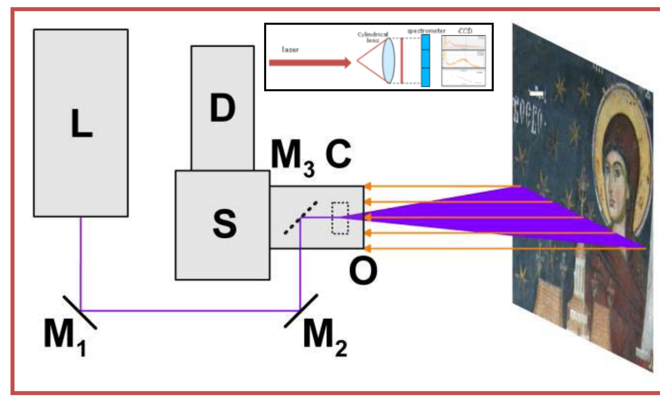
Application in retrieving former paintings or background drawings

Line scanner for hyperspectral fluorescence imaging

Collection of both reflectance and fluorescence spectra (LIF and TR-LIF)

Laser excitation @ 266 nm or 355 nm suitable to consolidants and pigments characterization

LIF (Laser Induced Fluorescence) scanning systems were designed and built in order to obtain analytical information on 2D images of the outermost layers on CH surfaces.
A fast, non invasive, remote (up to 25 m), sensitive and selective technique was developed. After automatic preprocessing data are released as false color reflectance and fluorescence images suitable to the identification of original and added materials.

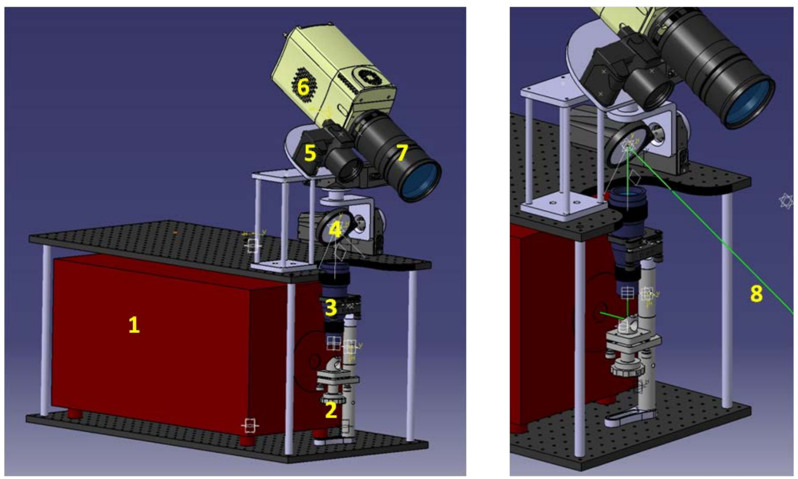


The laser beam is shaped as a light blade, thus there is no need to vary in-plane θ angle, the scan system controls only the bending φ. The entire line profile is imaged on the monochromator slit, which spreads the entire spectrum collected at each point on the squared ICCD at 90º. **Time Resolved** data are obtained collecting **LIF spectra** at different delays, by gating the camera.

Large Area LIF imaging

Apparatus

- KrF laser at 248 nm
- repetition rate of 500 Hz
- pulse duration of 10 ns
- Energy max 20 mJ
- ICCD + filter wheel (8 filters)



1.Laser
2. Mirror
3.beam expander
4.scanning mirror
5.Camera
6.ICCD
7.collecting optics
8. laser beam

Labview program

- **To define area in the scene**
- **To set experimental parameters**
- **To control different components**
- **To acquire data**
- **Preliminary data processing**

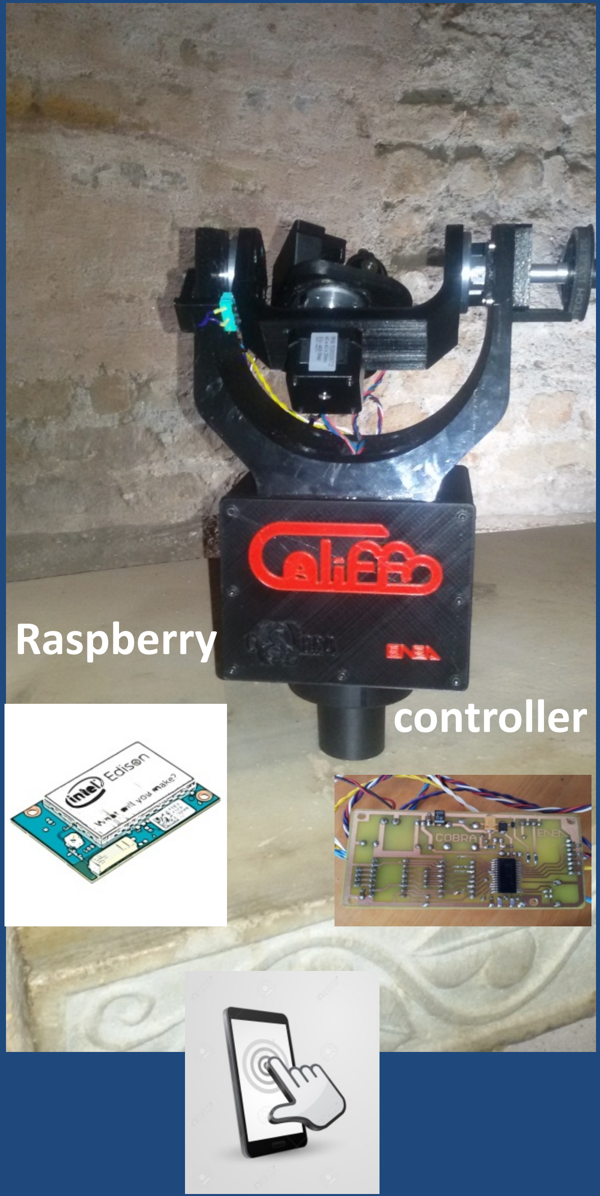
System advantages

- Reduced acquisition time (Scan time 60s/band for 10 m x 10 m area)
- Reduced data processing (selected spectral bands)
- Compact
- Remote (up to 30m)

LIF compact fluorescence point scanner CALIFFO

Micro spectrometer +collecting optics

ExcitationLaser
(@405nm)



CALIFFO (**C**ompact **A**dvanced **L**aser **I**nduced **F**luorescence **F**riendly **O**perating system) is a prototype developed at ENEA for laser induced fluorescence measurements, with violet excitation and visible detection. It is a scanning system of reduced size, weight and power consumption developed for *in situ* applications at short distances (2 – 5 m).

Its main application field is the detection and characterization of **bio-attack** on CH surfaces. The post-processing of acquired data allows to create maps able to highlight the presence of degradation forms.

CALIFFO can be completely controlled in remote way by tablet or smartphone.

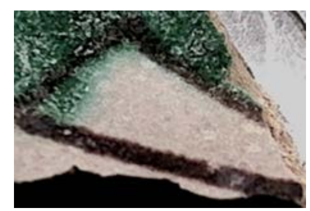
Integrate Laser Scanner for remote surface analysis and stratigraphy

ILS: An Integrate instrument for remote LIBS (exc. @1064 nm), **Raman** (exc. @ 355 nm) **and LIF** (exc. @ 355 nm).

Developed for security applications, successfully tested on CH surfaces: Ceramics, coins.

Characteristics in LIBS measurements

- Measurement distance: 10.5 m (range 8- 30 m)
- Two color cameras: to collect large scene and details
- Choice of the scanning area
- Wi-Fi remote control of the instrument
- Single shot LIBS spectrum 200-850 nm
- Samples depth profiling: 20 laser shots in 6 points per sample or coating type.



Ceramic fragments remotely examined in a lab. demonstration

Post processing of spectra and spectroscopic data

Needs to handle large amount of data in multispectral images

acronym	Processing technique
PCA	**Principal Component Analysis** Linear transformation of the input variables: maximize the variance explained by each output variable.
SAM	**Spectral Angle Mapper** Spectral projection operator that geometers the "distance" between the spectra.
MCR	**Multi Curve Resolution Analysis** Decomposition of a large number of spectra into simple components using appropriate constraints which allows to obtain physical meaning to decomposition (non-negativity of spectra and concentrations, mono mode, …)
PARAFAC	**Parallel Factor Analysis** Allows to identify all the components with direct physical meaning.

$$\alpha = \cos^{-1}(\hat{u},\hat{w}) = \frac{\sum_{i=1}^{N} u_i w_i}{\sqrt{\sum_{i=1}^{N} u_i^2 \sum_{i=1}^{N} w_i^2}}$$

$$x_{ik} = \bar{x}_k + \sum_{\ell=1}^{N} p_{\ell k} t_{i\ell} + e_{ik}$$

PCA

$$e_{ij} = 1 - \frac{\sqrt{\int (s_i(x) - s_j(x))^2 dx}}{\sqrt{\frac{1}{N} \int \sum_j^N s_j^2(x) dx}}$$

COBRA Project – Spectroscopic laser scanners applications

REGIONE LAZIO

Main objective

To develop and disseminate methods, technologies and advanced tools for the conservation of cultural heritage, based on the application of radiation and Enabling Technologies.

Selected case studies in field campaigns carried out upon conservators' request:

1. The blue demon tomb in Tarquinia Etruscan necropolis
2. The greek chapel in Priscilla catacombs Rome
3. Roman fresco's in S. Alessandro catacomb near Rome.
4. Marble statues in Palazzo Altemps Museum, Rome
5. The Orants marble sarcophagus in S. Sebastian Catacomb, Rome
6. Egyptian sarcophagi from Milan, under restoration in Rome

COBRA

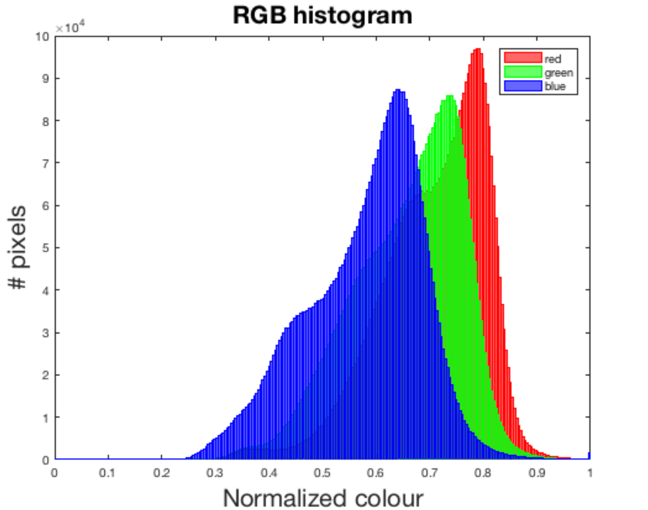
Sviluppo e diffusione di metodi, tecnologie e strumenti avanzati per la COnservazione dei Beni culturali, basati sull'applicazione di Radiazioni e di tecnologie Abilitanti

A Latium regional project entirely dedicated to technology transfer and innovation in the CH conservation (Jul. 21,2015 – Dec. 20, 2017) ENEA

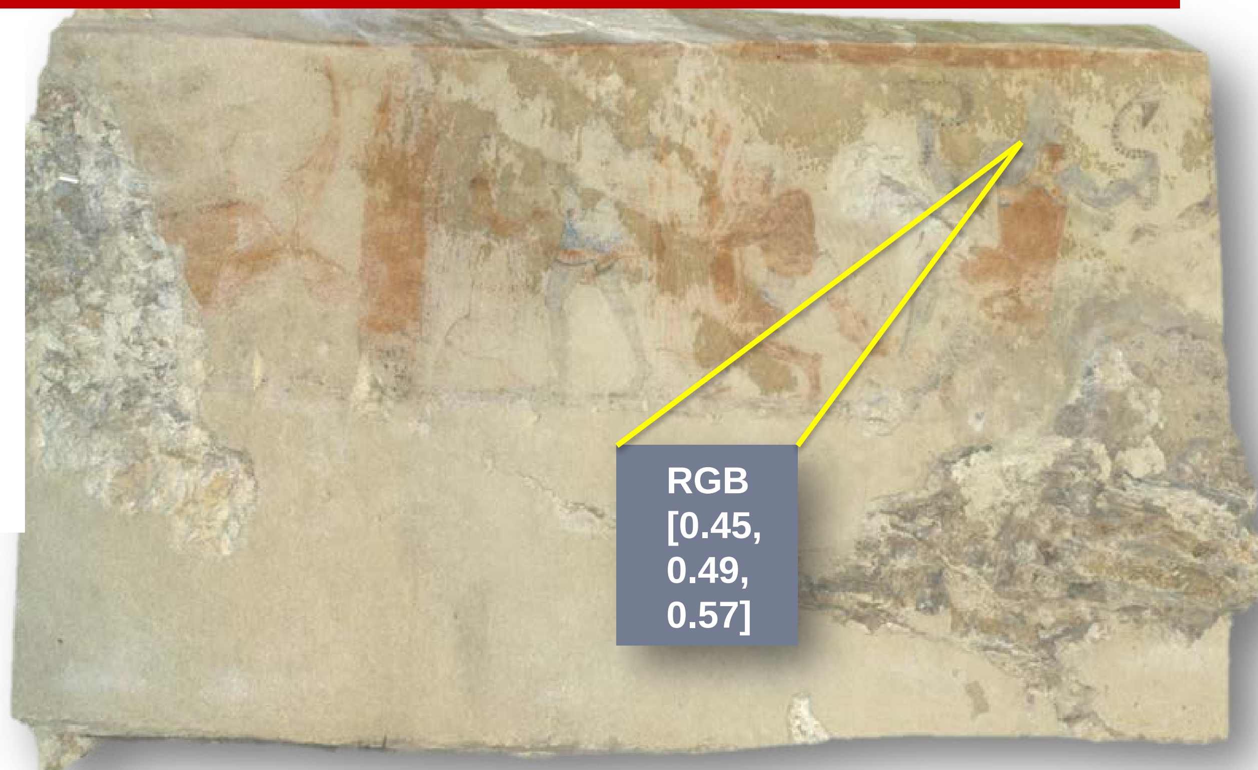
Needs of integrate application of spectroscopic techniques

1. The Blue demon Etruscan tomb in Tarquinia
RGB-ITR reflectance and color analysis

Questions: original pigments – 1. *were the demons really blue?*
modern consolidants – 2. *are they still there?*
how the murales was realized – 3. *is it a true "fresco"?*



Normalized reflectivity distribution from the RGB calibrated channels

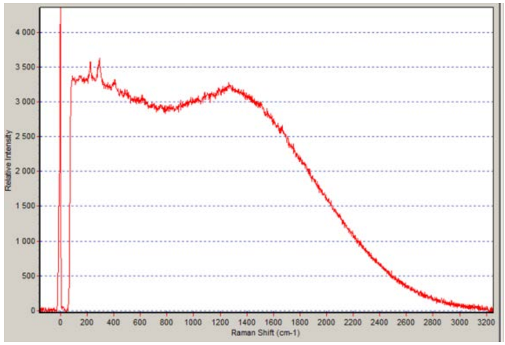


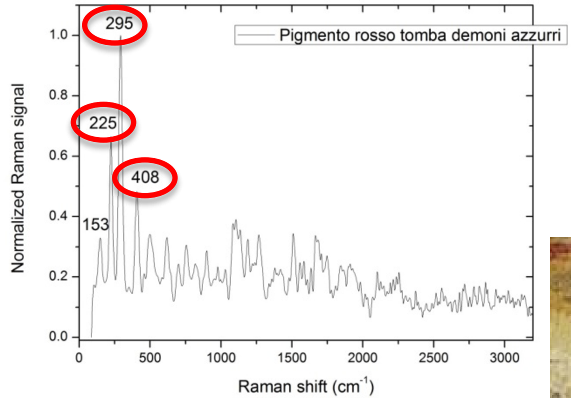
Colorimetric answer #1: now they currently look greysh – what was the original color?

Needs of further spectroscopic analyses

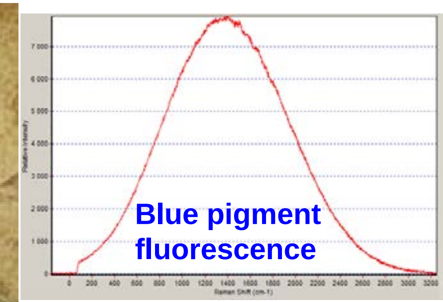
Raman in situ analyses of pigments

Red pigment identification: hematite from red ochre

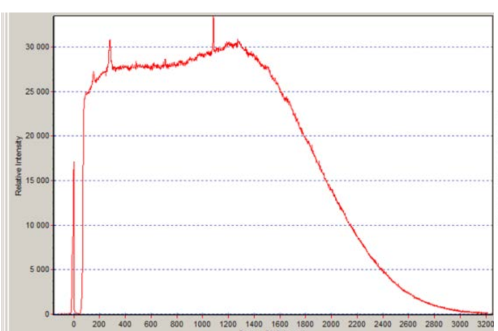


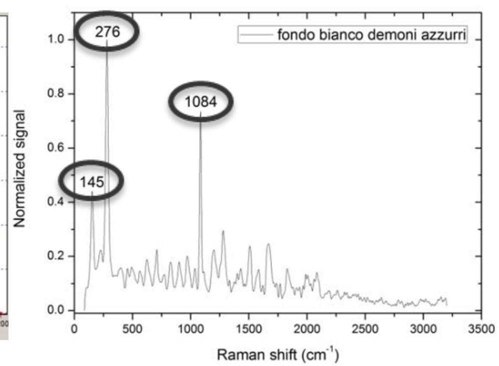


«Blue» pigment identification: impossible due to the intense fluorescence upon excitation @785 nm (*)



(*) see also P. Westlake et al. Anal. Bioanal. Chem. (2012) 402: 1413-1432



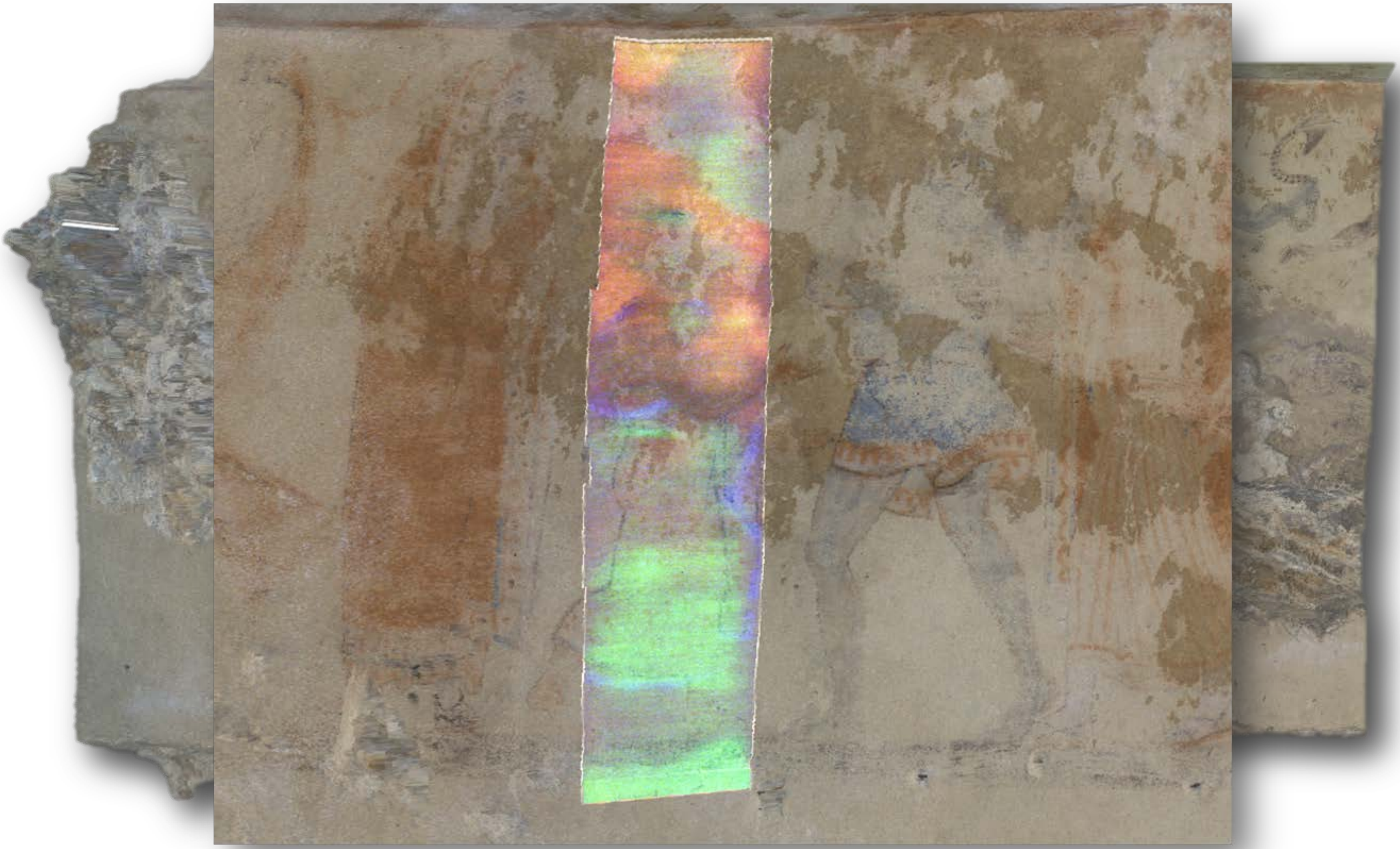


White pigment identification: calcite, used as preparatory layer.

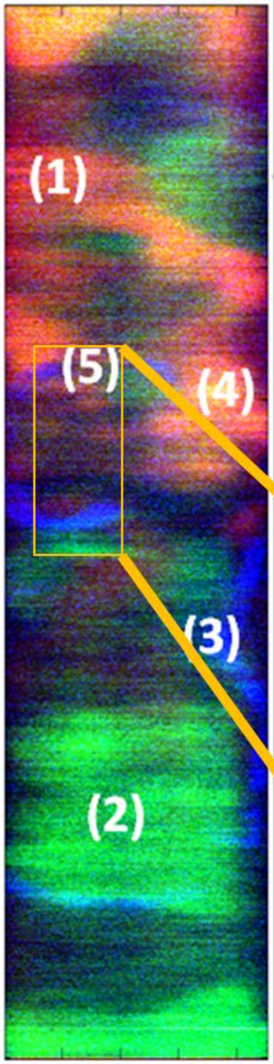
Absence of carbonatation in mineral pigments.

Answer #3 it is not a true fresco.

Overlap of LiF image on the 3D color model

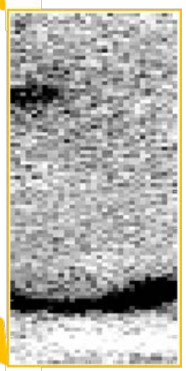


LIF data analysis
line scanner with excitation @266 nm

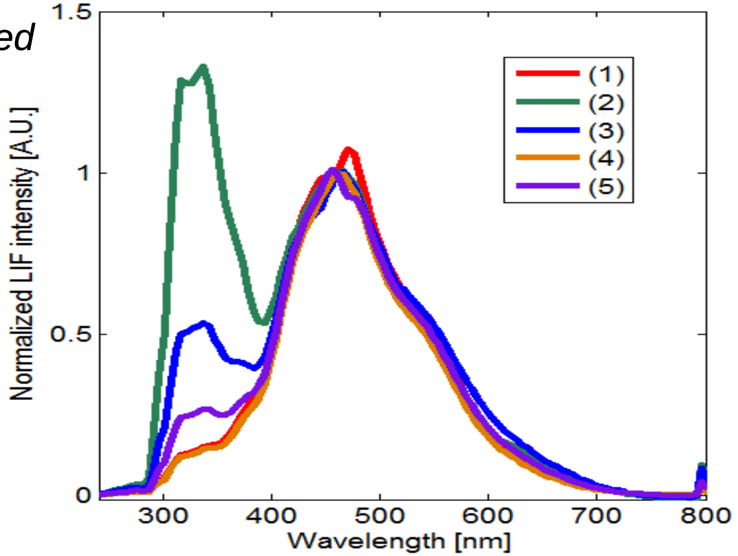


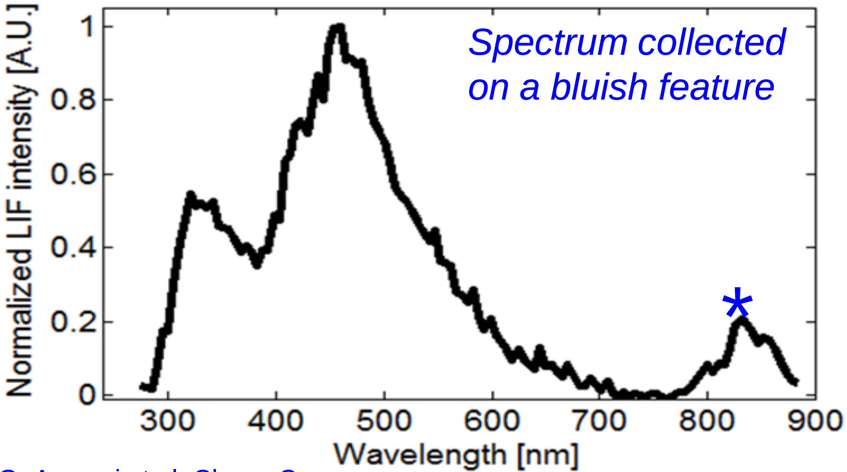
False color fluorescence image

Monochromatic image @800 nm



Spectra collected at each point



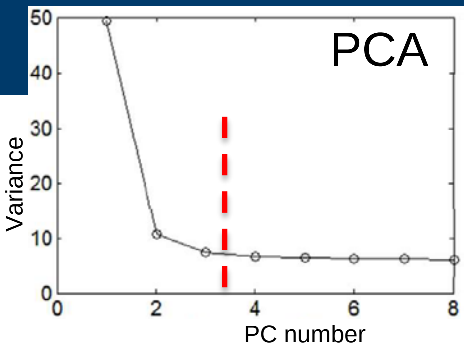


Spectrum collected on a bluish feature

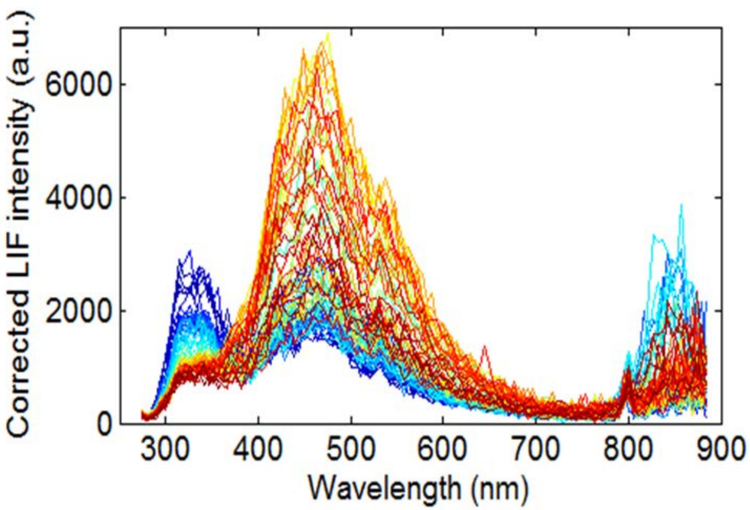
* G. Accorsi et al. Chem. Commun. (2009) 23: 3392-3394.

Statistic analysis: PCA and MCR

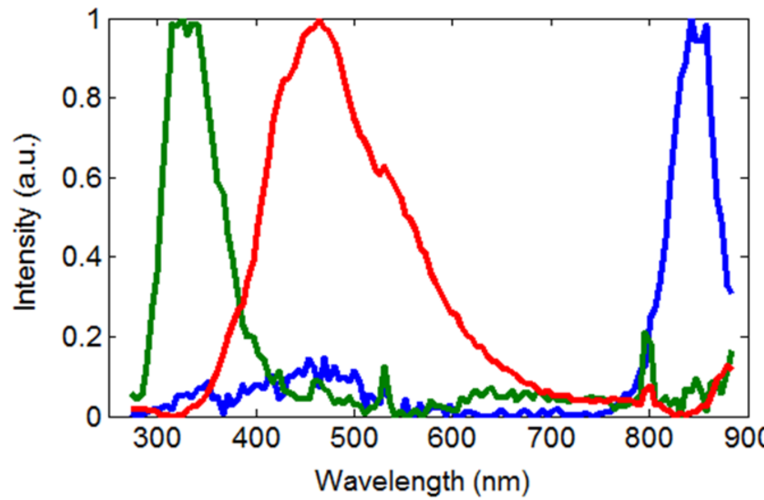
Blind PCA shows that most variance is accounted for in the first 3 components, associated respectively to the intense UV emission, the broad visible band and a few weak features. No spectral assignment is possible.



MCR Deconvolution



320 nm 470 nm 850 nm



Consistent with the intense fluorescence observed during Raman measurement upon exc. @785 nm

Three components are isolated:

1- Broad visible band

2- Intense localized UV peak

3- Weak visible features and strong near IR emission

Assignment

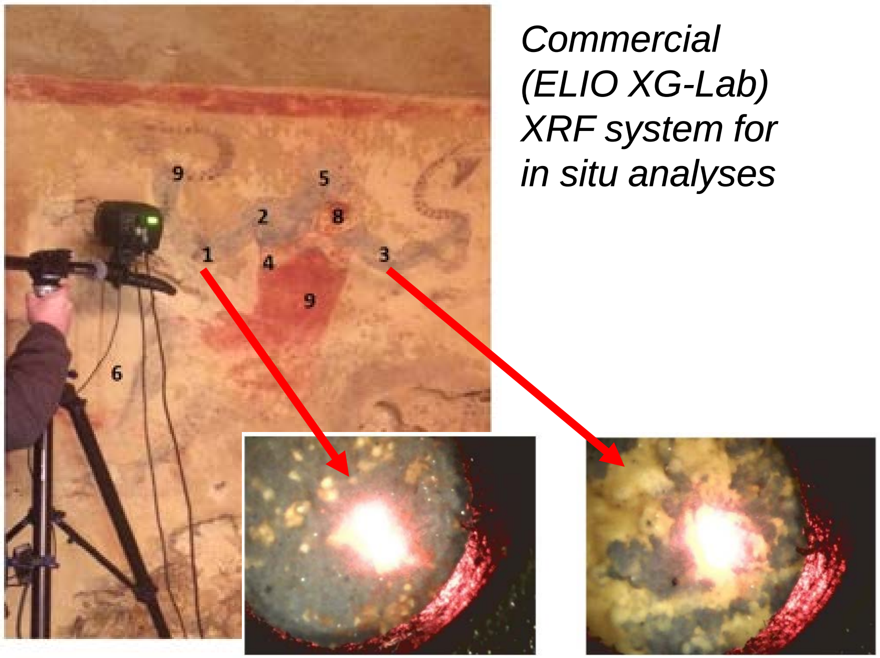
Preparatory layer

Paraloid consolidant

“Blue” pigments

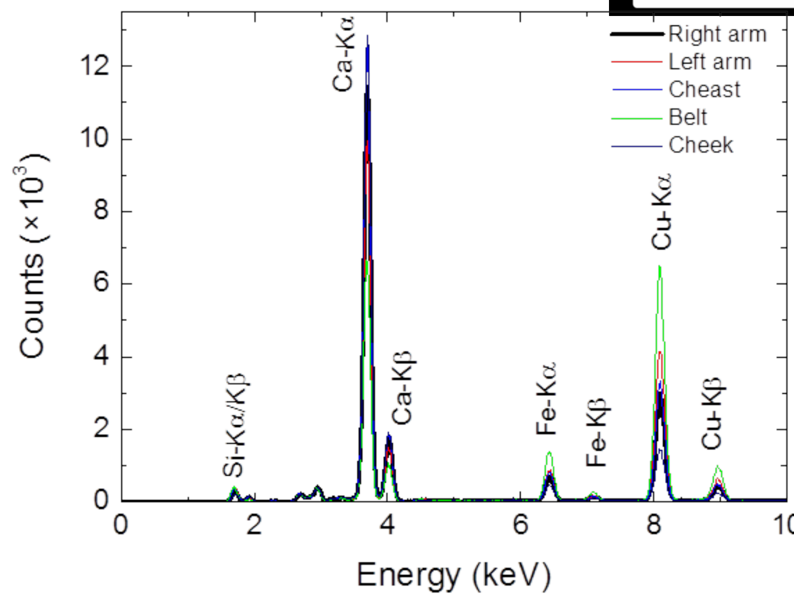
Answer #2 Paraloid is still there, as used to keep the painted layer on the wall.

In situ X ray Fluorescence point analyses
Cross confirmations



Commercial (ELIO XG-Lab) XRF system for in situ analyses

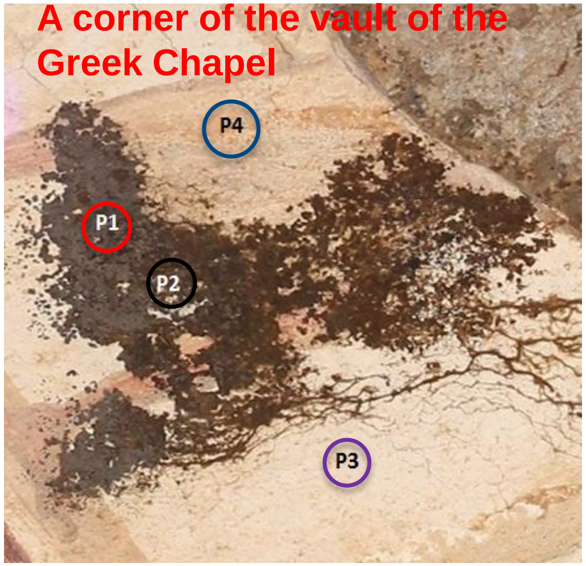
XRF spectra at the labelled points



- «Blue pigment» analysis: the presence of Ca/Cu/Si supports the assignment as cuprorivaite ($CaCuSi_4O_{10}$ or $CaO·CuO·4SiO_2$), known as **Egyptian Blue**.
- Red and brown pigments: the presence of iron confirmed the use of ochres, i.e. iron oxides (red - hematite, yellow - goethite).
- Black pigments: no characteristic elemental emission, C-based pigments of organic origin.
- Consolidants: no information from XRF, as expected for paraloids.

Answer #1 The demons were meant to look blue

Frescoes in Priscilla's Catacombs in Rome
Laser scanners for biodegradation analysis



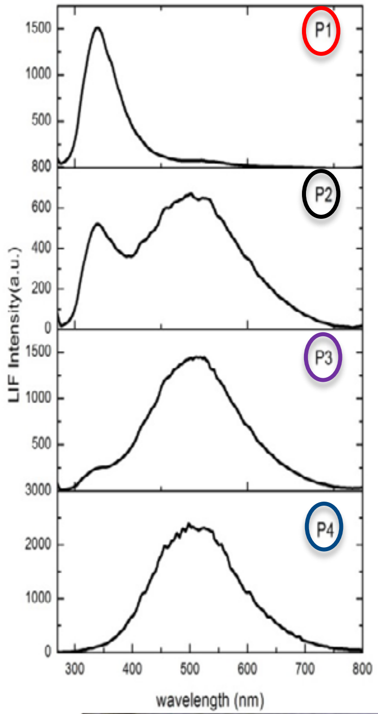
P1 - subarea where the biomass appears more dense

P2 – subarea where the biomass is less dense

P3 - subarea where the bio-deterioration is not evident naked-eye

P4 - far away from the biomass area

LIF spectra at selected points



P1 - intense emission band at 340 nm, identifying the biological material present in that area

P2 - the emission in intensity band at 340 decreases and a large band at 500 nm appears

P3 - Band at 340 nm still present, low intensity, and band at 500 nm increased in intensity

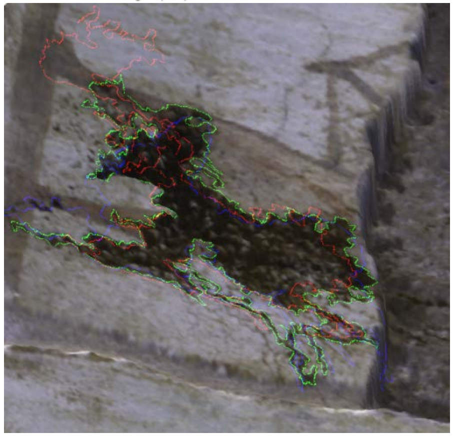
P4 - Band at 500 nm is the only band present

Persistence of the fluorescence band at 340 nm in **P3** → possibility of **early detection by LIF** of areas attacked by microorganisms not visible in this stage

Question: Is it possible an early detection of bio-attack?

Answer: YES by remote LIF

Contribution to bio-attack monitoring by means of biofilm area's circumscription by the post processing analysis of the RGB-ITR 3D model →



New successive colonization of other areas is visible 4 and 8 months after the first observation, due to spread of microorganisms

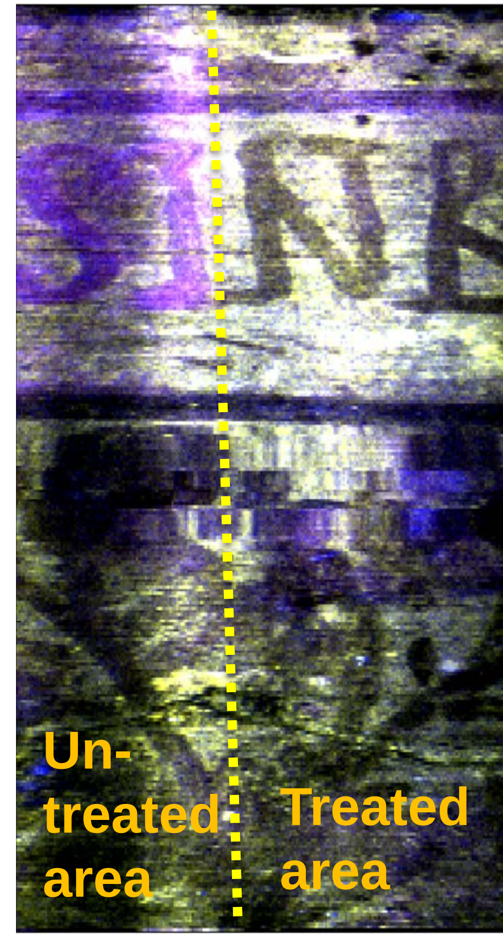
ENEA

2. Fresco's in S. Alessandro Catacomb: G6 and G15
Reflectance and fluorescence imaging

Needs for spectroscopic diagnostics during the fresco's restoration

picture

Reflectance image



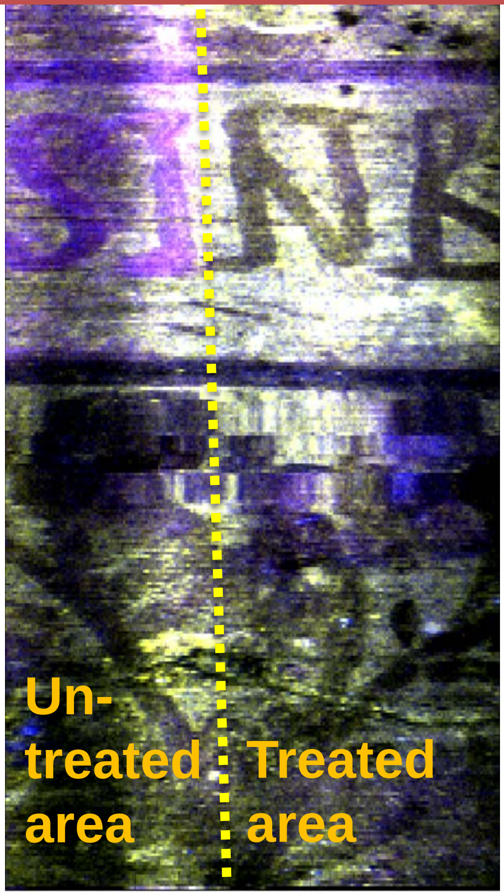
False color fluorescence image

Is it possible by spectroscopic imaging to read the lost part of the inscription? **YES by LIF**

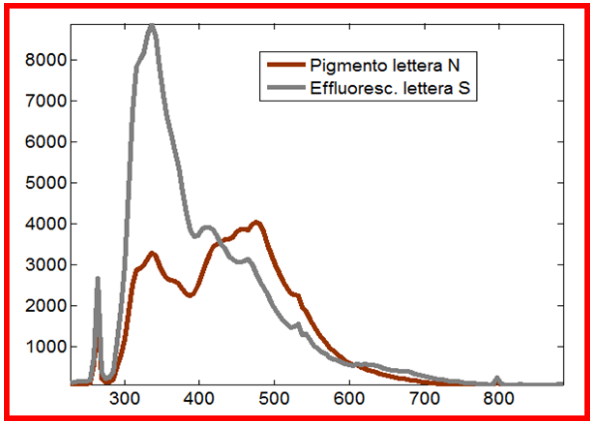
LIF imaging on G6 – the lost inscription

Questions: Possibility to clean 1. Is the painted layer still present?
Efficiency of cleaning 2. What consolidant was used?
Original materials and dating 3. Which pigments were used?

Picture of the G6 fresco



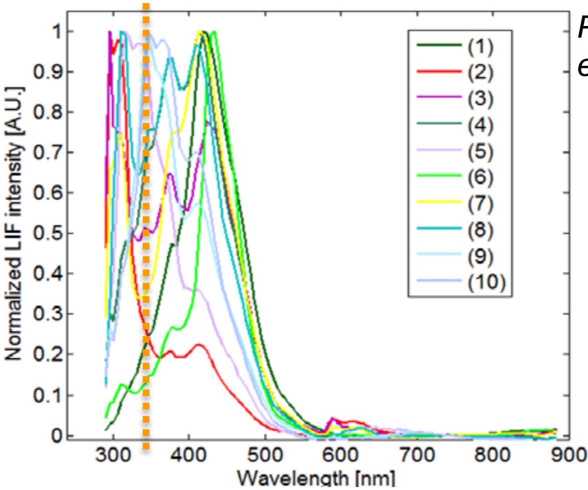
False color LIF image @560, 420, 330nm



Result: a peculiar spectral signature @340 nm from a consolidant on the missing letters and other decorations.

Answer #1. **YES** The efflorescence is covering the missing letters where the consolidant was used.

Attempt of consolidant assignment by LIF



Reference consolidant spectra upon excitation @266 nm

SiEt reference sample: St. John white and red ochre on plaster

Discrimination among consolidants with significant emission near 340 nm has been attempted by SAM, projecting spectra collected at S. Alessandro onto each reference spectrum.

Result of SAM analysis

Class	Commercial name	θ angle (rad.)
Acrilics	Primal B60	0,78
	Acrytal C12	0,51
	Dispersion K	0,87
	Plextol D498	0,45
	Ase 60	0,87
	Dispersion PU 52	0,49
	Primal AC35	0,79
Vinyls	EVA	0,34
	PVA	0,42
	PVA+PVAC	0,43
SiEt	ESTEL 1000	0,29

Best matching minimizes θ angle.

Nevertheless LIF was able to detect the presence of a consolidant and determine its surface distribution, alone it could not clearly identify the consolidant.

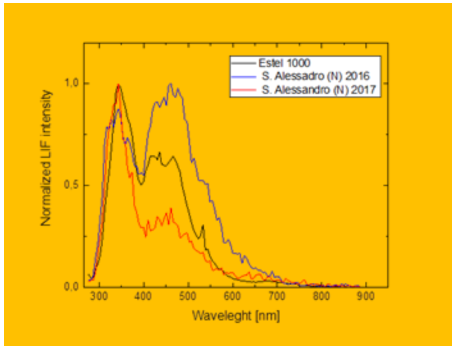
The latter information is needed for its efficient removal and successive surface treatments.

Consolidant assignment after integration of all spectroscopic data

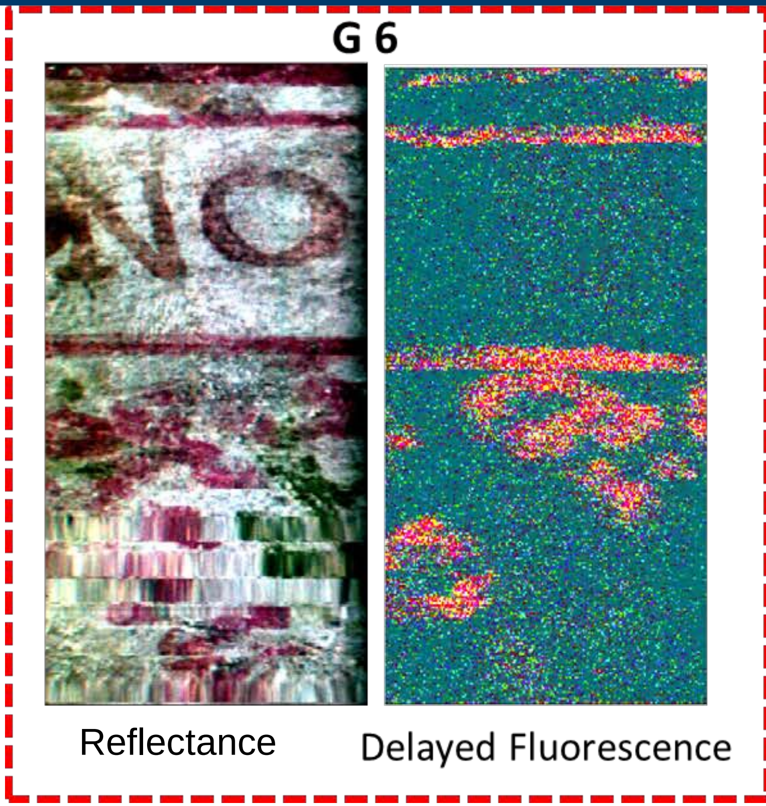
Summary of results from different spectroscopic investigations on consolidants with emission near 340 nm (upon excitation @266 nm)

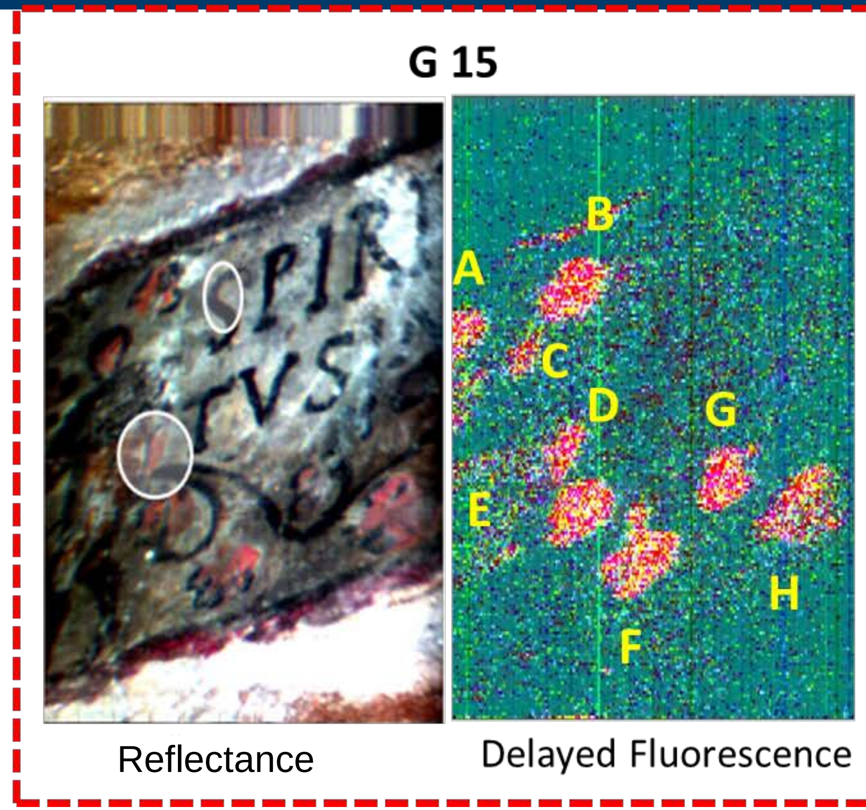
	S. Alessandro	SiEt	Vinyls	Acrilics
LIF	340 nm band: **Intense**	340 nm band: **Intense**	340nm band: **Intense (in most cases)**	340nm band: **Present in some cases (AC35)**
Time Resolved LIF	340nm band: **Prompt**	340nm band: **Prompt**	340nm band: **Delayed**	340nm band AC35 **Delayed**
RAMAN	Peak at 1291cm $^{-1}$ (No vinyl band at 630cm $^{-1}$)	Peak at 1295 cm $^{-1}$	Peak at 630 cm $^{-1}$ (No peak at 1296 cm $^{-1}$)	Peak at 1296 cm $^{-1}$ Primal AC35 Plextol D492

Answer #2. Combined analysis confirms the identification of SiEt: Estel 1000 - A nasty consolidant responsible for localized saline efflorescence when used in humid environment, its incomplete removal was verified by LIF one year later.

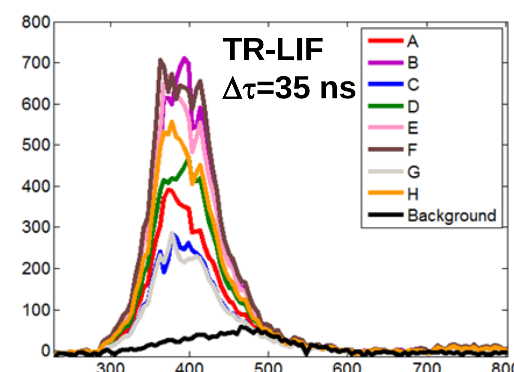


Time Resolved LIF analyses
Red pigments assignment confirmed by in situ Raman and XRF

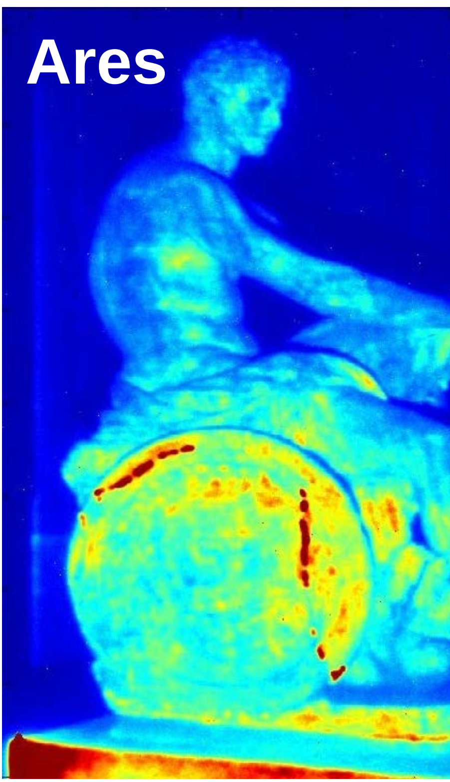


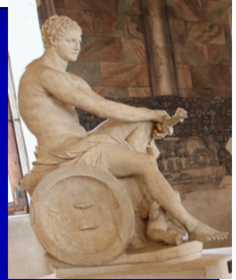


- TR-LIF imaging mapped the distribution of red and orange pigments on fresco's surfaces, both peaked @ 380, 400 nm.
- They are characterized by the same decay time at about 8-12 ns.
- Raman analysis confirmed **red ochre** **(G6)** and a mixture of **red ocher and minium** **(G15).**



3. The same pigments were utilized, fresco's are contemporary





Palazzo Altemps Ludovisi collection of classic marbles

The Roman statue was restored by Bernini - Question: Is it possible to trace this old intervention?

Starting from the *FORLAB* fluorescence images, the application of the data processing developed

permitted us to discriminate different stone materials.

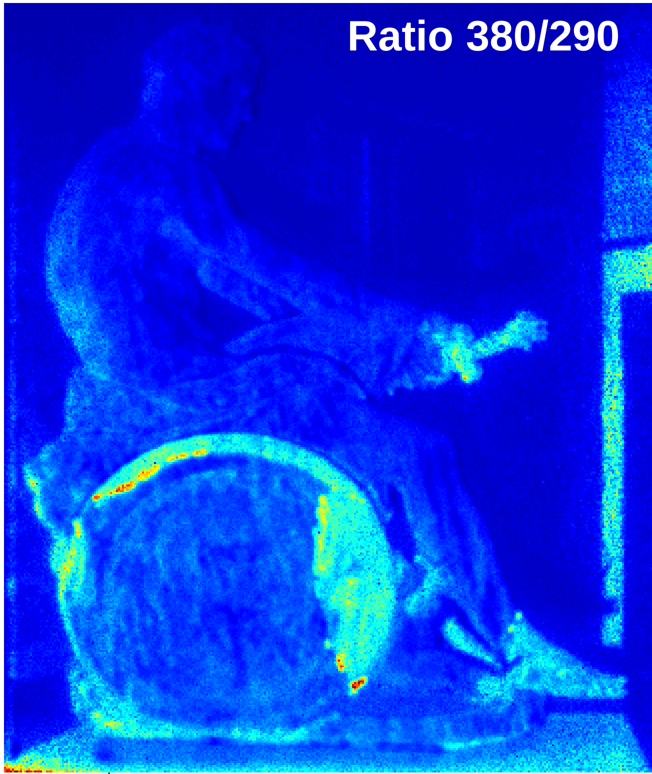
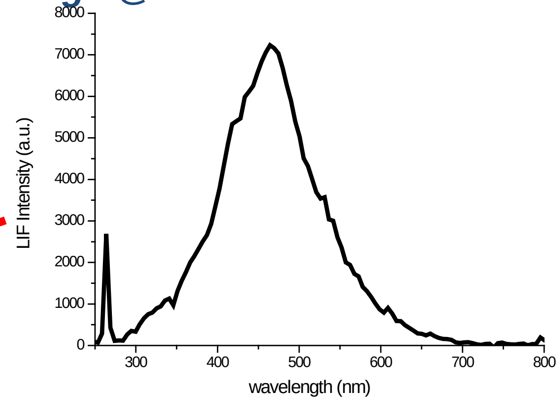
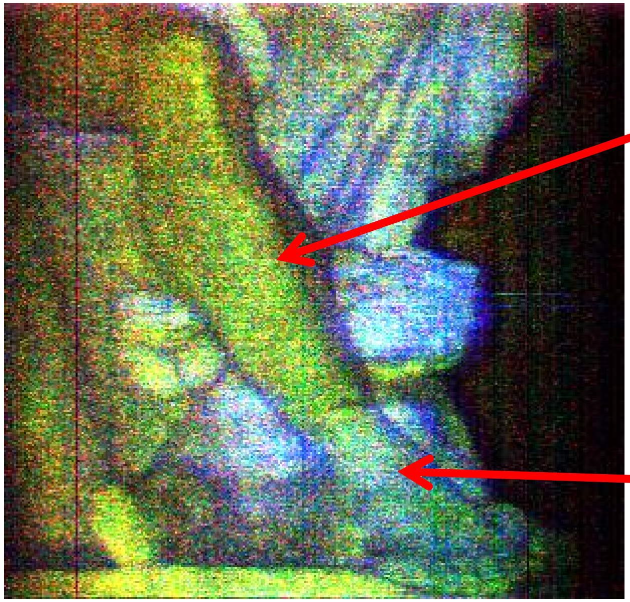


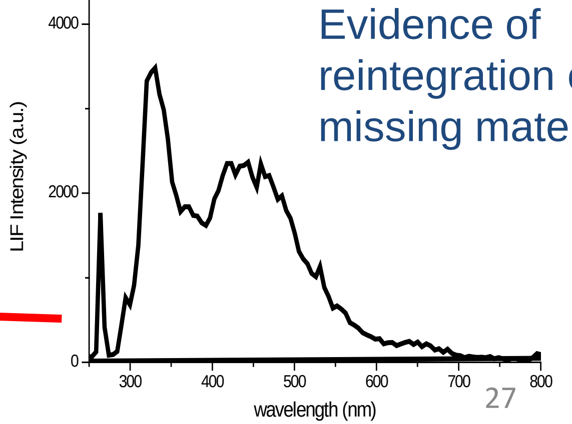
Image @ 380nm



Evidence of reintegration of missing material



LIF spectra collected in the areas pointed by red arrow (LIF scanning prototype was used)

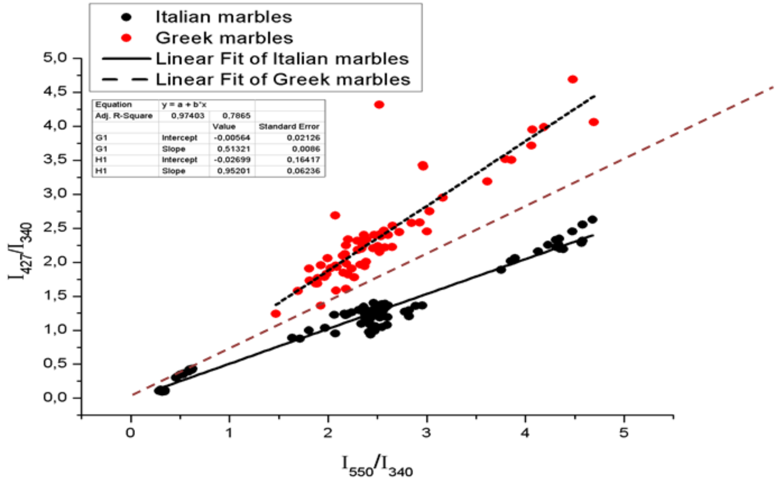


False colors LIF image

White marble type identification on LIF images

Development of an automatic algorithm to discriminate Greek marble (penthelic) from Italian marble (Carrara)

The algorithm is based on fluorescence intensity ratio at selected couples of detection channel

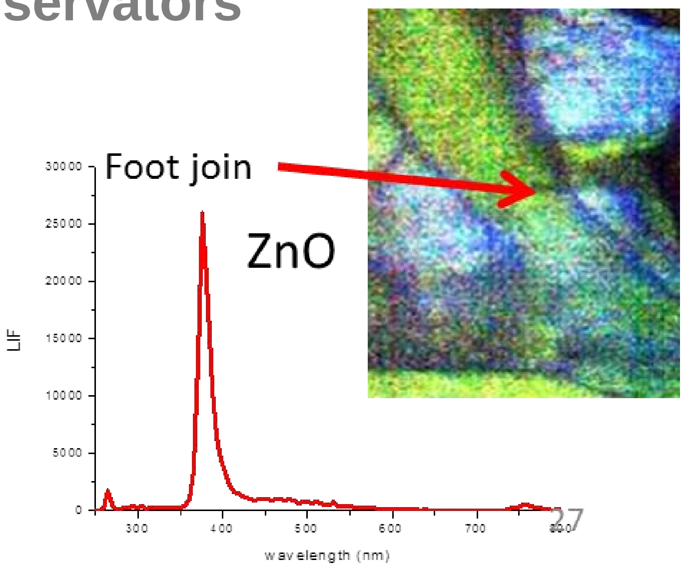


Greek marble in the statue (yellow)

Answer: Automatic recognition of «original» Greek marble from Italian marble added during the «renaissance restoration» is possible

LIF imaging on white marble statues

Additional Information on materials supporting art historians and conservators



Raman bands revealed at:
1084 cm^{-1} calcite $CaCO_3$
1007 cm^{-1} gypsum $CaSO_4$

- Different marbles used for integration in historic restorations (XVI century)
- Identification of white pigments on junctions.
- Detection and distribution of degradation products (in combination with Raman)
- Search for waxes and other historical coatings, detected also on other statues of the collection.

Sarcophagus of "Orants"- San Sebastian Catacombs
Marble identification

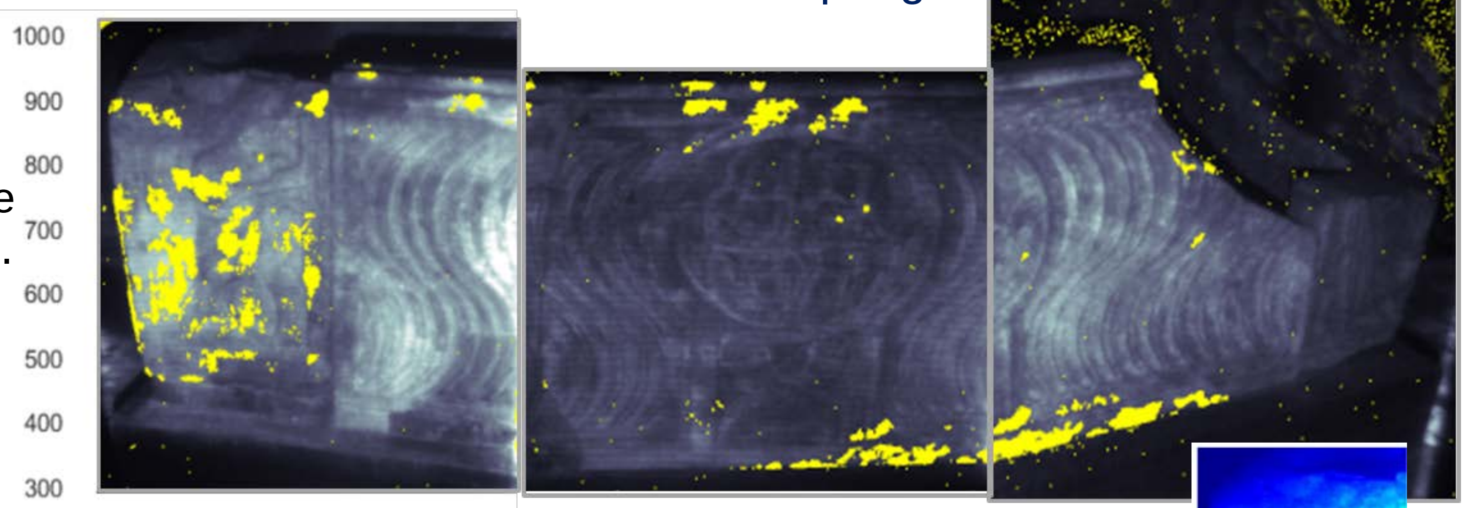
The sarcophagus is a marble sculpture made between the 3rd and 4th centuries AD and preserved in the Sarcophagi Museum of the catacomb of San Sebastian in Roma.

Question:

> geographical origin of the three pieces (left, central, right) constituting the sarcophagus

Processed fluorescence images with application of the recognition algorithm.

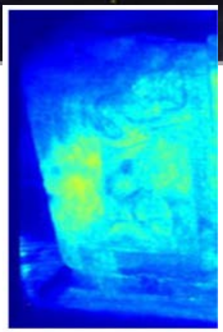
Small yellow areas correspond to encrustations.



Answer:

> It is all Italian marble

Additionally the presence of natural waxes was revealed in images collected at 415 nm



Characterization of painted wood artifacts

Egyptian Sarcophagi under restoration in Rome

Peftjauyauyaset (XXVI din. -VII-VI century BC) sarcophagus from Archaeological Museum of Milan

The Case containing the anthropoid sarcophagus where the mummy was accommodated and the sarcophagus itself were investigated.

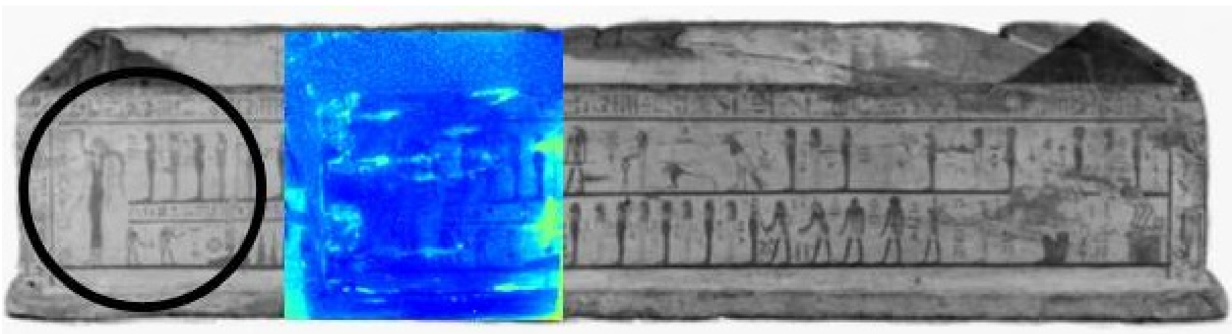
Polychrome decorations are present inside the sarcophagus and on the external surfaces of the case.

Question: is it possible to map former interventions at the wood surfaces?

ENEA

LIF imaging on sarcophagus

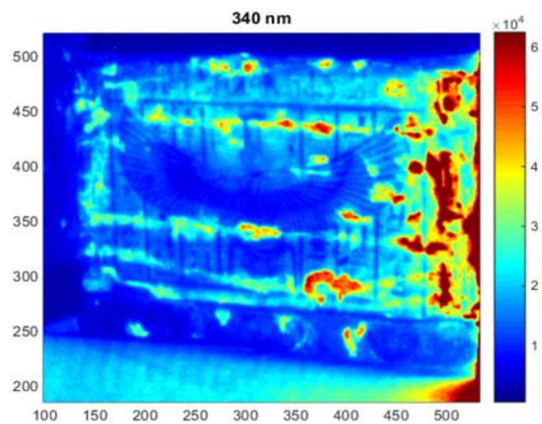
Slice of the long side LIF image obtained by 340/380nm spectral ratio



Casket

The areas highlighted in the image correspond to areas which were restored by means of acrylic materials.

Winged goddess Nefti on the short side of the casket and LIF image filtered at 340 nm

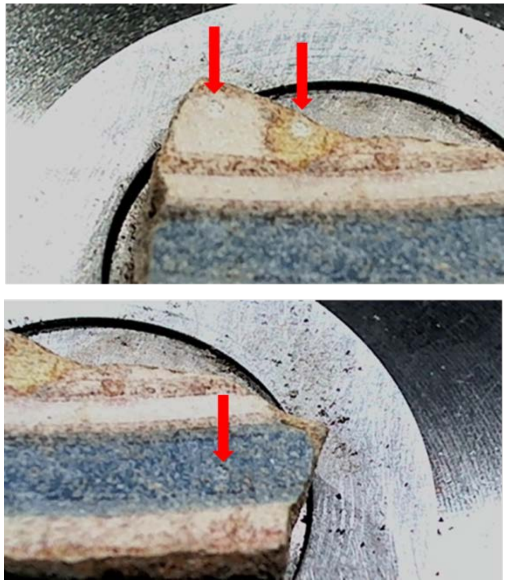


Intense fluorescence emissions in correspondence of fissures and cracks suggest presence of the acrylic product used as consolidation material for the ancient wood.

Answers: > LIF maps of formerly used acrylic consolidant are obtained
> Its use is demonstrated both on painted surface and on cracks

Remote LIBS on ceramic samples

Fragments from a «butto» near Tarquinia (XIII-XIX century)



Picture of a fragment taken by the on-line camera; LIBS craters marked by arrows

Why remote LIBS on ceramics? For their extensive use as coating on monumental walls in Mediterranean area.

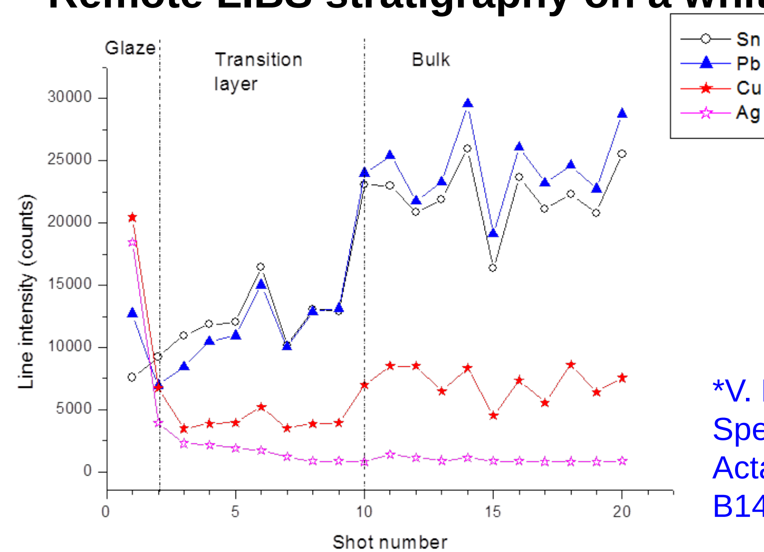
Glaze	White	Blue	Yellow	Light brown
Cu, Ag, Al, Ca, Mg, Mn, Fe, Sr, Na, Li, K	Cu, Ag, Pb, Sn	Co, Pb, Si, Al, Mg, Fe	Cu, Ag, Mg, Mn, Li, K, Rb	Cu, Ag

<u>Results</u>: Blue pigment is a cobalt based smalt, probably saffre.

The copper/silver rich glaze in the first layer and in the yellow luster suggest possible dating to this fragment in the XVI century*, according to Piccolpasso receipt for pottery.

*F. Colao et al. Spectrochim. Acta (2002): B57 1219-1234

Remote LIBS stratigraphy on a white area



*V. Lazic et al. Spectrochim. Acta (2018): B149 ,1-14

The complete study compares LIBS, PIXE and XRF data for different CH samples*

ENEA

REGIONE LAZIO

ADAMO Technologies of Analysis, Diagnostics and Monitoring for the preservation and restoration of Cultural Heritage

A·D·A·M·O

TECNOLOGIE DI ANALISI, DIAGNOSTICA E MONITORAGGIO PER LA CONSERVAZIONE E IL RESTAURO DI BENI CULTURALI

Oct. 2, 2018 – Jan 1, 2020

Progettoadamo.enea.it

A Research project in the Center of Excellence of the District of Technologies for Culture of Lazio Region

Participants: ENEA, INFN, CNR, Uni. Rome Sapienza, Uni. Rome Tor Vergata, Uni. Roma Tre, Uni. Tuscia (Viterbo)

Project objectives

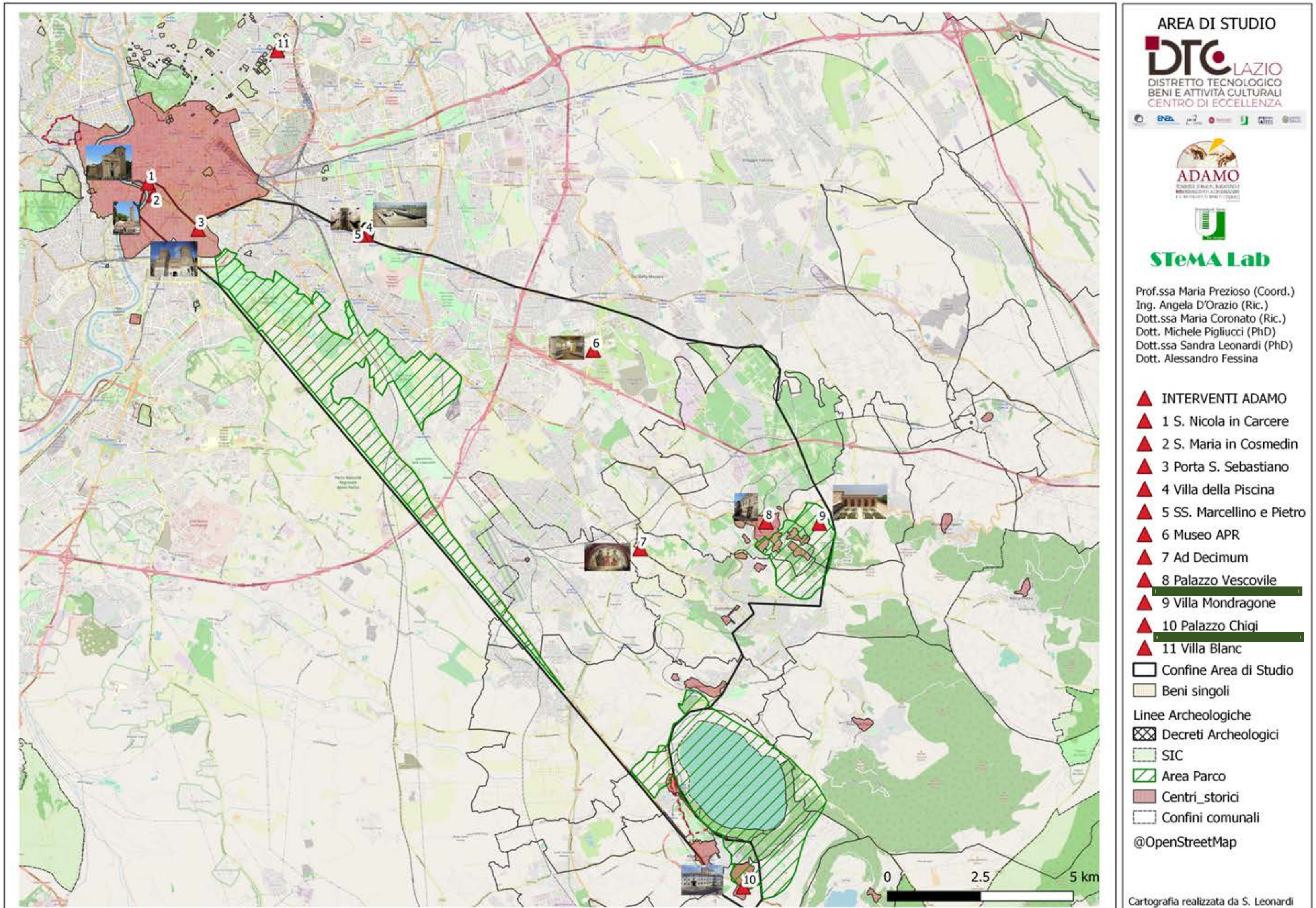
1. Technology transfer on relevant themes
2. Services to enterprises based on facilities offered by DTC partners
3. Demonstrations in selected cases studies
4. Development of prototypes and test of innovative products

Integrate applications of remote, in-situ and laboratory instruments for spectroscopic diagnostics

DTC LAZIO

CENTRO DI ECCELLENZA

Contest analysis and choice of demonstration sites



Bishop's Palace In Frascati: Hall of Landscapes

RGB-ITR 3D digitalization

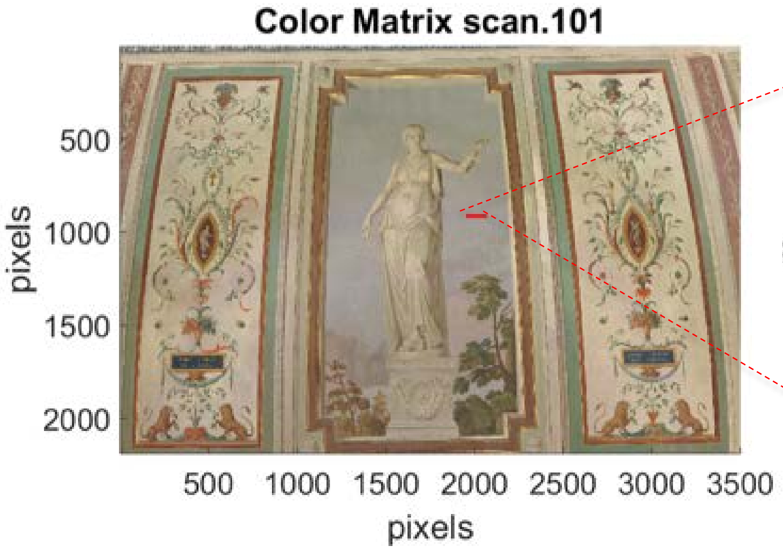
The *Hall of Landscapes* appears as a colorful room fully decorated with tempera painted canvas covering all the walls, where painted areas and wood frames create the illusion of an architectonic structure.

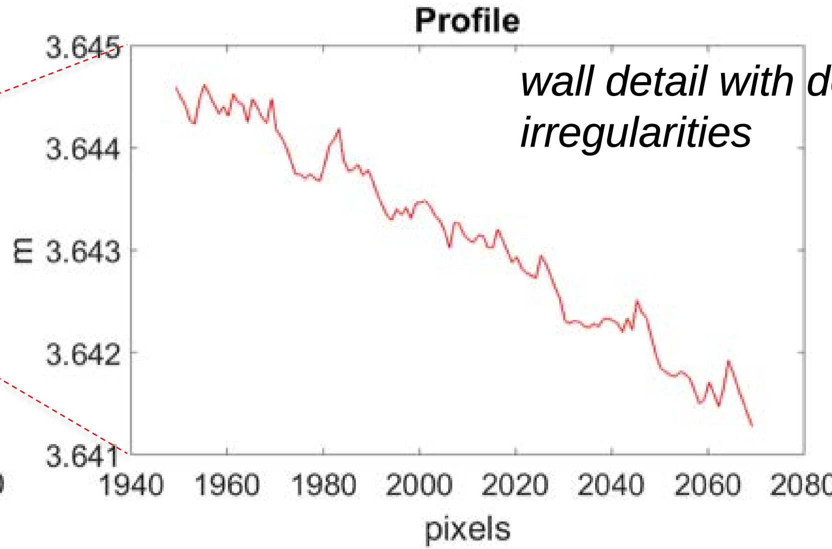
Ceiling detail where the restored areas (repaints after discoloration) are detected →

Questions:

- Location of residual damage from former water infiltration
- Location of current damages on canvas and other painted surfaces

Bishop's Palace In Frascati: Hall of Landscapes
RGB-ITR 3D digitalization and LIF imaging





wall detail with detected irregularities

LIF investigation of the wooden cover at fireplace in the same room.

A carefully repainted crack is evident in the 380/450 nm LIF image.

Answers:

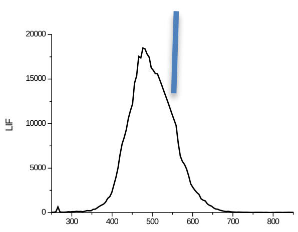
- Residual damages are detected by both techniques as discoloration, morphology changes, repainted cracks

Bishop's Palace In Frascati: "Stufette" room
TR-LIF spectroscopy and imaging

Two decorated small bathrooms belonging to the pope niece Lucretia Della Rovere, recently restored.

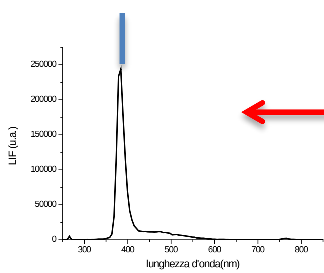
Question:
Can we detect early damage?

Reference reflectance image collected by the LIF scanning system

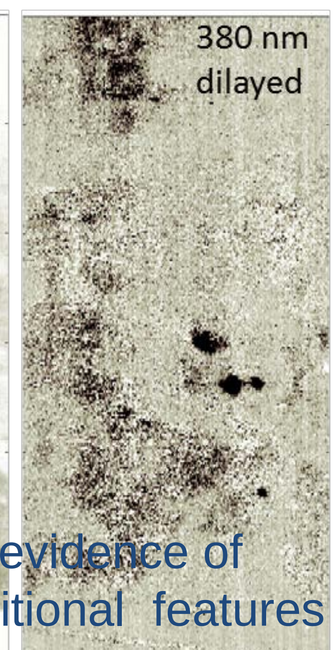


Color degradation @550 nm

ZnO retouches @380 nm



Answer: YES for p.c.



TR evidence of additional features

Marble busts gallery of Chigi Palace at Ariccia

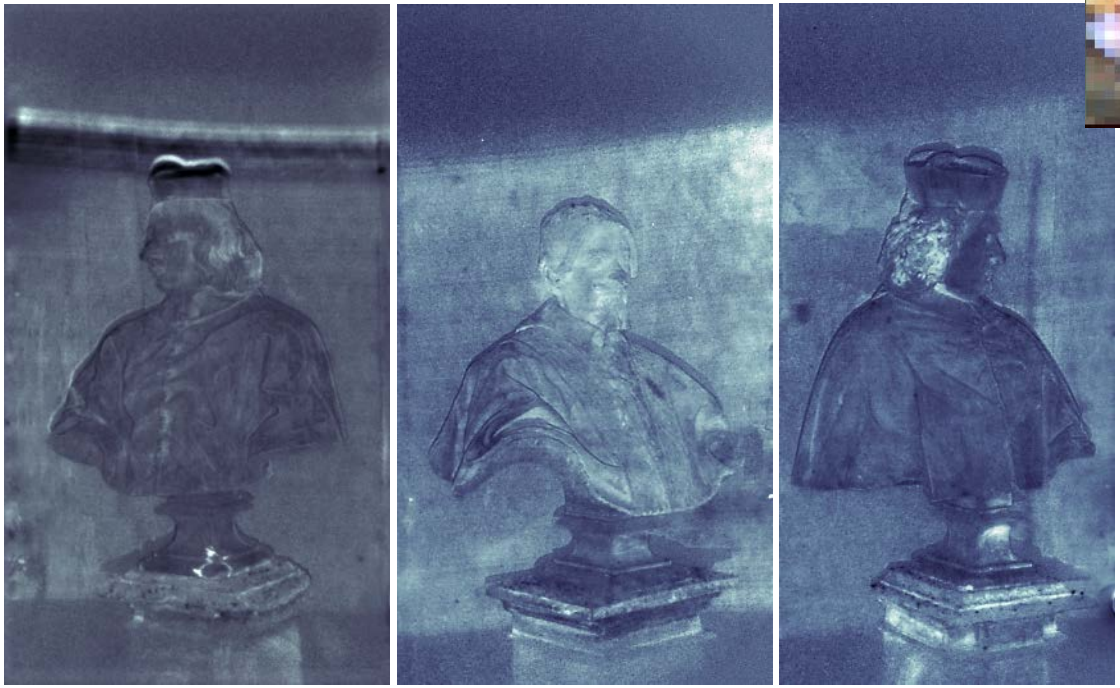
Imaging LIF [ENEA]

LIF imaging by FORLAB prototype

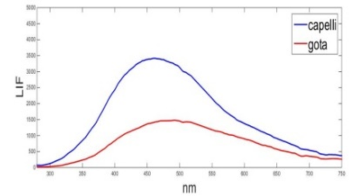
An important Baroque collection

LIF spectral image reconstruced in false colors (400-500-600nm)

Question:
> Was the marble surface treated for aesthetic purposes?



Processed FORLAB images



The emission bands are centerd at different wavelength on face and hair:

- No presence of acryl (original surfaces)
- Presence of wax on the hair

Answer: YES added material is present on the hair (assignment in progress)

Picture-gallery of Chigi Palace at Ariccia

High resolution IR-ITR laser scanner

Chigi Palace in Ariccia represents a unique example of baroque home remained intact over the centuries. The palace was transformed into a magnificent baroque residence by Gian Lorenzo Bernini in the XVIIth century.

The picture-gallery contains paints from Mario de Fiori and other Roman baroque artists (The Four Seasons), sometimes working together on the same canvas.

Question:

> Is it possible to remotely reveal changes of mind of the last author?

3D IR-ITR image

Revealing artist's changes of mind «Ripensamenti»

Remote high resolution IR-ITR sub-surface inspections

Hidden details
not seen in the
visible spectrum

from IR-ITR image

Mario de Fiori - Springtime

IR-ITR features

Maximum working range: 15-20m
Maximum spatial resolution at 10m: 1mm
No shadows
No ambient illumination interference

Answer:
> Yes, with high sensitivity and high resolution, without any image post-processing

Conclusions and Future Work plan for laser diagnostics on CH surfaces

Conclusions

- Spectroscopic techniques (LIF and TR-LIF, Raman, XRF) allowed to obtain remotely and *in situ* unique information on different CH surfaces.
- Image processing algorithms suitably developed for semi-automatic applications were applied to obtain space distribution of different surface features.
- 3D high resolution color models are useful to precisely locate spectroscopic data collected on different points and 2D fluorescence images.
- The integration of different remote optical and spectroscopic techniques is often the only way to solve complex real challenges from case studies in CH samples in order to effectively answer conservators questions.

Future Work plan

- RGB-ITR wavelength extension: the additional near IR 1.5 μm channel for subsurface investigation will be integrated in short; a further UV source (@355 nm) will be added for UV imaging; implementation of up to 8 wavelengths is planned in the IR – to UV range.
- Addition of Raman imaging in the ILS prototype, already integrating LIF/LIBS and Raman; its operation up to 30 m on real CH surfaces.
- Addition of a short pulse (ps) laser source on LIF imaging prototype to fast acquisition of time resolved images has been proposed (E-RIHS.it Lazio).

Roberta Fantoni

Salvatore Almaviva, Luisa Caneve, Francesco Colao, Massimo Francucci, Massimiliano Guarneri, Violeta Lazic, Antonio Palucci, Adriana Puiu, Ottavia Santorelli*, Valeria Spizzichino,

ENEA, Fusion and Technologies for Nuclear Safety and security Dep., Technology Applications for security and Health, Diagnostic and Metrology Lab. Frascati Research Centre (Italy) - *research fellow

Martina Romani

INFN-Department of Industrial Engineering, University of Rome "Tor Vergata"